FACULTY OF PSYCHOLOGY AND EDUCATIONAL SCIENCES

SCHIZOTYPAL EMOTION PERCEPTION AND THE ROLE OF NORADRENALINE

THE HIDDEN FACES OF NEUTRALITY

Word count: 17,054

Nora Tuts
Student number: 01509243

Supervisor(s): Dr. Julie Hall, Prof. Dr. Ruth Krebs

A dissertation submitted to Ghent University in partial fulfillment of the requirements for the degree of Master of Science in Psychology (Clinical Psychology)

Academic year: 2018 – 2020

GHENT UNIVERSITY

Acknowledgements

In choosing this thesis topic, I was immediately drawn to the combination of a clinical and neurological aspect. Admittedly, my name appearing in the title may have played a part. You could say it called out to me. I anticipated a challenging yet educational process, filled with ups and downs and diversions, and it did not disappoint. I would not have made it this far without the help of a few important people, for which some thank yous are in order.

To Leila Van Imschoot, with whom I shared this journey, for helping me stay afloat when I was having trouble keeping my head above water. To my promotor, Dr. Julie Hall, for the consistent support and guidance throughout this two-year long process. Also to Prof. Dr. Ruth Krebs and the greater UGent institution for providing this opportunity.

Thank you to those who stand closest to me for not only tolerating me during these demanding weeks but for consistently proving that I am so lucky to be surrounded by the people I am surrounded by. To my parents, who are physically further away but still dropped everything to proof-read the final version – I am immensely grateful for all the years of encouragement. These past five years have been a privilege.

Preamble concerning COVID-19

When the COVID-19 outbreak resulted in an abrupt cancellation of all academic activities, we were still in the midst of testing participants. Although the termination occurred when we were only 6 participants away from our intended sample size, it further prevented us from compensating for the participants whose data we were unable to use due to coding malfunctions. Seeing as these lost data were limited to only one of the three variables of interest, we were able to perform most of the necessary statistical analyses, albeit with a slightly smaller general sample size and a much smaller sample size for the variable whose data was unusable. In conclusion, the COVID-19 outbreak only partially affected us from attaining our initial goals, for which we believe we were only moderately limited in the completion of this thesis.

This preamble was drawn up in consultation between the student and the supervisor and was approved by both parties.

Corona Verklaring Vooraf

Toen de uitbraak van COVID-19 resulteerde in een abrupte afbouw van alle academische activiteiten, waren we nog volop participanten aan het testen. Hoewel de stilstand plaatsvond toen we slechts 6 deelnemers verwijderd waren van de beoogde steekproefomvang, heeft het ons verder belet om te compenseren voor de proefpersonen waarvan we de gegevens niet konden gebruiken vanwege een coderingsdefect. Aangezien deze verloren data beperkt was tot slechts één van de drie onderzochte variabelen, konden we de nodige statistische analyses grotendeels uitvoeren, zij het met een iets kleinere algemene steekproefomvang en een significant kleinere steekproefomvang voor de ene afhankelijke variabele waarvan een deel van de data onbruikbaar was. Concluderend kan worden gesteld dat de COVID-19 uitbraak ons slechts gedeeltelijk heeft belet bij het bereiken van onze oorspronkelijke doelstellingen, waardoor we naar onze mening slechts matig beperkt waren in de voltooiing van deze masterproef.

Deze preambule werd in overleg tussen de student en de promotor opgesteld en door beide goedgekeurd.

Abstract

Schizotypy is a term used to describe a combination of characteristics that are qualitatively similar to psychotic disorders but whose presence is quantitatively less profound. Previous research has shown that the presence of schizotypal traits can alter the processing of emotions, in that these individuals tend to evaluate emotional expressions more negatively. Many inconsistencies remain surrounding the association of these alterations with specific traits and specific emotions. Furthermore, to this date no consensus has been reached regarding the most suitable way of conceptualizing schizotypy and on its possible etiological factors. In this study, we aimed to further clarify schizotypal emotion processing while considering a possible noradrenergic basis of schizotypy. Using the Oxford-Liverpool Inventory of Feelings and Experiences and a morphed faces paradigm, we investigated whether high scorers on these subscales differentially evaluated facial expressions of different emotions and intensities. We simultaneously measured pupillary responses as a proxy for noradrenaline levels. We found that only higher scorers on the impulsive nonconformity subscale tended to evaluate facial expressions more negatively but did not find indications that high schizotypy individuals processed facial expressions more slowly. We were unable to substantiate the noradrenaline hypothesis of schizotypy but found indications that noradrenaline may play a role in emotion processing. As we are the first to study this combination of factors, these findings may be an initial indication of possible relations between schizotypy, noradrenaline and emotion processing, which can be further elaborated on in future research.

Samenvatting

Schizotypie is een term die wordt gebruikt om een combinatie van kenmerken te beschrijven die kwalitatief vergelijkbaar zijn met psychotische stoornissen, maar waarvan de aanwezigheid kwantitatief minder uitgesproken is. Eerder onderzoek heeft aangetoond dat de aanwezigheid van schizotypische kenmerken de verwerking van emoties kan aantasten, in die zin dat deze personen de neiging hebben om emotionele uitingen negatiever te evalueren. Er heerst nog onduidelijkheid omtrent de samenhang met specifieke eigenschappen en emoties. Daarnaast is het tot op heden onbeslist wat de meest geschikte manier is om schizotypie te conceptualiseren en wat de potentiële etiologische factoren zijn. Door middel van deze studie hebben we getracht om schizotypische emotieverwerking verder te verduidelijken en een mogelijke noradrenerge basis van schizotypie te onderzoeken. Met behulp van de 'Oxford-Liverpool Inventory of Feelings and Experiences' vragenlijst en 'morphed-faces' onderzochten we of hoogscoorders op deze subschalen gelaatsuitdrukkingen van verschillende emoties en intensiteiten anders beoordelen. Tegelijkertijd registreerden we de pupilreacties ter bepaling van de noradrenaline gehaltes. De resultaten suggereren dat enkel hoogscoorders op de impulsieve nonconformiteits-subschaal de neiging hebben om gelaatsuitdrukkingen negatiever te beoordelen, we vonden echter geen aanwijzingen dat schizotypische kenmerken samenhangen met een langzamere verwerking hiervan. Onze resultaten kunnen een noradrenaline hypothese van schizotypie niet verder onderbouwen, maar tonen wel aan dat noradrenaline een mogelijke rol speelt in emotieverwerking. Aangezien wij de eerste zijn die deze combinatie van factoren bestuderen, vormen deze bevindingen mogelijks een aanvankelijke indicatie van de potentiële relaties tussen schizotypie, noradrenaline en emotieverwerking, dat verder kunnen worden uitgewerkt in toekomstig onderzoek.

Table of Contents

Many of us recognize the experience of briefly thinking that a pile of clothes on a chair is a person, have trouble staying focused, have had the urge to break something, or do not actually enjoy trying new foods. While some of these experiences may be very common, and some may occur less frequently, it may be surprising to read that all can be classified as 'psychotic-like'. The most commonly used term for this conglomerate of experiences is Rado's *schizotypy*, formed from a contraction of the words "schizophrenic" and "phenotype" (Rado, 1953). A common societal misconception is that schizotypal experiences, such as illusions or hallucinations but also lack of self-control, disorganized thoughts or lack of pleasure, are only experienced by people carrying a diagnostic label. However, there is growing evidence, and acceptance, for such experiences in sub-clinical individuals. A cross-national study recorded a mean lifetime prevalence of psychotic-like experiences of 5.8 % (McGrath et al., 2015), with other studies recording an even higher prevalence such as 17.5% in the Netherlands NEMEIS study (Van Os, Hanssen, Bijl & Ravelli, 2000) and up to 75% in a large UK sample (Pechey & Halligan, 2012). Despite methodological differences playing a role in the notable discrepancy between these values, all values imply a significant portion of the population, which testifies to the importance of exploring the implications of these experiences.

In this paper, we first discuss the traits that characterize schizotypy and the models that have been constructed to help conceptualize it, before taking a closer look at a specific aspect of day-to-day life that may be different in schizotypal individuals. We then consider a possible neurochemical basis to schizotypal traits and touch on the way in which this may alter their experiences. Finally, we discuss the aim of this study and its relevance in the broader literature.

What Is Schizotypy?

Schizotypy has similarities with the psychotic illnesses that warrant a diagnosis, but at a sub-clinical level and with less intrusive repercussions for the daily lives of these individuals (Grant, Green & Mason, 2018; Mohr & Ettinger, 2014). The typical characteristics that are combined under the term schizotypal traits can generally be classified into different symptom-based clusters. Examined with respect to the affected domains, the symptoms can be grouped into features concerning personality, cognition and perception. The personality traits include suspicious, paranoid and other schizophrenia-related personality features. The cognitive features include subtle

difficulties in organizing and expressing thoughts coherently, problems with sustained attention and executive functioning, as well as certain deficits in social cognition and emotion processes. With regard to perception, differences concerning audio-visual stimuli and internal proprioceptive signals have been noted (Lenzenweger, 2018). Alternatively, the symptoms can be classified with respect to the nature of the experiences, spanning across the affected domains described above. This method results in a positive dimension (aspects that are 'added to' the life experience, aspects that are usually not present), a negative dimension (elements that are usually present in daily life but seem to be absent in this group) and a cognitive disorganization dimension (Kwapil & Barrantes-Vidal, 2014; Mason & Claridge, 2006). The positive dimension includes the more psychotic-like features: odd beliefs, magical ideation, delusions, perceptual sensory irregularities such as illusions or hallucinations, and paranoid ideas. The negative dimension consists of features such as flattened affect, disinterest in others, deficits in energy and motivation, and poverty of speech. The disorganization dimension includes mild trouble with organizing and expressing thoughts and behavior as well as more extreme features such as formal thought disorder and severely disorganized actions (Kwapil & Barrantes-Vidal, 2014). This three-factor structure has been replicated in the majority of factor-analytic studies. Other studies, however, indicate a fourth, fifth or even sixth dimension. For instance, an impulsive nonconformity dimension is sometimes included as it may cover specific aspects which the other dimensions fail to adequately encompass (for a review on the dimensions see Fonseca-Pedrero, Garcia-Cueto, & Muñiz, 2007).

Support for a dimensional classification can be found in the differential relations between the currently speculated dimensions and various psychological factors surrounding affect, cognition and social functioning, among others (for a review see Kwapil & Barrantes-Vidal, 2014; Lenzenwegger, 2018). The majority of studies suggest that the relative dominance of various traits have differential effects on the functioning of the individual, which illustrates that approaching schizotypy as a whole construct without considering the dimensions is insufficient. In other words, despite the lack of a global consensus, it can be generally agreed that schizotypy is inherently multi-dimensional.

Models of schizotypy.

Various experts have developed models that aim to further conceptualize the term Rado (1953) introduced as schizotypy. A first model was proposed by Meehl (1962),

which assumes that individuals presenting these characteristics carry a genetic predisposition to a neural defect dubbed “schizotaxia”, which in turn could lead to a schizotypal personality organization or even schizophrenia (Meehl, 1962, p. 830). It was later nuanced into a ‘quasi-dimensional’ model by Claridge (1997), as it considers a continuum in relation to the severity of schizotypal traits, but only considers this continuum to exist in the realm of illness (Grant, Green, & Mason, 2018). Indeed, within this quasi-dimensional model, these characteristics are always seen as abnormal. On the contrary, the ‘fully-dimensional’ model, suggested by Eysenck (1952) and later further established by Claridge (1996), considers these same traits as part of the “natural variation in brain functioning” (Grant et al., 2018, p. S557). In this perspective, clinical conditions with psychotic aspects (such as schizophrenia or Schizotypal Personality Disorder, among others) are placed at the extreme of a continuum that exists in both realms, health and illness. This means that the same psychotic aspects can be present in healthy individuals, naturally to a lesser extent. Specifically, the transition from health to illness is influenced by a wide range of biological and psychological factors, in contrast to the mainly genetic approach adopted by Meehl (1962) (for a review on these models, see Grant et al., 2018).

Grant and colleagues (2018) stress the importance of clearly stating the theoretical model that an investigation is based on. Thus, this paper will be written based on the fully-dimensional model, in which we consider the definition of schizotypy as “a range of enduring personality traits, reflected in cognitive style and perceptual experiences, arising from a combination of polygenetic and environmental determinants, which are normally distributed within the general population” (Grant et al., 2018, p. S558). Furthermore, we take the established differential effects of various schizotypy traits into account by approaching schizotypy as a dimensional construct. By means of the current research, we aim to shed light on what is known to this date about the differential effects of schizotypy dimensions on emotion processing.

Emotion Processing and Schizotypal Traits

The characteristics of schizotypy, described in the first section of this paper, include differences in social cognition and emotion processes as well as differences in perceptual experiences. This study aims to explore whether a propensity to schizotypal experiences has implications on emotion perception, to shed light on a possible

neurochemical basis of this relationship, and to highlight the importance of any possible emotion perception anomalies found.

The majority of existing literature suggests poorer recognition of emotions in people with schizotypy (Abbott & Green, 2013; Brown & Cohen, 2010; Germine & Hooker, 2011; Morrison et al., 2013; Williams et al., 2007). Morrison et al. (2013) notably reported medium range effect sizes regarding the relative inaccuracy of facial affect recognition between a schizotypy group and a control group. Results indicate a bias towards the recognition of negative emotions (i.e. “Anger”, “Disgust”, “Fear”, “Sadness”) in high scorers on schizotypy scales, labeling positive facial expressions (i.e. “Happiness”, “Surprise”), and especially neutral facial expressions, as more negative than control groups (Brown & Cohen, 2010; Williams et al., 2007). In the experiment conducted by Brown and Cohen (2010), the schizotypy group performed worse than the control group in recognizing emotions, particularly in the face of low intensity expressions, as well as in identifying neutral faces. In making valence evaluations of the faces, the authors found no significant differences between the two groups. However, post-hoc analyses led to the identification of correlations between valence ratings and specific dimensions, such that higher disorganization scores were related to more negative ratings of facial expressions. In terms of reaction times, they similarly found no significant group difference but did find that higher scores on the negative dimension were related to a quicker labeling of faces. Importantly, seeing as facial recognition accuracy, reaction times and valence were not correlated, Brown and Cohen (2010) were able to show that mutual associations between their dependent variables did not account for the achieved findings, allowing for the results to be more conclusively interpreted as an effect of schizotypal traits.

Other studies also highlight the variation of facial expression perception depending on the types of schizotypal traits expressed, although the specifics of the variation remain unclear due to inconsistent results. One study found a negative association between all three dimensions (positive, negative and cognitive disorganization) and emotion recognition accuracy (Germine & Hooker, 2011). Contrarily, other studies only found the same negative association regarding the negative dimension (Abbott & Green, 2013; Morrison et al., 2013; Williams et al., 2007) or regarding the cognitive disorganization dimension (Brown and Cohen, 2010). With respect to reaction times similar incongruencies are present. Contrary to the findings published by Brown & Cohen (2010), individuals with a familial high risk for schizophrenia needed more time to label facial emotions (Eack et al., 2010). Despite this difference,

both studies reported a negative bias in the attribution of emotions to neutral faces. Notwithstanding the unclarity regarding the role of each dimension, an association between schizotypy and reduced facial emotion recognition accuracy is clear in all of the aforementioned studies (for a more detailed review, see Statucka & Walder, 2017 or Giakoumaki, 2016). Although the inconsistencies limit our ability to draw conclusions, they simultaneously demonstrate that a unidimensional approach to schizotypy would result in a loss of important information regarding the relationship between specific schizotypal traits and emotion recognition. Making a distinction between schizotypal trait clusters when analyzing results is essential when aiming for comprehensiveness.

The importance of this type of research is further demonstrated in studies including functional outcome measurements. For example, Brown and Cohen (2010) found a correlation between more negative valence evaluations of emotional faces and lower subjective ratings of quality of life. They further suggested that the biased interpretation of facial emotion expressions could play a role in social misunderstandings, misinterpretations of intentions and difficulties understanding social situations or predicting the behavior of others. Similarly, Abbott and Green (2013) found associations between impaired affect discrimination and subclinical measurements of social anxiety in individuals with high scores on negative schizotypy, adding that this could reflect a risk for social isolation and/or communication problems. Aguirre et al. (2008) hypothesize that impaired emotion perception may affect their ability to start or keep friendships by the failure to make sufficient empathic comments. A similar connection between empathic accuracy and social functioning was found, where deficits in affective empathy served as a mediator between negative schizotypy and impaired social functioning (Hengry, Bailey, & Rendell, 2008). The deduction that these emotion processing differences may not be so harmless justifies our choice to focus on this aspect of day-to-day life in the current study.

Etiology of Schizotypal Traits

We mentioned earlier that this paper considers a possible neurochemical basis for differences between people who express low versus high levels of schizotypal traits. The definition of schizotypy considered in this paper (see page 3) states that schizotypy arises from a "combination of polygenetic and environmental determinants" (Grant et al., 2018, p. S558). To this date, there is very little conclusive research on the etiology of schizotypal traits. In what follows, we attempt to summarize part of the existing literature

on this topic, motivate our focus on a neurochemical possibility and link this hypothesis to the functional impairments in terms of emotion processing.

Genetic research has led to the identification of various candidate schizotypy genes, of which the catechol-O-methyltransferase (COMT) gene has been studied most. A common variation leading to a valine (Val) to methionine (Met) substitution changes the functional activity of the enzyme it codes for. This enzyme is crucial for the breakdown of catecholamines such as dopamine (DA), adrenaline and noradrenaline (NA). The Val/Val genotype leads to higher activity of the enzyme, which in turn leads to a lower synaptic level of catecholamines and consequently results in a decline in catecholamine activity (Walter, Fernandez, Snelling, & Barkus, 2016). The high activity variant has been linked to higher levels of self-reported schizotypy (Avramopoulos et al., 2002; Schürhoff et al., 2007) and schizophrenia (for a review see Walter et al., 2016). Considering that there is substantial overlap between schizotypy and the clinical expressions of the same traits, the results concerning schizophrenia can shed light on the possible underlying processes that result in the presence of schizotypal traits. Accordingly, we can consider a link to the two-syndrome hypothesis of schizophrenia, which suggests that positive symptoms (including thought disorders and incoherent thinking) are caused by limbic catecholamine overactivity and negative symptoms (including cognitive impairment) are caused by prefrontal catecholamine underactivity (Yamamoto & Hornykiewicz, 2004). Given that COMT plays a role in various brain areas including a prominent role in the prefrontal brain (Chen et al., 2004; Smolka et al., 2005), the relation between COMT and schizophrenia as well as schizotypy is plausible (Avramopoulos et al., 2002).

The role COMT plays has largely been interpreted in relation to dopaminergic activity. The link between DA and schizotypy stems from the dimensional approach, leading authors to postulate that if DA has etiological connections to schizophrenia, as many studies have shown, it might also be linked to schizotypal traits (Mohr & Ettinger, 2014). Such research has shown a positive correlation between high scores on schizotypy and striatal presynaptic DA release (Woodward et al., 2011). More specifically, disorganized traits have been positively linked to D2 DA receptor availability (Chen et al., 2012), whilst stress-induced striatal DA release is positively correlated to a high score on negative schizotypy, but not on positive schizotypy (Soliman et al., 2008). As such, DA does not seem to explain all schizotypy symptoms, which suggests that other factors must be considered. As nicely stated by Mohr and Ettinger (2014, p. 7), “variance in schizotypy may be explained in part by alterations to the DA system. Of

course … the DA system does not act in isolation but in constant and complex interactions with other neurotransmitter systems".

One of the other neurotransmitter systems that may be involved in schizotypy is the noradrenergic system, a system that is also associated to COMT, as previously stated. Various researchers have developed theories on the role of NA given that this neurotransmitter can explain some aspects of schizophrenia that the dominant dopamine hypothesis of the time could not (Hartman, 1976; Hornykiewicz, 1982, 1986). For example, the dopamine hypothesis is unable to account for the delay of therapeutic effects given the immediate neurochemical changes implemented by dopamine enhancing drugs. Furthermore, increases in dopaminergic receptors may be solely related to the motor symptoms. Moreover, these increases may be a result of treatment and not an effect of the illness itself (Hornykiewicz, 1982). These complications suggest the involvement of other neurotransmitter systems.

Despite this growing interest, the role of NA remained unclarified. This led to a review article on the NA hypothesis of schizophrenia, written by two prominent researchers in this field who aimed to "correct the persistent neglect of NA" (Yamamoto & Hornykiewicz, 2004, p. 913). Evidence supporting this hypothesis included the differential effects that medication had on patients when targeting the noradrenergic versus the dopaminergic system (where results favored the former), the elevated levels of NA in schizophrenic patients (pre- and post-mortem), and a widespread presence of this catecholamine in the cortex and limbic forebrain (Yamamoto & Hornykiewicz, 2004). This is further supported by the wide range of cognitive functions NA is presumed to influence including, but not limited to, arousal, attention, novelty-oriented behavior, anxiety, fear and aggressiveness (Yamamoto & Hornykiewicz, 2004). Ten years later, Yamamoto, Shinba, & Yoshii (2014) published a review on the role of NA in schizophrenia, which showed that hyperactivity of the noradrenergic system better explained positive symptoms associated with schizophrenia than the overactivity of the dopaminergic system. This also applies to the hypoactivity of noradrenergic systems in comparison to dopaminergic systems and negative symptoms. This conclusion was supported by evidence obtained in various areas, including psychophysiological, psychopharmacological and biochemical studies (for a detailed overview of the results, see Yamamoto, 2013).

Further support for the suggested etiological role of NA has been found in studies that illustrate the role of prefrontal NA and cognitive functions in schizophrenia (for a review see Fitzgerald, 2014). Fitzgerald states that NA could be an etiological factor in

“at least some cases of schizophrenia” and highlights that this does not imply that elevated NA stands alone in its etiological role but that it “may be an important, additional [factor]” (Fitzgerald, 2014, p. 501). As such, this NA hypothesis warrants future research, not only in relation to clinically diagnosed schizophrenia, but also in relation to schizotypal traits. This is especially important given the fact that studies conducted with schizophrenia patients suffer from confounding factors originating from the disease itself. Indeed, the elevated stress experienced or the administered neuroleptic treatment may be able to account for increased NA levels (Fitzgerald, 2014). The general lack of research surrounding the involvement of NA in non-clinical samples with schizotypal traits motivates our choice to focus on this neurochemical substance in the present study.

