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Associations between iris characteristics and personality in adulthood

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Abstract

Variable and person-oriented analyses were used to explore the associations between personality and three previously untested general iris characteristics: Crypts, pigment dots, and contraction furrows. Personality data, as measured by the NEO PI-R and ratings of iris characteristics from 428 undergraduate students were collected. Crypts were significantly associated with five approach-related behaviors, i.e., Feelings, Tendermindedness, Warmth, Trust and Positive Emotions, whereas furrows were associated with Impulsiveness. These findings suggest that crypts, probably via the neurodevelopmental control gene Pax6, induce tissue deficiencies in the left anterior cingulate cortex, which in turn influence the extent individuals engage in approach-related behaviors. The results from using a person-oriented analysis suggested that people with different iris configurations tend to develop along different personality trajectories. Future longitudinal studies, twin-studies, and genetic association studies, may benefit from collecting iris data and testing candidate genes for crypt and furrows.

Keywords: personality; iris characteristics/Crypts/pigment dots/contraction furrows; candidate genes/Pax6/Six3/Lmx1b; anterior cingulate; hemispheric asymmetries.

Introduction

The idea that personality differences are related to iris characteristics is not new. In 1965, Cattell observed differences in cognitive styles between blue and brown eyed subjects (Cattell, 1965) and since then eye color has been found to be related to a great variety of physiological and behavioral characteristics. Dark eyed people have on average higher scores on extraversion, neuroticism (Gentry et al., 1985), ease of emotional arousal (Markle, 1976) and sociability (Gary and Glover, 1976). However, there are a number of studies that fail to replicate the personality findings, typically because the effect tends to fade after early childhood. For instance, Rubin and Both (1989) found that blue-eyed children in kindergarten and Grade 2 were overrepresented in groups of extremely withdrawn youngsters, whereas no association could be found in Grade 4 or between eye color and extreme sociability in any grade. Furthermore, in subjects around 20 years of age, eye color failed to account for any difference between high vs low scorers on personality measures (Lester, 1987; Rim, 1983). Consequently, it has been assumed that the biological mechanisms that may underlie the association between eye color and social wariness in early childhood tends to be “overcome” around age 9 when the increasing influence of social environmental factors has gained momentum (Rubin and Both, 1989).To our knowledge, no research has been reported concerning eye color and its relation to personality since 1998, when Coplan et al. (1998) found a significant eye color by gender interaction for social wariness in a sample of 3.5 – 5.5 year old toddlers. This finding raised further questions regarding the phenotypic penetrance of the suggested biological mechanism involved. Leading researchers in the field concluded that eye color can not be a useful marker for personality in older ages (Coplan et al., 1998; Rosenberg and Kagan, 1989; Rubin et al., 1989).

One of the reasons eye color has been considered to be a useful biomarker is its high heritability (98%), and the fact that eye color does not change much over time (Bito et al., 1997). Others key reasons are that eye color can be linked to biological mechanisms that provide a somewhat speculative, but still plausible, biological explanation for the associations found. For instance, Kagan suggested that melanin production in the eyes (the pigment that colors the eye brown), may be associated with norepinephrine and cortisol production, which are biological indices of behavioral inhibition (Kagan et al., 1988; Reznick, 1989). High levels norepinephrine and cortisol can thus potentially both inhibit melanin production in the eye, as well as increase responsiveness of the limbic system, which has been associated with higher scores of inhibition (Rosenberg et al., 1989). Placental cortisol level during the initial stages of pregnancy and the gene POMC, which are likely to play an important role in individuals' response to varying levels of arousal (Kupfermann, 1991) and to the synthesis of melanin (Pawelek and Korner, 1982), have also been suggested to contribute to the associations found.

However, if one carefully examines people's irises, it is clear that there are other iris characteristics than eye color that potentially could be associated with personality, such as Fuch's crypts, contraction furrows and pigment dots. To take one example, if the biological mechanisms associated with the frequency of Fuchs' crypts (a measure characterized by different degrees of hypoplasia of the anterior border layer and underlying stroma in the iris), influence behavior, then biological mechanisms other than those suggested to be associated with eye color can be responsible for the associations. This study explores the association between iris characteristics other than eye color and personality. Three general iris characteristics that to our knowledge not have been considered previously will be tested.

The iris characteristics of interest in this study are depicted in Figure 1: Frequency of Fuchs' crypts in the main stroma leaf (which from now on only will be called "crypts"); frequency of pigment dots; and the distinction and extension of contraction furrows. These iris characteristics are moderately to highly heritable, show no sex differences, and are stable over time (Larsson et al., 2003).

