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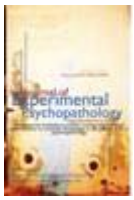

The Subjective-Objective Disjunction in Psychometrically-Defined Schizotypy: What it is and Why it is Important?

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Abstract

An interesting set of findings has emerged from the literature regarding schizotypy. Individuals with psychometric schizotypy self-report pathology in certain neuropsychological, affective experiential, expressive and olfactory abilities and subjective quality of life at levels between one and two standard deviations more severe than their non-schizotypal peers; a level often similar to that seen in chronic schizophrenia. Objectively however, individuals with psychometric schizotypy do not show concomitant impairments in these domains. This “subjective-objective” disjunction is remarkable in that samples are largely drawn from college settings; thus likely reflecting the healthiest individuals within the schizophrenia-spectrum. We propose that this disjunction can be conceptualized as a “cognitive bias”, and that it reflects a dysfunction in the systems underlying reasoning and self-evaluation. In this article, we lay out evidence underlying the subjective-objective disjunction and discuss potential methodological and psychological issues that may explain this phenomenon.

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Keywords: schizotypy, cognitive, bias, emotion, anhedonia, subjective, objective, olfaction

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Introduction

Schizophrenia is a severe mental disease associated with a massive cost both in emotional suffering and economic impact (American Psychiatric Association, 2013; Tandon, Keshavan, & Nasrallah, 2008). Despite hundreds of thousands of published studies to date examining schizophrenia, its etiology is not well explicated. There is a pronounced heritable component to schizophrenia (Tandon et al., 2008), though best estimates of the collective contribution of known individual genetic anomalies are less than 10% (Ng et al., 2009). At this point, it is clear that schizophrenia is not, in and of itself, heritable. Rather, schizophrenia is a rare and often unfortunate condition stemming from an interaction of relatively common genetic and epigenetic anomalies. Accordingly, the majority of "at-risk" individuals in the population lack the necessary components to develop the diagnosable disorder. Nonetheless, putatively "at-risk" individuals show schizophrenia-like signs/symptoms and presumably convey the genetic risk to their biological offspring. The "personality organization" associated with this risk – reflecting both genetic and environmental factors, is often referred to as "schizotypy" (Lezenweger, 2006; Meehl, 1962). While schizotypy is not pathological per se, it is often defined, or at least measured, in terms of positive (e.g., referential thinking, suspiciousness, perceptual aberrations), negative (e.g., social anhedonia, diminished expressivity) and disorganized (e.g., eccentric behavior, odd speech) traits – phenomenon that are similar to the cardinal symptom clusters of schizophrenia, but presumably attenuated in severity. The present review highlights a seemingly paradoxical pattern of findings emerging in the empirical literature concerning a disjunction between functioning assessed from subjective versus objective measures. In at least five key functional domains, schizotypy is associated with subjective concerns that are dramatic in magnitude; often similar to that reported by patients with chronic schizophrenia. However, in corresponding objective domains, these same individuals show functioning that is generally unremarkable. This subjective-objective disjunction may hold importance for understanding, measuring and treating the schizophrenia-spectrum. In the following review, we will provide an overview of this subjective-objective disjunction and consider psychological processes that may underlie it.

Organizational notes

There are several important considerations regarding the present review. First, although there is relative agreement on what the term "schizotypy" refers to at a conceptual level, there are contrasting approaches to studying it (e.g., family-study, clinical high-risk, Schizotypal Personality Disorder (SPD), and self-report/"psychometric" methods). The psychometric method, which will be the focus of this paper, employs a relatively inexpensive and efficient screening procedure that often, but not always, occurs in large samples of undergraduate college students from relatively prestigious and large universities (e.g., research Tier 1 US universities). The fact that psychometrically-defined

schizotypy tends to occupy the most healthy region of the schizophrenia-spectrum is particularly striking because, as will be discussed in this paper, it resembles chronic schizophrenia in key domains.

Second, the present review is not meant to encompass the extant schizotypy literature in its totality. We do not mean to imply that schizotypy is primarily a "subjective" phenomenon. Indeed, the literature is full of objective abnormalities in schizotypy that are potentially consistent across studies and sizable in magnitude. For example, abnormalities in early perceptual processes, such as those involving perception of diffuse red light (Bedwell, Brown, & Miller, 2003; Bedwell, Chan, Trachik, Rassovsky, 2013; Koychev, El-Deredy, Haenschel & Deakin, 2010) and latent inhibition (Lubow & Gewirtz, 1995), are quite robust in the schizotypy literature. Relatedly, smooth-pursuit and antisaccade abnormalities (Ettinger, Corr, Mofidi, Williams, & Kumari, 2013; Kee, Horan, Wynn, Mintz, & Green, 2006), abnormal dopaminergic and other neural functions (Ettinger, Meyhofer, Steffens, Wagner, & Koutsouleris, 2014; Mohr, Landis, & Brugger, 2006), and even subtle dermatoglyphic (Chok, Kwapil, & Scheuermann, 2005) and neurological "soft sign" (Kaczorowski, Barrantes-Vidal, & Kwapil, 2009) anomalies have been found in many studies. Moreover, psychometric schizotypy is associated with diagnosis of schizophrenia-spectrum disorders (assessed via structured clinical interview) both concurrently (Raine, 1991) and longitudinally Chapman, Chapman, Kwapil, Eckblad, & Zinser, 1994; Gooding, Tallent, & Matts, 2005). That being said, the present review will provide a relatively thorough evaluation of five specific domains of functioning; including data from three meta-analyses and studies conducted both from our and other laboratories. It might be tempting to discount the present findings as lacking empirical support. However, the conclusion that psychometrically-defined schizotypy is characterized by dramatic subjective and discordant and largely normal objective functions is based on multiple peer-reviewed studies produced by researchers across the world. As discussed later in this paper, this disjunction does not appear to be a result of methodological, response bias-related, or other confounding factors.

