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The Relationship Between Schizotypal Traits and Affect-driven Volition in Healthy Adults

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Abstract
Avolition in schizophrenia has been attributed to an underlying decoupling between affect and volitional action. It may be demonstrated behaviourally in the Anticipatory Consummatory Pleasure (ACP) task, whereby subjects may adjust the viewing (in time or future probability) of images with positive or negative affective content. Correspondence between response vigour and perceived affective intensity of the images was typically poorer in people with schizophrenia than healthy controls. Here, we investigated if ACP performance would be similarly modulated by schizotypal traits in the non-clinical population. Schizotypal traits were assessed in healthy adult volunteers using Schizotypal Personality Questionnaire-Brief before evaluation of ACP performance. Association between the three schizotypal traits and affect-volition coupling was examined by correlative analysis followed by comparison between dichotomized clusters. Affect-volition coupling appeared to correlate positively with increasing schizotypal traits, especially in the interpersonal and disorganization dimensions. Direct comparison between the two clusters of subjects demarcated with respect to all three schizotypy dimensions showed that actions motivated by future affective outcomes was selectively potentiated, as opposed to in-the-moment outcomes, in the higher schizotypy cluster. The positive modulation of affect-volition coupling by schizotypal traits seen here was unexpected given the robust decoupling reported in people with schizophrenia. Our data also contradicted with previous ACP studies reporting either an opposite or null relationship between schizotypy and affect-volition coupling. We speculate that the relationship across a more extended continuum of schizotypal traits may follow an inverted U-shape, thus either ends of the continuum is associated with suboptimal ACP performance.

Keywords Avolition · Motivation · Schizotypy · Schizophrenia · SPQ-B

Avolition is a prominent negative symptom of schizophrenia that contributes to the “loss of energy and drive” characteristic in *dementia praecox* as described by Emil Kraepelin, who attributed its emergence to “disjointed volitional behaviour” rather than a primary failure to perceive or comprehend emotional cues (Kraepelin, 1920/1974). As a result, willed actions are no longer tightly coupled with current or anticipated affective experiences. Volitional behaviour, including pleasure-seeking behaviour (appetitive motivation) and avoidance of displeasure (defensive motivation) may thus become disorganized and appear inappropriate. Efforts to capture the hypothesized disconnection between emotion and volitional behaviour has led to the development of the anticipatory and consummatory pleasure (ACP) task by Heerey and Gold (2007). The task is designed to distinguish between behaviour intended to favour exposure to images with positive affective content (as opposed to behaviour disfavouring exposure to images with negative affective content) in the future and behaviour intended to extend (or shorten) the viewing time to such positive (or negative) images in-the-moment. This distinction emphasizes the temporal separation between the affect-driven instrumental

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behaviour and the expected outcomes, and it is captured by the terms: *anticipatory* vs. *consummatory,* respectively.

Subjects with schizophrenia spectrum disorders – from first-episode to chronic patients – consistently performed poorly in the ACP task (Heerey & Gold, 2007; Lui et al., 2016a; Xie et al., 2017; Lam et al., 2023). The vigour of their behaviour showed weaker concordance with the perceived emotional intensity of the depicted images, compared with healthy control subjects. The robust deficit was always demonstrated against the background of intact emotional discrimination. Efforts to examine the task's ability to detect early psychosis and individuals at risk have yielded some support suggesting that ACP deficiency may constitute a behavioural endophenotype of schizophrenia. Xie et al. (2017) reported the presence of schizophrenia-like deficits in the ACP task in unaffected first-degree relatives of schizophrenia patients. Other studies examining the task's sensitivity to schizotypy personality traits in the general population, however, have disagreed on whether people with strong schizotypal traits were deficient in the ACP tasks (Xie et al., 2017) or not (Lui et al., 2016b).

Schizotypy refers to a set of heterogeneous but correlated personality traits that capture characteristics similar to pathological experiences in schizophrenia patients. Schizotypy is conceived as a continuum of inter-individual variability associated with psychosis proneness in the general population (Meehl, 1990; Claridge, 1994; Van Os et al., 2009). It is a construct considered to be instrumental in understanding the aetiology and development of schizophrenia (Barrantes-Vidal et al., 2020). In addition to experiential resemblance, linkage between schizotypy in the general population and disorders on the schizophrenia spectrum has been substantiated on genetics, psychopharmacological, and neuropsychological grounds (Ettinger et al., 2014; Nelson et al., 2013). The dimensional organization of schizotypal traits (Raine et al., 1994; Wuthrich & Bates, 2006; Mason & Claridge, 2006; Barrantes-Vidal et al., 2013; Davidson et al., 2016) also mirrors the clinical/diagnostic distinction of positive and negative schizophrenia symptoms (e.g., Andreasen and Olsen, 1982), and the clustering of symptoms based on functional brain imaging in schizophrenia patients (e.g., Liddle et al., 1992).

Psychometric analysis of the Schizotypal Personality Questionnaire (SPQ) has yielded three latent factors: cognitive-perceptual (CP), interpersonal deficit (IP), and disorganization (DO) (Raine et al., 1994; Raine & Benishay, 1995; Davidson et al., 2016). The latent factor CP is considered a *positive* schizotypy dimension for it comprises experiences similar to psychotic symptoms, characterised by magical and paranoid ideation, ideas of reference, and unusual perceptual experiences. The latent factor IP, on the other hand, represents a *negative* schizotypy dimension and comprises traits such as social anxiety, lack of close friendship, and constricted affect. The latent factor DO refers to odd behaviour and odd speech, and it has been linked to elevated negative affect (Kemp et al., 2018).