Noradrenaline and Emotion Processing

Besides including NA for its possible etiological role in schizotypal traits, we also seek to clarify its involvement in emotion processing. A previous study using a genetic approach found that a NA transporter gene may be one of the factors that modulates attention to facial expressions (Yang et al., 2016). Another study established a link between NA and attention to emotional stimuli by showing a greater increase in phasic NA in response to emotional stimuli than to neutral stimuli (De Martino, Strange & Dolan, 2008). NA further plays an important role in the processing of emotional information, possibly to accommodate for amygdala activation when presented with emotional stimuli (Van Stegeren et al., 2004) or to aid in response regulation to emotional stimuli (Outhred et al., 2013).

A handful of studies have investigated the relationship between drugs that are specific NA reuptake inhibitors (i.e. reboxetine) and facial expression recognition. In one study, a single dose of reboxetine seemed to improve recognition of happy facial expressions but did not aid in the recognition of other emotions (Harmer, Hill, Taylor, Cowe, & Goodwin, 2003). This effect persisted even when speed, memory, attention and subjective mood ratings were controlled for, further supporting an interpretation of the results from a neurobiological perspective. Another study found that the chronic administration of the same drug reduced the recognition of fear and anger (Harmer et al., 2004). Although we are left unable to form conclusions on the exact nature of the relationship between NA and emotion perception, there seems to be a reasonable amount of evidence pointing to an involvement of NA in facial expression recognition.

Moreover, we intend to investigate whether individual differences in facial emotion perception in people with schizotypal traits can be explained by altered NA activity. Relating back to the explanation of the potential role of COMT in the development of schizotypy, this enzyme is known to play a role in a variety of brain structures, including the amygdala (Smolka et al., 2005). Similarly, NA boasts a widespread innervation throughout the entire cortex as well as to several subcortical structures, an innervation that is generally denser than that of DA (Farley, Price, & Hornykiewicz, 1978; Yamamoto & Hornykiewicz, 2004). Hornykiewicz (1982, p. 484) even suggested that NA is a "'limbic monoamine' par excellence", explicitly associating it with the system responsible for our emotions. Currently however, this line of research has been explored to a lesser extent. By including a proxy for noradrenaline levels in this study we may be able to simultaneously provide further support for its involvement in emotion processes, schizotypy, and schizotypal emotion processing.

Contribution of the Current Study

Firstly, we aim to determine whether or not people with high scores on specific schizotypy dimensions evaluate emotional faces more negatively and more slowly than people with lower scores. Therefore, we extend Brown and Cohen's study (2010) with a few adaptations: we use a scale which is not only more suited for non-clinical populations but also ensures a consistent dimensional approach to schizotypy and employ an emotional paradigm more specific to this target population.

Earlier in this paper we discussed the lack of consensus on which model best describes schizotypal traits and on the dimensional structure of schizotypy. A contributing factor to the inconsistencies in existing literature is the fact that many studies are based on psychometrically-defined schizotypy, meaning the reported severity of schizotypy is based on the scores on the employed assessment instruments. However, each assessment instrument was developed based on a different model and therefore reflects the assumptions of that model. As a consequence, research results are influenced by the theoretical basis of each instrument while they intend to measure the same thing.

The Oxford-Liverpool Inventory of Feelings and Experiences (O-LIFE) was developed based on the fully-dimensional model, contrary to the Schizotypal Personality Questionnaire (SPQ), another popular diagnostic questionnaire that is based on the quasi-dimensional scale. The O-LIFE focuses on trait-based aspects of schizotypy, with

the intention to make it more suited for use in non-clinical populations (Mason & Claridge, 2006). This extension of its application to a broader target population is crucial when considering a fully-dimensional model. The O-LIFE items were derived from the results of what at the time of its construction, was the most extensive study of schizotypal traits (Mason & Claridge, 2006). It considers a four-component structure (positive, negative, cognitive disorganization and an additional dimension, impulsive nonconformity) in contrast to the SPQ which assesses a three-component structure (positive, negative, and cognitive disorganization). Seeing as the O-LIFE has been employed less frequently in previous literature, very little is known about the effects of this fourth dimension to this date. In the current study, we use the short O-LIFE (sO-LIFE) to measure schizotypal traits, given its foundations in the fully-dimensional model, broad scope and suitability for non-clinical samples.

We further stress the importance of a carefully selected emotional paradigm, as methodological differences may be a main source for the inconsistencies in the existing research surrounding schizotypal emotion processes. Most of the studies mentioned above used tests comprised of static high and low intensity emotional faces (Abbott & Green, 2013; Brown & Cohen, 2010; Morrison et al., 2013; Williams et al., 2007), with some studies using more difficult variations of this concept by morphing (Germine & Hooker, 2011) or degrading (van ‘t Wout et al., 2004) the emotional faces. Increasing the difficulty of the task is an attempt to improve ecological validity, as static faces are generally criticized for inadequately representing the facial expression perception that happens in everyday life. The possible influence of the type of stimulus is shown by the fact that certain studies that employ more complex stimuli, such as short audio/visual depictions of a social interaction, result in strikingly different findings (see Abbott & Byrne, 2013). The study that used degraded stimuli in an attempt to increase the difficulty of the task (a process which consists of filtering the faces to reduce the visual contrast), was one of the few that did not find any significant differences between the schizotypy and the control group (van ‘t Wout et al., 2004). In this case, it is possible that the results were undermined by floor effects, meaning the task was too difficult (Giakoumaki, 2016). Additionally, recognizing positive emotions may be easier than recognizing negative emotions, which may imply that certain items in tests might not be sensitive enough for the subtle differences between schizotypal and control groups (Williams et al., 2007).

In this light, we decided to use morphed facial expressions, where facial expressions of different intensities are created by morphing a neutral and an emotional expression. This makes it possible to control the degree of ambiguity for both positive

and negative emotions, slightly increasing the difficulty of the task and allowing us to more precisely explore the role of this ambiguity. We further include both negative and positive emotions to ensure a sufficient scope and increase sensitivity. As results show that schizotypy and control groups differ most in the perception of low-intensity and neutral faces, we focus on these types of faces as stimuli for a valence evaluation.

Secondly, we explore whether or not NA possibly plays an etiological role in schizotypal traits and whether or not it plays a functional role in the perception of emotions. To this end, we include a parallel exploration of this possible neurochemical basis through the incorporation of pupil response measurements which serve as a proxy measurement for NA.

In summary, this study is unlike others in our use of a more ecologically valid emotional paradigm, a more appropriate assessment instrument and a biochemical component approached by means of recent technology, to focus on an area of research that has proven significant to this specific population based on previous findings.

In line with other studies, we recognize the importance of research with schizotypy samples. On the one hand, research with this population is valuable in that it introduces a possibility to investigate shared aspects with psychotic disorders without the confounds of medication, social isolation or institutionalization (Abbott & Green, 2013). For example, given that various papers highlight that deficits in facial emotion recognition persist over time, regardless of possible symptomatologic improvements, the pervasive nature of these deficits suggests that they could be a trait-related vulnerability marker for the extreme expressions of the schizotypy spectrum (Aguirre et al., 2008; Bediou et al., 2007; Morrison et al., 2013; Penn, Sanna, & Roberts, 2008). On the other hand, research with schizotypy samples is important in relation to the real-world correlates within the daily life experiences of schizotypes themselves. It has been found that high scorers on schizotypy scales express more difficulties with psychosocial functioning, finding it harder to connect to others, reporting problems in their relationships with peers and family members, and sometimes experiencing long-term interpersonal complications as an effect of increased suspiciousness (Aguirre et al., 2008; Lenzenweger, 2018; Rosell et al., 2014). More objectively, even marriage rates are lower in people who score high on schizotypal traits (Lenzenweger, 2018). Given the importance of the recognition and interpretation of facial emotional signals on human social interactions (Aguirre et al., 2008), exploring emotional perception in healthy participants with schizotypal traits may aid in improving these social challenges. An understanding of the difficulties that at-risk individuals experience is crucial to any

attempts that aim to ameliorate their social experiences. Moreover, given that people who score high on schizotypal traits are at higher risk for developing psychotic illnesses, it is of high importance to find ways to improve the quality of their social interactions, as impaired social functioning could be a source of stress that in turn could predict psychosis conversion (Bediou et al., 2007).

Hypotheses

Evidently, the role of NA, as well as the emotional processing in people with schizotypy are still poorly understood. This study aims to clarify this gap in the literature, by investigating the three variables together, which will allow us to draw careful conclusions on the nature of the relationship between NA activity and emotional processes in people with schizotypal traits. The hypotheses of this paper are as follows:

(1) Higher scores on all dimensions of the sO-LIFE are associated with a more negative judgement of facial expressions in all emotional categories, given the negative bias associated to schizotypy. We expect that especially negative facial expressions and low intensity facial expressions are more negatively evaluated by high scorers on the sO-LIFE than low scorers.

(2) Higher scores on all dimensions of the sO-LIFE are associated with longer reaction times, given the general difficulty with neutral and ambiguous faces within schizotypy. We expect one exception to this trend, namely that individuals with higher scores on the negative schizotypy scale (*introvertive anhedonia*) will evaluate higher intensity faces portraying negative emotions (sadness, anger, disgust) faster in comparison to low scorers, given that their characteristics reflect a propensity towards negative affect.

(3) sO-LIFE scores are associated to pupil dilation values (as a proxy of NA). More specifically, we expect higher pupil dilation values in subjects with higher scores on the more positive schizotypy scales (mainly *unusual experiences*, but also *cognitive disorganization* and *impulsive nonconformity* as these more closely relate to the positive dimension [Mason & Claridge, 2006]) and lower pupil dilation values in subjects with higher scores on the more negative schizotypy scale (*introvertive anhedonia*). In relation to the facial expressions, we expect a greater pupil dilation in response to more intense, emotional faces than to less

intense emotional and neutral faces (Bradley, Miccoli, Escrig, & Lang, 2008; Duque, Sanchez & Vazquez, 2014; Wang et al., 2018).

Method

Sample

In the current study, 54 individuals between the ages of 18 and 35 (*M* = 24.67, *SD* = 4.12) participated (originally the study aimed for a sample size of 60 people, the COVID-19 outbreak in Belgium in March 2020 resulted in an abrupt limitation to the testing period). Of the 54 participants, 42 were female and 12 were male. Participants were recruited through the sampling platform connected to Ghent University (SONA System) and through social media groups. The exclusion criteria were a history of neuropsychiatric illnesses, ingestion of medicine with neurochemical effects (such as antidepressants of anxiolytics) and the necessity of glasses. Initially all volunteering participants were allowed to participate, but towards the end of the sampling period we switched to a heterogenous purposive sampling approach in an attempt to obtain greater variability in the sample. In this phase, participants were selected based on the criterium of at least one sO-LIFE subscale score that was at least one standard deviation higher than the mean (based on the findings published in Mason, 2006). Participants received a small reward of 10 euros following the completion of the experiment or were rewarded with a credit for an undergraduate psychology course. Written informed consent was obtained from all participants before study participation. Approval was granted from the faculty ethical committee prior to the commencement of the study.

Materials

Schizotypal traits.

The sO-LIFE is a questionnaire used to measure psychosis-proneness that is highly suited for non-clinical samples. It consists of four sub-scales: *unusual experiences, cognitive disorganization, introvertive anhedonia* and *impulsive nonconformity* (Mason & Claridge, 2006). It has an established high internal consistency (Mason, Claridge, & Jackson, 1995; Rawlings & Freeman, 1997), test-retest reliability

(Burch, Steel, & Hemsley, 1998) and factor validity (Mason, 1995). This short version consists of 43 yes/no questions, with sample items such as:

- "*When in the dark do you often see shapes and forms even though there is nothing there?*" (Unusual experiences)
- "*Are you easily confused if too much happens at the same time?*" (Cognitive disorganization)
- "*Are there very few things that you have ever enjoyed doing?*" (Introvertive anhedonia)
- "*Would you like other people to be afraid of you?"* (Impulsive nonconformity)

In addition, we selected the Positive and Negative Affect Schedule (PANAS) questionnaire (Crawford & Henry, 2004) as a supporting instrument to the sO-LIFE. It was also selected in function of a further exploration of the role of positive and negative affect states on emotion perception. The questionnaire consists of 20 items, in which respondents are asked to indicate the extent to which they felt a specific emotion over the past week on a 5-point scale (1: Very slightly or not at all – 5: Extremely). Results are given in the form of a *positive affect* score (PA) and a *negative affect* score (NA). This instrument has an established construct validity and reliability (Cloninger, Przybeck, & Svrakic, 1991; Crawford & Henry, 2004).

Noradrenaline levels.

Pupillometry has been established as an index for NA levels (Aston-Jones & Cohen, 2005; Gabay, Pertzov, & Henik, 2011; Koss, 1986). We measured the Task Evoked Pupillary Response (TEPR) using the EyeLink 1000 at a rate of 250 Hz in a windowless room with constant artificial lighting. Only the output for the right eye was used. Participants sat 57 cm away from a standard computer screen displaying the stimuli, using a chinrest to maintain this distance. A baseline pupil size was measured for each trial during a 200ms pre-stimulus interval while the participant focused on a fixation cross. The stimulus window in which we measured the pupil responses was 3000ms (the full timeframe in which the facial expression was presented). In accordance with the pupil data pre-processing method applied by Carsten, Desmet, Krebs & Brass (2019), EyeLink software (EyeLink Data Viewer 3.2.1, 2018) was used to restrict data to the baseline and stimulus segments and to perform eyeblink and blink saccade removal (including 100ms before and after blinks to control for the effects of eyelid occlusion). Technical issues with regard to time-stamp messages resulted in a loss of data for the

first 23 participants. Additionally, the eye tracker was unable to detect the pupil of one participant. This resulted in a final sample of 30 participants for pupillometry data analysis. R software (R Core Team, 2013) was used to remove outliers (values that were 3 standard deviations above or below the mean). Next, the 'na.approx' package (Zeileis & Grothendieck, 2005) was used to linearly interpolate missing data. Subtractive baseline correction was performed to obtain the change in pupil size per trial (average of the stimulus measurement – average of the baseline measurement). Trials were excluded if more than 50% of the baseline or stimulus measurement was missing. In total, 1034 trials met the exclusion criteria (23.93% of all trials). Pre-processing often includes the z-transformation of pupil dilation values per participant, to partly control for inter-individual pupil dilation differences. However, as our data analysis technique (linear mixed models) can take individual differences into account, no z-transformations per participant were conducted.

Emotion processing.

The emotional stimuli consisted of 72 greyscale male and female faces. Pictures were selected from the NimStim facial expression database (Tottenham et al., 2009). The pictures were morphed between a neutral face and an emotional face in 10% intervals. More specifically, this resulted in 8 pictures that vary from a 100% neutral – 0% emotion picture to a 30% neutral – 70% emotion picture in 10% intervals (100% – 0%, 90% – 10%, 80% – 20%, etc.). An example is provided in Figure 1. We follow Jhung et al. (2010) in placing a cutoff at the 70% emotion mark, as by this point the emotion is far less ambiguous and therefore less valuable to our study. Pictures were morphed using Interface software (Kramer, Jenkins & Burton, 2016). The five different emotions that we studied are "Happiness", "Surprise", "Sadness", "Anger" and "Disgust". As other studies often face criticism that only one positive emotion is included (mostly "Happiness"), we decided to also include "Surprise". Although there is no consensus on the valence of "Surprise", or whether it has a fixed valence or not, this multidimensionality could be interesting to explore (Fontaine, Scherer, Roesch & Ellsworth, 2007; Noordewier & Breugelmans, 2013). We used two models, one male and one female, to control for possible effects of the gender displayed. This resulted in 72 pictures of emotional faces, as the 100% neutral face is the same across all emotions (7 different emotion intensities x 5 emotions x 2 models + 1 100% neutral face per model). Additionally, the images were controlled for luminance by decreasing the contrast and matching the brightness to allow

for the recording of pupillary dynamics as described above. During the task, the participants were asked to evaluate the valence of each facial expression (i.e. how positive or negative they judge the emotional face).

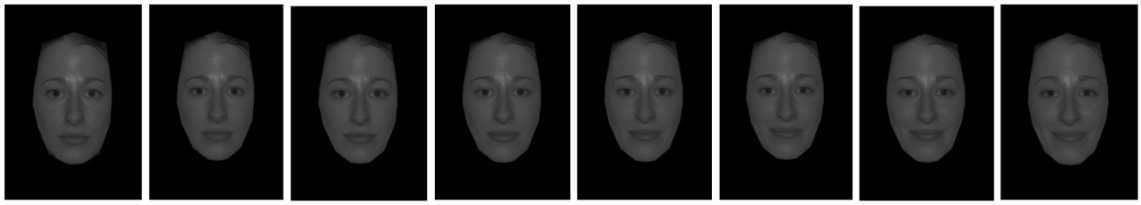

Figure 1. Example of a set of morphed faces (“Happiness”)

Procedure

Participants were asked to fill out the sO-LIFE questionnaire online, prior to their appointment. Following a standardized protocol, during the 1-hour session they completed the emotion processing task as well as a parallel task for an associated study in alternating order. The participant sample was shared with the associated study. Prior to connecting the participants to the Eyelink 1000, they were first asked to fill out two additional questionnaires (PANAS for this study and another questionnaire for the associated study). We also requested their payment information at this point. Once connected to the eyetracker and following the standard calibration procedure, the experimental task began.

The emotion processing task was programmed in Python using the PsychoPy3 package (Peirce, 2007). The task started with a short training session of 10 practice trials in which all emotions were displayed. Participants first saw a fixation cross to focus the gaze of the participant and to record the baseline pupil measurement. The fixation cross was displayed for 1 second in 80% of the trials. We changed the duration of the fixation cross in 20% of the trials, introducing the needed variability to aid in measuring the pupil dilation signal (variable inter-stimulus interval). Next, the participants were presented with an emotional or neutral face on top of the fixation cross for 3 seconds, after which they were asked to complete the valence evaluation. The participants used a computer mouse to answer on a semantic differential scale, consisting of a line which represents the spectrum from positive to negative with neutral placed in the middle. The line was separated into 10 intervals, producing an output of whole numbers between 1 and 11. This was done to simplify data analysis and in function of the practical significance of the results. The response time was measured in milliseconds as the time from the moment

the scale appeared to the moment the participant chose a location on the semantic differential spectrum, with a maximum response time of 4 seconds. This marked the end of a trial. A trial sequence is visualized in Figure 2. The maximum total time of a trial was 9 seconds. Following the practice items, the order of presentation of the 72 stimuli was randomized per participant over emotions and intensities to control for order effects. Once all 72 stimuli had been presented, participants got a short break to rest their eyes, after which the entire block was repeated. This resulted in two trials per intensity, per emotion, per model (total of 144 trials). The maximum total time of the experiment was approximately 23 minutes (including the 10 practice trials). The participants were debriefed following the termination of the study.

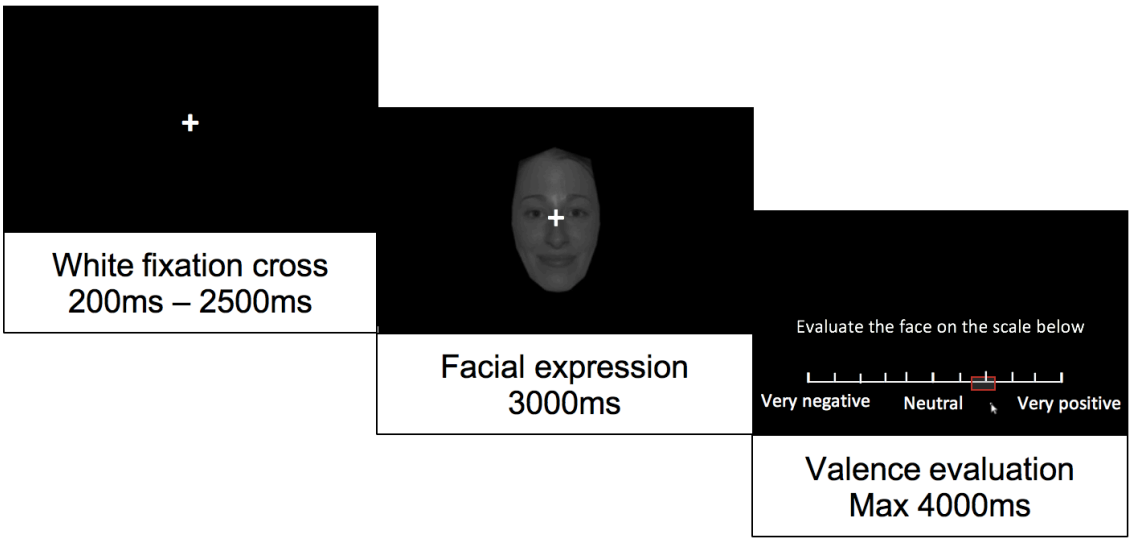

Figure 2. Representation of a trial sequence

Data Analysis

Linear Mixed Models were used to analyze the data in LMMGui (Magezi, 2015) and in R software using the 'lme4' package (Bates, Mächler, Bolker, & Walker, 2015). The linear mixed model technique was selected in consideration of the expected missing data as well as the repeated nature of the experiment. Prior to creating a model, we explored the multicollinearity between the sO-LIFE scales through inspection of the inter-correlations. We also correlated the PANAS scores to the sO-LIFE scores. A high correlation would be an indication to exclude the PANAS scores from the model (to avoid multicollinearity). A low correlation could provide additional information. We further examined a possible gender effect between the male and female image by performing a

regression between the gender of the image and the valence ratings, response times and pupil dilations separately. Where this regression produced a significant result, the gender of the image was considered as a possible relevant predictor in the statistical model. An average was taken between the two repeated trials. The final data pool consisted of one valence rating, one response time value and one pupil dilation value for each combination of the five emotions and eight intensities per model (total of 36 combinations x 2 genders).