Finally, much like schizophrenia and most psychiatric disorders more generally, schizotypy is a phenotypically heterogeneous construct and it is as yet unclear whether schizotypy reflects a single process, as conceptualized by Meehl and others (Lenzenweger, 2006; Meehl, 1962) or whether it reflects independent processes (Kwapil, Gross, Silvia & Barrantes-Vidal, 2013, Kwapil & Chun, 2015). This presents an issue for the present review in that many studies define schizotypy as a limited set of traits, and conclusions drawn for one set of schizotypy traits may not generalize to others. Moreover, there are differences across studies in which measures were used to identify individuals with schizotypy. Regarding the latter point, it is worth noting that measures of positive and negative schizotypy generally correlate highly with each other (e.g., Suhr & Spitznagel, 2001, Jackson & Claridge, 1991, though see Gross, Mellin, Silvia Barrantes-Vidal, & Kwapil 2014 for a potential exception). Regarding the former point, note that the subjective-objective disjunction has not shown differential association to specific positive, negative and disorganized traits (e.g., Chan et al., 2008; Chun, Minor, & Cohen, 2013, Cohen, Callaway, Najolia, Larsen, & Strauss, 2012, Cohen, Auster, MaCaulay, & McGovern, 2013) and that meta-analyses have been conducted in at least three of the domains discussed in this paper. Heterogeneity issues will be discussed further at the conclusion of this paper. In the following section, we review the literature documenting this subjective-objective disjunction as it pertains to neuropsychological, affective, expressive, olfactory and quality of life functions.

The Subjective-Objective Disjunction in Schizotypy Operationalized

Neuropsychology

Neuropsychological impairments are central to the schizophrenia spectrum (American Psychiatric Association, 2013) and to its underlying vulnerability (e.g., 1962), and are major foci of endophenotype research in schizophrenia. Consider that the majority of candidate vulnerability markers in the NIMH-sponsored multi-site Consortium on the Genetics of Schizophrenia study reflect cognitive abilities in some capacity (Seidman et al., 2015). Recent research suggests that individuals with psychometrically-defined schizotypy self-report relatively dramatic and broad concerns about their neuropsychological functions (e.g., memory, language, attention). For example, in a recent study of individuals with high levels of psychometrically-defined positive, negative, and disorganized schizotypy traits, endorsement of neuropsychological complaints (e.g., "I forget appointments, dates or meetings", "I fail to recognize people I know"; Osman, Valeri, Osman, & Jones, 1992) was on the order of two standard deviations above a psychometrically-defined control group (Chun et al., 2013). High levels of concerns with executive and memory

functioning in individuals with psychometrically-defined schizotypy have also been reported (Chan et al., 2008; Laws, Patel, & Tyson, 2008). It is important to note that endorsement of neuropsychological concerns is considered so integral to schizophrenia vulnerability that it is considered a defining feature of schizotypy in some psychometric studies, *vis a vis* disorganized traits (e.g., "I sometimes forget what I am trying to say"; Raine, 1991). Importantly, subjective neuropsychological concerns are relatively ubiquitous in their relationship to positive, negative, and disorganization schizotypy traits and, thus, are not simply circular in nature in their association with disorganization (e.g., Chan et al., 2008; Chun et al., 2013).

Evidence for neuropsychological dysfunction, as defined using clinically-based objective measures, is much more tenuous. While the literature is replete with examples of individuals with psychometrically-defined schizotypy demonstrating statistically lower scores on specific neuropsychological tests, such as those involving working memory, verbal memory, executive functioning, language and attention, there are many null findings in the field as well. To shed light on this issue, our laboratory conducted a meta-analysis of published studies examining performance using standardized neuropsychological measures in psychometrically-defined college samples (Chun et al., 2013). Across ten different neuropsychological domains, only two showed effect sizes outside the negligible range; and these were both on the order of a quarter standard deviation (i.e., set-shifting ability: k = 14, d = -.22; working memory: k = 12, d = -.27). Heterogeneity analysis – comparing effect sizes as a function of positive, negative or disorganized traits, did not reveal significant differences in neuropsychological functioning across symptom domains. Thus, the level of subjective concern appears to far outweigh the level of objective performance deficits in college students with schizotypy.