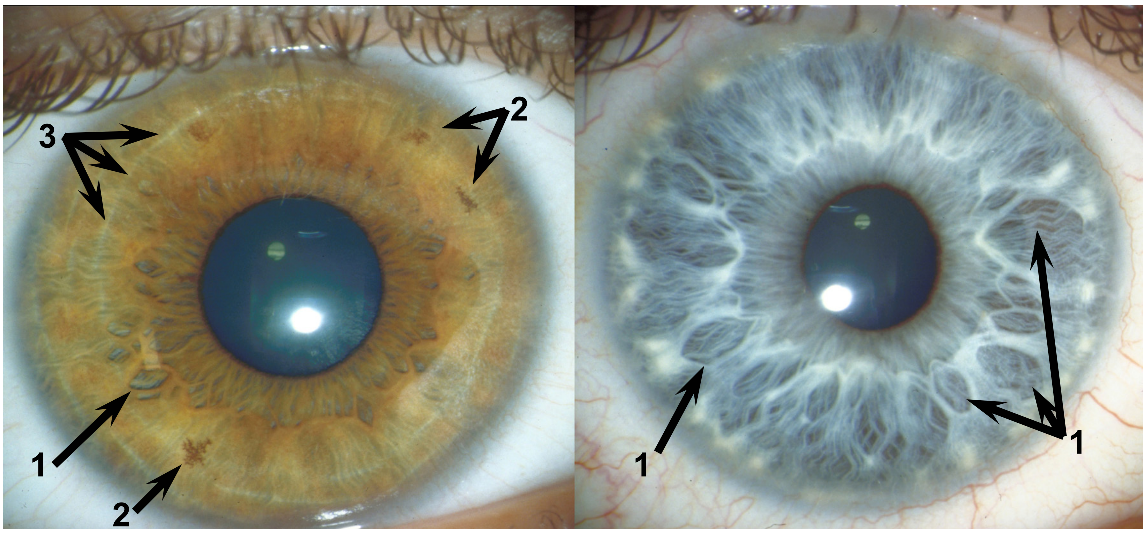

Fig 1. The numbered arrows point toward the iris characteristics of interest. 1 Furchs' crypts in the main stroma leaf; 2 Pigment Dots; 3 Contraction Furrows.

Crypts and contraction furrows are measures that are related to the thickness and the density of the iris. Crypt frequency is characterized by different degrees of hypoplasia in the two top cell layers in the iris i.e., anterior border layer and underlying stroma, whereas contraction furrows are characterized by different degrees of hypoplasia or density conditions in any of the five cell layers present in the iris (Oyster, 1999). What is intriguing about these cell layers is that genes that influence the growth of precursors to these cell layers during the embryological development also cause tissue loss in the brain. For example, the genes Pax6, Six3 and Lmx1b have been recognized as candidate genes for crypts and contraction furrows (Hsieh et al., 2002; Pressman et al., 2000; Sale et al., 2002) and the embryological events that make these genes plausible candidates for crypt and contraction furrows has been reviewed (Larsson and Pedersen, 2004). In addition, the most recent studies available confirm that Pax6 is a likely candidate gene for tissue differences in the iris. Pax6 dosage influence the muscle-cell differentiation in the iris (Jensen, 2005), and Davis-Silberman et al., (2005) conclude that (p. 2474) iris stroma defects are likely to be due to cell-non-autonomous events, where Pax6 regulates the expression of the cells which are required for the adhesion of the iris stroma. Thus, it is possible that Pax6, Six3, and Lmx1b which influence the growth of the precursors to the cell layers in the iris , could influence the variability of crypts and contraction furrows typically present in peoples irises (Hsieh et al., 2002; Pressman et al., 2000; Sale et al., 2002; Simpson and Price, 2002).

Furthermore, the expression pattern of these genes in the brain supports the notion that these iris characteristics can be associated with personality. In the first study published that has demonstrated a major genetic contribution to frontal lobe dysfunction, family members with a mutation in *Pax6* showed high rates of unusual behavior including disinhibition, impulsive behavior, impaired social understanding and impaired verbal inhibition (Heyman et al., 1999). In addition, magnetic resonance imaging (MRI) in this family (Ellison-Wright et al., 2004) demonstrated local gray and white matter changes in anterior cingulate cortex (approximate Brodmann area 24, 32), as well as posterior white matter abnormalities in corpus callosum extending posteriorly into cingulate cortex, which are brain areas that have been associated with personality (Davidson, 2001; Johnson et al., 1999; Posner and Rothbart, 1998). Healthy university subjects with larger right anterior cingulate gyrus (Brodmann's area 24a, 24b and 25), score higher on Harm Avoidance, which measure emotional responses that regulate withdrawal-related behaviors, whereas subjects with larger left cingulate gyrus, score higher on Novelty seeking, which measure emotional responses that regulate approach-related behaviors (Pujol et al., 2002). Indeed, anatomical data revealed that hemispheric asymmetry in the anterior cingulate gyrus was very common (83% of cases, n = 100) and that surface measures of the right anterior cingulate gyrus accounted for 24% of the variance in Harm Avoidance. Overall, these findings are consistent with the assumed specialization of each hemisphere in the control of individual differences in withdrawal –and approach-related behaviors (Davidson, 1992; 2001; Davidson and Irwin, 1999; Pujol et al., 2002).

Moreover, the fact that the production of dopamine (Kohwi et al., 2005) and noradrenalin neurons (Jaworski et al., 1997), has been associated with Pax6 functioning provides another link to personality (Reif and Lesch, 2003; Rosenberg et al., 1989). But Pax6 is not the only candidate gene for crypt frequency and contraction furrows that potentially could influence personality. Lmx1b is required for the survival of the dopaminergic neurons in the mesolimbic system (Burbach et al., 2003), as well as essential for the production of serotoninergic neurons (Ding et al., 2003), and Six3, which is a downstream target to Pax6 (Simpson et al., 2002), controls the division of the brain into two hemispheres (Wallis and Muenke, 2000). Thus, based on these findings we assume that tissue differences in the iris, such as crypts and contraction furrows, could be associated with Pax6, Six3 and Lmx1b, which in turn could be associated with personality.

The links between pigment dots and personality is less well documented, but nevertheless, pigment dots could potentially be associated with personality, as the development of pigment dots is in part regulated by neurotransmitters produced by the autonomic nervous system (Hu, 2000; Hu et al., 2000; Mukuno and Witmer, 1977), which in turn is influenced by the extent the individual engage in withdrawal -and approach related behaviors (Davidson et al., 1999). Thus, through the expression patterns of Pax6, Six3 and Lmx1b in the iris and the brain, crypts, contraction furrows and pigment dots may be associated with both brain structures and neurotransmitters that influence personality. However, there is no evidence available which shows that these genes influence crypt and contraction furrows directly. In addition, other candidate genes for crypt and contraction furrows have been recognized (Larsson et al., 2004).