Once the above aspects were controlled for, we performed three linear mixed model analyses, each relating to one of the three dependent variables (valence ratings, reaction times and pupil dilation values), consistent with our established hypotheses. It was not deemed beneficial to increase the complexity of the analysis by creating one global model, considering that independency of the dependent variables was confirmed (all r's ≈ 0.002). For each model we considered the *unusual experiences* score (Un.Exp), *cognitive disorganization* score (Cogn.Dis), *introvertive anhedonia* score (Introv.Anh) and *impulsive nonconformity* score (Imp.Nonc) (all of continuous nature), the emotion type (categorial nature, 5 levels) and the intensity (categorical nature, 8 levels) as fixed effects, with a random effect for participants. All questionnaire scores were normalized to improve model fit. The factor *intensity* was categorized into four levels to facilitate model convergence: "neutral" (0%), "low" (10%-20%), "medium" (30%-50%) and "high" (60%-70%). In defining an adequate model, variance inflation factors (VIFs) were taken into account alongside theoretical considerations. The model assumptions (i.e. homoscedasticity, normally distributed residuals) were verified through visual inspection of residual plots. Statistical significance was obtained using Satterthwaite's method. An alpha level of .05 was used for all statistical tests. Coefficients of determination (R^2 or partial R^2) were computed for significant effects to quantify effect-sizes. Post-hoc calculations were performed based on Estimated Marginal Means using the Tukey correction.

Results

Descriptive statistics on the questionnaire results (sO-LIFE and PANAS) are shown in Table 1. A visualization of the distribution of scores for each sO-LIFE scale is provided in the supplementary materials (Figure S1). Inter-correlations between the questionnaire scales (shown in Table 2) did not indicate problematic multicollinearity. Results from the regressions for the image gender each of the dependent variables are included in Table 3.

Table 1

Descriptive Statistics of Questionnaire Results

Variable	*N*	*M*	*SD*	Min.	Max.
Un.Exp	54	3.481	2.553	0	10
Cogn.Dis	54	6.296	3.219	0	11
Introv.Anh	54	2.222	1.621	0	7
Imp.Nonc	54	2.722	2.013	0	9
PA	54	32.982	4.962	18	42
NA	54	20.907	7.180	10	46

Table 2

Pearson Correlations between Questionnaire Dimensions

	Un.Exp	Cogn.Dis	Introv.Anh	Imp.Nonc	PA	NA
Un.Exp	*1.000*	0.274	0.270	0.500	0.422	0.422
Cogn.Dis	0.274	*1.000*	0.237	0.410	-0.255	0.514
Introv.Anh	0.270	0.237	*1.000*	0.262	-0.121	0.216
Imp.Nonc	0.500	0.410	0.262	*1.000*	-0.208	0.550
PA	0.422	-0.255	-0.121	-0.208	*1.000*	-0.373
NA	0.422	0.514	0.216	0.550	-0.373	*1.000*

Table 3

Initial Regressions for the Effect of Image Gender on each Dependent Variable

Variable	Num DF	DenDF	F value	*p*-value
Valence ratings	1	7767	20.31	< .001
Reaction times	1	7774	0.001	.9695
Pupil dilation values	1	3284	5.344	.0209

Valence Ratings

To test our first hypothesis that facial emotion perception would be different between subjects with higher scores on schizotypal traits, a linear mixed model was used to determine if valence ratings differed significantly as a function of sO-LIFE scores. The initial significance of the regression between the image gender and the valence rating given ($F(1, 7767) = 20.31$, $p < .001$) indicated that this predictor may be relevant to the model. The VIFs of the full model (all sO-LIFE subscales, *image gender*, *emotion*, and *intensity* as well as interactions between the sO-LIFE scales and the other predictors)

were elevated (values provided in Table S1 of the supplementary materials). Considering that the predictors *emotion* and *intensity* and the sO-LIFE subscales were crucial to our design and our hypotheses, we inspected whether VIFs improved when removing the variable *image gender*. Indeed, the model without *image gender* returned more acceptable VIFs (values provided in Table S2 of the supplementary materials). The final model included *unusual experiences, cognitive disorganization, introvertive anhedonia, impulsive nonconformity*, *emotion* and *intensity* and the interactions between the sO-LIFE subscales and the other predictors as fixed effects as well as a random intercept for participants. Visual inspection of the model residuals (see Figure S2 in the supplementary materials) showed a near-normal distribution and no significant violations of the homoscedasticity assumption.

We found a statistically significant main effect of *impulsive nonconformity* on valence ratings ($F(1, 55.1) = 12.91$, $p = .001$, and $R^2 = 0.002$ (95% CI [0.000, 0.005])), showing that higher scores on the *impulsive nonconformity* scale were associated with lower valence ratings. No other sO-LIFE subscales showed significant main effects on valence ratings (all p's > .05). The main effect of *emotion* was statistically significant ($F(4, 4266.4) = 622.12$, $p < .001$, and additive partial $R^2 = 0.000$). Averaged over levels of *intensity*, "Sad" faces were awarded the lowest valence ratings ($M = 4.75$, $SE = 0.08$, 95%CI [4.60, 4.91]), followed by "Disgusted" faces ($M = 4.89$, $SE = 0.08$, 95%CI [4.73, 5.04]), "Angry" faces ($M = 4.97$, $SE = 0.08$, 95%CI [4.81, 5.12]) and "Surprised" faces ($M = 5.51$, $SE = 0.08$, 95%CI [5.36, 5.66]). "Happy" faces were given the highest ratings ($M = 6.92$, $SE = 0.08$, 95%CI [6.77, 7.08]). We further found that *emotion* interacted significantly with *impulsive nonconformity* ($F(4, 4267.6) = 3.47$, $p = .008$, and additive partial $R^2 = 0.000$) and *introvertive anhedonia* ($F(4, 4265.2) = 2.85$, $p = .022$, and additive partial $R^2 = 0.000$). The interaction between *emotion* and *unusual experiences* provided a marginally statistically significant result ($F(4, 4265.2) = 2.25$, $p = .061$, and additive partial $R^2 = 0.000$). The interactions between *emotion* and these subscales are visualized in Figure 3.

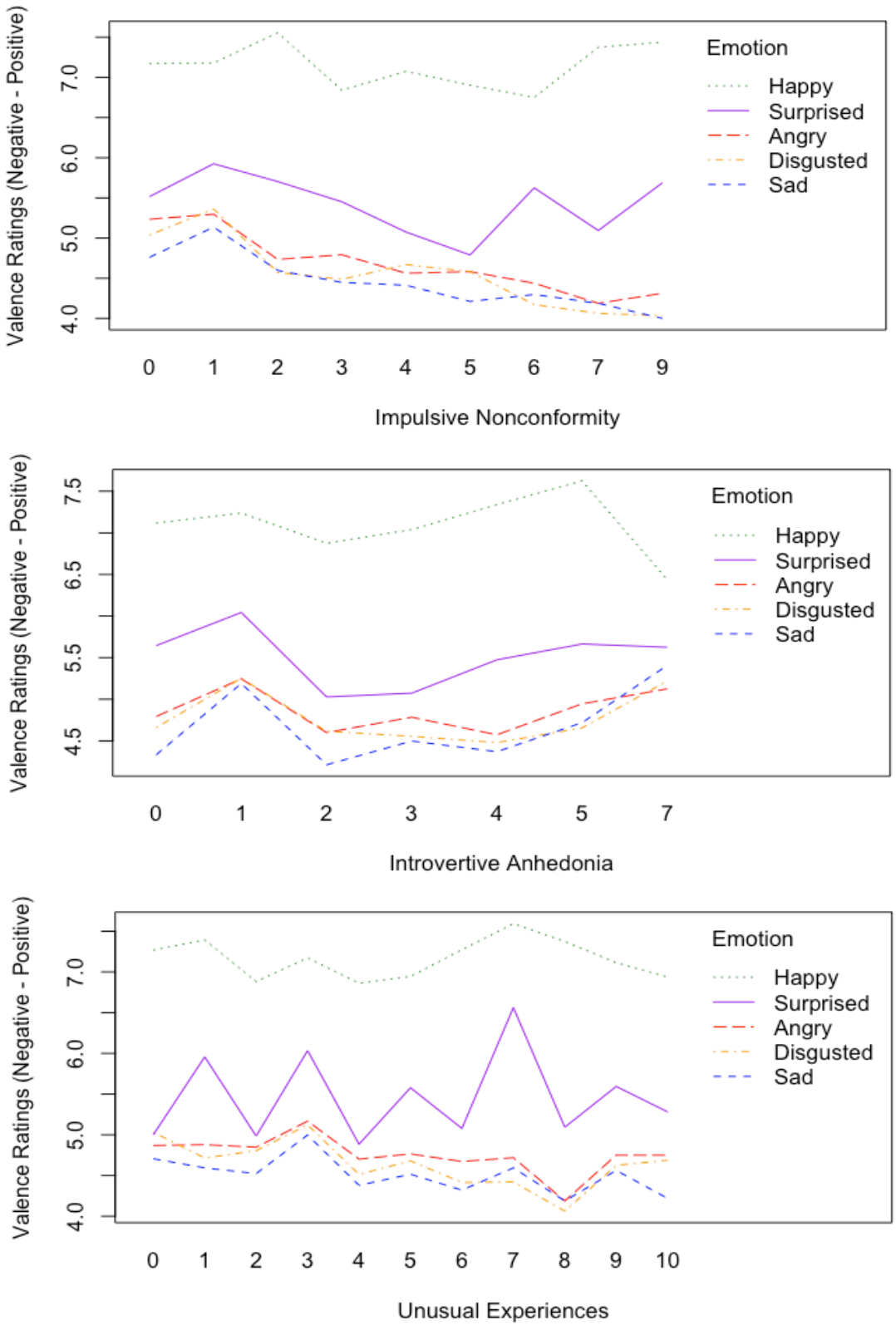

Figure 3. Interactions between sO-LIFE Subscales and *Emotion* (DV: Valence Ratings)

In post-hoc analyses, all but one of the interactions between *impulsive nonconformity* and the types of emotions were statistically significant (all *p*'s ≤ .002). The post-hoc analysis results show that with increasing *impulsive nonconformity* scores, average valence ratings decrease by a factor of -0.338 (*SE* = 0.095, 95% CI [-0.526, -0.149]) for "Angry" faces ($p < .001$), by a factor of -0.304 (*SE* = 0.095, 95% CI [-0.492, -0.115]) for "Disgusted" faces ($p = .002$) and by a factor of -0.317 (*SE* = 0.095, 95% CI [-0.505, -0.128]) for "Sad" faces ($p = .001$). With regard to "Surprised" faces, average valence responses decrease by a factor of -0.361 (*SE* = 0.095, 95% CI [-0.549, -0.174], $p < .001$). Only the interaction with emotion type "Happy" was not statistically significant ($p = .110$). These results are averaged over intensities. The trend visualized in Figure 3 seems to suggest that the influence of *impulsive nonconformity* is most prominent with respect to the negative emotions. The downward trend is less consistent with respect to "Surprised" faces. The post-hoc results regarding the interaction between *emotion* and *introvertive anhedonia* show no statistically significant interactions (all *p*'s > .05). With respect to the interaction between *emotion* and *unusual experiences*, only one statistically significant interaction was found. When presented with "Surprised" faces, higher scores on the *unusual experiences* scale were associated with higher valence ratings by a factor of 0.192 (*SE* = 0.091, 95% CI [0.011, 0.372], $p = .038$). An important contributing factor to consider is the disproportionately fewer number of participants with higher in comparison to lower sO-LIFE scores (as shown in Figure S1 in the supplementary materials). In fact, only four participants scored higher than 5 on the *impulsive nonconformity* scale and only one participant scored higher than 5 on the *introvertive anhedonia* scale. The results from the higher end of the scale are thus based on fewer participants, increasing the relative contribution of individual scores to the overall results.

We also found a statistically significant main effect of *intensity* ($F(3, 4266.0) = 189.18$, $p < 0.001$, and additive partial $R^2 = 0.067$). *Intensity* interacted significantly with *emotion* ($F(12, 4265.9) = 173.26$, $p < .001$, and additive partial $R^2 = 0.204$), as shown in Figure 4. The post-hoc estimated marginal means (see Table 4) show that pictures with higher intensities were consistently and significantly assigned more extreme evaluations, towards the more positive or more negative side depending on the emotion shown. The interaction between *emotion* and *intensity* with regard to valence responses simultaneously serves as a manipulation check with respect to the morphing applied to the faces. The results confirm that we were successful in creating a gradation with respect to the intensity of the emotion expressed. The contrast between neutral and low

intensity faces was often statistically insignificant (Surprised: p = .571, Angry: p = .605, Disgusted: p = .997). This was anticipated, considering the high degree of similarity between neutral and low intensity faces due to the fact that the neutral expression is substantially more apparent than the morphed emotion at low intensity levels. Interestingly, this contrast was statistically or marginally statistically significant with respect to Happy and Sad faces (p < .001 and p = 0.083 respectively). This suggests that these two emotions are more easily identified in low proportions than other emotions.

The faces showing a "Surprised" emotion show a less steep decline in comparison to other emotions. Indeed, the post-hoc results show proportionally more insignificant intensity contrasts than the contrasts produced with respect to the other emotions. It is striking, however, that even high intensity "Surprised" faces were given relatively modest evaluations (M = 5.27, SE = 0.096, 95% CI [5.08, 5.46]). Even so, the trend reveals that higher intensity faces were evaluated as more negative than low intensity faces.

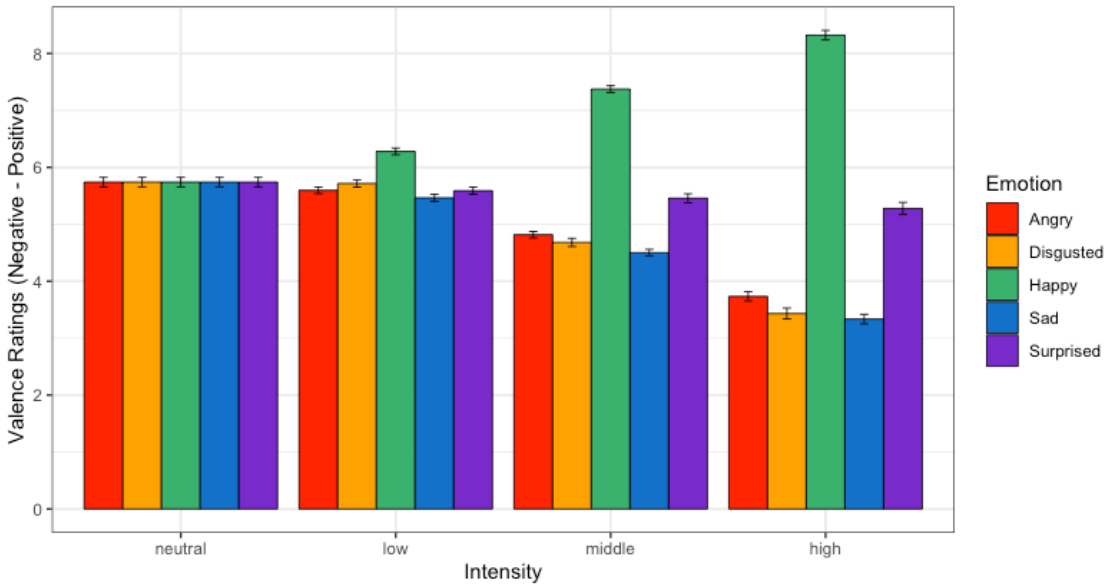

Figure 4. Interactions between *Intensity* and *Emotion* (DV: Valence Ratings)
Error bars represent standard errors.

Table 4

Estimated Marginal Valence Rating Means per Emotion and Intensity

Intensity	emmean	SE	lower.CL	upper.CL	t.ratio	p.value
Emotion = Angry:						
neutral	5.73	0.117	5.51	5.96	49.02	<.001
low	5.59	0.096	5.40	5.78	58.37	<.001
middle	4.81	0.088	4.64	4.99	54.93	<.001
high	3.73	0.096	3.54	3.92	38.92	<.001
Emotion = Disgusted:						
neutral	5.73	0.117	5.51	5.96	49.02	<.001
low	5.71	0.096	5.52	5.90	59.63	<.001
middle	4.68	0.088	4.50	4.85	53.38	<.001
high	3.43	0.096	3.24	3.62	35.78	<.001
Emotion = Happy:						
neutral	5.73	0.117	5.51	5.96	49.02	<.001
low	6.27	0.096	6.09	6.46	65.50	<.001
middle	7.37	0.088	7.20	7.54	84.12	<.001
high	8.32	0.096	8.13	8.50	86.81	<.001
Emotion = Sad:						
neutral	5.73	0.117	5.51	5.96	49.02	<.001
low	5.46	0.096	5.27	5.65	56.99	<.001
middle	4.50	0.088	4.32	4.67	51.32	<.001
high	3.33	0.096	3.14	3.52	34.76	<.001
Emotion = Surprised:						
neutral	5.73	0.117	5.50	5.96	49.11	<.001
low	5.58	0.096	5.40	5.77	58.30	<.001
middle	5.45	0.088	5.28	5.63	62.24	<.001
high	5.27	0.096	5.08	5.46	55.03	<.001

To explore the interaction between sO-LIFE subscales and neutral faces, relevant to the purpose of this paper, we analyzed the trend between the subscales and *intensity*. *Intensity* interacted significantly with *cognitive disorganization* ($F(3, 4268.3) = 2.74$, $p = .042$) and marginally significantly with *impulsive nonconformity* ($F(3, 4266.9) = 2.57$, $p = .053$) and *unusual experiences* ($F(3, 4265.2) = 2.27$, $p = .078$) (shown in Figure 5). Only with respect to the interaction with *impulsive nonconformity* was this trend confirmed in post-hoc calculations. Averaged over the levels of *emotion*, results suggest that the effect of *impulsive nonconformity* is greater with respect to neutral faces than to low, middle and high intensity faces, gradually decreasing as intensity increases. Additionally, higher

scorers on the *impulsive nonconformity* scale tended to give lower valence evaluations to neutral faces by a factor of -0.374 (*SE* = 0.099, 95%CI [-0.570, -0.179], $p < .001$). Although Figure 5 contains indications of a possible association between the other sO-LIFE subscales and *intensity*, we must be wary of the effects of range-restriction within all subscales on these results.

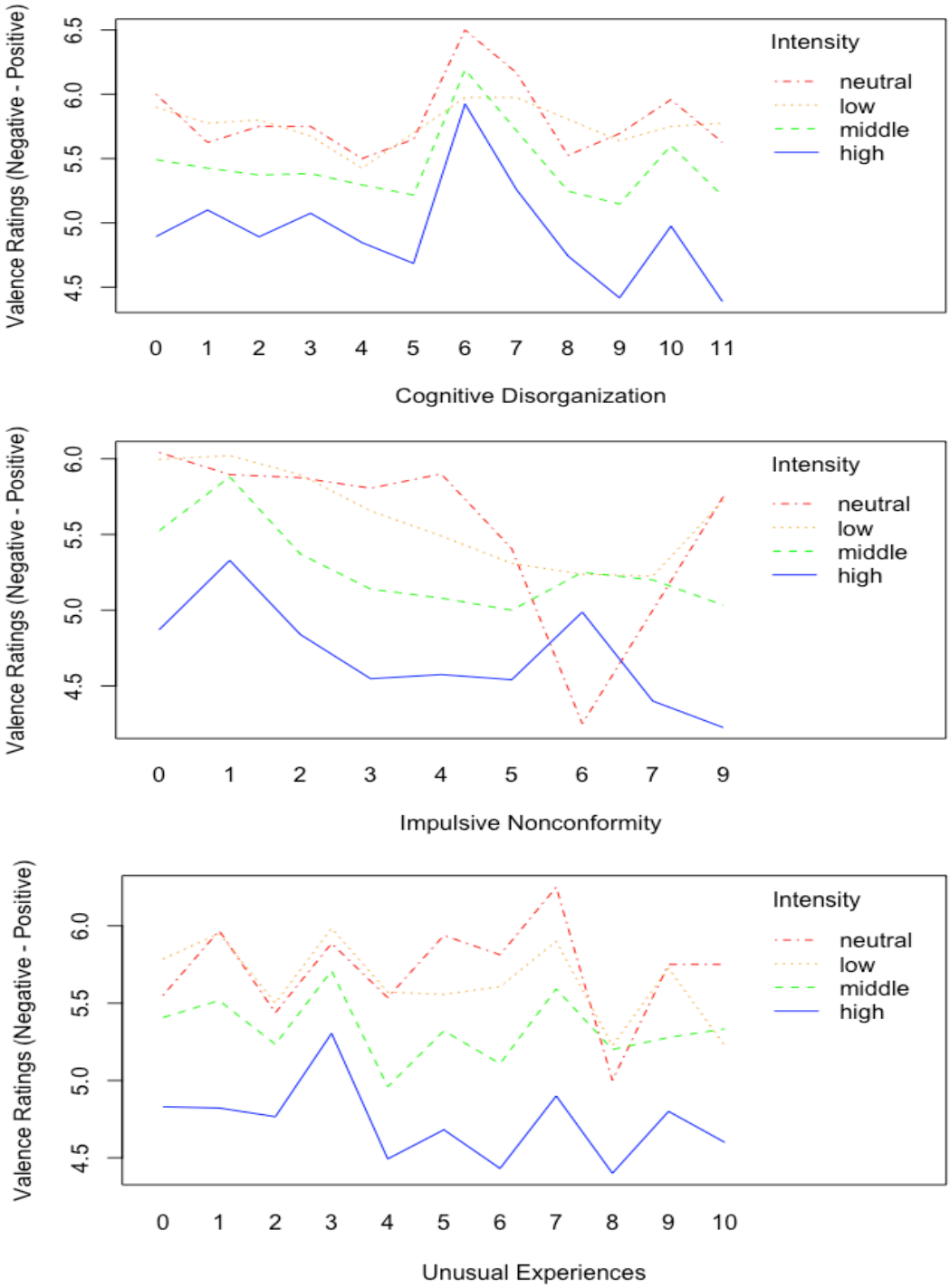

Figure 5. Interactions between sO-LIFE Subscales and *Intensity* (DV: Valence Ratings)

The overall model fit was R^2 = 0.566 (95% CI [0.553, 0.586]). Estimates suggest that the random intercept for participant amplifies the explained variance by 8.4% (conditional R^2 = 0.650). Only about two thirds of the variance observed can be accounted for with our model, which suggests that many other factors could have played a role. Despite the initial significance of the regression between *image gender* and the valence rating given (F(1, 7767) = 20.31, p < .001), we were unable to include this predictor due to high levels of multicollinearity. It may be that a gender-effect can account for some of the residual variation.