There are important qualifications in interpreting these findings. Of particular note, the Chun et al. (2013) meta-analysis focused solely on validated "clinical" tests. Cognitive science-based tests have been used to understand neuropsychological functions in schizotypy; tests that often offer improved sensitivity and precision over their clinical counterparts (e.g., Carter & Barch, 2007). Moreover, these measures can be paired with electrophysiological and neuroscience methods to detect more subtle cognitive anomalies, for example, as part of the Cognitive Neuroscience Treatment Research to Improve Cognition in Schizophrenia project (CNTRICS; Carter & Barch, 2007). Of note, basic visual processing dysfunctions in schizotypy samples have been established by at least two groups using visual event related potentials (Bedwell et al., 2013; Koychev et al., 2010). Schizotypy has also been associated with dopaminergic (see Mohr & Ettinger, 2014 for a review) and brain structure (see Ettinger et al., 2012 for a review) abnormalities directly tied to neuropsychological functions. Importantly, to our knowledge, no existing studies demonstrate objective abnormalities at a level approximating either that seen in diagnosable schizophrenia or in self-reported cognitive domains of schizotypy. Thus, while it is clear that the brains of college students with high levels of psychometrically-defined schizotypal features are abnormal, the link between these abnormalities does not support the relatively extreme dysfunctions reported.

Affective Experience

Abnormalities in affective experience are considered critical to schizotypy. Trait anhedonia was regarded as a necessary, but not sufficient, component to schizotypy in some theories (Meehl, 1962), and, more recently, has been associated with the development of diagnosable schizophrenia-spectrum personality pathology (e.g., Kwapil, 1998). Anhedonia is also a negative prognostic indicator in patients with schizophrenia (Blanchard & Panzarella, 1998), and is generally regarded as an intractable and particularly pernicious feature of the illness (Blanchard, Horan, & Brown, 2001). Investigation into hedonic experience in schizophrenia has revealed a seeming paradox. On one hand, patients with schizophrenia report high levels (e.g., typically 1-2 standard deviations above controls) of trait anhedonia on questionnaires, and are rated as being high in anhedonia by trained raters using symptom rating scales. On the other hand, laboratory studies have revealed that patients with schizophrenia report similar levels of state, or "in the moment" hedonic experience as nonpsychiatric controls when evaluating controlled stimuli, such as pictures, videos, social interactions, sounds and food (see Cohen, Najolia, Brown, & Minor, 2011; Kring & Moran, 2008 for potential explanations). Interestingly, individuals with psychometrically-defined schizotypy do not show this "state" versus "trait" discrepancy. Similar to patients with schizophrenia, individuals with psychometric schizotypy show high levels of trait anhedonia on subjective measures and are rated as being anhedonic by trained interviewers (Blanchard, Collins, Aghevli, Leung, & Cohen, 2011; Horan, Blanchard, Clark, & Green, 2008). However, they also

report having abnormally low levels of pleasant emotional experience during laboratory mood induction studies; a finding that has been replicated in at least eleven studies (e.g., Cohen, Callaway, et al., 2012; Ferguson & Katkin, 1996; Fiorito & Simons, 1994; Fitzgibbons & Simons, 1992; Gooding, Davidson, Putnam, & Tallent, 2002; Mathews & Barch, 2006; Najolia, Cohen, & Minor, 2011) with only two null findings to our knowledge (Berenbaum, Snowhite, & Oltmanns, 1987; Germans & Kring, 2000). In a recent study, we directly compared "state" anhedonia between college students with high levels of psychometrically-defined schizotypy and patients with schizophrenia and peer psychiatric control groups (e.g., Cohen, Callaway et al., 2012). The schizotypy group reported significantly less state pleasant affect than each of the other groups in response to a wide range of neutral, pleasant and unpleasant stimuli. With respect to trait measures of positive affect, the schizotypy group was similar to the patient groups, who were all abnormally low compared to the control groups. Thus, individuals with psychometric schizotypy reported being as or more pathological with respect to "anhedonia" than patients with schizophrenia.