In order to discriminate between the biological pathways that theoretically could influence the presumed association between iris characteristics and personality, and to more fully evaluate a potential role by Pax6, we test three hypotheses. They draw heavily on Pax6 expression pattern in the anterior cingulate cortex as documented by Ellison-White et al (2004), in conjunction with the findings made by Pujol et al (2002) and Davidson et al (1992, 1999, 2001). These hypothesis increase in their specificity, and if all three hypotheses are found to be correct, then the likelihood that Pax6 is involved, relative to other candidates, is expected to increase. Thus, based on the findings reviewed above, we expect, first, that crypt more often than other iris characteristics will be associated with personality. Crypt is related to greater tissue loss in the iris than the other two iris characteristics, which in turn may reflect greater tissue loss in the brain (which makes it likely that more measures of personality are associated with crypts than the other iris characteristics). Second, because the tissue damage that was due to Pax6 mutations in anterior cingulate cortex primarily affected the left hemisphere (Ellison-Wright et al., 2004), and this hemisphere primarily relates to approach-related behaviors (Davidson, 1992; 2001; Davidson et al., 1999), we expect that crypt frequency in most cases will be related approach-related behaviors. Third, because greater tissue loss in the iris, may reflect greater tissue loss in the left anterior cingulate cortex, we expect individuals with an open crypt structure (those with more tissue loss in the iris) to score lower on traits that relates to approach-related behaviors than those with a dense crypt structure. Furthermore, in order to deepen the analysis the present study combines a variable –and person oriented approach. As has been repeatedly shown within a holistic interactionistic framework, person-oriented approaches are able to answer different questions than more traditional variable-oriented approaches (Bergman and Magnusson, 1997; Magnusson and Stattin, 1998; von Eye and Bergman, 2003). For example, in variable-oriented analysis the relationship among variables and their way of functioning in the totality of an individual is assumed to be the same for all individuals. However, this prerequisite may not be fulfilled in the present study since most of the genetic variance for each iris characteristic is independent of the other iris characteristics (Larsson et al., 2004). In other words, the behavioral meaning of having a specific crypt frequency may depend on which other iris characteristics are present in any one iris (Lander and Schork, 1994). Person-oriented analysis takes these possibilities into considerations and is based on the perspective that the individual organism can be thoroughly understood only as a totality (Bergman et al., 1997). Furthermore, this totality is assumed to result from self-organization. This means that although there are, theoretically, an infinite variety of differences with regards to process characteristic and observed states at a detailed level, at a more global level there will often be a small number of more frequently observed patterns (Bergman et al., 1997; Bergman et al., 2003). This principle of self-organization has been demonstrated in many human biological systems and has been applied to the development of the neural, sensory and cognitive systems (Post and Weiss, 1997) as well as personality (Bosma and Kunnen, 2002; Carver and Scheier, 2002). Consequently, we expect that from the embryological events that form the adult iris (detailed level), distinct configurations of iris characteristics will occur in the population studied. Furthermore, if the iris characteristics that define these naturally occurring configurations are associated with personality, then we expect that these configurations will define subgroups of individuals that differ from each other on personality in a systematic manner. Developmentally, the individuals in these subgroups may represent different trajectories in regards to personality, and subgroups with more tissue loss in the iris are, just as in the variable-oriented analysis, expected to score lower on approach-related behaviors. Moreover, because the relationship among the iris variables and their way of functioning in the totality of an individual is *not* likely to be the same for all individuals (Lander et al., 1994; Larsson et al., 2004), the effect size in the variable-oriented analysis is expected to be lower than in the person-oriented analyses.

To sum up, the purpose of this study is to explore the association between iris characteristics other than eye color and personality, using both variable- and person-oriented analyses, as well as highlight genes expressed in the iris that potentially could be candidate genes for personality. In performing the variable-oriented analysis we test three hypotheses which together explore the likelihood that the neurodevelopmental control gene Pax6 influences personality. In performing the person-oriented analyses, which deepen the analysis, we test the extent to which self-organizing properties of the developmental system creates configurations of iris characteristics that can identify subgroups of individuals who differ in their personality. In comparing the effect size in the variable– and person-oriented analyses, we explore how efficiently the self-organizing properties of the developmental system can identify individuals who differ in their personality.

Method

Participants and recruitment procedure

The participants were all undergraduate student volunteers at Örebro University, Sweden, recruited from programs in Psychology (47%), Social studies (30%), Economics (10%), Automatic Data Processing (5%), Political Science (4%) and Engineering (4%). Most participants were female (80 % of 428 participants). The mean age of the sample was 26.6 years (19-52 years, SD=7.1). The participants were recruited after a regular lecture by the first author, who was given an opportunity to describe the study. Consenting participants filled out the NEO PI-R personality questionnaire where they were not disturbed (Costa and McCrea, 1992), however Psychology and Social studies students responded to a computerized version of NEO PI-R in a group setting with 15 students. Close-up iris color photography was taken individually in a lab setting at the university.

There were two waves of data collection. In the first wave of data collection, all students that volunteered were accepted as participants. In the second wave, only those individuals with irises that were most similar to scale-step 1 and 3-5 on the crypt frequency scale (see below) were accepted. This was done in order to arrive at approximately the same number of participants with each level of crypt frequency.

Measures

Personality

Personality was assessed with the Swedish version of the NEO PI-R (Costa et al., 1992), which is considered to be a reliable and valid assessment of the Five Factor Model of Personality. Eight-item scales measured six specific facets for each of the five broad factors. The internal consistencies (Cronbach's alpha) were overall high, ranging from .69 to .85 (Mean = .72) and did not differ substantially from what has been found for other samples with NEO PI-R measured in Sweden and other countries.