Successful generalization of the ACP findings in schizophrenia spectrum disorders to schizotypal traits would be a significant extension that reinforces schizotypy as "a unifying construct for linking a broad continuum of clinical and subclinical manifestations" (Kwapil & Barrantes-Vidal, 2015), especially with respect to the negative schizotypy dimensions (correspond to the latent factors labelled IP and DO). To date, data pertinent to this hypothesis are available from only two studies by Raymond Chan and colleagues. Notably both studies had adopted an extreme group approach conducted in college students. First, Lui et al. (2016b) compared 31 high negative schizotypy with 28 low negative schizotypy subjects, defined respectively, as one standard deviation (SD) above or below the mean in the Scales for Physical and Social Anhedonia (Chapman et al., 1976) from a pool of 1,863 college students. The two groups could not be differentiated across all aspects of ACP performance. In their second attempt, Xie et al. (2017) introduced a more extreme criterion for their high negative schizotypy subjects ($n = 32$), defined as 1.96 SD above the mean Chapman Social Anhedonia Scale (SAS) score based on an initial pool of 2,994 college students. The criterion for the comparison control group, however, was substantially relaxed, which comprised an equal number of subjects with below-average SAS scores. This design led to the emergence of a significant group difference. A loosening of the concordance between the intensity of emotional reaction to affective pictures and the vigour of response to seek/avoid seeing the pictures was observed in the high negative schizotypy group. The authors concluded that negative schizotypy (assessed by social anhedonia) was associated with affect–volition decoupling. They further suggested that Lui et al. (2016b) failed to detect a similar group difference because their criterion for high negative schizotypy group was not sufficiently extreme (Xie et al., 2017, *pp*1480).

However, the conclusions reached by Xie et al. (2017), including their dismissal of Lui et al.'s (2016b) null finding, remain far from uncontentious. Reliance on the extreme group approach in studies of this kind is increasingly being criticized and discouraged (e.g., Cohen, 1983; Irwin and McClelland, 2003; MacCallum et al., 2002; Preacher et al., 2005). An intrinsic limitation of the extreme group approach is the inability to provide a dimensional picture on the relationship between schizotypal traits and emotion-behaviour decoupling across the continuum of schizotypy in the general population. 97–98% of data in their initial pool of subjects had been effectively ignored by Lui et al. (2016b) and Xie et al. (2017), but these centrally located data were essential for assessing variability in the most representative segment of the population. To fill this lacuna, the present study was conceived as an alternative to the extreme group approach, in elucidating the relationship between schizotypal traits and affect-volition coupling as captured by the ACP task. Moreover, we recruited subjects from a wider spectrum of community-living adults rather than focussing solely on college students.

The present study constituted an attempt to resolve the inconsistency emerged from the two studies so far (Lui et al., 2016b; Xie et al., 2017) by testing the hypothesis that the presence of affect-volition decoupling in schizophrenia may be generalized to schizotypal traits in the non-clinical adult population. And if so, whether schizotypal traits might preferentially modify anticipatory or consummatory affect-driven instrumental response. Finally, since the degree of affect-volition decoupling has been linked to the severity of concomitant working memory deficits in schizophrenia (Heerey & Gold, 2007; Lam et al., 2023), we had included the specific working memory test previously used – namely, the letter-number span test (Gold et al., 1997). The present study, however, was not designed as a comprehensive evaluation of how schizotypal traits might modify working memory function in general (e.g., Tek et al., 2002; Xie et al., 2018).

Method

Subjects

Male and female subjects, aged between 18 and 60 years old, were recruited from the community by advertisements and word-of-mouth. Inclusion criteria included the ability to read standard Chinese, verbal communication in Cantonese or Mandarin, and corrected vision. Three potential subjects who reported a history of mental disorders (including schizophrenia spectrum disorders, major depression, mania, anxiety, impulse control disorders, neurodevelopmental disorders, or substance use disorders under the classes of substances specified by the DSM-5, except for tobacco or caffeine) in themselves or in their first-degree relatives were excluded. Additional exclusion criteria were the presence of neurological (brain) damage or any physical disabilities that could directly interfere with performance in any test, and pregnancy, but none was excluded on these grounds. To minimize confounding due to long-term medications, subjects suffering from diabetes, autoimmune diseases, chronic inflammatory diseases, chronic pain, cardiopulmonary diseases, cancer, or other chronic diseases requiring long-term medications were excluded, but none met these criteria. Nine subjects who reported visual impairment or reduced vision (e.g., cataract or glaucoma) were not invited. Two subjects discontinued participation after the initial first contact. A total of 105 (52 female and 53 male) Chinese subjects participated in the experiment (mean age = 39.93, SD = 12.21 years). All subjects had provided their written informed consent before the study began. Demographic characteristics, including age, gender, marital status, education, and employment, were collected. The final data analyses were conducted in 91 subjects because 14 subjects were dropped. Besides one subject whose Phase 2 data was lost due to technical failure and two subjects who did not respond at all in Phase 1 of the ACP task, the final analysis also excluded three subjects who made responses inconsistent with the pleasantness ratings they previously assigned to the images (i.e., not complying with the instructions and thus considered as *invalid* responses) in over 20% of trials in the ACP task. Finally, to ensure the meaningful computation of affect-volition coupling indices in the ACP task (see later), five and three subjects were dropped due to insufficient coverage (i.e., fewer than 3 distinct levels) of the valence domain [1–5] or domain [5–9] in Phase 1 and Phase 2, respectively. Table 1 summarizes the demographics of the final 91 subjects, including their comparison between the two clusters (higher vs. lower schizotypy) identified for subsequent contrast in ACP performance.

Procedures

This study was conducted in accordance with the Declaration of Helsinki (World Medical Association, 2013) and had been approved by the Institutional Review Board of The Hong Kong Polytechnic University (#HSEARS20210524002). The experimenter first explained the purpose and requirements of the study to all potential subjects and provided them a document with relevant information. Subjects satisfying the inclusion criteria were invited to join the study, and their written consent requested. Next, demographic data (included age, gender, marital status, education level, and employment status) were collected before completing the Chinese version of Schizotypal Personality Questionnaire-Brief (SPQ-B). To assist interpretation, the subjects were also requested to fill in three additional questionnaires: the Patient Health Questionnaire-9 (PHQ-9), the General Self-Efficacy Scale (GSE), and the Brief Social Phobia Scale (BSPS). In keeping with the previous ACP studies (Lui et al., 2016b; Xie et al., 2017; Lam et al., 2023), the Temporal Experience of Pleasure Scale (TEPS) and letter-number sequence (LNS) test – as detailed below – were conducted to explore the association with hedonic and working memory function, respectively. The ACP task was then conducted, followed by the LNS test 5 min later. The entire study took about 90 min to complete.