Studies examining behavioral, psychophysiological and neurobiological correlates of emotional experience procured during laboratory studies generally suggest that pleasant emotions are unremarkable in schizotypy. For example, analysis of implicit behavior (i.e., reaction time data) in response to affective stimuli using the implicit association test (Cohen, Beck, Najolia, & Brown, 2011), incidental learning tasks (Mathews & Barch, 2006) and modified Stroop tasks (Mohanty et al., 2005; Wout, Aleman, Kessels, Larai, & Kahn, 2004 but see Mohanty et al., 2008) in individuals with high levels of psychometrically-defined schizotypy have generally failed to find abnormalities. The findings supporting a psychophysiological or biological basis for affective deficits in psychometrically-defined schizotypy are equally sparse. Gooding and colleagues (Gooding et al., 2002) examined startle response as a function of emotion states in individuals with psychometrically-defined social anhedonia and matched controls and found no group differences when pleasant mood was induced. Similarly, Fiorito and Simons (1994) and Fitzgibbons and Simons (1992) reported no group differences in skin conductance between individuals with psychometric physical anhedonia and controls following laboratory mood manipulations. Paradoxically, there is some evidence to suggest that individuals with psychometrically-defined schizotypy show exaggerated psychophysiological responses. At least three studies to date have found increased electrophysiological activity in response to affective stimuli in individuals with high levels of psychometrically-defined schizotypy (Karcher & Shean, 2012; Raine, Benishay, Lencz, & Scarpa, 1997; Raine, Venables, Mednick, & Mellingen, 2002), and one study has reported elevated amygdala and hippocampal activity in response to affectively laden verbal stimuli (Mohanty et al., 2005). Abnormalities in limbic structures – particularly relevant to the experience of hedonic emotions, have generally not been observed while individuals with elevated schizotypy observe pleasant stimuli (e.g.,Hooker et al., 2014). In sum, while college students with psychometric schizotypy consistently report being similarly or more anhedonic than outpatients with schizophrenia, there is scant evidence of a concomitant attenuated behavioral or physiological response.

Expressivity

A third disjunction is observed in communicative gestures. Diminished expressivity (a.k.a., blunted affect and alogia) is a hallmark symptom of schizophrenia characterized by reduced facial, vocal, and hand gestural expressions. Constricted affect – a less severe form of these symptoms – is a trait considered integral to schizotypy, and is a diagnostic symptom of Schizotypal Personality Disorder (SPD; American Psychatric Association, 2013). Self-report measures of expressivity have substantiated the claim that individuals with psychometrically-defined schizotypy express themselves less intensely and frequently than their peers (e.g., Llerena, Park, Couture, & Blanchard, 2012). Moreover, measures of constricted affect have been associated with reductions in social functioning and quality of life (Cohen & Davis, 2009). However, studies employing objective measures of expressivity have, for the most part, failed to find evidence of diminished expressivity. In four separate studies from our laboratory, we have failed to find notable abnormalities in college students with high levels of psychometrically-defined schizotypy in speech production and prosodic expressivity – measured using acoustic analysis of their natural speech procured during laboratory speaking tasks (Cohen, Auster, McGovern, & MacAulay, 2014b; Cohen & Hong, 2011; Cohen, Iglesias, & Minor, 2009; Cohen, Morrison, Brown, & Minor, 2012). Similarly, we have failed to find evidence of facial expressive deficits, measured using computerized facial analysis procured during similar tasks (Cohen, Morrison, & Callaway, 2013). These null findings are particularly remarkable in that the schizotypy samples were defined, in part, on extreme scores on a constricted affect scale (i.e., Cohen, Matthews, Najolia, & Brown, 2010). Studies employing behavioral coding of individuals engaged in laboratory mood induction procedures report similar findings. In Leung, Couture,

Blanchard, Lin and Llerena (2010), self-reported expressivity deficits were on the order of 1.5 SD in socially anhedonic versus non-anhedonic individuals; while behavioral ratings were generally non-significant and were, at best, on the order of .5 SDs (Mean *d* value = .34; range of *d* values = .07 to .59). Similarly, Llerena et al. (2012) reported that behavioral ratings of individuals with social anhedonia did not significantly differ from controls during a role-play task (Mean *d* value = .14; range of *d* values = .04 to .22). Importantly, several recent studies have demonstrated that expressive deficits may occur exclusively in males within the context of viewing unpleasant images (Mitchell, Ragsdale, Bedwell, Beidel, Cassisi, 2015) or with positive schizotypy features (Bedwell, Cohen, Trachik, Deptula, Mitchell, 2014). In total though, college students with psychometrically-defined schizotypy report profound deficits in expressive and communicative abilities, but their objective performance in the laboratory is generally intact.