Iris characteristics

Close-up photos, where the diameter of the iris on the 36x24 mm Fujicolor, Professional 100 ASA slide film was about 22 mm, were taken of both irises from all subjects. An Olympus OM-4T camera with a double sided flash device from Lena Medical Photo Design Systems, and a Olympus 50 mm macro lens with a 1:2 converter was used. The shutter speed was 60 and the aperture was set to 16. To assist focus adjustment and to standardize the extent the iris was dilated, a lamp with standard brightness was shown into the subjects' irises during focus and photography. To prevent blurring caused by involuntary movements from the subjects, all participants rested their cheek on a stand during the procedure. The iris photos were transformed to digital pictures using Minoltas 35 mm Dimage Scan Dual film scanner. In order to make it possible to rate the photos on a computer screen, the resolution of the digitalized color pictures was 768 x 512 pixels (96 pixels/inch). A high contrast color computer screen (Brand: Eizo; Model: FlexScan F55) with 1024 x 768 / 85 Hz resolution (0.28 mm Dot Pitch CRT; fH:27-70 kHz/fV: 50-120 Hz) and the software program Photo Shop 7.0 was used during the rating process.

Three scales, one for each iris characteristic of interest, were constructed: frequency of crypts, pigment dots and extension and distinction of contraction furrows. Specially trained raters independently reviewed the photographs of the right iris and judged which scale step to which each photo was most similar. The raters' judgments were scored on an ordinal scale. Scale construction, the rating procedure and the reliability of the procedures are reported in detail in Larsson et al., 2003. The pictures used for the scales may be seen at: http://www.molvis.org/molvis/v10/a98/ (or obtained directly from the first author).

Analysis

The first set of analysis was variable-oriented in nature and tested if our three expectations derived from Pax6 expression pattern in the anterior cingulate cortex were correct. This was done by performing a Pearson correlations analysis between the three iris characteristics and the personality measures. Due to the fact that the facet level traits in NEO PI-R have their own biological basis (Jang et al., 1998) and the necessity to include as specific measures as possible has been emphasized in studies such as ours (Heyman et al., 1999), both facet level traits and the main domains of personality were included in the analysis. The distributions of the iris characteristics used in these analyses are presented in table 1.

Table 1. Distribution of iris characteristic

Iris characteristic and scale description	Number of Observations
Fuchs' crypt frequency	
1 – Only parallel and/or densely packed curly fibres	129
2 – Spots of wavy fibres and 1-3 two shallow crypts	169
3 – Four shallow crypts or more	130
Pigment dots	
1 – Absence of, or only minute grains of pigment dots	280
2 – One pigment dots or more	148
Contraction furrows	
1 – Extending less than ¼ circle	106
2 – Extending between ¼ and 8/10 of a circle	142
3 – More distinct, extending 8/10 of one circle or more	180

In the second set of analysis, we performed the person-oriented analysis. They tested if the iris configurations that typically exist in early adults can identify subgroups of individuals that differ in their personality in a systematic manner. First a cluster analysis based on WARD's method (Peck and Williams, 2002) was performed. Only the iris characteristics that were found to be significantly associated with personality in the correlation analysis were included. A four cluster solution was chosen which explained 77 % of the total variance in the sample. The variance explanation was higher than the minimum criterion of 67%, recommended by Bergman, Magnusson, and El-Khouri (2003). A one-way variance analysis (ANOVA, posthoc = Tukey HSD) were used to investigate if any significant mean difference in personality existed between the clusters. Both facet level traits and the main domains of personality were included in the variance analysis.

Finally, to explore how efficiently the self-organizing properties of the developmental system could pick out subgroups of individuals that differed in their personality, we calculated the effect size (Cohen, 1988) for all associations that were found to be significant in the variable -and person-oriented analysis.

Results

The results in the variable-oriented analysis are presented in Table 2. We found that two of the five domains were significantly associated with crypt frequency: Openness to experience and Agreeableness. In contrast, furrows were only associated with Neuroticism, and pigment dots were not associated with any of the main domains of personality. Not surprisingly, most of the correlations between the specific facets of personality and crypt frequency were found for facets belonging to the two domains with significant associations. Thus, our first hypothesis – i.e., that most association should involve crypt frequency – was confirmed. Furthermore, our second and third hypothesis – i.e., that crypt frequency in most cases should be related to approach-related behaviors and that individuals with a dense crypt structure should score higher on such behaviors – was also confirmed. Most of the significant associations to crypts pinpointed behaviors that measure approach-related behaviors and individuals with a dense crypt structure scored higher on such behaviors; i.e., Warmth, Positive Emotions, Openness to Experience, Feelings, Agreeableness, Trust and Tendermindedness.

In addition, the magnitude of the associations with the iris characteristics was as expected quite modest and ranged from .10 to .15. No associations for eye color on personality could be found (results not shown).

Table 2. Pearson correlation between iris characteristics and the personality measures

Personality measure	Iris Characteristics		
	Crypts	Pigment dots	Furrows
Neuroticism	-.04	.06	.11*
Anxiety	-.02	-.01	.06
Angry-Hostility	.04	.07	.04
Depression	.01	.07	.09
Self-Consciousness	-.05	.08	.09
Impulsiveness	-.06	.02	.15**
Vulnerability	-.08	.04	.07
Extraversion	-.09	-.02	.04
Warmth	-.15**	-.04	.04
Gregariousness	-.05	-.06	-.01
Assertiveness	-.01	-.02	-.00
Activity	-.05	.00	.05
Excitement Seeking	.01	.01	.07
Positive Emotions	-.13**	.01	.03
Openness to Experience	-.10*	.01	-.06
Fantasy	-.01	.02	-.03
Aesthetics	-.13**	.01	-.06
Feelings	-.14**	-.05	-.03
Actions	-.03	.02	-.06
Ideas	-.01	.03	.02
Values	-.07	-.03	-.08
Agreeableness	-.10*	-.06	-.00
Trust	-.11*	-.05	-.01
Straightforwardness	-.04	-.10*	.03
Altruism	-.06	.01	.03
Compliance	-.04	-.01	-.02
Modesty	-.04	-.05	-.01
Tendermindedness	-.13**	-.03	-.03
Conscientiousness	-.07	-.05	-.09
Competence	-.02	-.07	-.09
Order	.00	-.03	-.08
Dutifulness	-.06	-.09	-.01
Achievement Striving	-.08	-.03	-.06
Self-Discipline	-.08	-.03	-.12**
Deliberation	-.04	.03	-.04

*p < .05; **p < .01.