In conclusion, our overall hypothesis that higher scores on all sO-LIFE dimensions would impact valence ratings was largely supported. Three of the four dimensions showed significant associations between sO-LIFE scores and valence responses. These associations were most prominent with respect to the *impulsive nonconformity* scale, especially when considering negative and more ambivalent facial expressions.

Reaction Times

A different linear mixed model was used to test our second hypothesis, namely that reaction times would differ significantly as a function of sO-LIFE scores. Given that the preliminary regression between the image gender and response times provided an insignificant result (F(1, 7774) = 0.001, p = .970), *image gender* was not considered a relevant predictor. The full model (all sO-LIFE subscales, *emotion*, and *intensity* as well as interactions between the sO-LIFE scales and the other predictors) provided acceptable VIFs (values provided in Table S3 of the supplementary materials). The final model thus included a main effect of *unusual experiences, cognitive disorganization, introvertive anhedonia, impulsive nonconformity*, *emotion* and *intensity* and the interactions between the sO-LIFE scales and the other predictors as fixed factors as well as a random intercept for participants. Visual inspection of the initial model residuals (see Figure S3 in the supplementary materials) showed indications of heteroscedasticity. For this reason, a log transformation was applied to the reaction time values. Figure S4 shows the log-transformed model residuals which now reflect a near-normal distribution and no significant violations of homoscedasticity.

The mean reaction time was 0.85 seconds (SD = 0.41). We found a statistically significant effect of *emotion* (F(4, 4267.5) = 5.32, p <.001, and additive partial R^2 = 0.000) and *intensity* (F(3, 4266.9) = 38.55, p < .001, and additive partial R^2 = 0.001). The

interaction term between *intensity* and *emotion* (visualized in Figure 6) did not yield a statistically significant result ($F(12, 4266.9) = 0.90$, $p = .546$). With regards to the main effect of emotion, the interaction plot suggests that positive emotional faces are generally reacted to more quickly than negative emotional expressions. Post-hoc contrasts partly confirm this trend, with (marginally) statistically significant contrasts when comparing reaction times to "Happy" faces and to "Angry" ($p = .059$) and "Sad" faces ($p = .029$), averaged over intensity levels. Especially the contrasts between negative emotions and "Surprised" faces yielded statistically significant results (all p's < .045).

We further hypothesized that higher intensity faces would be evaluated faster, assuming that a more ambiguous face would require a longer evaluation time. Post-hoc results stand in stark contrast to our initial expectations. Across all emotions, higher average reaction times were recorded in response to higher intensity faces than to lower intensity faces (all p's < .05, see Table S4 in the supplementary materials). In the analysis of specific contrast pairs, we found that especially the differences between reaction times to neutral faces and reaction times to high intensity faces were statistically significant (all p's < .05). Compliant with the interaction plot trends, with respect to the emotions "Surprised", "Happy" and "Disgusted" the contrasts between neutral and middle intensity faces produced statistically significant results (all p's < .05). The contrasts between reaction times to neutral faces and to low intensity faces were not statistically significant across all emotions (all p's > .05). Again, we can relate this to the high degree of similarity between neutral and low intensity faces. Only for the emotion "Happy" was the contrast between middle and high intensity statistically significant ($p = .029$).

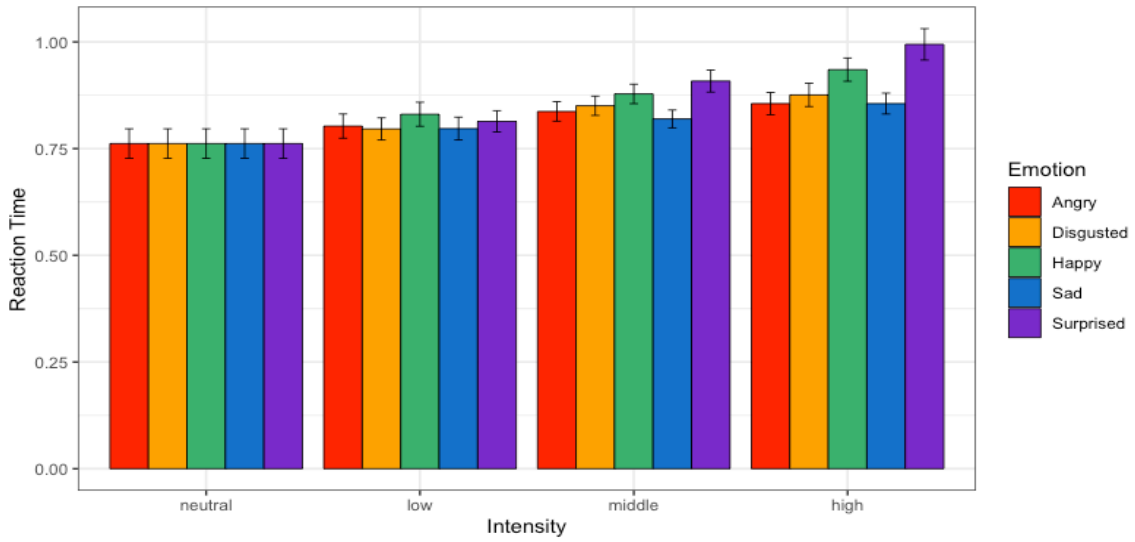

Figure 6. Interactions between *Intensity* and *Emotion* (DV: Reaction Time)
Error bars represent standard errors.

We found no statistically significant main effects of the sO-LIFE scales (all *p*'s > .05). The interaction we expected between *introvertive anhedonia* and the type of emotion was not statistically significant either ($F(4, 4265.8) = 0.39$, $p = .817$). We did find a statistically significant interaction between *introvertive anhedonia* and *intensity* ($F(3, 4265.8) = 3.48$, $p = .015$, and additive partial $R^2 = 0.000$) and *cognitive disorganization* and *intensity* ($F(3, 4270.3) = 2.92$, $p = .033$, and additive partial $R^2 = 0.000$), shown in Figure 7. Although Figure 7 seems to suggest an influence of *introvertive anhedonia* and *cognitive disorganization* on reaction time, post-hoc estimated marginal means failed to produce statistically significant values (all *p*'s > .05). Range-restriction in the sO-LIFE subscales may have influenced the results.

We further specified an expectation that higher intensity faces portraying negative emotions (sadness, anger, disgust) would be evaluated faster by participants with higher scores on the *introvertive anhedonia* scale, given that these characteristics possibly reflect a propensity towards negative affect. The three-way interaction between *introvertive anhedonia*, *emotion*, and *intensity* was not statistically significant ($F(12, 4265.8) = 0.59$, $p = 0.849$). This result suggests that this propensity had no significant influence on reaction time.

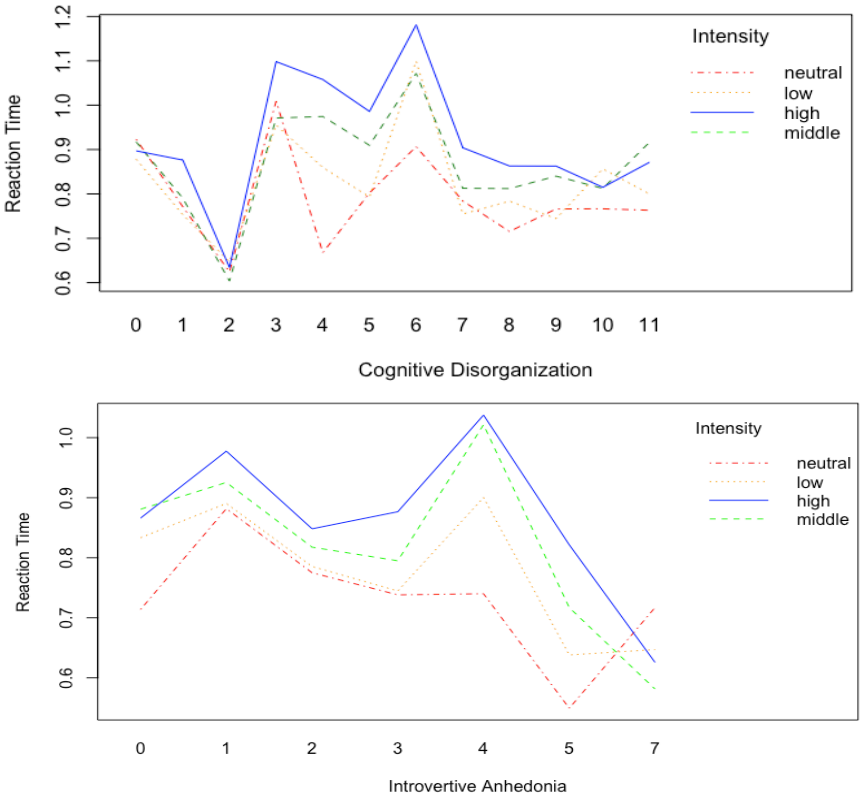

Figure 7. Interactions between sO-LIFE Subscales and *Intensity* (DV: Reaction Time)

The overall model fit was R^2 = 0.048 (95% CI [0.056, 0.082]). This value suggests that many other factors could have played a role in determining the reaction time. Estimates suggest that the random intercept for participant accounts for roughly 49.2% of the observed variation (conditional R^2 = 0.54). This result suggests a high level of inter-individual variation, significantly more prominent than the model results recorded.

In conclusion, our overall hypothesis that the scores on sO-LIFE dimensions would impact reaction times was not supported. Nor could we support our hypothesis of an interaction between emotion, intensity and negative schizotypy.

Pupil Dilation Values

A third linear mixed model was constructed to test our third and last hypothesis, namely that sO-LIFE subscales would be positively or negatively associated to pupil dilation values depending on the subscale considered and that pupil dilations would be larger in response to more intense emotional faces than to less intense and neutral faces. The initial regression between the image gender and the pupil dilation values provided a significant result (F(1, 3284) = 5.34, p = .021),) which indicated that this predictor may be relevant to the model. The VIFs of the full model (all sO-LIFE subscales, *image gender*, *emotion*, and *intensity* as well as interactions between the sO-LIFE scales and the other predictors) were elevated (values provided in Table S5 of the supplementary materials). Considering that the predictors *emotion* and *intensity* and the sO-LIFE subscales were crucial to our design and our hypotheses, we inspected whether VIFs improved when removing the variable *image gender*. Indeed, the model without *image gender* returned more acceptable VIFs (values provided in Table S6 of the supplementary materials). The final model included *unusual experiences, cognitive disorganization, introvertive anhedonia, impulsive nonconformity*, *emotion* and *intensity* and the interactions between the sO-LIFE subscales and the other predictors as fixed effects as well as a random intercept for participants. Visual inspection of the model residuals (see Figure S5 in the supplementary materials) showed a near-normal distribution and no significant violations of the homoscedasticity assumption.

Results show a statistically significant main effect of *intensity* on pupil dilation (F(3, 2111.86) = 4.44, p = .004, and additive partial R^2 = 0.002), shown in Figure 8. Post-hoc analyses (see Table 5) showed a statistically significant contrast between neutral and high intensity faces (p = .008), where pupil dilation values were estimated to be 53.68 units lower on average in response to neutral faces than to high intensity faces

(*SE* = 16.8, 95% CI [-96.8, -10.6]), averaged over levels of *emotion*. The contrast between neutral and middle intensity faces was also statistically significant (p = .016), with pupil dilation values estimated to be 46.73 units lower on average in response to neutral than to middle intensity faces (*SE* = 15.8, 95% CI [-87.3, -6.2]), averaged over levels of *emotion*. These results support for our hypothesis that more intense faces elicit greater pupil dilation. However, the contrasts between neutral and low, low and middle, and middle and high intensity were not statistically significant (p =.416, p = .329 and p = .943 respectively).

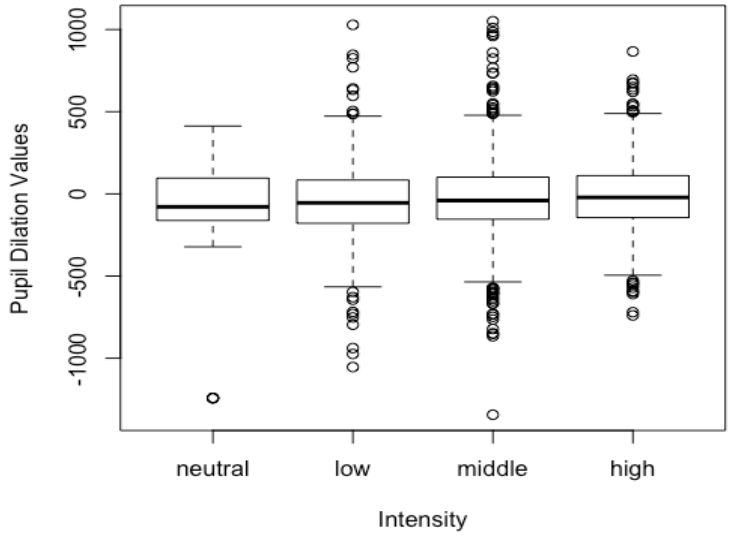

Figure 8. Effect of *Intensity* on Pupil Dilation Values

Table 5

Estimated Pupil Dilation Marginal Means (averaged over Emotion)

Contrast	estimate	SE	lower.CL	upper.CL	t.ratio	p.value
Neutral – low	-25.76	16.8	-68.9	17.36	-1.536	0.416
Neutral – middle	-46.73	15.8	-87.3	-6.20	-2.964	0.016
Neutral – high	-53.68	16.8	-96.8	-10.60	-3.204	0.008
Low – middle	-20.97	12.4	-52.9	10.93	-1.69	0.329
Low – high	-27.92	13.6	-62.9	7.11	-2.049	0.170
Middle – high	-6.95	12.4	-38.8	24.87	-0.561	0.943

The main effect of *emotion* on pupil dilation values was not statistically significant ($F(4, 2110.62) = 0.45$, $p = .769$). The interaction term between *emotion* and *intensity* was also statistically insignificant ($F(12, 2110.34) = 1.02$, $p = .428$) (see Figure 9). Post-hoc estimated marginal mean calculations likewise provide predominantly insignificant results (see Table 6). There is a trend however, of negative pupil dilation values, meaning pupils tended to constrict upon stimulus presentation. Although the *p*-values are insignificant, across emotions we again see the effect of the intensity of the faces, in this case being that high intensity faces showed less constriction. The trend seen in Figure 9 supports this observation.

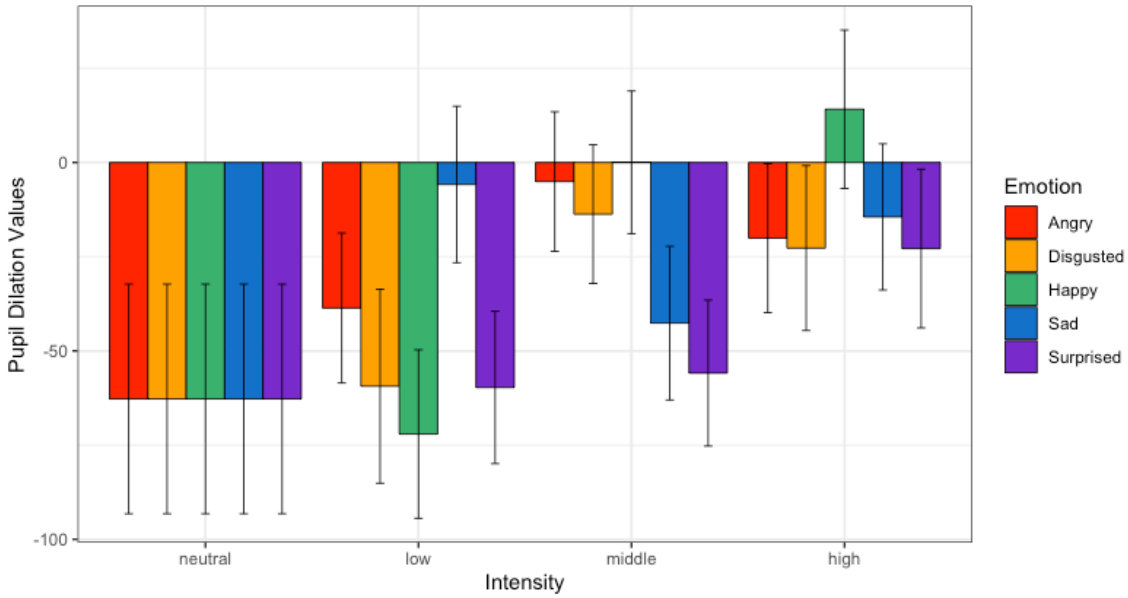

Figure 9. Interactions between *Intensity* and *Emotion* (DV: Pupil Dilation Values) Error bars represent standard errors.

Table 6

Estimated Marginal Pupil Dilation Means per Emotion and Intensity

Intensity	emmean	SE	lower.CL	upper.CL	t.ratio	p.value
Emotion = Angry:						
neutral	-68.69	35.5	-138.4	1.00	-1.936	0.0534
low	-36.68	27.9	-91.6	18.28	-1.316	0.1897
middle	-8.16	25.4	-58.3	42.02	-0.322	0.7482
high	-24.16	28.1	-79.6	31.31	-0.859	0.3915
Emotion = Disgusted:						
neutral	-68.69	35.5	-138.4	1.00	-1.936	0.0534
low	-48.55	28.6	-105	7.88	-1.696	0.0914
middle	-11.08	25	-60.5	38.36	-0.443	0.6582
high	-28.66	28.3	-84.5	27.17	-1.012	0.3127
Emotion = Happy:						
neutral	-68.69	35.5	-138.4	1.00	-1.936	0.0534
low	-69.30	28.0	-124.4	-14.16	-2.478	0.0140
middle	2.93	25.4	-47.2	53.10	0.116	0.9081
high	12.94	28.1	-42.5	68.38	0.460	0.6459
Emotion = Sad:						
neutral	-68.69	35.5	-138.4	1.00	-1.936	0.0534
low	-2.26	28.2	-57.8	53.28	-0.080	0.9362
middle	-39.04	24.9	-88.3	10.24	-1.568	0.1194
high	-14.78	28.0	-70.0	40.47	-0.527	0.5985
Emotion = Surprised:						
neutral	-68.69	35.5	-138.4	1.00	-1.936	0.0534
low	-58.40	28.1	-113.8	-3.01	-2.079	0.0389
middle	-54.97	24.7	-103.9	-6.01	-2.222	0.0281
high	-20.91	27.8	-75.7	33.87	-0.753	0.4525

We did not find any significant main effects of the sO-LIFE subscales on reaction time (all *p*'s > .05). We did find statistically significant interaction effects between *cognitive disorganization* and *intensity* ($F(3, 2112) = 5.16$, $p = 0.002$, and partial $R^2 = 0.001$) and *introvertive anhedonia* and *intensity* ($F(3, 2110.45$, $p = 0.003$, and partial $R^2 = 0.002$) (shown in Figure 10). Post-hoc calculations show that the effects of both subscales are only significant in the face of neutral expressions (both *p*'s < .05), suggesting a relatively larger dilation in response to neutral faces than the average dilation values recorded in our sample. With respect to expressions of other intensities the effects are not statistically significant (all *p*'s > .05). We further found a marginally statistically significant interaction effect between *cognitive disorganization* and *emotion*

($F(4, 2112.42) = 2.33$, $p = .054$, and additive partial $R^2 = 0.000$). Post-hoc calculations reveal, however, that none of the trends were statistically significant (all p's > .05).

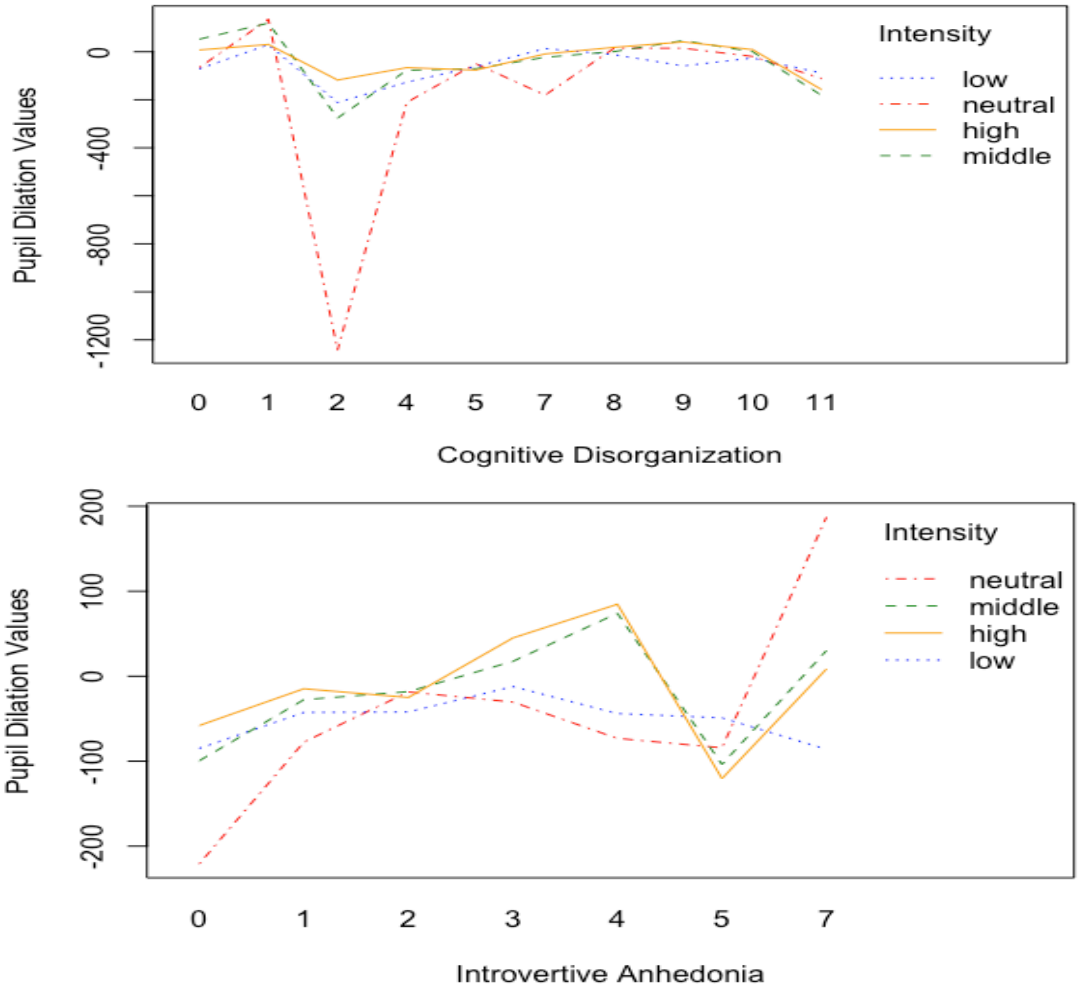

Figure 10. Interactions between sO-LIFE Subscales and *Intensity* (DV: Pupil Dilation Values)

The overall model fit was $R^2 = 0.074$ (95% CI [0.09, 0.134]). Estimates suggest that the random intercept for participant amplifies the explained variance by 13.4% (conditional $R^2 = 0.208$). This result illustrates an important effect of inter-individual variation as well as indicating that many other (unknown) factors played a role in determining the pupil dilations. One of these factors is possibly related to the image gender, given the significant regression initially performed. Above all, we must acknowledge the relatively high standard errors and significant presence of outliers in conjunction with the unexpected results pointing to constriction instead of dilation. The

limitations to the pupillometry approach will be expounded in the Discussions section of this paper.