Olfaction

A fourth subjective-objective disjunction concerns olfactory functions. Besides the inconvenience of not being able to accurately identify or appreciate certain smells and tastes, olfactory dysfunctions are of interest because they are closely tied to brain circuitry central to schizophrenia pathology (Turetsky, Hahn, Borgmann-Winter, & Moberg, 2009) and, from a functional perspective, social behavior and motivations (Malaspina & Coleman, 2003). From an evolutionary perspective, olfaction is important for communication between and across species. There is a fairly large literature documenting that patients with schizophrenia are impaired at identifying olfactory stimuli (for meta-analyses, see Cohen, Brown, & Auster, 2012b; Moberg et al., 1999). Moreover, there is a smaller, but relatively consistent literature documenting abnormal subjective experiences of olfactory stimuli, characterized by reports of reduced intensity and pleasure in response to olfactory stimuli (e.g., Cohen, Brown, et al., 2012b). In this regard, both objective and subjective domains of olfaction appear to be affected in schizophrenia (Schneider et al., 2007). In a recent meta-analysis of psychometric schizotypy in college students, objective performance on olfaction identification tests was normal (k = 5; d = -.14; in Cohen, Brown, & Auster, 2012a; Seghers, McCleery, & Docherty, 2011). However, there is evidence that subjective experience of olfactory stimuli is abnormal. A recent study comparing subjective and objective olfactory functions in patients with schizophrenia, college students with schizotypy, and psychiatric and nonpsychiatric controls found that individuals with psychometrically-defined schizotypy were normal with respect to olfactory identification, but impaired in olfactory experience compared to psychiatric and nonpsychiatric control groups (Auster, Cohen, Callaway, & Brown, 2014). The schizotypy group was not significantly different in subjective olfactory report compared to patients with schizophrenia. Thus, in schizotypy, the self-reported experience of olfaction is affected in a way that objectively assessed ability is not.

Quality of Life

Quality of life – defined in terms of both subjective and objective well-being – is a critical variable for understanding the schizophrenia-spectrum. In schizophrenia, a near ubiquitous declination in quality of life has been found (Heider et al., 2007). Individuals with psychometrically-defined schizotypy have also reported reduced quality of life (Cohen & Davis, 2009; Seghers et al., 2011). A recent study examined how this reduction compares with that seen in chronic outpatients with severe mental illness (i.e., schizophrenia, bipolar disorder and chronic unipolar depression), and whether this declination, if present, was similar in magnitude across subjective (e.g., “how satisfied are you with your quality of life?”) and objective (e.g., “what kinds of social, financial, and other resources do you have?”; Lehman, 1995) domains of life quality. The measure of life quality covered a broad range of areas, including health, legal and safety, financial, social, family, housing and recreational concerns. Results suggest that, for the most part, college students with psychometric schizotypy resembled their non-schizotypal peers in objective quality of life, and both of these student groups had significantly more objectively-defined resources (e.g., financial, social) than the patient group, suggesting a higher objective quality of life. However, in terms of subjective quality of life, schizotypy and chronic patient groups resemble each other and were both abnormally low compared to their relative control groups (Cohen, Auster, et al., 2013). It is important to note that high levels of psychometrically-defined schizotypy are often associated with relative impairments in academic and social functioning (Blanchard et al., 2011, Llerena et al., 2012; Chapman, Edell, & Chapman, 1980), though these are not synonymous with quality of life resources. In short, college students with psychometrically-defined schizotypy reported experiencing quality of life at a similar level as chronic patients with severe mental illness, yet their objective quality of life does not appear consistent with this.

What Might, or Might Not Underlie the Subjective-Objective Disjunction?

Not Simply a Global Response Bias

Having made the case that there is a disjunction between subjective and objective variables in at least some important functional domains for individuals with psychometrically-defined schizotypy, let us discuss potential psychological underpinnings. A first process that should be entertained involves a response bias. It is possible that the subjective-objective disjunction simply occurs as a byproduct of recruiting individuals who are "pathological yea-sayers" – individuals who, for impression management, demand characteristics, or other reasons, indiscriminately endorse pathology on questionnaires. After all, there is potential circularity in the finding that individuals identified based on self-reported, though relatively circumscribed, measures of pathology also report broader psychopathology on other self-report measures. There are several reasons that this sort of response bias does not satisfactorily explain the subjective-objective disjunction. First, and perhaps most importantly, the extant literature is replete with examples of objectively assessed anomalies associated with psychometric schizotypy. Of particular note, cross-sectional and longitudinal studies have found that college students with psychometric schizotypy meet criteria for psychotic and schizophrenia-spectrum disorders, measured using structured clinical interviews, at abnormally high rates (Raine, 1991) and have relatively high rates of diagnosable schizophrenia-spectrum disorders in their biological families (Tarbox & Pogue-Geile, 2011). Thus, from a construct validity perspective, psychometrically-defined schizotypy is not simply a subjective phenomenon.

Second, a lack of self-reported dysfunction is observed on some self-report measures administered to college students with schizotypy. Of particular note, positive, negative and disorganization scales are by no means redundant, and they often show only modest convergence with each other (e.g., *r*'s < .52; Cohen et al., 2010). Thus, individuals are not indiscriminately endorsing schizotypy traits. Relatedly, individuals with psychometrically-defined schizotypy completing comprehensive measures of self-reported psychopathology (e.g., the Minnesota Multiphasic Personality Inventory) fail to produce abnormal validity profiles or elevated scores on all/most scales (Lenzenweger, 1991; Merritt, Balogh, & DeVinney, 1993; Penk, Carpenter, & Rylee, 1979) and sometimes fail to show evidence on scales presumed to tap psychosis-proneness (Bolinskey & Gottesman, 2010; Hunter, et al., 2014). Relatedly, many studies recruiting schizotypy groups also employ infrequency scales – measures that assess endorsement of infrequently occurring events, some of which have a pathological tone (e.g., "I have never combed my hair before going out in the morning"; Chapman & Chapman, 1983). Scorers exceeding a threshold of endorsed infrequency items are typically excluded from the respective study. Thus, individuals with psychometric schizotypy are at least able to effectively discriminate between frequently and infrequently endorsed items. It is also noteworthy that, in Cohen et al., (2013), individuals with psychometrically-defined schizotypy were relatively normal with respect to self-reported objective quality of life variables. In sum, it seems unlikely that the subjective-objective disjunction simply reflects an isomorphic response bias.