We are aware that we are conducting many analyses in Table 2, and that if we would apply a strict, conservative Bonferroni correction, all our significant results would vanish to non-significance. Nevertheless, for two of the three measures of iris characteristics, the number of significant correlations obtained is significantly above chance. As to the associations between crypts and the Big Five measures, we conducted 35 separate analyses. By chance, we would expect 1.75 analyses with a p value of .05 or lower (35 analyses x 0.05 = 1.75) and 0.35 analyses with a p value of .01 or lower (35 analyses x 0.01 = 0.35). For crypts, we obtain 8 significant correlations at the .05 level and 5 at the .01. For furrows, we obtain 3 correlations with a p value of .05 or lower and 2 at the p value of .01 or lower. Hence, for crypts and furrows, the numbers of significant correlations are well above the chance. For pigment dots, on the other hand, the findings are not much different from chance expectations. Moreover, the fact that most of the significant associations in table 2 are consistent with our hypotheses decrease the likelihood that these findings are due to random effects. The significant results in the person-oriented analysis, which pinpoint the same behaviors, also support this notion.

In the person-oriented analysis a four cluster solution was chosen based on the criteria that each group should differ as much as possible in their iris morphologically, as well as define subgroup with a sufficient number of members to make the variance analysis that followed meaningful. Only the iris measures that were significantly associated with personality in the variable-oriented analysis were included in the cluster analysis. The result of the analysis, which represents the configurations of iris characteristic that typically exists in early adults, is presented in Table 3.

Two different types of configurations emerged. The individuals in clusters 1 and 2 had a dense crypt structure whereas cluster 3 and 4 contained individuals with an open crypt structure. The amount of furrows that existed in each of these clusters further differentiated between the clusters. Cluster 1 and 4 individuals had few contraction furrows whereas subjects in cluster 2 and 3 had many.

Table 3. The configurations of iris characteristic that typically exists in early adults

Iris characteristic and scale description	Cluster 1 N = 143[1]	Cluster 2 N = 155[2]	Cluster 3 N = 73[3]	Cluster 4 N =57[4]
Crypt frequency				
1 – Only parallel and/or densely packed curly fibres	Yes	Yes	-	-
2 – Spots of wavy fibres and 1-3 two shallow crypts	Yes	Yes	-	-
3 – Four shallow crypts or more	-	-	Yes	Yes
Contraction furrows				
1 – Extending less than ¼ circle	Yes	-	-	Yes
2 – Extending between ¼ and 8/10 of a circle	Yes	-	Yes	-
3 – More distinct, extending 8/10 of one circle or more	-	Yes	Yes	-

[1] $Mean_{Crypts} = 1.61$ / $Mean_{Furrows} = 1.65$
[2] $Mean_{Crypts} = 1.52$ / $Mean_{Furrows} = 3.00$
[3] $Mean_{Crypts} = 3.00$ / $Mean_{Furrows} = 2.34$
[4] $Mean_{Crypts} = 3.00$ / $Mean_{Furrows} = 1.00$

The one-way analysis of variance that tested if any mean differences emerged between these four clusters, produced results which were in agreement with our expectations (Table 4). Overall, individuals in the clusters with more tissue loss in the iris scored lower on approach-related behaviours, compared with those with a dense iris structure. For example, the individuals in cluster 3 scored significantly lower than the individuals in cluster 1, on all approach-related behaviours that in the variable-oriented analysis was found to be significantly associated to crypts. Hence, tissue loss in the iris was in the person-oriented analysis just as in the variable-oriented analysis associated with lower scores on approach-related behaviors.

Table 4. Means of the personality measures with standard deviations within parentheses in each of the four clusters, with test for mean differences between the clusters (one-way ANOVA, posthoc = Tukey HSD)

Personality measure	Cluster 1 N = 143	Cluster 2 N = 155	Cluster 3 N = 73	Cluster 4 N = 57	*df*	*F*
Neuroticism	-.15 (.89)	.16 (1.01) [1]	.01 (1.08)	-.11 (1.08)	3; 423	2.63*
Impulsiveness	-.14 (.95)	.19 (.96) [1]	-.04 (1.14)	-.18 (1.11)	3; 423	3.52*
Extraversion	-	-	-	-	-	-
Warmth	.13 (.97) [3]	.03 (.95)	-.26 (1.13)	-.13 (.99)	3; 423	2.90*
Positive Emotions	.13 (.92) [3]	.05 (1.02)	-.26 (1.09)	-.11 (.97)	3; 423	2.86*
Openness to Experience	.17 (.99) [3]	-.00 (.98)	-.30 (1.07)	-.06 (.88)	3; 423	3.82**
Aesthetics	.21 (.96) [3]	-.01 (.97)	-.35 (1.09)	-.06 (.90)	3; 423	5.42**
Feelings	.22 (.94) [3]	.01 (1.01) [3]	-.38 (1.00)	-.15 (.96)	3; 423	6.49**
Values	.12 (.97) [3]	.00 (.99)	-.34 (1.10)	.07 (.87)	3; 423	3.67**
Agreeableness	.18 (.97) [3]	-.04 (1.01)	-.18 (1.09)	-.14 (.88)	3; 423	2.92*
Trust	.20 (.93) [3]	-.03 (.98)	-.22 (1.17)	-.09 (.90)	3; 423	3.48**
Tendermindedness	.20 (.93) [3]	-.07 (1.02)	-.20 (1.08)	-.12 (.91)	3; 423	3.57**
Conscientiousness	.11 (.94) [3]	-.02 (.94)	-.31 (1.04)	.17 (1.14) [3]	3; 423	3.53*
Achievement Striving	.04 (.93) [3]	.04 (.97) [3]	-.33 (.99)	.16 (1.15) [3]	3; 423	3.39*
Self-Discipline	.20 (.95) [3]	-.08 (.98)	-.39 (1.00)	.19 (1.02) [3]	3; 423	6.84**

* The table show Z-transformed values. Elevated numbers indicates between which clusters a significant mean difference was observed (posthoc = Tukey HSD) * $p < .05$; ** < .01.