PANAS Contribution

Initial correlations between the PANAS scores and the sO-LIFE scores showed no significant collinearity (see Table 2). This was taken as an indication that the PANAS scores could possibly provide additional information. To this end, we included a Positive Affect (*PA*) and Negative Affect (*NA*) predictor into the previous models to explore the added value.

We found no statistically significant main effects of *PA* or *NA* on valence responses or on reaction times (all *p*'s > .05). Only one marginally statistically significant interaction effect was found, between *NA* and *emotion* in relation to the valence responses ($F(4, 4265.7) = 2.36$, $p = .051$ and additive partial $R^2 = 0.001$). However, post-hoc analyses were unable to withhold statistically significant *NA* trends with respect to the different emotion types (all *p*'s > .05). This leads us to conclude that no noteworthy relations between self-reported positive affect or negative affect on response or reaction time were observed in this study.

Discussion and Conclusions

In this paper, schizotypy is previously defined as "a range of enduring personality traits, reflected in cognitive style and perceptual experiences, arising from a combination of polygenetic and environmental determinants, which are normally distributed within the general population" (Grant et al., 2018, p. S558). This study aimed to shed light on eventual emotion perception differences in people with higher compared to lower levels of schizotypal traits, including an exploration of a possible neurochemical determining factor in the etiology of these traits. In this study, we were able to partially support existing findings on emotion perception differences. We were unable to verify a developing noradrenaline (NA) hypothesis with respect to the origin of schizotypy, despite simultaneously providing support for its role in emotion processing. We have further provided supplementary findings with respect to a dimension of schizotypy that has been studied less extensively in previous research. In what follows, we more elaborately discuss the obtained results and relate our findings to both previous work and future possibilities.

Emotion Processing and Schizotypal Traits: Our Findings

Previous literature has identified a relation between schizotypal traits and both a negative bias in the labeling emotions and lower valence evaluations of emotional expressions (Abbott & Green, 2013; Brown & Cohen, 2010; Eack et al., 2010; Germine & Hooker, 2011; Morrison et al., 2013; Williams et al., 2007). The specifics of this relation remain unclear to this date, especially when considering the dimensions of schizotypy in which these differences are most strongly exhibited. Emotional impairments have previously been inconsistently related to the positive, negative and/or the cognitive disorganization dimension (Abbott & Byrne, 2013; Abbott & Green, 2013; Brown & Cohen, 2010; Germine & Hooker, 2011; Williams et al., 2007). Whereas the findings with respect to these dimensions could not be confirmed, we did find such an association with respect to the fourth dimension studied, impulsive nonconformity. Our results showed that individuals with higher scores on the impulsive nonconformity scale tended to evaluate faces more negatively compared to average rating tendencies, across different emotions and different intensities. Although we found indications that the positive and negative schizotypy traits may also exhibit a similar bias, post-hoc results were unable to conclusively confirm an association. The findings with respect to the impulsive nonconformity scale alongside indeterminate associations with the positive and negative dimensions do support the general finding that schizotypy is associated with a negative-bias in emotion processing (Brown & Cohen, 2010; Eack et al., 2010; Williams et al., 2007).

We found that this effect was most prominent with respect to negative emotions and not significant with respect to happy facial expressions, similar to the findings published by Brown and Cohen (2010) and Williams and colleagues (2007). The suggested specificity to negative emotions is consistent with findings for related populations such as schizotypal personality disorder (Ripoll et al., 2013) and schizophrenia (Johnston, Katsikitis & Carr, 2001). Previous literature also indicates that it is with respect to low intensity, ambiguous and neutral faces that schizotypy groups differ from control groups (Brown & Cohen, 2010). This challenge does not seem to be limited to facial expressions, with similar findings concerning ambiguous situational characteristics (Quirk, Subramanian & Hoerger, 2007). Likewise, the specificity to more ambiguous stimuli has also been observed in related subgroups such as schizophrenia patients (Kohler et al., 2003; van‘t Wout et al., 2007) and relatives of schizophrenia patients (Bediou et al., 2007; Eack et al., 2010). In our study, the impulsive nonconformity

dimension interacted with intensity, with the effect of this dimension gradually decreasing with increasing intensity. This suggests that it is principally in the face of low-intensity stimuli that higher scorers differ from low scoring participants. Neutral faces were similarly evaluated more negatively by high scorers on the impulsive nonconformity scale, although the extent to the negative bias was not substantially higher compared to the negative bias recorded in response to emotional faces.

Alternatively, we find support for the specificity of this bias to ambiguous stimuli in the significant association between the impulsive nonconformity scale and the unusual experiences scale and "Surprised" faces, seeing as "Surprise" is known to be a fairly ambivalent emotion (Fontaine et al., 2007; Noordewier & Breugelmans, 2013). Interestingly, the nature of this association differs between the two subscales, with impulsive nonconformity negatively influencing valence ratings and unusual experiences positively influencing valence ratings. This difference is first and foremost consistent with the ambivalent nature of "Surprise". To elaborate on this trend, we speculate that impulsive nonconformity and its anti-social aspects may have shaped a more negative interpretation of this emotion, while unusual experiences and its reflection of positive schizotypy (i.e. magical thinking) may have led to a more positive interpretation. It nevertheless remains important to consider the highly subjective and contextual nature of the interpretation of "Surprise" alongside the possibility that specific schizotypal traits may play a role in determining which interpretation is followed. The general lack of consistent findings with respect to the role of each dimension on emotion processing as previously illustrated prevent us from performing a well-founded comparison with previous findings, and as such we cannot conclusively comment on the trends we observed.

The general observation that the associations seem to be more apparent within the impulsive nonconformity scale may indicate that emotion processing deficits may not be a construct-wide attribute. An important limitation in this respect is the modest number of high scoring participants on each scale, in spite of the fact that we modified our sampling method towards the end of the testing period in an attempt to avoid such an occurrence. We presume that range-restriction effects prevented us from being able to consider the full scope of each dimension. However, as the negative bias associated with impulsive nonconformity was apparent throughout the range of the scale, we infer that the range-restriction does not necessarily invalidate the association observed. In future research, a larger and more strategically accumulated sample could improve this

limitation, and further elaborate on the rudimentary associations revealed within this study.

The authors of the sO-LIFE questionnaire report that the impulsive nonconformity scale contains mostly disinhibition and impulsivity characteristics (Mason et al., 1995). They also describe an anti-social element, which may be able to explain the observed negative bias in emotion perception. Mason et al. (1995) further make the note that moderate scores on this scale may reflect a freer and less conforming lifestyle, similar to what is often witnessed in higher education students. Our sample included, but was not limited to, participants who belong to this category. Still, should this aspect have played a determining role, we would expect the distribution of scores to reflect a higher number of participants reporting moderate scores, instead of being skewed significantly to the right. We must further consider results from more recent sO-LIFE validity studies which question the consistency of its factorial structure (three or four factors), and more specifically the validity of the impulsive nonconformity scale (Fonseca et al., 2015; Lin et al., 2013). On the other hand, the specificity of our findings to this scale may indicate that the impulsive nonconformity dimension does indeed cover aspects that the other dimensions do not. Although it is evident that more factor analysis and validation studies are necessary, seeing as the sO-LIFE was designed specifically based on schizotypal characteristics, it remains plausible that the underlying concept to the impulsive nonconformity scale includes a schizotypal element.

Impulsive nonconformity is a dimension that has been studied less extensively in schizotypy studies, given its specificity to the O-LIFE scale. As the majority of previous studies concerning schizotypy populations were performed using SPQ results (for a review see Giakoumaki, 2016), it is understandable that this link has not been highlighted to this date. On the other hand, it is surprising that no consistent associations were found with the three remaining subscales, considering that these most closely resemble SPQ dimensions. Furthermore, it is noteworthy that the distribution of cognitive disorganization scores seemed to face less range-restriction, yet still previous findings with respect to this dimension could not be replicated. Considering that Pearson correlations between sO-LIFE subscales and SPQ-Brief Revised subscales do not supersede 0.52 (as seen in Fonseca-Pedrero, Ortuño-Sierra, Mason & Muñiz, 2015), we can conclude that these subscales only partly measure the same things. This could explain the discrepancy mentioned above. Other authors have referenced the influence of the use of different schizotypy scales on obtained results in emotion processing research, for example in relation to a 2004 study where the use of the Launay-Slade

Hallucination Scale (1981) may have been the reason the authors were not able to record any significant differences between schizotypy and control groups (Giakoumaki, 2016; van 't Wout et al., 2004). Other methodological differences could also have played a role in the inconsistency we observed (i.e. different emotion paradigm, different data analysis strategies, different sample, etc., as discussed more extensively below).

We included the Positive and Negative Affect Scale (PANAS) in our research as a complementary and possibly supplementary tool to the sO-LIFE. No significant relations between the PANAS subscales and valence ratings or reaction times were found. This suggests that neither self-reported positive affect nor negative affect influence facial expression evaluation. This in itself is an unexpected finding, considering the 'mood congruency effect' which states that individuals with negative emotional states interpret emotional expression as more negative, with the opposite being true for individuals with positive emotional states (Csukly, Czobor, Simon, & Takács, 2008). Previous research using the PANAS scale is inconsistent, with one study associating higher negative affect to impaired perception of sad faces (Gur et al., 1992), other studies associating higher negative affect to improved recognition of sad faces (Rus-Calafell, Gutiérrez-Maldonado & Frerich, 2013; Suzuki, Hoshino, Shigemasu & Kawamura, 2007), and yet other studies finding no significant relations between emotion recognition accuracy and PANAS scores (Heberlein, Padon, Gillihan, Farah, & Fellows, 2008; Paradee, Lumley, Rapport & Hanks, 2008). Our results seem to support the latter. Furthermore, the fact that we were able to report significant associations based on the sO-LIFE scores but not on the PANAS scores suggests that characteristics unique to the sO-LIFE scale reflect the determining components. In conclusion, by means of this study, we may have been able to provide more insight into emotion processing in schizotypal individuals, further contributing to the small amount of existing literature on this topic.

Additional findings.

The valence rating results also shed light on an associated topic in emotion perception research, namely the question of whether "Surprise" is a positive or negative emotion. Our results indicate that "Surprise" follows the trend of more negative evaluations with increasing intensity, suggesting a classification as a more negative than positive emotion. This finding is consistent with previous results with respect to facial emotion identification (Neta, Davis & Whalen, 2011; Noordewier & Breugelmans, 2013). On the other hand, this trend may be subjective to the modelling of the emotion, and not

the emotion itself. That is to say, it is possible that the two models happen to show a more negative type of “Surprise” than a more positive type of “Surprise”. Moreover, a frequent confusion between “Surprise” and “Fear” has been noted (Ekman et al., 1987). To take this possible confusion into account, future researchers could first ask participants to label the emotion they saw before providing a valence evaluation (similar to the method applied by Jusyte & Schönenberg, 2014). The delay and additional processing this method introduces may, however, influence the valence ratings themselves. Nonetheless, the less distinct trend we observed relative to the trends seen in other emotions may have been caused by more varied valence evaluations, indicative of the more subjective interpretation of this emotion. On the other hand, the fact that even at high intensity levels “Surprised” faces were assigned relatively modest evaluations can be interpreted as an illustration of its ambivalent nature, being neither extremely positive nor extremely negative. This also indicates that the confusion with “Fear” was not pronounced in our study, as in such a case we would expect a lower average valence evaluation.

Limitations in emotional paradigms.

We previously discussed that emotional paradigms can be a determining factor in obtained results. This may have been one of the factors that influenced the discrepancy between our results and the results of the similar study performed by Brown & Cohen (2010). Although we both employed the use of static low and high intensity facial expressions, in this study we were able to more specifically control the degree of ambiguity of the facial expressions through the use of a morphed faces paradigm. The unchanging nature of the faces was crucial to the attribution of a specific valence evaluation to a specific expression intensity and accommodated a more stable measurement of the pupil dilation values. Our manipulation check was successful, with a consistent and significant increase/decrease in valence evaluations (depending on the type of emotion) with increasing intensity of the facial expression displayed. Although the morphed faces paradigm was expressly chosen for its suitability to our aims, experts are increasingly suggesting the use of more complex emotion paradigms, such as dynamic faces, that may be able to more closely represent/approximate real-life emotion perception (Abbott & Byrne, 2013; Brown & Cohen, 2010; Prehn et al., 2013; Williams et al., 2007). Not only would this increase the ecological validity of obtained results, it may also reveal other emotion perception differences not discussed to this date. The inclusion

of contextual cues could also prove to be beneficial, especially when working with more subjective emotions such as “Surprise”.

We also decided to work with fixed intervals in the valence rating scale. Although a free-answer scale might have increased the sensitivity to more subtle differences in the valence ratings, this would also have decreased the practical significance of the obtained results. On the other hand, it may be worthwhile for future studies to use more sensitive scales, to determine whether or not even small differences in emotion valence rating patterns exist with respect to the sO-LIFE dimensions.

On another note, multicollinearity indications did not allow us to explore the effects of the image gender on valence evaluations. Previous literature has shown a trend of female faces often being evaluated as more positive than male faces (Garrido & Prada, 2017; Harris, Hayes-Skelton & Ciaramitaro, 2016). This supports our assumption that the image gender may be able to account for some of the residual variation not accounted for by our statistical models. We only included two models, one of each gender. This may have been insufficient to extract the gender effect from within the other effects at play. It is possible that the inclusion of an additional model of each gender (or more) could have diminished the multicollinearity with other predictors. Future studies with a focus on this aspect, or with a similar aim but with a larger experimental time frame, could consider the inclusion of supplementary models to explore this possible gender-effect.

More generally, by means of this experimental design we cannot discern whether the differences found reflect specific emotion perception differences, or more general perceptual variation. Prehn et al. (2013) suggest the use of control stimuli (i.e. non-emotional, non-facial stimuli such as objects) to determine whether it is solely on emotional content that subgroups differ. It is further important to acknowledge that we cannot conclusively decide that the observed emotional dissimilarities are specific to schizotypy, irrespective of the debated validity of the impulsive nonconformity scale. A group comparison design is more suited for such conclusions. In future research, such a design could be adopted to further consolidate the initial associations between schizotypy and emotion processing we observed in the current study.

Implications of valence rating findings.

It is worth mentioning that the effect sizes of all discussed results are considerably low (some failing to supersede 0.00), especially in comparison to a larger main effect of

the type of emotion on the valence ratings (as theoretically expected). On the other hand, the fact that associations were found while controlling for the much larger effect of the type of emotion could signify that these initial findings are worth further exploration. Brown & Cohen (2010) did not report effect sizes or confidence intervals for the association they found between cognitive disorganization and lower valence ratings. As they are, to the best of our knowledge, the only researchers that have studied valence evaluations of emotional faces in schizotypy groups, there are insufficient prior studies to allow us to perform an effect size comparison. Brown & Cohen (2010) did, however, find that lower valence ratings of emotional faces were associated with lower self-reported quality of life. They suggest that this negative bias may be detrimental to social enjoyment, interpretations of others' intentions and the ability to react to and express emotions (Brown & Cohen, 2010). We were unable to find existing research surrounding which amount of negative bias leads to the discussed social consequences. Comparative studies to this end could be useful for future research, as a way of determining which individuals are more vulnerable than others.

The further implications of a negative bias were discussed in the introduction of this paper. Associations between emotion perception impairments and social anxiety, risk for social isolation, impaired social functioning and emotional communication difficulties have been established (Abbott & Green, 2013; Aguirre et al., 2008; Lenzenweger, 2018; Rosell et al., 2014; Statucka & Walder, 2017). Furthermore, consistent negative biases could lead to the development of maladaptive social schema in predicting the behavior of others (Brown & Cohen, 2010). It should be made clear that facial affect recognition cannot possibly be the only factor influencing social functioning in schizotypes, as confirmed by Statucka and Walder (2017), but the existing research converges in the high probability that this skill plays a significant role. That being said, differences do not limit themselves to facial emotion processing. Emotional intelligence (Aguirre et al., 2008) and empathic accuracy deficits (Henry, Bailey, & Rendell, 2008) have been found in psychometrically-defined schizotypes compared to people with few schizotypal traits. Ripoll et al. (2013) found similar empathic accuracy deficits in a schizotypal personality disorder group and further found that this measure was correlated to insufficient social support. Kerns (2005) found that individuals with positive schizotypy tended to pay more attention to their emotions but experienced less emotional clarity, which they hypothesized may contribute to difficulties relating to mood regulation. Also concepts such as theory of mind have been found to be impaired (Gooding & Pflum, 2011). This all testifies to the importance of maintaining a comprehensive approach in

studying emotional processes, opening up many possibilities for not only future research, but also future intervention.

However, given that the research that has been conducted to this date is all of cross-sectional nature, we cannot make inferences about the causality between impairments in emotion perception and social difficulties (Abbott & Green, 2013). In other words, it is possible that impairments in emotion perception lead to social difficulties, but it is also possible that it is the social difficulties themselves that affect emotion perception. Similarly, many studies mention the possibility that comorbid mood disorders can possibly play a moderating role in these findings (Brown & Cohen, 2010; Statucka & Walder, 2017; Penton-Voak, Munafò & Looi, 2017). On the other hand, there is also evidence suggesting that negative processing biases may be able to predict future depressive symptoms even after controlling for present and previous depressive episodes (Rude, Wenzlaff, Gibbs, Vane & Whitney, 2002). Longitudinal studies are necessary to elucidate the question of causality. Meanwhile, the eventual moderation by comorbid mood disorders can be controlled for in schizotypy studies. By inclusion of the PANAS, we showed that negative affect levels did not significantly influence emotion perception. In studies with group-comparison designs, the inclusion of a psychopathology control group (individuals with mood disorders) alongside schizotypy groups (in accordance with the observed multidimensionality) and a general control group may be effective in determining the role of these comorbid disorders (Morrison et al., 2013).

Speed of Emotion Processing

Our second measure of interest was the time needed to provide the valence ratings. Previous literature has shown an association between groups at risk for schizophrenia and reaction times to emotional faces, although the direction of the association was not consistent between studies. For example, one study recorded quicker reaction times compared to control measurements while another study reported slower reaction times (Brown & Cohen, 2010; Eack et al., 2010). Our findings do not suggest an association between schizotypy and reaction times across emotions and intensities. We did find indications of associations between the cognitive disorganization and introvertive anhedonia dimensions and intensity. Especially with respect to the introvertive anhedonia dimension, the interaction plot seems to suggest that higher scorers may have reacted more quickly to facial expressions of different intensities. Post-

hoc calculations were not effective in further describing this association. Introvertive anhedonia was not associated with the type of emotion in this study, for which our hypothesis that a propensity to negativity would be associated with a quicker response to negative stimuli of high intensities was not supported. We presume that the previously mentioned limitation of range-restriction in the sO-LIFE scale scores may again have limited our ability to detect trends in schizotypal processing. Nevertheless, the lack of significant global results could be a positive sign. As mentioned by Statucka & Walder (2017), slower face affect processing could be detrimental to social interactions. Our results suggest that schizotypy groups may not face this challenge with respect to social cognitive habits after all.

We had expressed a general supposition that neutral and low intensity faces would require a longer evaluation time than more intense, less ambiguous expressions, due to the general difficulty schizotypy groups seem to face with neutral and ambiguous stimuli (Brown & Cohen, 2010). In contrast to this expectation, results across all emotions showed that reaction times to higher intensity faces were greater than reaction times to lower intensity faces. One possible explanation for this occurrence is that the valence rating scale included a “Neutral” label in the middle of the line. This could have caused participants to quickly evaluate a facial expression as neutral, and in doing so not have to further decide exactly where on the scale from negative to positive to place their answer. We can extend this reasoning to the low intensity faces, given the high degree of similarity between the neutral and low intensity faces. However, this reasoning would imply that the middle intensity faces would prove to be the most difficult to evaluate, as no labels were provided between the positive end, the neutral middle and the negative end. This is not the trend we observed. High intensity faces were consistently the faces that required the longest reaction time. Perhaps even at these “high” intensities (60-70% emotional expression, 30%-40% neutral), a degree of ambiguity remained that demanded a longer processing time. Conducting a similar experiment with inclusion of 100% emotional faces could help determine whether or not this trend would persist. Another possible explanation of the quickest reaction times to neutral faces is that these faces were not morphed with other faces. Following this reasoning, it is possible that despite the ambiguous nature of neutral facial expressions, participants may have been able to detect their naturalistic, unmorphed nature, making them easier to identify and evaluate.