Table 1 Participants' Demographic Characteristics

Demographic characteristics	Final *N* = 91	Cluster 1 *N* = 21	Cluster 2 *N* = 70
Age (yr)			
Mean ± SD	39.0 ± 12.2	38.1 ± 11.1	39.3 ± 12.5
Median (Range)	38 (18–59)	39 (18–59)	38 (18–59)
Gender			
Male	45 (49.5%)	11 (52.4%)	34 (48.6%)
Female	46 (50.5%)	10 (47.6%)	36 (51.4%)
Marital Status			
Single (never married)	46 (50.5%)	10 (47.6%)	36 (51.4%)
Married	44 (48.4%)	11 (52.4%)	33 (47.1%)
Divorced or widowed	1 (1.1%)	0 (0%)	1 (1.4%)
Education			
Secondary or below	13 (14.3%)	2 (9.5%)	11 (15.7%)
College of Vocational training	4 (4.4%)	2 (9.5%)	2 (2.9%)
Undergraduate	39 (42.9%)	9 (42.9%)	30 (42.9%)
Postgraduate & above	35 (38.5%)	8 (38.1%)	27 (38.6%)
Employment			
Gainfully employed	62 (68.1%)	17 (81.0%)	45 (64.3%)
Full-time student	18 (19.8%)	3 (14.3%)	15 (21.4%)
Unemployed	4 (4.4%)	0 (0%)	4 (5.7%)
Homemaker/housewives and retirees	7 (7.7%)	1 (4.8%)	6 (8.6%)

Note. The demographic characteristics of the final 91 subjects are summarized. The last two columns compared the demographic of the two dichotomized clusters (Clusters 1 and 2 correspond to the higher and lower schizotypy clusters, respectively) that were subsequently compared (see **Results** later). The two clusters did not significantly differ in their average age (one-way ANOVA) or other demographic variables summarised as frequency data (Fisher's exact test).

Measures

Schizotypal Personality Questionnaire-Brief (SPQ-B)

The validated 22-item Chinese version of SPQ-B (Ma et al., 2010, 2015) was used to assess and quantify schizotypal personality traits. The three SPQ-B subscores: cognitive-perceptual (CP), interpersonal (IP), and disorganization (DO) were computed as instructed in the original SPQ-B (Raine & Benishay, 1995). The SPQ-B is a self-report instrument containing 22 items selected from the original 74-item SPQ (Raine, 1991). The 22 items were listed on a page in the order as specified by Raine and Benishay (1995, see their Table 1) and subjects responded with either *Yes* or *No* to each item. All items with a *Yes* response scored 1 point. The CP subscore was computed as the summative scores of 8 items. The IP subscore referred to the summative score of 8 other items. The summative score of the remaining 6 items formed the DO subscore.

The Anticipatory and Consummatory Pleasure (ACP) Task

The Chinese version of the ACP task was kindly provided by Lui et al. (2016a), which was translated from the original task described by Heerey and Gold (2007). It was implemented in E-Prime® 2.0 (Psychological Software Tools, PA, USA) on a laptop PC equipped with a 14-inch LCD screen running the MS Windows 10 OS. The task procedures including all the instructions have been fully reported elsewhere (Lam et al., 2023). Briefly, the task comprised two distinct phases, each consisted of multiple discrete trials.

In Phase 1, each trial began with the presentation of a set of three unique images simultaneously presented on the screen. Their contents always belonged to the same category of emotional valence, i.e., pleasant (positive valence), unpleasant (negative valence), or neutral according to the International Affective Picture System (IAPS, Lang et al., 2008). The subjects were prompted to rate the set of images on separate 9-point Likert-like scales in terms of (*i*) pleasantness-unpleasantness, and then (*ii*) how emotionally arousing the pictures appeared to them in a continuum from extremely calm (towards feeling relaxed, calm, or dull) to extremely arousing (towards feeling excited, frantic, trembling, or restless). The set of images was then removed from the screen, followed by a 2-second window during which the subjects were instructed to reduce the likelihood of seeing the images again if they found them unpleasant (by pressing "xzxz…" on the keyboard) or increase the likelihood if they found them pleasant (by keying "mnmn…"). They were explicitly told that the desired effect was proportional to the speed of their key pressing, and they should refrain from responding if the images just shown were considered neither emotionally positive nor negative (i.e., emotionally neutral). Images used were taken from the IAPS database (accessible upon request at https://csea.phhp.ufl.edu/media.html). 14 trials featured images of positive valence, 14 trials featured images with negative valance, and 14 with emotionally neutral images, as categorized by the IAPS normative database. The sequence of the 42 trials was randomized.

Next, Phase 2 began with relevant on-screen instructions and verbal guidance by the experimenter if necessary. In Phase 2, 30 sets of images were selected from those featured during Phase 1 with the restriction that 10 sets of images were randomly drawn from each valence category. Contrary to what the subjects were told, the selection was totally independent of their responses recorded in Phase 1. The order of the 30 sets of images used across the 30 trials in Phase 2 was randomized independently for each subject. Now, the subjects were told that the viewing time of unpleasant and pleasant images could be directly shortened (down to a minimum of 3 s) and lengthened (up to a maximum of 10 s), respectively, by the designated key presses as in Phase 1, and in a manner that also depended on the key pressing speed. Subjects were again instructed to refrain from responding to images they considered as emotionally neutral. The default viewing time was 5 s if no key presses were registered.

Computation of Affect-volition Coupling Indices in the ACP Task

An index of affect-volition coupling was computed based individual performance in each phase of the ACP task for subsequent correlative analysis with the three SPQ-B subscores and other secondary measures (as described later). Because the profile of key-press vigour (in Hz) typically followed a ∨-shaped profile when expressed as a function of the subjective valence ratings (from 1 = *very unpleasant* to 9 = *very pleasant*) that the subjects had assigned to the images presented across trials, with a minimum in trials featuring neutral images (rating = 5), a quadratic polynomial equation was fitted to each subject's response profile by the least squared method. The convexity of the fitted quadratic curve, as measured by the quadratic coefficient of the equation (denoted "*q*") was taken as an index of affect-volition coupling. $q > 0$ (a positive *q* value) corresponds to the expected ∨-shaped profile, with larger *q* indicating steeper rise of response rate as perceived valence becomes increasingly more *unpleasant* or more *pleasant* (i.e., further deviating from 5). $q = 0$ corresponds to a flat profile suggesting a complete loss of affect-volition coupling, while $q < 0$ (a negative *q* value) corresponds to a ∧-shaped profile. q_A and q_C were computed for each subject to index the affect-volition coupling of anticipatory response (in Phase 1) and the affect-volition coupling of consummatory response (in Phase 2) of the ACP task, respectively. The quadratic polynomial fitted to individual data (for Phase 1 and Phase 2 separately) further allowed us to impute the key press rates across the entire valence domain [1, 2, 3, …9] for both descriptive and interpretative statistics.