But the variance-analysis also demonstrated that furrows were associated with mean differences between clusters that had the same crypt structure. For example, subjects in cluster 1 and 2, which both contained individuals with a *dense* crypt structure, scored differently on the Neuroticism domain as well as the facet scale Impulsiveness in this domain. The individuals in cluster 1 who had *few* furrows, scored significantly lower than individuals in cluster 2 who had *many* furrows. Likewise, subjects in cluster 3 and 4, which both contained individuals with an *open* crypt structure, scored differently on Conscientiousness domain as well as the facet scales Achievement-striving and Self-discipline in this domain. The individuals in cluster 3 who had *many* furrows, scored significantly lower than individuals in cluster 4 who had *few* furrows. Furrows were thereby associated with mean differences between clusters that had the same crypt structure, and the direction of these associations was consistent with the significant association found between furrows and Neuroticism, Impulsiveness and Self-Discipline in the variable-oriented analysis.

Especially noteworthy was that mean differences emerged on behaviors that were *not* significantly associated to crypts in the variable-oriented analysis. Mean differences between clusters 1 and 3 were observed for Values in the Openness to experience domain, as well as the Conscientiousness domain and the facet scales Achievement-striving and Self-discipline in this domain. These traits were not significantly associated to crypts in the variable-oriented analysis.

Table 5. The effect size for all associations that was significant in the variable –and person-oriented analysis

	Cohen's *d*					
	Variable-oriented analysis[1]		Person-oriented analysis[2]			
	Pearson Correlations		Cluster	Cluster	Cluster	Cluster
Personality measure	Crypts	Furrows	1 & 2	1 & 3	2 & 3	3 & 4
Neuroticism	-	.22*	.33*	-	-	-
Impulsiveness	-	.30**	.36*	-	-	-
Extraversion	-	-	-	-	-	-
Warmth	.30**	-	-	.37*	-	-
Positive Emotions	.26**	-	-	.39*	-	-
Openness to Experience	.20*	-	-	.47**	-	-
Aesthetics	.26**	-	-	.55**	-	-
Feelings	.28**	-	-	.62**	.40*	-
Values	-	-		.44**	-	-
Agreeableness	.20*	-	-	.36*	-	-
Trust	.22*	-	-	.39**	-	-
Straightforwardness	.20*	-	-	-	-	-
Tendermindedness	.26**	-	-	.41**	-	-
Conscientiousness	-	-	-	.42*	-	.44*
Achievement Striving	-	-	-	.38*	.38*	.49*
Self-Discipline	-	.24**	-	.61**	-	.57**

* $p < .05$; ** $p < .01$. [1] Cohen's $d = 2r / \sqrt{(1 - r^2)}$ were r is the Pearson correlation; [2] Cohen's $d = M_1 - M_2 / \sigma_{pooled}$, were M_1 is the mean in one of the cluster and M_2 is the mean in the other cluster. σ_{pooled} is the pooled standard deviation for the two clusters ($\sigma_{pooled} = \sqrt{[(\sigma_1^2 + \sigma_2^2) / 2]}$).

The effect sizes for all associations that were significant in the variable –and person-oriented analyses are presented in Table 5. Overall, the effect sizes in the person-oriented analysis were about twice as large as in the variable-oriented analysis.

Discussion

The introduction in this study reviews several possible biological pathways that theoretically could explain an association between iris characteristics and personality. In order to more fully evaluate a potential role by the neurodevelopmental control gene Pax6 we tested three hypotheses by performing both variable- and person-oriented analysis. These hypotheses draw heavily on Pax6 expression pattern in the human iris (Davis-Silberman et al., 2005; Jensen, 2005; Sale et al., 2002) as well as the anterior cingulate cortex as documented by Ellison-Wright et al. (1999) in conjunction with the findings made by Pujol et al., (2002) and Davidson et al., (1992, 1999, 2001). The specificity of the hypotheses predictions increased, and if all off them were found to be correct, then the likelihood that Pax6 would be involved, was expected to increase.

Our first hypothesis, that most of the associations with personality would be with crypt frequency, was confirmed. Furthermore, our second and third hypotheses were also confirmed; crypts were primarily associated with approach-related behaviors and individuals with a dense crypt structure scored higher than those with an open crypt structure on such behaviors. Thus, the findings in the variable-oriented analysis suggest that crypt frequency, probably via subtle Pax6 differences, induce tissue deficiencies in the left anterior cingulate cortex, which in turn influence the extent individuals engage in approach-related behaviors.

The results in the person-oriented analysis supported this notion, as the findings were essentially the same. Clusters with less tissue loss in the iris were associated with higher scores on approach-related behaviors and the significant mean differences between clusters 1 and 3 were systematically pinpointing such traits, i.e., Warmth, Positive Emotion, Feelings, Agreeableness, Trust and Tendermindedness (see Table 4).