Our results were further inconsistent with results published by Brown & Cohen (2010) in the reaction time trends per emotion. We found that, spanning across the different intensities, responses to happy faces were executed most slowly and responses to angry and sad faces were executed most quickly. This is opposite to Brown & Cohen's findings (2010), in which they recorded the quickest reaction times to happy faces and longest reaction times to angry faces. Our findings are also inconsistent with other findings from general literature, where most studies find that positive facial emotion expressions are generally detected and reacted to more quickly (Calvo & Lundqvist, 2008; Leppänen, Tenhunen & Hietanen, 2003; Palermo & Coltheart, 2004). There exists, however, a certain degree of inconsistency in the observation of a negative- or positive-bias, that may be influenced by methodological aspects (for a review, see Kauschke, Bahn, Vesker & Schwarzer, 2019). With respect to the current study, it may be that the morphed faces paradigm influenced our findings. The lowered degree of positivity in all happy faces as a result of the combination with neutral faces possibly increased the difficulty of deciding just how positive the facial expression was. Seeing as neutral faces are generally seen as more negative than positive (Kerestes et al., 2009), the combination of "Neutral" and "Happy" may have been more challenging than the combination of a neutral face with an already negative emotion. Another possibility is a phenomenon described by Estes & Verges (2008), who suggest that the speed of responding to negative stimuli is dependent on the nature of the response. If the valence of the stimulus is not relevant to the response, the required attentional detachment from the negative valence towards other cognitive processes may result in slower responses. On the other hand, when responses require valence evaluations, this additional disengagement is not required, for which the motor system is not suppressed, and reactions can be placed more quickly. Considering the centrality of valence evaluations in the responses in this study, our study is consistent with these findings. Alternatively, there are also evolutionary explanations for our results. It may be that the aversive nature of the negative facial expressions triggers a faster response, in light of the importance of quickly attending to negative (social) stimuli in function of survival (Kauschke et al., 2019).

On another note, our results further provide support for the multidimensionality of the emotion "Surprise". In comparison to other emotions, reactions to "Surprised" faces were consistently reacted to more slowly, which may be attributed to a more complex processing of this emotion. Furthermore, it seems that this emotion is subject to a greater effect of increasing intensity. The trend suggests that the more apparent the "Surprised"

facial expression, the longer the reaction time, which supports the notion of a complex processing associated with this ambiguous emotion.

Reaction time limitations.

The reaction time was measured as the time between the rating scale appeared and an answer was given. Although instructions were given to provide an answer as quickly as possible, we cannot be sure whether all participants consistently followed this request. It is also possible that increasing fatigue or decreasing motivation played a role, as the task generally lasted around 20 minutes with only one break to rest the eyes. We placed a maximum reaction time at 4 seconds. Only 7 trials were missing a valence rating as a consequence of exceeding the maximum time limit, which leads us to assume that the 4 second time period was by and large sufficient to provide an answer. It is possible that the combination of a sufficient time frame and the lack of a penalty to slower answers counteracted our request to answer rapidly. On the other hand, it may be interesting to do future research without instructions to react as quickly as possible and without an enforced time limit, to explore whether or not high schizotypy participants habitually take longer to evaluate faces in unrestricted circumstances.

Aside from the practical considerations of a reaction time approach, we suspect that two trials per condition may not have been sufficient to properly power the reaction time measurements. Considering the suggestion of minimally 1,600 observations per condition to effectively measure differences of 15ms (Brysbaert & Stevens, 2018), it is likely that by means of the current design we were not able to detect the effects we intended to observe. Despite that we were limited in the allotted time in which to execute the experiment and despite the likely increase in weariness associated with an increase in trials, future studies aiming to effectively measure reaction time differences must take these suggestions into account.

The coefficients of determination calculated showed that the model could account for only roughly 5% of the observed variance. Inclusion of the random intercept improved the explained variance to nearly 50%, for which we surmise that in the end, the reaction time trends observed were mainly caused by inter-individual differences in addition to a certain degree of error.

Noradrenaline Hypothesis of Schizotypal Traits

Our final measure of interest was the pupil dilation recorded in response to the emotional faces. This measurement was included as a proxy for NA (Aston-Jones & Cohen, 2005; Gabay, Pertzov, & Henik, 2011; Koss, 1986) in light of an evolving NA hypothesis of schizophrenia, and by extension, schizotypy. Studies suggest that the noradrenergic system may be a crucial part of the complex etiology of such characteristics (Fitzgerald, 2014; Yamamoto & Hornykiewicz, 2004 Hartman, 1976; Hornykiewicz, 1982, 1986). To the best of our knowledge, we are the first to include a NA measurement in a schizotypy study. Whilst our results do not support a general link between schizotypal traits and NA, our findings suggest that higher scorers on specific schizotypy dimensions may have shown differential pupillary responses to neutral faces.

Pupillometry findings.

Results showed that the scores on the cognitive disorganization and introvertive anhedonia subscales were associated with relatively larger pupil dilation values in response to neutral faces in comparison to the average pupil dilation values recorded in our sample. The effects on facial expressions of other intensities were not significant. This may be a reflection of the specificity mentioned earlier between schizotypy and a sensitivity to neutral facial expressions. In light of the NA hypothesis mentioned above, this finding can provide partial support for an association between schizotypy and NA. In the current study, we did not observe global effects of schizotypy on pupil dilation values. Although the general issue of range-restriction in the sO-LIFE scores may have limited our possibility of fully exploring this hypothesized relation, these results may form an indication that neither positive nor negative schizotypy is associated with increased or decreased NA levels, respectively. However, both positive and negative schizotypy traits can be found in the same individual, making it uncertain as to how the NA system will respond. This response could furthermore be event-related. A group-comparison design consisting of participants who either score high on positive schizotypy or high on negative schizotypy, but not both, could provide more refined insight into the relation between schizotypy traits and NA.

Our findings furthermore suggest that more intense emotional expressions elicit relatively larger pupil dilations (see Oliva & Anikin, 2018 for similar findings). We did not find a significant effect of emotion, similar to results published by Bradley et al. (2008). This supports the developing hypothesis that pupil dilations reflect a global emotional

arousal, irrespective of the valence of the emotional stimuli, despite other studies showing differential pupillary responses to different emotions (Carsten et al., 2019; Hammerschmidt, Kagan, Kulke & Schacht, 2018). We find further support for this hypothesis in how the lowest pupil dilation values were measured in response to neutral faces relative to emotional faces. Our findings are an extension of the results published by Bradley et al. (2008), given that they used more general pleasant, unpleasant and neutral stimuli including people but not specific to facial expressions.

In light of the association between emotion processing and NA described in the introduction of this paper, and considering the validity of pupillometry as a proxy for NA, the current findings provide additional support for the role of NA in emotion processing. In this respect, our findings are consistent with the results published by De Martino et al. (2008), who reported a greater increase of phasic NA in response to emotional stimuli than in response to neutral stimuli. As mentioned in the introduction, the exact nature of this proposed relation remains unclear with inconsistent findings surrounding the differential effects of NA on the recognition of specific emotions. Our lack of a significant main effect of emotion may suggest that such differential relations do not exist.

The model fit was fairly low at only 15.9% explained variance, of which the large majority of variance was explained by inter-individual differences. The remaining observed variance was not accounted for by our model. In light of the initial indications that the image gender may have played a significant role in pupil dilations, it may be that part of the residual variance can be attributed to a gender-effect (e.g. sexual arousal). The multicollinearity issues prevented us from exploring this aspect ourselves, but similar to what we expressed above, this may be an interesting consideration to further examine in future research. Even so, seeing as pupillary responses are influenced by a wide variety of factors, there are an unending amount of possible explanations for what caused the remaining variation. Undoubtedly, errors related to the limitations we faced will also have played a substantial role.

Pupillometry limitations.

The principal problem we faced was a high amount of lost data. Although we instructed participants to refrain from blinking as much as possible, we cannot determine the extent to which participants abided by this request. This instruction could have been improved by specifically requesting to limit eye blinks to the valence evaluation phase, as we were not interested in pupil dilation values during this time frame. Following

previously employed methods (see Carsten et al., 2019, for example), 100ms before and after blink saccades were removed to control for artifacts resulting from the closing of the eyelid. Much of this data was able to be interpolated, however the combination of frequent blinks and sporadic technical failure of the eye tracker culminated in a sizeable amount of data that met the exclusion criteria of 50% missing values within baseline or stimulus measurement (more specifically 23.93% of the complete set of feasible trials). In future research, we recommend the combination of a specified blink period and longer measurement intervals (both baseline and stimulus measurement) to compensate for eventual blinks.

Upon analyzing the data, we noticed that almost all pupil dilation values were negative, indicating constrictions instead of dilations. We had expected dilations due to an anticipated increased arousal to emotional stimuli (Bradley et al., 2008; Kret, Stekelenburg, Roelofs, & de Gelder, 2013). We were aware that the luminance difference between the pre-stimulus fixation cross and the facial expressions would prompt a pupillary light reflex but hypothesized that this light reflex would be equivalent between participants thus controlling for this effect (for similar approaches see Bradley et al., 2008; Carsten et al., 2019; Kret et al., 2013; Prehn et al., 2013). We further ensured that the luminance was equal between stimuli by decreasing the contrast, equating the brightness and ensuring that the fixation cross remained present throughout all stimulus presentations. This theoretically permitted any eventual supplementary inter-individual differences found to be attributed to responses to stimulus characteristics of interest (i.e. intensity of the stimulus, emotion type) or to individual characteristics of interest (i.e. schizotypal traits). While this hypothesis remains plausible, it seems the pupillary light reflex may have overshadowed the dilation associated with the task related pupillary response. To avoid the anticipated pupillary light reflex, some authors previously chose to limit pupillary analysis to an interval starting 2 seconds (Bradley et al., 2008) post stimulus presentation or even earlier (Prehn et al., 2013), as indications have been provided that by this time the pupil starts to dilate in response to the stimulus presented. There is, however, no consensus on the true latency of pupil responses to stimuli and of the duration of the pupillary light reflex. Seeing as our stimuli were only presented for 3 seconds, we refrained from applying similar strategies to avoid further data loss. Other authors (Blackburn & Schirillo, 2012) chose to explicitly control for this aspect by using an isoluminant baseline measurement (such as a blurred face), thus ensuring any pupillary changes were caused by the presentation of the stimulus itself. In light of our findings, we suggest such an approach for future research.

General limitations

As with other psychology research, we must also question the generalizability of the current findings. The frequent issue of a homogenous sample comprised of undergraduate psychology students was only partly applicable to our study. As previously stated, our sample included higher education students but was not limited to this demographic. Nevertheless, it remains possible that a limited variation decreased the likelihood of detecting existing trends. Similarly, while our sample was large enough to perform complex statistical analyses, a larger sample could have improved the study's power and counteracted range-restriction effects. Furthermore, considering the possibility of an influence of the image gender on valence ratings and pupil responses, a gender balanced sample may be beneficial should future studies aim to explore the effects of participant gender on this potential gender-bias.

Conclusions

By means of this study, we provide partial support for a negative bias associated to schizotypy and hereby contribute to the existing research on this vulnerability in this already vulnerable population. Our findings suggest that asocial schizotypy characteristics may be associated to more negative valence evaluations of facial expressions, most prominently with respect to faces expressing negative emotions. Despite indications that ambivalence may influence valence and pupillary responses in schizotypy groups, the results do not suggest that the observed negative bias is more apparent with respect to ambiguous stimuli. Our findings were unable to substantiate the NA hypothesis of schizotypy but support its involvement in emotion processing. By and large, these results may be a first indication of possible relations between schizotypy, NA and emotion processing, which can be further elaborated on in future research.

References

Abbott, G. R., & Byrne, L. K. (2013). Schizotypal traits are associated with poorer identification of emotions from dynamic stimuli. *Psychiatry Research, 207(1-2),* 40-44. doi: 10.1016/j.psychres.2013.03.005

Abbott, G. R., & Green, M. J. (2013). Facial affect recognition and schizotypal personality characteristics. *Early Intervention in Psychiatry, 7,* 58-63. doi: 10.1111/j.1751-7893.2012.00346.x

Aguirre, F., Sergi, M. J., & Levy, C. A. (2008). Emotional intelligence and social functioning in persons with schizotypy. *Schizophrenia Research, 104,* 255-264. doi: 10.1016/j.schres.2008.05.007

Aston-Jones, G., & Cohen, J. D. (2005). An Integrative Theory of Locus Coeruleus-Norepinephrine Function: Adaptive Gain and Optimal Performance. *Annual Review of Neuroscience, 28,* 403-450. doi: 10.1146/annurev.neuro.28.061604.135709

Avramopoulos, D., Stefanis, N. C., Hantoumi, I., Smyrnis, N., Evdokimidis, I., & Stefanis, C. N. (2002). Higher scores of self reported schizotypy in healthy young males carrying the COMT high activity allele. *Molecular Psychiatry, 7,* 706-711. doi: 10.1038/sj.mp.4001070

Bates D, Mächler M, Bolker B, & Walker S. (2015). “Fitting Linear Mixed-Effects Models Using lme4.” *Journal of Statistical Software*, 67(1), 1–48. doi: 10.18637/jss.v067.i01.

Bediou, B., Asri, F., Brunelin, J., Krolak-Salmon, P., D’Amato, T., Saoud, M., & Tazi, I. (2007). Emotion recognition and genetic vulnerability to schizophrenia. *British Journal of Psychiatry, 191,* 126-130. doi: 10.1192/bjp.bp.106.028829

Blackburn, K., & Schirillo, J. (2012). Emotive hemispheric differences measured in real-life portraits using pupil diameter and subjective aesthetic preferences. *Experimental Brain Research*, *219*(4), 447–455. doi: 10.1007/s00221-012-

3091-y

Bradley, M. M., Miccoli, L., Escrig, M. A., & Lang, P. J. (2008). The pupil as a measure of emotional arousal and autonomic activation. *Psychophysiology, 45(4)*, 602-607. doi: 10.1111/j.1469-8986.2008.00654.x

Brown, L. A., & Cohen, A. S. (2010). Facial emotion recognition in schizotypy: The role of accuracy and social cognitive bias. *Journal of the International Neuropsychological Society, 16,* 474-483. doi: 10.1017/S135561771000007X

Brysbaert, M., & Stevens, M. (2018). Power Analysis and Effect Size in Mixed Effects Models: A Tutorial. *Journal of Cognition, 1*(1), 1–20. doi: 10.5334/joc.10

Burch, G. S.J., Steel, C., & Hemsley, D. R. (1998). Oxford-Liverpool Inventory of Feelings and Experiences: Reliability in an experimental population. *British Journal of Clinical Psychology, 37,* 107-108. doi: 10.1111/j.2044-8260.1998.tb01284.x

Calvo, M. G., & Lundqvist, D. (2008). Facial expressions of emotion (KDEF): Identification under different display-duration conditions. *Behavior Research Methods, 40*(1), 109-115. doi: 10.3758/BRM.40.1.109

Carsten, T., Desmet, C., Krebs, R. M., & Brass, M. (2019). Pupillary Contagion Is Independent of the Emotional Expression of the Face. *Emotion, 19*(8), 1343-1352. doi: 10.1037/emo0000503

Chen, J., Lipska, B. K., Halim, N., Ma, Q. D., Matsumoto, M., Melhem, S., Kolachana, B. S., Hyde, T. M., Herman, M. M., Apud, J., Egan, M. F., Kleinman, J. E., & Weinberger, D. R. (2004). Functional Analysis of Genetic Variation in Catehol-O-Methyltransferase (*COMT*): Effects on mRNA, Protein, and Enzyme Activity in Postmortem Human Brain. *American Journal of Human Genetics, 75(5),* 807-821. doi: 10.1086/425589

Chen, K. C., Lee, I. H., Yeh, T. L., Chiu, N. T., Chen, P. S., Yang, Y. K., Lu, R. B., & Chen, C. C. (2012). Schizotypy trait and striatal dopamine receptors in healthy

volunteers. *Psychiatry Research: Neuroimaging,201*, 218-221. doi: 10.1016/j.pscychresns.2011.07.003

Claridge, G. (1996). Origins of Mental Illness: Temperament, Deviance and Disorder. *European Journal of Personality, 2(2),* 169-170.

Claridge, G. (1997). *Schizotypy: Implications for illness and health.* New York, NY, US: Oxford University Press. doi: 10.1093/med:psych/9780198523536.001.0001

Cloninger, C. R., Przybeck, T. R. & Svrakic, D. M. (1991). The Tridimensional Personality Questionnaire: U.S. normative data. *Psychological Reports, 69(3)*, 1047-1057. doi: 10.2466/PR0.69.7.1047-1057

Crawford, J. R., Henry, J. D. (2004). The Positive and Negative Affect Schedule (PANAS): Construct validity, measurement properties and normative data in a large non-clinical sample. *British Journal of Clinical Psychology, 43(3),* 245-265. doi: 10.1348/0144665031752934.

Csukly, G., Czobor, P., Simon, L., & Takács, B. (2008). Basic emotions and psychological distress: association between recognition of facial expressions and Symptom Checklist-90 subscales. *Comprehensive Psychiatry, 49,* 177-183. doi: 10.1016/j.comppsych.2007.09.001

De Martino, B., Strange, B. A., & Dolan, R. J. (2008). Noradrenergic neuromodulation of human attention for emotional and neutral stimuli. *Psychopharmacology*, *197*(1), 127–136. https://doi.org/10.1007/s00213-007-1015-5

Duque, A., Sanchez, A., & Vazquez, C. (2014). Gaze-fixation and pupil dilation in the processing of emotional faces: The role of rumination. *Cognition and Emotion, 28*(8), 1347-1366. doi: 10.1080/02699931.2014.881327

Eack, S., Mermon, D. E., Montrose, D. M., Miewald, J., Gur, R. E., Gur, R. C., Sweeney, J. A., & Keshavan, M. S. (2010). Social Cognition Deficits Among

Individuals at Familial High Risk for Schizophrenia. *Schizophrenia Bulletin, 36(6),* 1081-1088. doi: 10.1093/schbul/sbp026

Ekman, P., Friesen, W. V., O'Sullivan, M., Chan, A., Diacoyanni-Tarlatzis, I., Heider, K., Krause, R., LeCompte, W. A., Pitcairn, T., Ricci-Bitti, P. E., Scherer, K., Tomita, M., & Tzavaras, A. (1987). Universals and cultural differences in the judgments of facial expressions of emotion. *Journal of Personality and Social Psychology, 53*(4), 712–717. doi: 10.1037/0022-3514.53.4.712

Estes, Z., & Verges, M. (2008). Freeze or flee? Negative stimuli elicit selective responding. *Cognition, 108*(2), 557-565. doi: 10.1016/j.cognition.2008.03.003

EyeLink Data Viewer 3.2.1 [Computer software]. (2018). Mississauga, Ontario, Canada: SR Research Ltd.

Eysenck, H. J. (1952). The scientific study of personality. Oxford, England: Macmillan.

Farley, I. J., Price K. S., & Hornykiewicz, O. (1978). Monoaminergic Systems in the Human Limbic Brain. *Limbic Mechanisms,* 333-349. doi: 10.1007/978-1-4757-0716-8_12

Fitzgerald, P. J. (2014). Is elevated norepinephrine an etiological factor in some cases of schizophrenia? *Psychiatry Research, 215,* 497-504. doi: 10.1016/j.psychres.2014.01.011

Fonseca-Pedrero, E., Garcia-Cueto, E., & Muñiz, J. (2007). Multidimensionality of schizotypy under review. *Papeles del Psicologo, 28(2),* 117-126. Retrieved from https://www.researchgate.net/publication/251770622_Multidimensionality_of_schizotypy_under_review

Fonseca-Pedrero, E., Ortuño-Sierra, J., Mason, O. J., & Muñiz, J. (2015). The Oxford-Liverpool Inventory of Feelings and Experiences short version: Further validation. *Personality and Individual Differences, 86*, 338-343. doi: 10.1016/j.paid.2015.06.041

Fontaine, J. R. J., Scherer, K. R., Roesch, E. B., & Ellsworth, P. C. (2007). The world of emotions is not two-dimensional. *Psychological Science, 18*(12), 1050-1057. doi: 10.1111/j.1467-9280.2007.02024.x

Fox, J., & Monette, G. (1992). Generalized Collinearity Diagnostics. *Journal of the American Statistical Association, 87*(417), 178-183. doi: 10.2307/2290467

Gabay, S., Pertzov, Y., & Henik, A. (2011). Orienting of attention, pupil size, and the norepinephrine system. *Attention, Perception, & Psychophysics, 73(1),* 123-129. doi: 10.3758/s13414-010-0015-4

Garrido, M. V., & Prada, M. (2017). KDEF-PT: Valence, Emotional Intensity, Familiarity and Attractiveness Ratings of Angry, Neutral, and Happy Faces. *Frontiers in Psychology, 8*(2181). doi: 10.3389/fpsyg.2017.02181

Germine, L. T., & Hooker, C. I. (2011). Face emotion recognition is related to individual differences in psychosis-proneness. *Psychological Medicine, 41,* 937-947. doi: 10.1017/S00332917100001571

Giakoumaki, S. G. (2016). Emotion processing deficits in the different dimensions of psychometric schizotypy. *Scandinavian Journal of Psychology, 57,* 256-270. doi: 10.1111/sjop.12287

Gillespie, B. J., Hibbert, K. C., & Wagner, W. E. (2020). *A Guide to R for Social and Behavioral Science Statistics.* SAGE Publications.