Possibly a Cognitive Bias

An alternate explanation for the subjective-objective disjunction is that it reflects an earnest, albeit incorrect, appraisal formed by an evaluation of available evidence. That is, individuals with psychometrically-defined schizotypy may be convinced that their cognitive, emotional, expressive and olfactory functions and quality of life are impaired despite available evidence to the contrary. Thus, their abnormal self-report could reflect biases in perceiving and forming and maintaining beliefs in some manner. "Cognitive biases" are quite common in the general (i.e., non-schizotypal) population and, in many cases, are considered adaptive. For example, the self-serving bias – involving internal, stable and global attributions being made for positive versus negative events at a higher rate, is fairly robust in the general population (d = .96), but is notably smaller for individuals with depression (d = .21) and anxiety (d = .46) symptoms (Mezulis, Abramson, Hyde, & Hankin, 2004). Some researchers have gone so far as to propose that many cognitive biases, from an evolutionary perspective, conferred practical advantages to humans (e.g., Haselton, Nettle, & Andrews, 2005). In this manner, it may be the case that cognitive biases, largely present and adaptive in the general population, are abnormal in individuals with psychometric schizotypy. This is not unlike the "depressive realism" noted in the clinical science literature (Mezulis, Abramson, Hyde, & Hankin, 2004).

There has been considerable empirical and theoretical work done in understanding cognitive errors that humans commonly make and clarifying the cognitive and neurobiological systems that potentially underlie them. While a review of this topic is well beyond our scope here, it is worth briefly considering some potentially relevant psychological processes. From an information processing perspective, the systems involved in forming and maintaining beliefs are many, and can involve perceptual, long-term memory, working memory and attentional systems (Stanovich & West, 2008). An individual with deficits in autobiographical recall, for example, would be expected to have difficulty recalling self-referential information to support and maintain accurate beliefs. Interestingly, confabulation, a condition wherein individuals fabricate memories, would be expected to occur as a product of memory deficits (Johnson, O'Connor, & Cantor, 1997). Confabulation has been observed in patients with schizophrenia (Nathaniel-James & Frith, 1996).

"Higher-order" cognitive processes are also important for forming and maintaining self-referential beliefs, particularly in terms of assigning relative weight to various experiences (Pronin, Wegner, McCarthy & Rodriguez, 2006). "Biased" individuals may give abnormal importance to certain experiences over others when reporting their beliefs or in deriving peer norms. For example, an individual asked to subjectively evaluate their general cognitive ability may access their autobiographical stores for relevant experiences; perhaps identifying salient experiences (e.g., "winning a spelling bee"; "getting an A in a class"). These experiences will then be compared to their perceptions about others (e.g., "most people don't win a spelling bee or get A's in class") and can be used to develop a belief (e.g., "I am smart"). The relative weights these experiences are given, and the norms that they are compared against, are often made using relatively predictable algorithms. Biases can occur by inappropriately weighting information relevant to oneself (e.g., "I am getting an A" versus "My A is in a very easy class, and I have a D average in school") or others (e.g., "Everyone gets an A in this class"). A clinical example of the latter bias is seen in alcohol-users who generally report that their alcohol use is not abnormal, a belief primarily made, not based on under-reporting their actual consumption, but by over-estimating peer use (e.g., Buckner, Ecker, & Proctor, 2011).

Direct evidence of a higher-order cognitive bias in schizotypy has been established. The illusory superiority bias is a normally occurring bias associated with an overestimation of self-reported positive qualities and underestimation of negative qualities compared to others (Hoorens, 1993). For example, when appraising emotional experience, most individuals report that they experience more pleasant and less unpleasant emotions than their peers. A diminished illusory superiority bias could explain why schizotypal personality features are associated with subjective ratings that are abnormal relative to their peers. Evidence for this was found in a recent study from our laboratory examining emotional experience (Cohen, Auster, McGovern, & MacAulay, 2014a). Individuals with psychometrically-defined schizotypy and matched controls were compared in their self-report of emotions during laboratory emotion induction procedures and trait emotional experience questionnaires. Subjects were also asked to predict their peers' experiences using the same rating measures. As expected, controls rated their own emotions to be more pleasant and less unpleasant than peers. In contrast, the self versus other ratings were similar for individuals with psychometrically-defined schizotypy. It is not the case that individuals with psychometrically-defined schizotypy were more accurate in their own report of emotion (as in the aforementioned "depressive realism") since both schizotypal and non-schizotypal individuals showed peer ratings that were significantly below what most people actually reported experiencing. Put simply, non-schizotypal individuals rated others as being abnormal whereas schizotypal individuals rated both others and themselves as being similarly abnormal compared to controls. Interestingly, deficiencies in being able to effectively differentiate between "self" and "other" experiences has been central to early conceptualizations of schizotypy (Sullivan, 1962) and are supported in recent studies (e.g., Germine, Benson, Cohen, & Hooker, 2013; see also Nelson, Parnas & Sass, 2014).