But maybe the most intriguing finding was that also smaller tissue differences than crypts were of major importance. This was apparent in three different ways. First, the association between furrows and the facet scale Impulsiveness in the variable-oriented analysis were just as strong as the strongest association found for crypts. Second, in the person-oriented analysis furrows could differentiate between individuals who scored high and low on the Neuroticism and Conscientiousness domain, even when the individuals in these clusters had the same crypt structure. Third, when the combined effect of having specific configurations of crypts *and furrows* was taken into consideration in the person-oriented analysis, the effect sizes were on average about twice as large as in the variable-oriented analysis. Thus, it is apparent that even smaller tissue differences than crypts were of importance. Naturally emerging configurations of both crypt and furrows were, as expected, pinpointing subgroups of individuals that were especially likely to differ in their personality. Indeed, when both crypt and furrows were taken into consideration in the person-oriented analysis, mean differences in *all* main domains of personality emerged.

Overall, these findings support the notion that people with different iris configurations tend to develop along different trajectories in regards to personality. Furthermore, the self-organizational properties of the developmental system that are reflected in the iris appear to be quite efficient in pinpointing the individuals who differ in their personality. The effect sizes between the clusters in the person-oriented analysis ranged from *d* = .33 - .62, which is much larger than, for example, women's tendency to be more emotional than men, *d* = .05 - .30 (Brebner, 2003).

When considering which approach-related behaviors were most salient in the variable-oriented analysis, it was apparent that a group of five approach-related traits i.e., Feelings, Tendermindedness, Warmth, Trust and Positive Emotions, was driving the significant associations in the main domains. Both the significant associations with the facet scales in the Openness to Experience and Agreeableness domain in suggest that. People with a dense structure were more receptive to their inner feelings as well as tended to sympathize, and feel concern for other peoples need, more than people with an open crypt structure. Furthermore, the most robust results for crypt frequency suggest that people with a dense structure form warmer and more trustful attachments to others, as well as experience and express positive emotions such as joy, happiness and excitements, more often than those with an open crypt structure. Crypt frequency was thereby predominately associated with facet scales that tap the emotional space in the Extraversion, Openness to Experience and Agreeableness domains. Thus, tissue loss in the two top cell layers in the iris, as assessed by our crypt measure, is in this general sense most strongly associated with the emotional component of personality.

However, contraction furrows, which measure the thickness and density differences in all five cell layers in the iris, also appears to be associated with emotional functioning. Furrows were primarily associated with Impulsiveness, and people with many contraction furrows were less able to control their cravings and urges, than people with few contraction furrows. Thus, the variable-oriented analysis revealed that the behavioral impact of the two iris characteristics differs. Crypt frequency is most strongly related to the emotional space in the Extraversion, Agreeable and Openness to Experience domains, whereas the effect for contraction furrows is more specific, and relates directly to impulse control.

It is therefore interesting to note that when the principles of self-organizations were applied in the person-oriented analysis (Bergman et al., 1997), the configurations of iris characteristics that naturally emerge pinpointed clusters of individuals that scored significantly different on the Conscientiousness domain – a domain that was unrelated to the iris characteristics in the variable-oriented analysis. At first sight this may not be surprising since the inability to resist impulses, or poor self-control, generally also influences the active process of planning, organizing, and carrying out tasks, which are basic tendencies in the Conscientiousness domain (Costa et al., 1992). However, the fact the relationship with Conscientiousness domain *only* was possible to identify when both crypt *and furrows* were taken in consideration, suggest two things that previously have not been recognized. First, *small differences* in the extent people engage in approach-related behaviors - as assessed by crypt frequency – matters for how poor impulse control influences the Conscientiousness domain. Second, crypt frequency identifies *for whom* poor impulse control most likely also result in a tendency to score low on the Conscientiousness domain. Thus, given that it has been difficult to replicate associations between single genes and personality traits influenced by impulsive behavior (Persson et al., 2000; Reif et al., 2003), and that single genes generally explain less than 1.5% of the variance for a personality trait (Comings et al., 2000), our crypt frequency scale may be helpful to use in future association studies. If not considered, crypt frequency may mask potential association between candidate genes that potentially could influence the Conscientiousness domain, and potentially many other behavioral traits that *in part* are dependent on the individuals ability to exercise self-control

(Schmeichel and Baumeister, 2004). However, if the crypt frequency scale is considered, or even better, if the genes that determine crypt frequency can be identified, this may help to find genes that add up in their effect, which eventually can account for a greater proportion of the genetic variance that influence personality as well as other behaviors (Comings et al., 2000; Schmeichel et al., 2004). Thus, future association studies may be more fruitful, and their result more applicable on the individual level, if iris data is considered. The fact that people with different iris configurations tend to develop along different trajectories, and that the self-organizational property's of the developmental system that are reflected in the iris are quite efficient in pinpointing the individuals that differ most in their personality, also supports this notion.

The behavioral findings in this study suggests that because Pax6 induces tissue deficiencies in both the iris (Davis-Silberman et al., 2005) and the left anterior cingulate cortex (Ellison-Wright et al., 2004), it may influence the extent people engage in approach-related behaviors (Pujol et al., 2002). Indeed, there is a substantial body of research that supports this notion. For example, positive emotions experienced by monkeys increased the left-sided activation of their brain (Kosslyn et al., 2002). People with a positive disposition show greater relative left frontal EEG asymmetry at baseline and respond stronger to positive stimuli than to negative ones (Sutton and Davidson, 1997; Wheeler et al., 1993). Ten month old infants that do not cry when they are separated from their mothers exhibited more left-brain activation (Fox and Davidson, 1987). The thresholds for experiencing positive emotions is lower for people who display a left-sided activation pattern (Fox and Carlkins, 1993). In addition, these left-sided patterns are stable in both early childhood (Fox et al., 1992) and adulthood (Davidson, 2003). Thus, frontal brain asymmetries are exhibits enough stability and consistency to be considered an underlying biological disposition (Buss and Larsen, 2005).

Overall, these findings correspond well with our finding as well as the fact that the principal distribution and depth of crypts are present at birth (Oyster, 1999).