Gooding, D. C., & Pflum, M. J. (2011). Theory of Mind and psychometric schizotypy. *Psychiatry Research, 188*, 217-223. doi: 10.1016/j.psychres.2011.04.029

Grant, P., Green, M. J., & Mason, O. J. (2018). Models of Schizotypy: The Importance of Conceptual Clarity. *Schizophrenia Bulletin, 44(2),* S556-S563. doi: 10.1093/schbul/sby012

Gur, R. C., Erwin, R. J., Gur, R. E., Zwil, A. S., Heimberg, C., & Kraemer, H. C. (1992). Facial Emotion Discrimination: II. Behavioral Findings in Depression. *Psychiatry Research, 42*(24)., 241-251. doi: 10.1016/0165-1781(92)90116-K

Hammerschmidt, W., Kagan, I., Kulke, L., & Schacht, A. (2018). Implicit reward associations impact face processing: Time-resolved evidencefrom event-related brain potentials and pupil dilations. *NeuroImage, 179*, 557-569. doi: 10.1016/j.neuroimage.2018.06.055

Harmer, C. J., Hill, S. A., Taylor, M. J., Cowe, P. J., & Goodwin, G. M. (2003). Toward a Neuropsychological Theory of Antidepressant Drug Action: Increase in Positive Emotional Bias After Potentiation of Norepinephrine Activity. *The American Journal of Psychiatry, 160(5),* 990 – 992. doi: 10.1176/appi.ajp.160.5.990

Harmer, C. J., Shelley, N. C., Cowen, P. J., & Goodwin, G. M. (2004). Increased Positive Versus Negative Affective Perception and Memory in Healthy Volunteers Following Selective Serotonin and Norepinephrine Reuptake Inhibition. *The American Journal of Psychiatry, 161(7),* 1256-1263. doi: 10.1176/appi.ajp.161.7.1256

Harris, D. A., Hayes-Skelton, S. A., & Ciaramitaro, V. M. (2016). What's in a Face? How Face Gender and Current Affect Influence Perceived Emotion. *Frontiers in Psychology, 7*(1468). doi: 10.3389/fpsyg.2016.01468

Hartman, E. (1976). Schizophrenia: A Theory. *Psychopharmacology, 49,* 1-15. doi: 10.1007/BF0042746

Heberlein, A. S., Padon, A. A., Gillihan, S. J., Farah, M. J., & Fellows, L. K. (2008). Ventromedial Frontal Lobe Plays a Critical Role in Facial Emotion Recognition. *Journal of Cognitive Neuroscience, 20*(4), 721-733. doi: 10.1162/jocn.2008.20049

Henry, J. D., Bailey, P. E, & Rendell, P. G. (2008). Empathy, social functioning and schizotypy. *Psychiatry Research, 160*, 15-22. doi: 10.1016/j.psychres.2007.04.014

Hornykiewicz, O. (1982). Brain catecholamines in schizophrenia – a good case for noradrenaline. *Nature, 299,* 484-486. doi: 10.1038/299484a0

Hornykiewicz, O. (1986). Brain Noradrenaline and Schizophrenia. *Progress in Brain Research, 65*, 29039. doi: 10.1016/S0079-6123(08)60639-1

Jhung, K., Namkoong, K., Kang, J. I., Ha, R. Y., An, S. K., Kim, C., & Kim, S. J. (2010). Perception bias of disgust in ambiguous facial expressions in obsessive-compulsive disorder. *Psychiatry Research, 178(1)*, 126-131. doi: 10.1016/j.psychres.2009.11.023

Johnston, P. J., Katsikitis, M., & Carr, V. J. (2001). A generalised deficit can account for problems in facial emotion recognition in schizophrenia. *Biological psychology, 58(*3), 203–227. https://doi.org/10.1016/s0301-0511(01)00114-4

Jusyte, A., & Schönenberg, M. (2014). Threat processing in generalized social phobia: An investigation of interpretation biases in ambiguous facial affect. *Psychiatry Research, 217*, 100-106. doi: 10.1016/j.psychres.2013.12.03

Kauschke, C., Bahn, D., Vesker, M., & Schwarzer, G. (2019). The Role of Emotional Valence for the Processing of Facial and Verbal Stimuli – Positivity or Negativity Bias? *Frontiers in Psychology, 10,* 1654. doi: 10.3389/fpsyg.2019.01654

Kerestes, R., Labuschagne, I., Croft, R. J., O'Neill, B. V., Bhagwagar, Z., Luan Phan, K., & Nathan, P. J. (2009). Evidence for modulation of facial emotional processing bias during emotional expression decoding by serotonergic and noradrenergic antidepressants: an event-related potential (ERP) study. *Psychopharmacology, 202,* 621-634. doi: 10.1007/s00213-008-1340-3

Kerns, J. G. (2005). Positive Schizotypy and Emotion Processing. *Journal of Abnormal Psychology, 114*(3), 392-401. doi: 10.1037/0021-843X.114.3.392

Kohler, C. G., Turner, T. H., Bilker, W. B., Brensinger, C. M., Siegel, S. J., Kanes, S. J., Gur, R. E., & Gur, R. C. (2003). Facial Emotion Recognition in Schizophrenia: Intensity Effects and Error Pattern. *American Journal of Psychiatry, 160*(10), 1768-1774. doi: 10.1176/appi.ajp.160.10.1768

Koss, M. C. (1986). Pupillary dilation as an index of central nervous system α_2-adrenoceptor activation. *Journal of Pharmacological Methods, 15(1),* 1-19. doi: 10.1016/0160-5402(86)90002-1

Kramer, R. S. S., Jenkins, R., & Burton, A. M. (2016). InterFace: A software package for face image warping, averaging, and principal components analysis. *Behavior Research Methods*. Advance online publication.

Kret, M. E., Stekelenburg, J. J., Roelofs, K., & de Gelder, B. (2013). Perception of face and body expressions using electromyography, pupillometry and gaze measures. *Frontiers in Psychology, 4*(28). doi: 10.3389/fpsyg.2013.00028

Kwapil, T. R., & Barrantes-Vidal, N. (2014). Schizotypy: Looking Back and Moving Forward. *Schizophrenia Bulletin, 41(Suppl 2),* S366-S373. doi:10.1093/schbul/sbu186

Launay, G., & Slade, P. (1981). The Measurement of Hallucinatory Predisposition in Male and Female Prisoners. *Personality and individual Differences, 2*, 221-234. doi: 10.1016/0191-8869(81)90027-1

Lenzenweger, M. F. (2018). Schizotypy, schizotypic psychopathology and schizophrenia. *World Psychiatry, 17(1)*, 25-26. doi:10.1002/wps.20479

Leppänen, J. M., Tenhunen, M., & Hietanen, J. K. (2003). Faster Choice-Reaction Times to Positive than to Negative Facial Expressions. *Journal of Psychophysiology, 17*(3), 113-123. doi: 10-1027//0269-8803.17.3.113

Lin, A., Wigman, J. T.W., Nelson, B., Wood, S. J., Vollebergh, W. A.M., van Os, J., & Yung, A. R. (2013). Follow-up factor structure of schizotypy and its clinical

associations in a help-seeking sample meeting ultra-high risk for psychosis criteria at baseline. *Comprehensive Psychiatry, 54*(2), 173-180. doi: 10.1016/j.comppsych.2012.06.011

Magezi, D. A. (2015). Linear mixed-effects models for within-participant psychology experiments: an introductory tutorial and free, graphical user interface (LMMgui). *Frontiers in Psychology, 6*(2). doi: 10.3389/fpsyg.2015.00002

Mason, O. (1995). A confirmatory factor analysis of the structure of schizotypy. *European Journal of Personality, 9(4),* 271-281. doi: 10.1002/per.2410090404

Mason, O., Claridge, G., & Jackson, M. (1995). New scales for the assessment of schizotypy. *Personality and Individual Differences, 18(1)*, 7-13. doi: 10.1016/0191-8869(94)00132-C

Mason, O., & Claridge, G. (2006). The Oxford-Liverpool Inventory of Feelings and Experiences (O-LIFE): Further description and extended norms. *Schizophrenia Research, 82,* 203-211. doi: 10.1016/j.schres.2005.12.845

McGrath, J. J., Saha, S., Al-Hamzawi, A., Alonso, J., Bromet, E. J., Bruffaerts, R., Caldas-de-Almeida, J. M., Chiu, W. T., de Jonge, P., Fayyad, J., Florescu, S., Gureje, O., Haro, J. M., Hu, C., Kovess-Masfety, V., Lepine, J. P., Lim, C. C., Mora, M. E., Navarro-Mateu, F., Ochoa, S., … Kessler, R. C. (2015). Psychotic Experiences in the General Population: A Cross-National Analysis Based on 31,261 Respondents From 18 Countries. *JAMA Psychiatry, 72(7),* 697-705. doi: 10.1001/jamapsychiatry.2015.0575

Meehl, P. E. (1962). Schizotaxia, Schizotypy, Schizophrenia. *American Psychologist.* Retrieved from http://www.subjectpool.com/ed_teach/y4general_paper/meehl1962.pdf

Mohr, C., & Ettinger, U. (2014). An overview of the association between schizotypy and dopamine. *Frontiers in Psychiatry, 5,* 184. doi: 10.3389/fpsyt.2014.00184

Morrison, S. C., Brown, L. A., & Cohen, A. S. (2013). A multidimensional assessment of social cognition in psychometrically defined schizotypy. *Psychiatry Research, 210,* 1014-1019. doi: 10.1016/j.psych.res.2013.08.020

Neta, M., Davis, F. C., & Whalen, P. J. (2011). Valence resolution of facial expressions using an emotional oddball task. *Emotion, 11*(6), 1425-1433. doi: 10.1037/a0022993.

Noordewier, M. K. & Breugelmans, S. M. (2013). On the valence of surprise. *Cognition and Emotion, 27*(7), 1326-1334. doi: 10.1080/02699931.2013.777660

Oliva, M., & Anikin, A. (2018). Pupil dilation reflects the time course of emotion recognition in human vocalizations. *Scientific Reports, 8*, 4871. doi: 10.1038/s41598-018-23265-x

Onur, O. A., Walter, H., Schlaepfer, T. E., Rehme, A. K., Schmidt, C., Keysers, C., Maier, W., & Hurlemann, R. (2009). Noradrenergic enhancement of amygdala responses to fear. *Social Cognitive and Affective Neuroscience, 4(2),* 119-126. doi: 10.1093/scan/nsn049

Outhred, T., Hawkshead, B. E., Wager, T. D., Das, P., Malhi, G. S., & Kemp, A. H. (2013). Acute neural effects of selective serotonin reuptake inhibitors versus noradrenaline reuptake inhibitors on emotion processing: Implications for differential treatment efficacy. *Neuroscience and Biobehavioral Reviews, 37,* 1786-1800. doi: 10.1016/j.neubiorev.2013.07.010

Palermo, R. & Coltheart, M. (2004). Photographs of facial expression: Accuracy, response times, and ratings of intensity. *Behavior Research Methods, Instruments, & Computers, 36*(4), 634-638. doi: 10.3758/BF03206544

Paradee, C. V., Lumley, M. A., Rapport, L. J., & Hanks, R. A. (2008). Circadian Preference and Facial Emotion Recognition Among Rehabilitation Inpatients. *Rehabilitation Psychology, 53*(1), 46-53. doi: 10.1037/0090-5550.53.1.46

Pechey, R., & Halligan, P. (2012). Prevalence and correlates of anomalous experiences in a large non-clinical sample. *Psychology and Psychotherapy: Theory, Research and Practice, 85,* 150-162. doi: 10.1111/j.2044-8341.2011.02024.x

Penn, D. L., Sanna, L. J., & Roberts, D. L. (2008). Social Cognition in Schizophrenia: An Overview. *Schizophrenia Bulletin, 34(3),* 408-411. doi: 10.1093/schbul/sbn014

Penton-Voak, I. A., Munafò, M. R., & Looi C. Y. (2017). Biased Facial-Emotion Perception in Mental Health Disorders: A Possible Target for Psychological Intervention? *Psychological Science, 26*(3), 294-301. doi: 10.1177/0963721417704405

Peirce, J. W. (2007). PsychoPy—psychophysics software in Python. Journal of neuroscience methods, 162(1-2), 8-13.

Prehn, K., Kazzer, P., Lischke, A., Heinrichs, M., Herpertz, S. C., & Domes, G. (2013). Effects of intranasal oxytocin on pupil dilation indicate increased salience of socioaffective stimuli. *Psychophysiology, 50,* 528-537. doi: 10.1111/psyp.12042

R Core Team. (2013). *R: A language and environment for statistical computing.* R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/.

Rado, S. (1953). Dynamics and classification of disordered behaviour. *American Journal of Psychiatry, 110*, 406-416. doi: 10.1037/0021-843X.101.3.567

Raine, A. (1991). The SPQ: A Scale for the Assessment of Schizotypal Personality Based on DSM-III-R Criteria. *Schizophrenia Bulletin, 17(4)*, 555-564. doi: 10.1093/schbul/17.4.555

Rawlings, D., & Freeman, J. L. (1997). Measuring paranoia/suspiciousness. In G. Claridge (Ed.), *Schizotypy: Implications for illness and health* (pp. 38-60). New

York, NY, US: Oxford University Press. doi: 10.1093/med:psych/9780198523536.003.0003

R Development Core Team. (2008). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0. http://www.R-project.org

Ripoll, L. H., Zaki, J., Perez-Rodriguez M. M., Snyder, R., Strike, K. S., Boussi, A., Bartz, J. A., Ochsner, K. N., Siever, L. J., & New, A. S. (2013). Empathic accuracy and cognition in schizotypal personality disorder. *Psychiatry Research*, *210*(1), 232–241. doi: 10.1016/j.psychres.2013.05.025

Rosell, D. R., Futterman, S. E., McMaster, A., & Siever, L. J. (2014). Schizotypal Personality Disorder: A Current Review. *Current Psychiatry Reports*, *16(7),* 452. doi: 10.1007/s11920-014-0452-1.

Rude, S. S., Wenzlaff, R. M., Gibbs, B., Vane, J., & Whitney, T. (2002). Negative processing biases predict subsequent depressive symptoms. *Cognition and Emotion, 16*(3), 423-440. doi:10.1080/02699930143000554

Rus-Calafell, M., Gutiérrez-Maldonado, J., & Frerich, N. (2013). Schizotypy, alexithymia and affect as predictors of facial emotion recognition capability using static and dynamic images. *Anuario de Psicología, 43*(1), 7-21.

Schürhoff, F., Szöke, A., Chevalier, F., Roy, I., Méary, A., Bellivier, F., Giros, B., & Leboyer, M. (2007). Schizotypal Dimensions: An Intermediate Phenotype Associated With the COMT High Activity Allele. *American Journal of Medical Genetics Part B (Neuropsychiatric Genetics, 144B,* 64-68. doi: 10.1002/ajmg.b.30395

Sergerie, K., Chochol, C., & Armony, J. L. (2007). The role of the amygdala in emotional processing: A quantitative meta-analysis of functional neuroimaging studies. *Neuroscience and Biobehavioral Reviews, 32,* 811-830. doi: 10.1016j.neubiorev.2007.12.002

Smolka, M. N., Schumann, G., Wrase, J., Grüsser, S. M., Flor, H., Mann, K., Braus, D. F., Goldman, D., Büchel, C., & Heinz, A. (2005). Catechol-*O*-Methyltransferase *val*^{158}*met* Genotype Affects Processing of Emotional Stimuli in the Amygdala and Prefrontal Cortex. *The Journal of Neuroscience, 25(4),* 836-842. doi:10.1523/jneurosci.1792-04.2005

Soliman, A., O'Drisoll, G. A., Pruessner, J., Holahan, A. V., Boileau, I., Gagnon, D., Dagher, A. (2008). Stress-Induced Dopamine Release in Humans at Risk of Psychosis: A [^{11}C]Raclopride PET Study. *Neuropsychopharmacology, 33,* 2033-2041. doi:10.1038/sj.npp.1301597

Statucka, M., & Walder, D. J. (2017). Facial affect recognition and social functioning among individuals with varying degrees of schizotypy. *Psychiatry Research, 256,* 180-187. doi: 10.1016/j.psychres.2017.06.040

Suzuki, A., Hoshino, T., Shigemasu, K., & Kawamura, M. (2007). Decline or improvement? Age-related differences in facial expression recognition. *Biological Psychology, 74*, 75-84. doi: 10.1016/j.biopsycho.2006.07.003

Tottenham, N., Tanaka, J. W., Leon, A. C., McCarry, T., Nurse, M., Hare, T. A., Marcus, D. J., Westerlund, A., Casey, BJ., & Nelson, C. (2009). The NimStim set of facial expressions: Judgements from untrained research participants. *Psychiatry Res, 168*(3), 242-249. doi:10.1016/j.psychres.2008.05.006.

Van Os, J., Hanssen, M., Bijl, R. V., & Ravelli, A. (2000). Strauss (1969) revisited: a psychosis continuum in the general population? *Schizophrenia Research, 45*, 11-20. doi: 10.1016/S0920-9964(99)00224-8

Van Stegeren, A. H., Goekoop, R., Everaerd, W., Scheltens, P., Barkhof, F., Kuijer, J. P.A., & Rombouts, S. A.R.B. (2004). Noradrenaline mediates amygdala activation in men and women during encoding of emotional material. *NeuroImage, 24,* 898-909. doi: 10.1016/j.neuroimage.2004.09.011

van ‘t Wout, M., Aleman, A., Kessels, R. P.C., Larøi, F., & Kahn, R. S. (2004). Emotional processing in a non-clinical psychosis-prone sample. *Schizophrenia Research, 68,* 271-281. doi: 10.1016/j.schres.2003.09.006

Walter, E. E., Fernandez, F., Snelling, M., & Barkus, E. (2016). Genetic Consideration of Schizotypal Traits: A Review. *Frontiers in Psychology, 7:1769.* doi: 10.3389/fpsyg.2016.01769

Wang, C-A., Baird, T., Huang, J., Coutinho, J. D., Brien, D. C., & Munoz, D. P. (2018). Arousal Effects on Pupil Size, Heart Rate, and Skin Conductance in an Emotional Face Task. *Frontiers in Neurology, 9:1029.* doi: 10.3389/fneur.2018.01029

Williams, B. T., Henry, J. D., & Green, M. J. (2007). Facial affect recognition and schizotypy. *Early Intervention in Psychiatry, 1,* 177-182. doi: 10.1111/j.1751-7893.2007.00023.x

Woodward, N. D., Cowan, R. L., Park, S., Ansari, M. S., Baldwin, R. M., Li, R., Doop, M., Kessler, R. M., & Zald, D. H. (2011). Correlation of Individual Differences in Schizotypal Personality Traits With Amphetamine-Induced Dopamine Release in Striatal and Extrastriatal Brain Regions. *American Journal of Psychiatry, 168(4),* 418-426. doi: 10.1176/appi.ajp.2010.10020165

Quirk, S. W., Subramanian, L., & Hoerger, M. (2007). Effects of Situational Demand Upon Social Enjoyment and Preference in Schizotypy. *Journal of Abormal Psychology, 116*(3), 624-631. doi: 10.1037/0021-843X.116.3.624

Yamamoto, K., & Hornykiewicz, O. (2004). Proposal for a noradrenaline hypothesis of schizophrenia. *Progress in Neuro-Psychopharmacology & Biological Psychiatry, 28,* 913-922. doi: 10.1016/j.pnpbp2004.05.033

Yamamoto, K., Shinba, T., & Mitsunobu, Y. (2014). Psychiatric symptoms of noradrenergic dysfunction: A pathophysiological view. *Psychiatry and Clinical Neurosciences, 68,* 1-20. doi: 10.1111/pcn.12126

Yang, X., Ru, W., Wang, B., Gao, X., Yang, L., Li, S., Xi, S., & Gong, P. (2016). Investigating the genetic basis of attention to facial expressions: the role of the norepreniphrine transporter gene. *Psychiatric Genetics, 26(6),* 266-271. doi: 10.1097/YPG.0000000000000146

Zeileis A., & Grothendieck, G. (2005). zoo: S3 Infrastructure for Regular and Irregular Time Series. *Journal of Statistical Software*, *14(*6), 1–27. doi: 10.18637/jss.v014.i06.