To avoid influence of spurious key presses, only valid trials were included in the computation. A trial was deemed *invalid* if 20% or more of the key presses registered were inconsistent with the valence rating the subject had assigned to the images featured on that trial. This criterion was not applied to trials with images rated 4 to 6 because of their proximity to the neutral (indifference) point of 5 (following Heerey and Gold, 2007; Lui et al., 2016b). Only subjects who had valid trials across at least three distinct valence ratings in domain [1–5] and domain [5–9] were included in the derivation of q_A and q_C described above. These indexes are more sensitive in comparison with previous analytical approach (e.g., Heerey and Gold, 2007) whereby valid trials were pooled into three categories: *undesirable*, *indifferent*, and *desirable*, by mapping onto three non-overlapping domains with valence ratings: [1–3], [4–6], and [7–9], respectively. Although it is feasible to compute a quadratic coefficient across these three categories (e.g., Lam et al., 2023), variation across valence ratings inside each category was essentially lost.

The final analysis of ACP data included 91 subjects after 14 subjects were dropped due to data loss (n = 1), excessive (> 20%) invalid trials (n = 3), insufficient variability in the valence ratings across valid trials (n = 8) to reliably compute coupling indices, q_A or q_C, described above (see Table 1).

Valence-arousal Coupling in the ACP Task

We have previously observed that schizophrenia patients exhibited a weaker correlation between ratings in valence (pleasantness-unpleasantness) and arousal of all images used across trials (Lam et al., 2023). Two separate correlation coefficients were computed for each subject: one based on all images rated from very unpleasant to neutral (1–5), and the other from trials with images rated from neutral to very pleasant to (5–9). The computed Pearson's product moment coefficients were submitted to Fisher's *z*-transformation and denoted as $z_{r(unpleasant)}$ and $z_{r(pleasant)}$, respectively.

Letter-Number Sequencing (LNS)

After the experimented read out a string of unique alphanumeric characters, the subjects were requested to re-state the numbers in ascending order followed by the letters in alphabetical order. The alphanumeric strings increased sequentially from two to nine characters, with four unique strings evaluated at each length. The task was terminated if all four attempts at a given length failed. The total correct responses and maximum length completed were scored. The LNS task (Gold et al., 1997) was widely included in previous ACP studies evaluating schizophrenia or schizotypy to assess verbal working memory (Heerey & Gold, 2007; Chu et al., 2020; Lui et al., 2016a; Xie et al., 2017; Lam et al., 2023).

The Temporal Experience of Pleasure Scale (TEPS)

TEPS is a self-report instrument for assessing pleasure experience. It was developed by Gard et al. (2006, 2007) in an attempt to differentiate volitional control from emotional experience by separating pleasure experience into its temporal components. To this end, separate items were designed to tap anticipatory (i.e., to be experienced in the future, e.g., "*When I'm on my way to an amusement park, I can hardly wait to ride the roller coasters*") or consummatory (i.e., in the moment, e.g., "*I love it when people play* *with my hair*") pleasure (Klein, 1984). The original 18-item self-report TEPS questionnaire provides separate anticipatory and consummatory subscores, and Gard et al. (2007) reported that schizophrenia patients showed a preferential impairment in anticipatory pleasure. TEPS has also been shown to differentiate people with strong schizotypal traits (e.g., Visser et al., 2020). The 20-item Chinese version of the TEPS used here was developed and validated by Chan et al. (2012, 2016) which included two additional items to align better with Chinese culture and attitude regarding the seeking and consumption of pleasure. Subjects responded to each item on a 6-point Likert-like scale (from 1="very false for me" to 6="very true for me"). Four TEPS subscores were computed: anticipatory-abstract, anticipatory-context, consummatory-abstract, and consummatory-context, which corresponded to the four-factor structure identified by Chan et al. (2012). According to Chan et al. (2012), the abstract-context dichotomy distinguishes the degree to which the pleasure characterized in an item is embedded within a more concrete context, e.g., "*When I think of something tasty, like a chocolate chip cookie, I have to have one.*" as opposed to a more abstract context, e.g., "*I look forward to a lot of things in my life*".

Secondary Instruments

Three additional self-report instruments were administered to allow an overview of the psychological relevance of the SPQ-B subscores in terms of depressive mood, self-efficacy, and social phobia. These included the validated Chinese versions of (*i*) the 9-item Patient Health Questionnaire-9 for assessing depressive signs (PHQ-9, Spitzer et al., 1999; Yu et al., 2012), (*ii*) the 10-item self-reported questionnaire of General Self-Efficacy (GES, Schwarzer and Jerusalem, 1995; Zhang & Schwarzer, 1995) that has been reported to correlate with emotion, optimism, and work satisfaction, and (*iii*) the 18-item Brief Social Phobia Scale (BSPS), measuring fear, avoidance, and physiological arousal associated with social phobia was adopted (Davidson et al., 1991, 1997; Cao et al., 2016). The summative scores obtained from the PHQ-9 and GES, and the three BSPS subscale scores were used to characterize potential psychological differences between the two dichotomized clusters (see **Results**).

Statistical Analysis

All data analyses were performed using IBM SPSS Statistics for Windows (version 26; IBM Corp, NY, USA). Initial data processing, including the use of polynomial curve fitting to capture individual subjects' characteristics of ACP response profile by the least squared method, was performed in MS Excel. The association between the calculated ACP performance indices (Lam et al., 2023) and the three SPQ-B subscores was first assessed by Pearson's correlation, and effect size was indexed by R^2. *k*-means clustering procedure was performed to construct two dichotomized groups ($k=2$, *a priori*) with normalized SPQ-B subscores (CP, IP and DO). Initial centroids were determined by SPSS, and the final clustering was robust against variation in initial centroids. Parametric ANOVAs were conducted to allow statistical comparison between the two clusters, including both one-way randomized block ANOVA, and mixed three-way ANOVA. Associated effect size was indexed by η_p^2. Post-hoc tests were conducted to examine significant interaction terms emerged from ANOVA based on the pooled variance of the associated error mean-square (MS) term. Demographic measures expressed as frequency were analysed by Fisher's exact test. A two-tailed criterion of Type-I error rate <0.05 was applied.