Furthermore, our Conscientiousness and Impulsiveness findings are also supported by previously published results. The anterior cingulate function at large is to integrate attentional and affective information that is critical for self-regulation, adaptability and it plays a crucial role in initiation, motivation and goal-directed behaviors (Devinsky et al., 1995; Thayer and Lane, 2000). The *ventral* region (BA 24a-c, 25, 32, 33) is primarily involved in assessing the salience of emotions, hurtful rejections and romantic love, for example, as well as the regulation of emotional responses involved in social interactions which assess one's own and other people's emotions and states of minds (Bartels and Zeki, 2000; Eisenberger and Lieberman, 2004; Simmons et al., 2005). The *dorsal* region (BA 24b'-c', 32') is primarily involved in response selection and the processing of cognitively demanding information. For example, the cognitions that are activated in reward related conflicts and the evaluation of different outcomes are processed in the dorsal anterior cingulate (Bush et al., 2000). Furthermore, damage to the anterior cingulate is associated with a host of social affective impairments including blunted affect, impulsivity, disinhibition and poor social judgments (Devinsky et al., 1995; Heyman et al., 1999). Thus, since process of planning, organizing and carry out tasks and resist impulses is so central for anterior cingulate functioning at large, as well as for the Conscientiousness domain, it is not surprising - given the expression pattern of Pax6 in the iris and brain - that individuals with different configurations of crypt and furrows scored differently on this domain.

These findings in conjunction with our findings indicate that there are relatively large literatures that support the notion that tissue loss in the iris potentially can be associated with tissue loss in the brain. However, there are also other biological pathways that may contribute to the associations found. As mentioned in the introduction, tissue differences in the iris may be associated with both brain structures *and* neurotransmitters that influence personality. The fact that even small differences in the monoamine systems during the embryological development of the brain has the strongest influence on the neural development of the anterior cingulate cortex, effects that persists into adulthood, further underscores this possibility (Levitt et al., 1997).

Thus, to elucidate these genetic developmental complexities additional studies are needed. However, given that the genetic complexities that underlie, the appearances of crypt and furrows probably are difficult to dissect (Aota et al., 2003; Davis-Silberman et al., 2005). It may be fruitful to investigate to what extent crypt and furrows can be a useful biomarker in its own right. The following highlights three areas were it may be especially rewarding to further investigate the usefulness of the iris as a biomarker:

MRI-studies can identify the extent crypt and furrows are associated with structural difference in the anterior cingulate cortex. Thus, crypt and furrows could potentially be biomarkers for developmental brain differences in large samples, would it not be too expensive and time consuming to collect MRI data of the brain. In contrast to MRI data, it takes about 3 min per person to take the digital photos needed, which readily can be rated automatically by an iris scanner once the algorithm currently used for personal identification (Daugman, 2003) is been modified to fit this purpose (J. Dougman, personal communication, July, 2, 1999). Such efforts would make it possible to study many neurodevelopmental questions that today are “impossible” to study in large samples. For example, does the behavioral meaning of having genes that influence the dopamine, serotonin and noradrenalin systems (Comings et al., 2000), change when the structure of the brain shifts?

Longitudinal-studies: Iris data may be able to map out how impulsive and approach-related behaviours of genetic origin, in interaction with environmental factors, influence dyadic relationships between family members. For example, it would be interesting to find out if scores on child disclosure, parental solicitation, parental control, parental support and parents' bad reactions to disclosure, differ from what is normal, in parental-child dyads where there is a low concordance between the child and the parent iris configurations. The fact that the expression pattern for Pax6 in the brain overlaps with the cortical foundation for maternal behaviors (mainly BA 24/32 and 47) and hurtful rejections (BA 24/32), in conjunction with our results in regards to approach-related and impulsive behaviors, suggests that the iris can be useful marker for biological mechanisms that influence the interaction between such child –and parent based behaviors (Eisenberger et al., 2004; Kerr and Stattin, 2003; Lorberbaum et al., 2002; Neiderhiser et al., 2004).

Twin-studies: The monozygotic (MZ) intra-pair twin correlation for crypt, pigment dots and furrows is .66, .58 and .79, respectively (Larsson et al., 2004). Thus, given that it actually is quite common, at least in some MZ pairs to observe intra-pair differences that are relatively large, especially in regards to crypt and pigment dot, and smaller iris differences than this were associated with personality differences in our sample, it is quite possible that small MZ intra-pair iris differences could contribute to *nonsystematic* nonshared environmental effects for personality, that is, random embryological events that make MZ twin less similar. In any event, since there is a quest for more theory an research in this area (Plomin et al., 2001; Plomin and Daniels, 1987; Turkheimer and Waldron, 2000). It is worth mentioning that by collecting iris data from MZ twins it may be possible to learn more about how non-systematic nonshared environmental effects, influence personality as well as other behaviors.

In conclusion, our hypothesis was largely confirmed. Crypts frequency is likely, via Pax6, to be associated with tissue deficiencies in the left anterior cingulate cortex, which in turn influences the extent individuals engage in approach-related behaviors. Furthermore, the self-organizing property of the developmental system that is reflected in the iris appears to be quite efficient in pinpointing individuals who differ in their personality. When both crypt and furrows were taken into consideration in the person-oriented analysis, mean differences in *all* main domains of personality emerged. Furthermore, the effect sizes in the person-oriented analysis were about twice as large as in the variable-oriented analysis. Overall, these findings support the notion that people with different iris configurations tend to develop along different trajectories in regards to their personality. Thus, it may be fruitful to investigate further the usefulness of the iris as a biomarker within a holistic interactionistic framework, using both variable -and person-oriented approaches. Future genetic association studies as well as MIR-, longitudinal- and twin-studies may benefit from collecting iris data and testing candidate genes for crypt and contraction furrows.

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