From a clinical perspective, it stands to reason that individuals with psychometric schizotypy exhibit abnormal cognitive biases relative to their peers. In laying out a Cognitive Therapy based model of SPD, Beck, Freeman, and Davis (2006) note a characteristic core belief that involves being "different, worthless and abnormal". Biased by this belief, undue weight is given to experiences highlighting eccentricities, abnormalities and failures over other "self-affirming" experiences. Similarly, experiences supporting the notion that other people are uncreative, competent and effective might be given undue weight when deriving peer norms. For example, an individual with schizotypy may derive the belief that their cognitive functioning is deficient based on giving undue weight to a few salient experiences (e.g., losing their cell phone, getting lost or forgetting names and phone numbers), discounting the cognitive

successes that they have had, and failing to accurately appraise the cognitive performances of their peers. Similarly, individuals with psychometrically-defined schizotypy may believe they are less expressive than their peers based narrowly on experiences where they felt socially awkward or anxious, and/or by focusing on perceived (but inaccurate) effectiveness of their peers. It also bears mention that these sorts of autobiographical beliefs have been related to societal stigma resulting from psychosis-like experiences (Schomerus, Matschinger & Angermeyer, 2013; Wiesjahn, Brabban, Jung, Gebauer & Lincoln, 2014).

Potential Mechanisms: A Reasoning Bias?

The notion that abnormalities with reasoning abilities are central to schizophrenia-spectrum pathology is not new. For example, building on Bayesian models of hypothesis testing, Garety and colleagues (Garety et al., 2005; Garety, Hemsley, & Wessely, 1991; Hemsley & Garety, 1986) have argued that delusional beliefs can be explained in terms of deviations from logic. That is, delusions arise when people make errors in evaluating their beliefs, in particular, in overestimating the probability that their hypotheses are true. Relatedly, Morrison and colleagues (Morrison & Haddock, 1997) have proposed that hallucinations reflect intrusive thoughts that are misattributed to the external world.

Subcomponents of the reasoning process have been delineated and examined within the schizophrenia-spectrum. Of note, the ”jumping to conclusions” bias, also referred to as the “inference-observation” bias, refers to a data-gathering bias where people reach conclusions based on relatively limited information. Sellen, Oaksford, & Gray (2005) have proposed that, in people with schizophrenia-spectrum disorders, this bias reflects an “overinclusive thinking” style such that semantically tangential concepts are abnormally activated. In this manner, individuals have difficulty differentiating relevant from irrelevant information (given that both are activated), and both may be taken as support for a belief. Some theorists have distinguished between the use of confirmatory evidence – information that supports the hypothesized belief in question, and disconfirmatory evidence – information that does not support, or even counters the hypothesized belief. These processes are thought to be important for different hypothesis-testing contexts (Klayman & Ha, 1987). A “Bias Against Disconfirmatory Evidence” (BADE) in particular, has been proposed as being important for schizophrenia-spectrum disorders. In general, there is considerable evidence to suggest these processes are impaired in patients with schizophrenia (Ross, McKay, Coltheart, & Langdon, 2015; Woodward, Moritz, Cuttler, & Whitman, 2006; Young & Bentall, 1997).

As yet, evidence for a reasoning bias as the basis for a subjective-objective disjunction in schizotypy is equivocal. A handful of studies to date have reported modest reasoning abnormalities in college schizotypy samples. For example, there is evidence of an abnormal Jumping to Conclusion (JTC) bias (Brugger & Graves, 1997; Keefe & Warman, 2011; Warman, Lysaker, Martin, Davis, & Haudenschield, 2007; Warman & Martin, 2006; White & Mansell, 2009) and BADE (Buchy, Woodward, & Liotti, 2007; Orenes, Navarrete, Beltran, & Santamaria, 2012; Woodward, Buchy, Moritz, & Liotti, 2007) in a number of published studies. When interpreting these studies, it is important to note that with very few exceptions, schizotypy was defined in terms of positive traits (e.g., magical ideation), thus, the relevance to the broader schizotypy construct is unclear. An exception to this involves Woodward et al., (2007), who found that BADE abnormalities were related to positive, but not negative or disorganized aspects of schizotypy. Moreover, the results are not entirely consistent across studies. For example, in contrast to many of the studies listed above (e.g., Brugger & Graves, 1997; Keefe & Warman, 2011), Warman et al., (2007) found that individuals with psychometrically-defined schizotypy performed normally on a JTC task but showed unusually high levels of confidence in their decisions relative to controls (potentially suggesting a reasoning bias of some kind). Moreover, the effects are generally not particularly strong. A recent meta-analysis on reasoning biases in the general population found a small effect size (r = -.10; k = 23) association between delusional ideation and abnormal reasoning, as measured using a bead drawing task (Ross, McKay, Coltheart, & Langdon, 2015). Reasoning biases reflect an interesting mechanism potentially underlying the subjective-objective disjunction, yet much empirical work remains (e.g., see Pinkham et al., 2014 for discussion of challenges in measuring cognitive biases in schizophrenia more generally).