Results

Correlative Analysis

The mean ($\pm$SD) of the total score in the SPQ-B in the 91 subjects was relatively low at 5.15 ± 4.24. The three SPQ-B subscores were also consistently low: CP: 1.96 ± 1.73, IP: 2.32 ± 2.10, and DO: 0.88 ± 1.26. The inter-correlations among the three SPQ-B subscores and their links to other mental-health and functional scores are summarized in Table 2. All three SPQ-B subscores significantly correlated with social phobia (BSPS) and depression (PHQ-9 total score) in the expected direction, but only the IP and DO subscores correlated significantly with self-efficacy (GSE score). By contrast, none of the three SPQ-B subscores showed any significant association with any of the four TEPS subscores.

Pearson's correlation was applied to evaluate association between schizotypal traits and ACP performance (Table 2). The three SPQ-B subscores were separately evaluated for an association with the two affect-volition indices: q_A, q_C, and the two indices of affect-arousal correlation: $z_{r(unpleasant)}$, $z_{r(pleasant)}$. Anticipatory affect-volition coupling (q_A) correlated positively with IP and DO subscores obtained from the SPQ-B ($p=0.001$) with modest effect size ($R^2=0.11$–0.12; see Fig. 1A and B). Hence, contrary to expectation, higher negative schizotypal traits were associated with stronger affect-volition coupling. This relationship was not evident with the consummatory affect-volition coupling (q_C), nor the positive schizotypal trait, namely the CP subscore obtained from SPQ-B (Fig. 1C). However, q_C was weakly associated with TEPS consummatory-abstract subscore ($R^2=0.08$, $p=0.005$) and GSE score ($R^2=0.09$, $p=0.003$).

Table 2 Summary of key correlations

		SPQ-*CP*	SPQ-*IP*	SPQ-*DO*	q_A	q_C	$z_{r(unpleasant)}$	$z_{r(pleasant)}$
(i)	**SPQ-*CP***				0.167	0.085	-0.089	**0.234 ***
	SPQ-*IP*	**0.413****			**0.338 ***	0.062	0.034	0.117
	SPQ-*DO*	**0.509****	**0.714****		**0.340 ***	0.104	-0.064	0.103
(ii)	**TEPS: anti/abs**	-0.028	-0.117	0.052	-0.056	0.180	-0.008	-0.021
	anti/ctxt	0.124	0.093	0.014	0.042	0.065	-0.073	-0.013
	cons/abs	0.099	0.080	0.029	0.067	**0.289***	**-0.217 ***	0.082
	cons/ctxt	0.154	-0.020	0.014	0.026	0.293	-0.107	0.180
(iii)	**PHQ-9: Total**	**0.214 ***	**0.397****	**0.232 ***	0.194	0.006	0.006	-0.002
	Difficulties	0.170	**0.309 ***	0.205	0.137	0.068	-0.048	-0.096
	BSPS: Total	**0.418****	**0.576****	**0.477****	0.171	-0.083	-0.021	0.079
	– Fear	**0.439****	**0.565****	**0.481****	0.190	-0.079	-0.009	0.079
	– Avoid	**0.376 ***	**0.537****	**0.481****	0.111	-0.103	-0.012	0.067
	– Physiol.	**0.307 ***	**0.465****	**0.293 ***	0.188	-0.024	-0.052	0.076
	GSE	-0.034	**-0.208 ***	**-0.209 ***	0.144	**0.307***	0.041	-0.083
(iv)	**LNS: Correct Scores**	-0.030	-0.066	-0.034	-0.031	**0.307***	-0.134	-0.170
	Max seq. length	0.032	-0.010	0.055	0.016	**0.276***	-0.157	-0.160

Note. (***i***) Correlation among the three schizotypal traits: *CP* (cognitive perceptual), *IP* (interpersonal deficit), and *DO* (disorganization) and four ACP performance indices: q_A and q_C (affect-volition coupling of anticipatory (Phase 1) and consummatory (Phase 2) responding, respectively); $z_{r(unpleasant)}$ and $z_{r(pleasant)}$ (affect-arousal coupling derived from images with subjective ratings valence ratings [1 to 5] and [5 to 9], respectively). (***ii***) Correlation with the four TEPS scores. (***iii***) Correlation with *PHQ-9*, *BSPS* and *GSE* scores. (***iv***) Correlation with verbal working memory performance in the LNS test. Significant correlations are highlighted (** $p<0.0001$; * $p<0.05$). All coefficients of correlation were associated with $df=89$ and $N=91$.

TEPS consummatory-abstract subscore also showed a weak association with affect-arousal coupling obtained across images rated as *unpleasant* to *neutral* ($R^2=0.05$, $p=0.04$). Affect-arousal coupling obtained across images rated as *neutral* to *pleasant*, by contrast, was associated with the CP subscore from the SPQ-B ($R^2=0.05$, $p=0.03$).

The LNS test of verbal working memory provided two intercorrelated measures ($r=0.836$, $df=89$, $R^2=0.70$, $p<0.0001$). They showed comparable positive correlation ($R^2=0.08$–0.09, $p<0.01$) with the affect-volition index, q_C, for consummatory response in the ACP task (Fig. 1D and E), but not with other ACP indices nor the three SPQ-B subscores (Table 2).

Comparison of ACP Performance Between Clusters of Higher vs. Lower Schizotypy

To further assess how schizotypal traits could influence ACP performance, we conducted a *k*-mean clustering with inputs of standardized SPQ-B subscores to dichotomize our subjects. This yielded two clusters with the smaller cluster ("higher schizotypy": $N=21$) scoring higher on all three schizotypal traits than the larger cluster ("lower schizotypy": $N=70$). Comparison between clusters by one-way ANOVA confirmed the presence of highly significant differences in all three schizotypal traits [CP: $F(1, 89)=37.43$, $p<0.0001$, $\eta_p^2=0.296$]; [IP: $F(1, 89)=116.09$, $p<0.0001$, $\eta_p^2=0.566$]; [DO: $F(1, 89)=272.72$, $p<0.0001$, $\eta_p^2=0.754$] (Fig. 2A).

Consistent with the correlative analysis, the two clusters were also distinguishable by the affect-volition coupling index for anticipatory responding (q_A), [$F(1, 89)=10.23$, $p<0.002$, $\eta_p^2=0.103$], but not consummatory responding (q_C), [$F(1, 89)=0.004$, $p=0.95$, $\eta_p^2=0.000041$], obtained from Phase 1 and Phase 2 of the ACP task, respectively (Fig. 2B). The two clusters also diverged in terms of their mean scores in PHQ-9, BSPS and GSE, but their TEPS scores were highly comparable (see Table 3).