Supplementary Materials

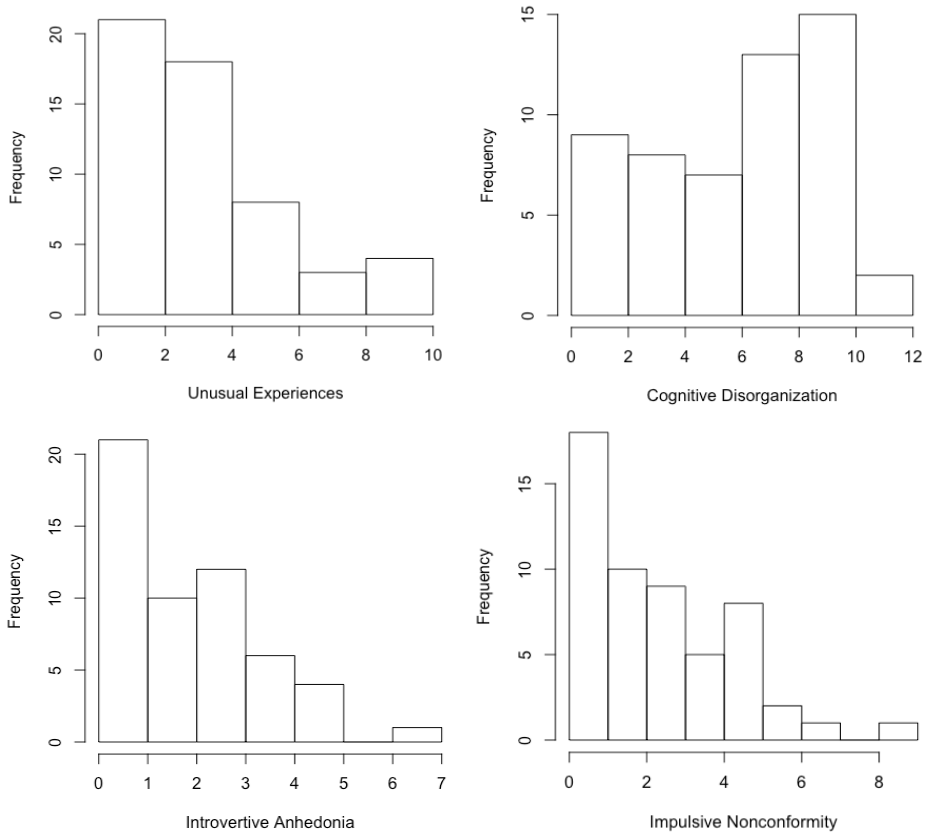

Figure S1. Distribution of sO-LIFE subscale

Table S1

VIFs of a Full Model (DV: Valence Ratings)

Variable	GVIF	Df	GVIF^(1/(2*Df))	(GVIF^(1/(2*Df)))^2
Imp.Nonc	6.95E+00	1	2.637037	6.953964139
Cogn.Dis	5.71E+00	1	2.389004	5.707340112
Introv.Anh	5.18E+00	1	2.275577	5.178250683
Un.Exp	6.34E+00	1	2.518145	6.341054241
Image gender	4.00E+01	1	6.324393	39.99794682
Emotion	6.55E+04	4	3.999897	15.99917601
Intensity	1.00E+03	3	3.162088	9.99880052
Imp.Nonc:Image gender	6.31E+01	1	7.943544	63.09989128
Cogn.Dis:Image gender	5.16E+01	1	7.183112	51.597098
Introv.Anh:Image gender	4.70E+01	1	6.858466	47.03855587
Un.Exp:Image gender	5.76E+01	1	7.58924	57.59656378
Imp.Nonc:Emotion	4.01E+05	4	5.016623	25.16650632
Cogn.Dis:Emotion	1.79E+05	4	4.535481	20.5705879
Introv.Anh:Emotion	1.24E+05	4	4.331797	18.76446525
Un.Exp:Emotion	2.79E+05	4	4.793341	22.97611794
Image gender:Emotion	1.97E+05	4	4.58957	21.06415278
Imp.Nonc:Intensity	4.52E+03	3	4.066517	16.53656051
Cogn.Dis:Intensity	2.46E+03	3	3.675044	13.5059484
Introv.Anh:Intensity	1.88E+03	3	3.512097	12.33482534
Un.Exp:Intensity	3.45E+03	3	3.886285	15.1032111
Image gender:Intensity	4.50E+03	3	4.063178	16.50941546
Emotion:Intensity	6.29E+08	12	2.326015	5.41034578
Imp.Nonc:Image gender:Emotion	1.05E+06	4	5.659202	32.02656728
Cogn.Dis:Image gender:Emotion	4.71E+05	4	5.117911	26.193013
Introv.Anh:Image gender:Emotion	3.24E+05	4	4.884715	23.86044063
Un.Exp:Image gender:Emotion	7.29E+05	4	5.405126	29.21538708
Imp.Nonc:Image gender:Intensity	1.60E+04	3	5.018886	25.18921668
Cogn.Dis:Image gender:Intensity	8.72E+03	3	4.536785	20.58241814
Introv.Anh:Image gender:Intensity	6.63E+03	3	4.334112	18.78452683
Un.Exp:Image gender:Intensity	1.22E+04	3	4.795894	23.00059926
Imp.Nonc:Emotion:Intensity	9.64E+10	12	2.86855	8.228579103
Cogn.Dis:Emotion:Intensity	8.54E+09	12	2.593034	6.723825325
Introv.Anh:Emotion:Intensity	2.85E+09	12	2.477152	6.136282031
Un.Exp:Emotion:Intensity	3.24E+10	12	2.741083	7.513536013
Image gender:Emotion:Intensity	1.37E+09	12	2.402336	5.771218257
Imp.Nonc:Image gender:Emotion:Intensity	1.94E+11	12	2.953432	8.722760579
Cogn.Dis:Image gender:Emotion:Intensity	1.73E+10	12	2.670141	7.12965296
Introv.Anh:Image gender:Emotion:Intensity	5.72E+09	12	2.550083	6.502923307
Un.Exp:Image gender:Emotion:Intensity	6.49E+10	12	2.821778	7.962431081

Note. Following guidelines published by Fox & Monette (1992), squared values of GVIF^(1/(2*Df)) (included in the final column) correspond to standard VIF values. Accordingly, values between 5 and 10 were considered indicative of possible multicollinearity, values above 10 were considered problematic.

Table S2

VIFs of the Final Model (DV: Valence Ratings)

Variable	GVIF	Df	GVIF^(1/(2*Df))	(GVIF^(1/(2*Df)))^2
Imp.Nonc	4.42E+00	1	2.10286	4.42202018
Cogn.Dis	3.63E+00	1	1.904055	3.625425443
Introv.Anh	3.30E+00	1	1.815496	3.296025726
Un.Exp	4.04E+00	1	2.009029	4.036197523
Emotion	4.10E+03	4	2.828944	8.002924155
Intensity	1.25E+02	3	2.235942	4.999436627
Imp.Nonc:Emotion	2.55E+04	4	3.554639	12.63545842
Cogn.Dis:Emotion	1.14E+04	4	3.214963	10.33598709
Introv.Anh:Emotion	7.85E+03	4	3.068075	9.413084206
Un.Exp:Emotion	1.76E+04	4	3.39495	11.5256855
Imp.Nonc:Intensity	5.77E+02	3	2.885261	8.324731038
Cogn.Dis:Intensity	3.14E+02	3	2.607525	6.799186626
Introv.Anh:Intensity	2.39E+02	3	2.491881	6.209470918
Un.Exp:Intensity	4.40E+02	3	2.757373	7.603105861
Emotion:Intensity	1.54E+05	12	1.64484	2.705498626
Imp.Nonc:Emotion:Intensity	2.38E+07	12	2.02932	4.118139662
Cogn.Dis:Emotion:Intensity	2.11E+06	12	1.834617	3.365819537
Introv.Anh:Emotion:Intensity	7.02E+05	12	1.752212	3.070246893
Un.Exp:Emotion:Intensity	7.97E+06	12	1.938899	3.759329332

Note. Following guidelines published by Fox & Monette (1992), squared values of GVIF^(1/(2*Df)) (included in the final column) correspond to standard VIF values. Accordingly, values between 5 and 10 were considered indicative of possible multicollinearity, values above 10 were considered problematic. Following Gillespie, Hibbert & Wagner (2020), elevated VIF values for interaction terms were deemed acceptable.

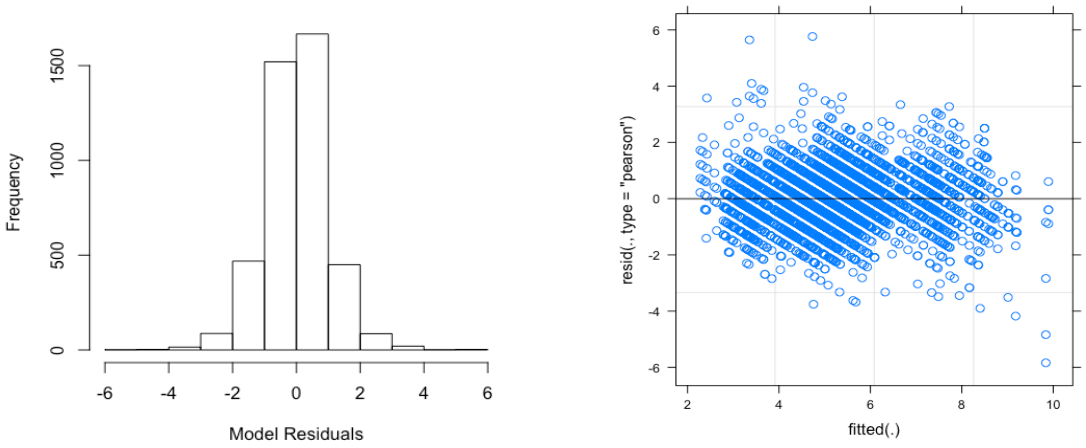

Figure S2. Normality and homoscedasticity of model residuals (DV: Valence Ratings)

Table S3

VIFs of the Full and Final Model (DV: Reaction Times)

Variable	GVIF	Df	GVIF^(1/(2*Df))	(GVIF^(1/(2*Df)))^2
Imp.Nonc	2.19E+00	1	1.479373	2.18854447
Cogn.Dis	1.79E+00	1	1.338718	1.79216588
Introv.Anh	1.64E+00	1	1.281007	1.64097893
Un.Exp	2.01E+00	1	1.417741	2.00998954
Emotion	4.11E+03	4	2.829732	8.00738319
Intensity	1.25E+02	3	2.235748	4.99856912
Imp.Nonc:Emotion	2.24E+04	4	3.497463	12.2322474
Cogn.Dis:Emotion	1.01E+04	4	3.164769	10.0157628
Introv.Anh:Emotion	6.86E+03	4	3.016915	9.10177612
Un.Exp:Emotion	1.54E+04	4	3.338302	11.1442602
Imp.Nonc:Intensity	4.64E+02	3	2.782032	7.73970205
Cogn.Dis:Intensity	2.52E+02	3	2.514004	6.32021611
Introv.Anh:Intensity	1.92E+02	3	2.402837	5.77362565
Un.Exp:Intensity	3.53E+02	3	2.658839	7.06942483
Emotion:Intensity	1.54E+05	12	1.64498	2.7059592
Imp.Nonc:Emotion:Intensity	2.20E+07	12	2.02277	4.09159847
Cogn.Dis:Emotion:Intensity	1.96E+06	12	1.828998	3.34523368
Introv.Anh:Emotion:Intensity	6.46E+05	12	1.746228	3.04931223
Un.Exp:Emotion:Intensity	7.34E+06	12	1.932273	3.73367895

Note. Following guidelines published by Fox & Monette (1992), squared values of GVIF^(1/(2*Df)) (included in the final column) correspond to standard VIF values. Accordingly, values between 5 and 10 were considered indicative of possible multicollinearity, values above 10 were considered problematic. Following Gillespie, Hibbert & Wagner (2020), elevated VIF values for interaction terms were deemed acceptable.

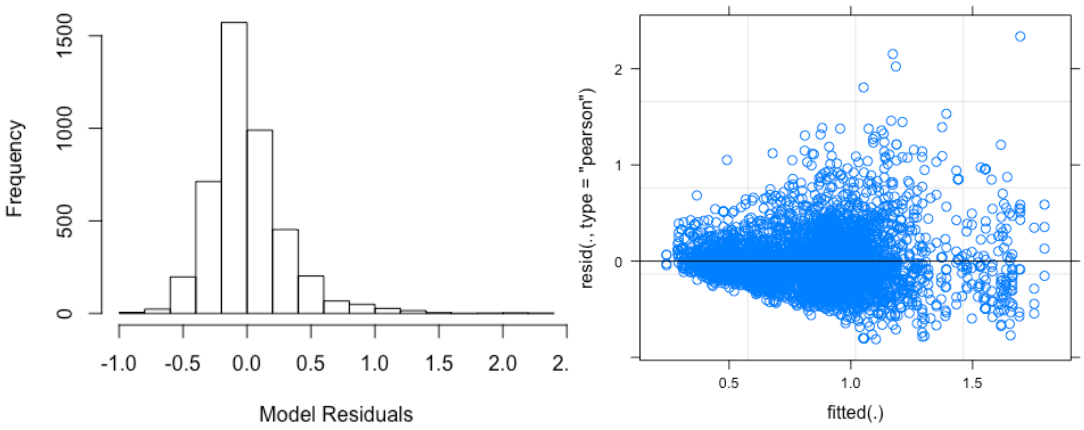

Figure S3. Normality and homoscedasticity of original model residuals (DV: Reaction Time)

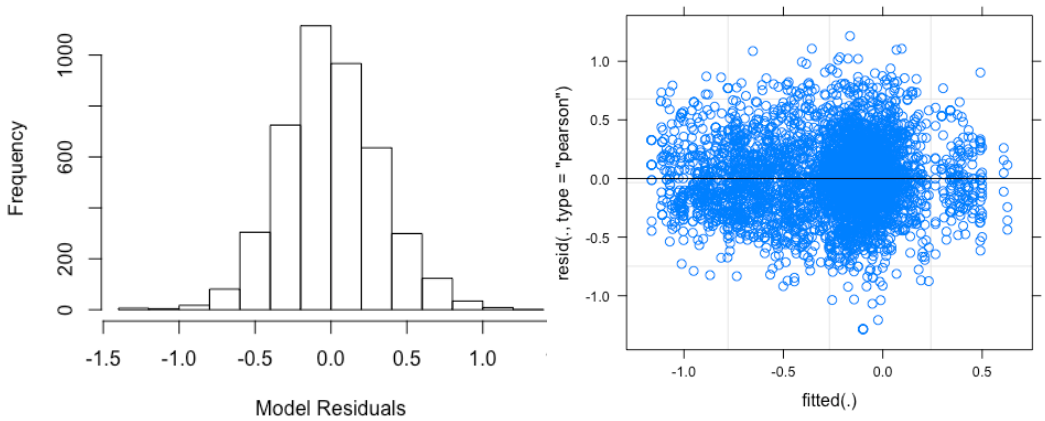

Figure S4. Normality and homoscedasticity of log-transformed model residuals (DV: Reaction Time)

Table S4

Estimated Marginal Reaction Time Means per Emotion and Intensity

Intensity	emmean	SE	lower.CL	upper.CL	t.ratio	p.value
Emotion = Angry:						
neutral	-0.368	0.0563	-0.479	-0.256	-6.527	<.001
low	-0.334	0.0518	-0.437	-0.232	-6.459	<.001
middle	-0.294	0.0502	-0.394	-0.194	-5.858	<.001
high	-0.253	0.0518	-0.356	-0.151	-4.895	<.001
Emotion = Disgusted:						
neutral	-0.368	0.0563	-0.479	-0.256	-6.527	<.001
low	-0.337	0.0518	-0.440	-0.234	-6.510	<.001
middle	-0.270	0.0502	-0.370	-0.170	-5.378	<.001
high	-0.242	0.0518	-0.345	-0.139	-4.677	<.001
Emotion = Happy:						
neutral	-0.368	0.0563	-0.479	-0.256	-6.527	<.001
low	-0.300	0.0518	-0.403	-0.197	-5.800	<.001
middle	-0.238	0.0502	-0.338	-0.139	-4.753	<.001
high	-0.159	0.0518	-0.262	-0.057	-3.077	.003
Emotion = Sad:						
neutral	-0.368	0.0563	-0.479	-0.256	-6.527	<.001
low	-0.343	0.0518	-0.446	-0.240	-6.630	<.001
middle	-0.302	0.0502	-0.401	-0.202	-6.009	<.001
high	-0.250	0.0518	-0.353	-0.148	-4.838	<.001
Emotion = Surprised:						
neutral	-0.366	0.0562	-0.477	-0.255	-6.514	<.001
low	-0.306	0.0518	-0.409	-0.203	-5.909	<.001
middle	-0.214	0.0502	-0.314	-0.114	-4.268	<.001
high	-0.144	0.0518	-0.247	-0.041	-2.775	.007

Note. Reaction time values were log-transformed. To interpret these values, the principle remains that lower values represent lower reaction times.

Table S5

VIFs of a Full Model (DV: Pupil Dilation Values)

Variable	GVIF	Df	GVIF^(1/(2*Df))	(GVIF^(1/(2*Df)))^2
Imp.Nonc	9.69E+00	1	3.113264	9.69241273
Cogn.Dis	1.15E+01	1	3.384835	11.457108
Introv.Anh	8.23E+00	1	2.868731	8.22961755
Un.Exp	1.19E+01	1	3.450189	11.9038041
Image gender	4.22E+01	1	6.494922	42.1840118
Emotion	1.27E+05	4	4.346423	18.8913929
Intensity	1.16E+03	3	3.239632	10.4952155
Imp.Nonc:Image gender	5.34E+01	1	7.307165	53.3946603
Cogn.Dis:Image gender	6.00E+01	1	7.746835	60.0134525
Introv.Anh:Image gender	4.85E+01	1	6.965684	48.5207536
Un.Exp:Image gender	5.73E+01	1	7.570738	57.3160739
Imp.Nonc:Emotion	3.29E+05	4	4.893314	23.9445219
Cogn.Dis:Emotion	6.53E+05	4	5.331408	28.4239113
Introv.Anh:Emotion	1.85E+05	4	4.552586	20.7260393
Un.Exp:Emotion	7.57E+05	4	5.431195	29.4978791
Image gender:Emotion	2.48E+05	4	4.724841	22.3241225
Imp.Nonc:Intensity	2.88E+03	3	3.77176	14.2261735
Cogn.Dis:Intensity	3.14E+03	3	3.825751	14.6363707
Introv.Anh:Intensity	2.19E+03	3	3.604871	12.9950949
Un.Exp:Intensity	2.96E+03	3	3.789571	14.3608484
Image gender:Intensity	4.90E+03	3	4.121126	16.9836795
Emotion:Intensity	1.28E+09	12	2.395504	5.73843941
Imp.Nonc:Image gender:Emotion	5.00E+05	4	5.156971	26.5943499
Cogn.Dis:Image gender:Emotion	7.89E+05	4	5.459321	29.8041858
Introv.Anh:Image gender:Emotion	3.37E+05	4	4.908042	24.0888763
Un.Exp:Image gender:Emotion	6.64E+05	4	5.342967	28.5472964
Imp.Nonc:Image gender:Intensity	8.40E+03	3	4.50861	20.3275641
Cogn.Dis:Image gender:Intensity	9.07E+03	3	4.566754	20.8552421
Introv.Anh:Image gender:Intensity	6.70E+03	3	4.341504	18.848657
Un.Exp:Image gender:Intensity	7.86E+03	3	4.459322	19.8855527
Imp.Nonc:Emotion:Intensity	9.96E+09	12	2.609763	6.81086292
Cogn.Dis:Emotion:Intensity	1.70E+10	12	2.668578	7.12130854
Introv.Anh:Emotion:Intensity	4.01E+09	12	2.512519	6.31275173
Un.Exp:Emotion:Intensity	1.55E+10	12	2.658003	7.06497995
Image gender:Emotion:Intensity	1.84E+09	12	2.432435	5.91674003
Imp.Nonc:Image gender:Emotion:Intensity	1.20E+10	12	2.6301	6.91742601
Cogn.Dis:Image gender:Emotion:Intensity	1.65E+10	12	2.665028	7.10237424
Introv.Anh:Image gender:Emotion:Intensity	6.10E+09	12	2.556934	6.53791148
Un.Exp:Image gender:Emotion:Intensity	1.13E+10	12	2.623153	6.88093166

Note. Following guidelines published by Fox & Monette (1992), squared values of GVIF^(1/(2*Df)) (included in the final column) correspond to standard VIF values. Accordingly, values between 5 and 10 were considered indicative of possible multicollinearity, values above 10 were considered problematic.

Table S6

VIFs of the Final Model (DV: Pupil Dilation Values)

Variable	GVIF	Df	GVIF^(1/(2*Df))	(GVIF^(1/(2*Df)))^2
Imp.Nonc	4.89E+00	1	2.210868	4.88793731
Cogn.Dis	5.26E+00	1	2.292526	5.25567546
Introv.Anh	4.39E+00	1	2.09499	4.3889831
Un.Exp	4.78E+00	1	2.187246	4.78404506
Emotion	4.52E+03	4	2.863324	8.19862433
Intensity	1.32E+02	3	2.256525	5.09190508
Imp.Nonc:Emotion	1.14E+04	4	3.215915	10.3421093
Cogn.Dis:Emotion	1.59E+04	4	3.349689	11.2204164
Introv.Anh:Emotion	8.02E+03	4	3.076178	9.46287109
Un.Exp:Emotion	1.03E+04	4	3.174104	10.0749362
Imp.Nonc:Intensity	3.34E+02	3	2.634315	6.93961552
Cogn.Dis:Intensity	3.39E+02	3	2.640611	6.97282645
Introv.Anh:Intensity	2.67E+02	3	2.536987	6.43630304
Un.Exp:Intensity	2.91E+02	3	2.574766	6.62941995
Emotion:Intensity	1.91E+05	12	1.659634	2.75438501
Imp.Nonc:Emotion:Intensity	1.54E+06	12	1.810488	3.2778668
Cogn.Dis:Emotion:Intensity	1.89E+06	12	1.825985	3.33422122
Introv.Anh:Emotion:Intensity	7.77E+05	12	1.759688	3.09650186
Un.Exp:Emotion:Intensity	9.40E+05	12	1.773683	3.14595138

Note. Following guidelines published by Fox & Monette (1992), squared values of GVIF^(1/(2*Df)) (included in the final column) correspond to standard VIF values. Accordingly, values between 5 and 10 were considered indicative of possible multicollinearity, values above 10 were considered problematic. Following Gillespie, Hibbert & Wagner (2020), elevated VIF values for interaction terms were deemed acceptable.

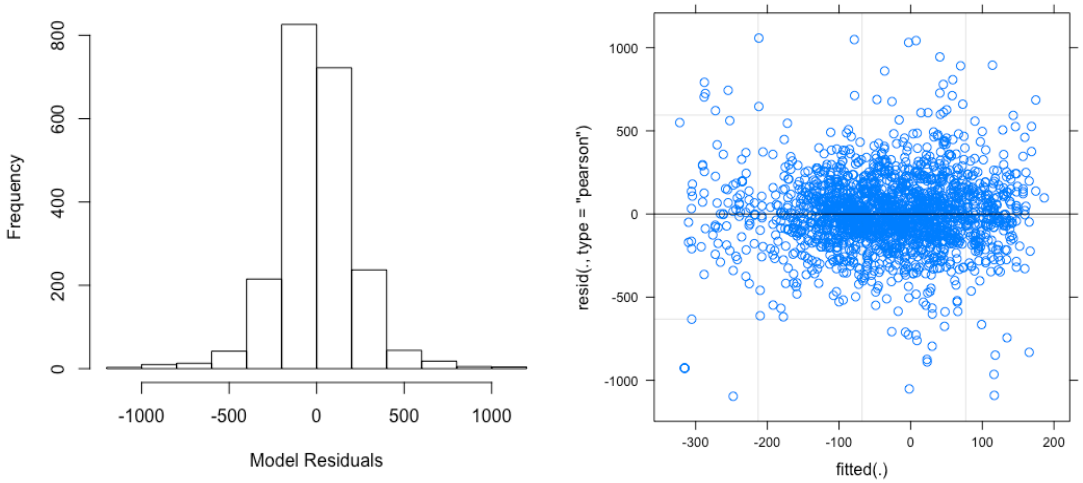

Figure S5. Normality and homoscedasticity of model residuals (DV: Pupil Dilation)