Future Directions

It is curious that the reasoning biases associated with schizotypy are consistently and potently negativistic in valence. To date, we are aware of no evidence to suggest that individuals with psychometric schizotypy have overly positive beliefs regarding themselves or their lives. If faulty reasoning occurs in isolation, the beliefs of individuals with psychometric schizotypy should be relatively random – due to inconsistency over time and across individuals with psychometrically-defined schizotypy in terms of valence. Rather, for each of the domains discussed in section three, individuals with psychometrically-defined schizotypy predictably present with a pessimistic, dysphoric, or otherwise negativistic appraisal of themselves and their experiences. Thus, it would seem negative-valence affective systems, or their associated regulatory systems are involved in some capacity – in essence, guiding beliefs towards more negativistic valences. As discussed above, Cognitive Therapy-based conceptualizations highlight negativistic core beliefs that involve being "different, worthless and abnormal". With this in mind, understanding the interface between cognitive and affective systems seems an important direction for future research, particularly in terms of the development of these negativistic self-oriented beliefs (see Roiser & Sahakian, 2013 for a discussion of this issue in depression).

It would also be important to evaluate the specificity of self-reported impairments to schizotypy, as it is possible that the anomalous reports reflect trait negative affect more generally. As previously discussed, there is a profound link between schizotypy and increased trait negative affect and decreased levels of trait positive affect (see Berenbaum & Fujita, 1994; Horan, 2008 for meta-analyses). What is unclear is whether trait negative affect is associated with anomalous self-reports beyond that the high levels already associated with schizotypal traits. As discussed above, depression and anxiety are associated with abnormal cognitive biases (Mezulis et al., 2004) as are personality traits and disorders (Beck et al., 2006). Moreover, clinical treatment of problem traits often involves targeting cognitive biases and distortions (Beck et al., 2006); at least, using cognitive-based therapies. Moving forward, it would be important to evaluate how self-reported anomalies are differentially related to schizotypy versus trait negative affect more generally.

A final issue involves schizotypy heterogeneity. Schizotypy reflects a range of positive, negative and disorganized traits, and individuals often show some, but not all traits. It has yet to be conclusively determined whether any of these traits are preferentially related to onset of future psychosis or schizophrenia symptoms, or a family history or future incidence of illness more generally (Tarbox & Pogue-Geile, 2011). Nonetheless, there is evidence that the subjective-objective disjunction occurs across positive, negative and disorganized schizotypal traits. The aforementioned meta-analyses of neuropsychological (Chun et al., 2013) and olfactory (Cohen, Brown, et al., 2012b) functions, for example, included a broad range of schizotypy measures tapping positive, negative and disorganized schizotypal traits. In contrast, the JTC bias and the BADE have primarily (but not exclusively) been examined in the context of fairly refined positive schizotypal traits. Thus, an important issue moving forward involves confirming if the subjective-objective disjunction actually manifests across a positive, negative and disorganized schizotypal traits, and determining if biases in belief formation and maintenance explain this potential disjunction similarly across different schizotypal traits.

Closing: Towards Meaningful Vulnerability Markers of Schizotypy

Despite decades of research and hundreds of peer-reviewed studies to date, our attempts to objectify schizotypy have fallen short. The findings from this review suggest that many candidate objective markers are only useful when considering their conceptually-overlapping subjective counterparts. Understanding why college individuals with psychometrically-defined schizotypy self-report high levels of pathology, yet fail to demonstrate commensurate levels of dysfunction, may be a critical entry point for gaining insight into schizophrenia vulnerability. A compelling explanation for the apparent subjective-objective disjunction in schizotypy involves cognitive biases, though other explanations likely exist that we are unaware of. The questions of whether the subjective-objective disjunction, and their potential cognitive biases reflect a heritable phenomenon that is related to and predictive of schizophrenia (or perhaps psychosis more generally) remains to be seen. We believe this reflects a very important, and very answerable question that could pay dividends in terms of understanding the neurobiological basis of schizophrenia and for early identification efforts aimed at reducing burden associated with the manifest illness.

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