Individual subjects' key press rates predicted by quadratic polynomial regression were subjected to further characterization in a 2×2×9 (Clusters × Phases × Valence ratings) ANOVA. When key presses were motivated to decide the future probability to the images shown in Phase 1 of the ACP experiment, the lower schizotypy cluster showed a marked increase in this anticipatory response than the lower schizotypy cluster. The separation progressively become more pronounced as the subjective valence assigned to the image increasingly deviated from the neural rating of 5, and it was symmetric between the directions towards unpleasantness and pleasantness (Fig. 2C). By contrast, for consummatory responding directed towards modifying image exposure time *in-the-moment* (i.e., Phase 2 of the ACP task), the two clusters were somewhat separated by their differential vigour of response towards unpleasant images (Fig. 2D). And the separation was relatively uniform across the range of unpleasant valence ratings. These impressions were supported by the emergence of a significant 3-way interaction, [$F(8, 712)=9.76$, $p<0.0001$, $\eta_p^2=0.099$]. It

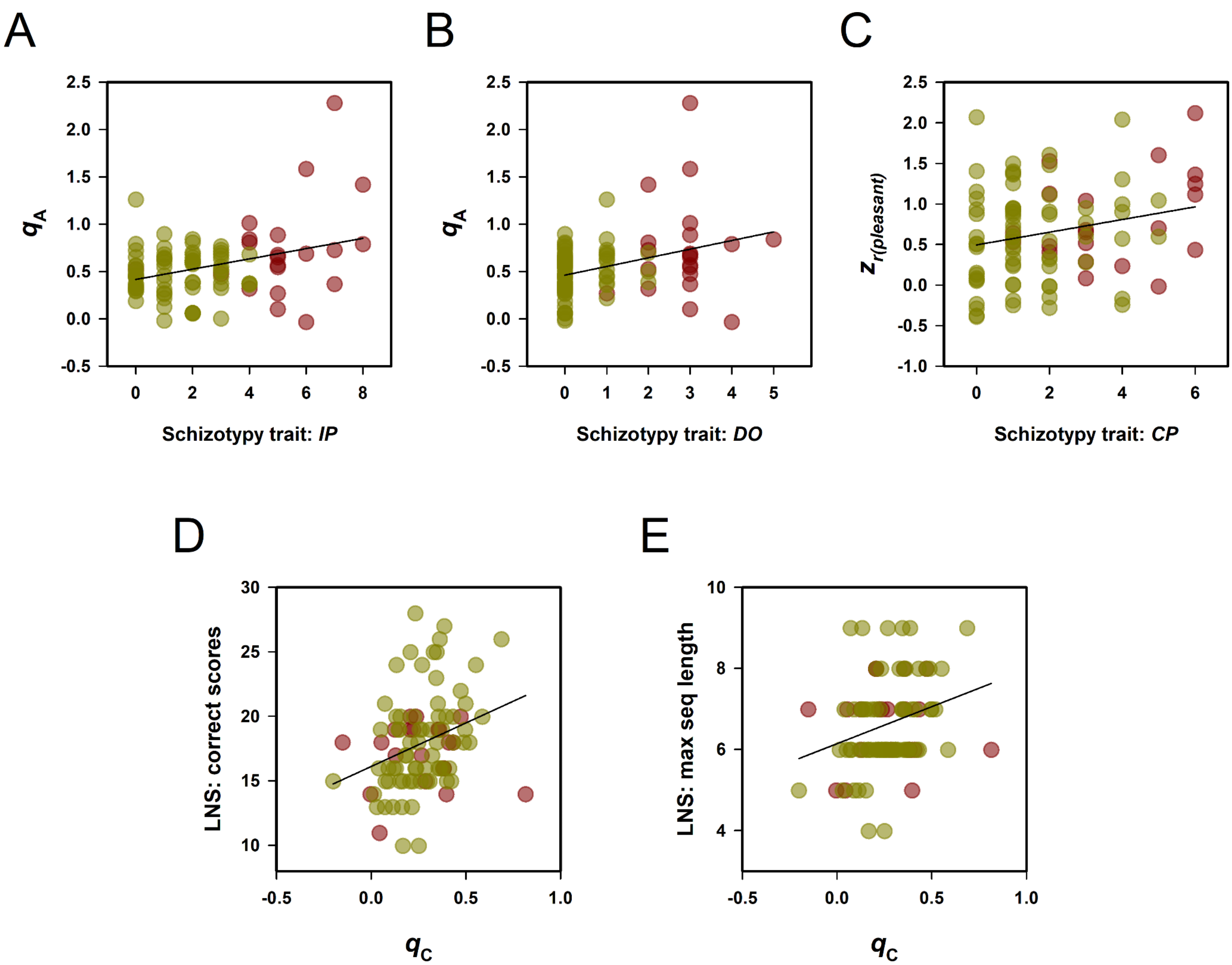

Fig. 1 Scattered plots of key significant correlations between subscores obtained from SPQ-B and ACP performance indices, and between ACP and LNS performance. Consistent with the outcomes of the correlative analysis, inspection of the scattered plots suggested a positive relationship between affect-volition coupling in anticipatory response (q_A), obtained in Phase 1 of the ACP task (anticipatory response) and two SPQ subscores commonly identified as negative schizotypal traits: (**A**) Interpersonal = *IP*, and (**B**) Disorganization = *DO*. In addition, the SPQ subscore, Cognitive-Perceptual = *CP*, commonly identified as a positive schizotypal trait, correlated significantly to the index of affect-arousal coupling $z_{r(pleasant)}$ that indexed the correspondence between pleasantness rating and arousal across images with pleasant ratings ranged from 5 to 9 (**C**). The affect-volition coupling for consummatory response was uniquely linked to the two LNS performance measures (**D** & **E**). The linear regression line shown in each plot was fitted to all 91 subjects. Membership to cluster 1 (*higher* schizotypy, $N = 21$) and cluster 2 (*lower* schizotypy, $N = 70$) is indicated by the red and green symbols in the scatter plots, respectively

was accompanied by a significant main effect of clusters, [$F(1, 89) = 6.35$, $p < 0.05$, $\eta_p^2 = 0.067$], clusters-by-valence interaction, [$F(8, 712) = 4.69$, $p < 0.0001$, $\eta_p^2 = 0.050$], and clusters-by-phases interaction, [$F(1, 89) = 6.83$, $p < 0.05$, $\eta_p^2 = 0.071$]. Supplementary ANOVAs restricted to either phase confirmed that the effect of clusters, [$F(1, 89) = 8.54$, $p < 0.005$, $\eta_p^2 = 0.088$], and clusters-by-valence interaction, [$F(8, 712) = 9.33$, $p < 0.0001$, $\eta_p^2 = 0.086$], only achieved statistical significance in Phase 1. Thus, ACP performance between the two clusters was primary differentiated by their anticipatory, but not consummatory, affect-volition response profile.

The two clusters did not differ in terms of affect-arousal coupling for images with subjective valence ratings in the range of 1–5 (from *very unpleasant* to *neutral*) or 5–9 (from *neutral* to *very pleasant*) (Fig. 2E). Individual mean and standard deviation of the two ratings also did not significantly differ between clusters (max $p = 0.15$, data not shown). The two clusters also did not differ in the proportion of valid trials in Phase 1 (Higher vs. Lower Schizotypy clusters: $99.32 \pm 0.65\%$ vs. $98.71 \pm 0.36\%$) or Phase 2 (Higher vs. Lower Schizotypy clusters: $97.94 \pm 0.66\%$ vs. $99.10 \pm 0.36\%$).

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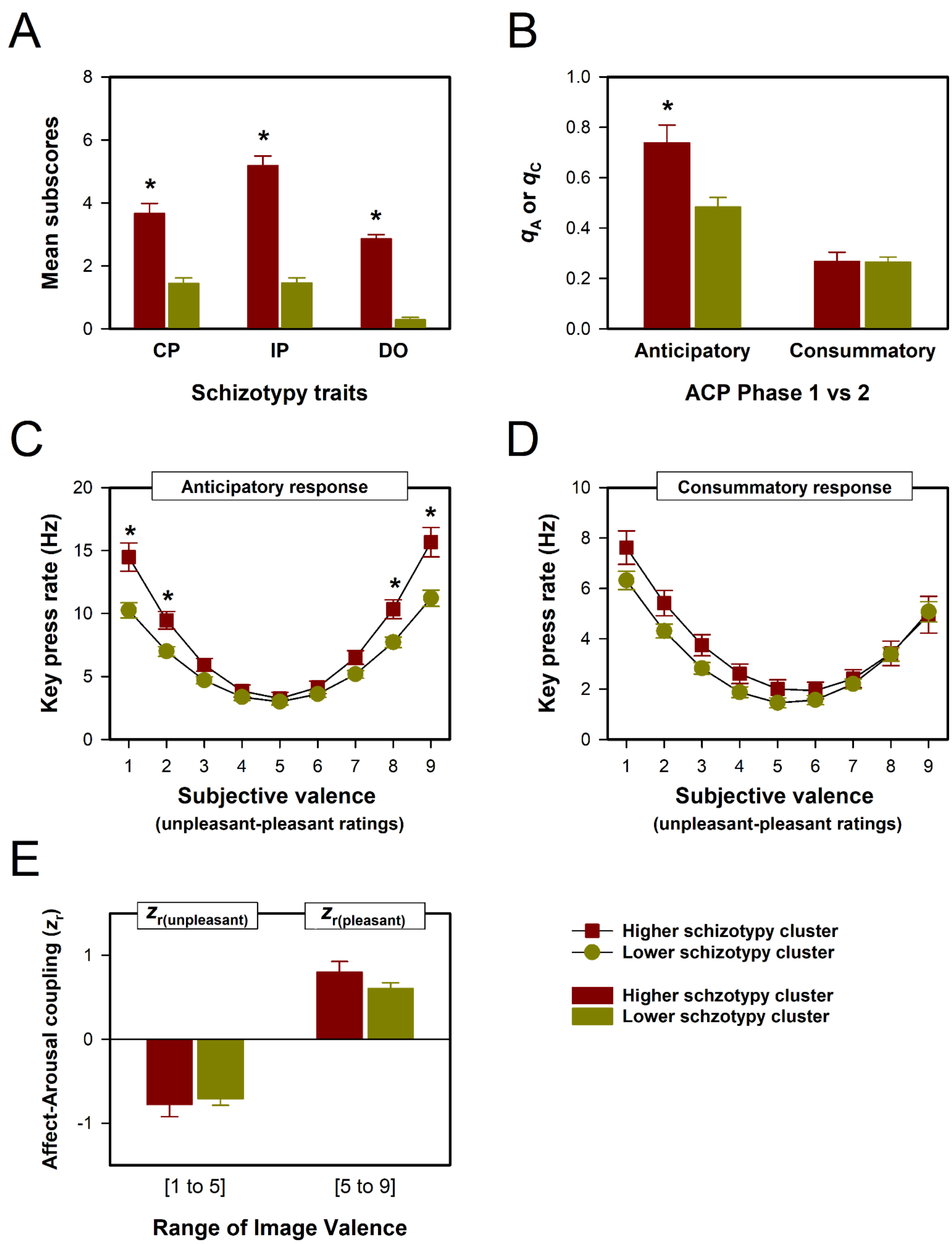

Fig. 2 Comparison of ACP performance of the two clusters of subjects obtained by k-mean clustering. (**A**) Divergence of all three SPQ-B subscores between the higher and lower schizotypy clusters. (**B**) the higher schizotypy cluster showed stronger affect-volition coupling for anticipatory but not consummatory responding. The response profile of anticipatory key press response rate (**C**) and of consummatory key press response rate (**D**) as a function of subjective valence based on individual quadratic regression. (**E**) Affect-arousal coupling indices [$z_{r(unpleasant)}$ and $z_{r(pleasant)}$] obtained by correlation between valence rating and arousal rating derived from images with subject valence ratings: 1 to 5 (very unpleasant to neutral) and 5 to 9 (from neutral to very pleasant), respectively, followed by Fisher's z-transformation. * indicates significant difference between the two clusters

Comparison of Psychological Profile and LNS Performance Between Clusters of Higher and Lower Schizotypy

The most notable demarcation of the two clusters by BSPS subscales, $\eta_p^2 = 0.18–0.33$, was fully consistent with the correlative analysis (Table 3) and suggestion that social anxiety – characterized by negative affect in social situations – is associated with both positive and negative schizotypal traits (Brown & Silvia, 2008). The expected divergence in PHQ-9 and GES was also significant but with a lower effect size, $\eta_p^2 = 0.05–0.06$. The higher-schizotypy cluster was marginally within the range of mild depressive symptoms (5–9), and the GSE score was not substantially below the normative weighted mean across genders reported by Schwarzer et al. (1997). Consistent with the overall correlative analysis, our two clusters were closely matched on TEPS. It was not surprising since we were also unable to differentiate between people with schizophrenia and healthy controls by TEPS (Lam et al., 2023; but also see Xie et al., 2017). However, this is not inconsistent with the specific correlation observed between consummatory-abstract scores in TEPS with q_C (Table 3).

Table 3 Summary of psychological profile and LNS performance between clusters of higher- and lower- schizotypy

	Higher-schizotypy Cluster (n = 21)	Lower-schizotypy Cluster (n = 70)	Inferential Statistics One-way ANOVA
TEPS:			
anticipatory abstract	18.33 ± 0.66	19.11 ± 0.36	$F_{(1,89)} = 1.06, p = 0.31, \eta_p^2 = 0.012$
anticipatory contextual	16.33 ± 0.90	15.86 ± 0.50	$F_{(1,89)} = 0.21, p = 0.65, \eta_p^2 = 0.002$
consummatory abstract	26.29 ± 0.95	26.53 ± 0.52	$F_{(1,89)} = 0.50, p = 0.82, \eta_p^2 = 0.001$
consummatory contextual	19.33 ± 0.82	19.81 ± 0.45	$F_{(1,89)} = 0.27, p = 0.61, \eta_p^2 = 0.003$
PHQ-9			
Total scores	5.10 ± 0.73	3.39 ± 0.40	$F_{(1,89)} = 4.19, p < 0.05, \eta_p^2 = 0.05$ *
Difficulties rating	1.67 ± 0.11	1.40 ± 0.06	$F_{(1,89)} = 4.36, p < 0.05, \eta_p^2 = 0.05$ *
BSPS:			
Total	28.67 ± 2.09	13.06 ± 1.15	$F_{(1,89)} = 42.88, p < 0.0001, \eta_p^2 = 0.33$ *
Fear	11.71 ± 0.89	5.44 ± 0.49	$F_{(1,89)} = 38.01, p < 0.0001, \eta_p^2 = 0.30$ *
Avoid	12.43 ± 0.91	5.81 ± 0.50	$F_{(1,89)} = 41.01, p < 0.0001, \eta_p^2 = 0.32$ *
Physiological	4.52 ± 0.54	1.80 ± 0.30	$F_{(1,89)} = 19.66, p < 0.0001, \eta_p^2 = 0.18$ *
GSE	23.00 ± 1.32	26.57 ± 0.73	$F_{(1,89)} = 5.60, p < 0.05, \eta_p^2 = 0.06$ *
Letter-Number Sequence (LNS):			
Total correct responses	17.19 ± 0.81	18.11 ± 0.44	$F_{(1,89)} = 1.01, p = 0.32, \eta_p^2 = 0.01$
Maximum sequence length	6.62 ± 0.24	6.63 ± 0.13	$F_{(1,89)} = 0.001, p = 0.97, \eta_p^2 = 0.0001$

Note. * indicates a significant difference (p < 0.05) was detected between clusters based on one-way ANOVA.

Discussion

The present study did not support the hypothesis that higher schizotypy amongst non-clinical adults was associated with schizophrenia-like deficiency in the ACP task indicative of weaker affect-volition coupling. Contrary to the expectation that schizotypal traits would capture characteristics similar to the psychopathology of schizophrenia, our study had yielded an opposite relationship. Specifically, higher schizotypal score in our sample was associated with stronger (rather than weaker) affect-volition coupling, particularly in the response motivated by future (but not in-the-moment) affective outcomes – also known as *anticipatory* or *representational* volitional behaviour (Klein, 1984; Heerey & Gold, 2007). At first glance, our finding is hard to reconcile with the two previous reports that also examined the relationship between schizotypal traits and affect-volition coupling in Chinese people (although from Chinese cities different from the present study). While Lui et al. (2016b) reported that ACP performance was largely independent of schizotypy, Xie et al. (2017) concluded that affect-volition coupling was deficient amongst people with higher schizotypy scores. Xie et al.'s (2017) attempt to dismiss the null results reported in Lui et al.(2016b) was also far from convincing (see below). Against this backdrop, our finding did little to resolve the disagreement but has seemingly added to the uncertainty regarding whether a simple and robust relationship between schizotypal traits and affect-volition coupling exists, and if so, what direction it may assume. Caution is also warranted given that the limited effect size of our correlative evidence because it implied that nearly 90% of inter-subject variation in the index of *anticipatory* affect-volition coupling may not be statistically attributed to individual differences in either the IP or DO schizotypal traits within our sample (Table 2; Fig. 1A and B). The impact of the variation in schizotypy in the non-clinical population appears pale by comparison with the robust deficit reported in people with schizophrenia spectrum disorders (Heerey & Gold, 2007; Chu et al., 2020; Lui et al., 2016a; Lam et al., 2023), even though our between-group comparison following the clustering of subjects has reinforced our correlative outcomes (Fig. 2).

To integrate the divergent results between the studies outlined above is a challenge and would necessarily be speculative. Yet, it may provide impetus and direction for further investigation. To this end, we contend that methodological inconsistency in combination with the intrinsic weakness of the extreme group approach (see Introduction) has contributed to the confusion. And a potential synthesis may be feasible after considering the differing sample characteristics resulting from the inconsistent and somewhat arbitrary construction of the comparison groups by previous authors. One parsimonious and inclusive model may be formulated based on the hypothesis that the expression of emotion-behaviour coupling from low to high schizotypy scores follows an inverted U-shaped relationship. The model posits that deviation from some intermediate level of schizotypy in either direction (lower or higher) is associated with a decline in the strength of affect-volition coupling (Fig. 3).

By adopting an extreme group approach, the two earlier studies had recruited an initial pool of subjects substantially larger (20–32 times) than ours. Their construction of the two extreme groups were however notably different. Not only was the high negative schizotypy group defined differently, namely 1 vs. 1.96 SD above the pooled mean of

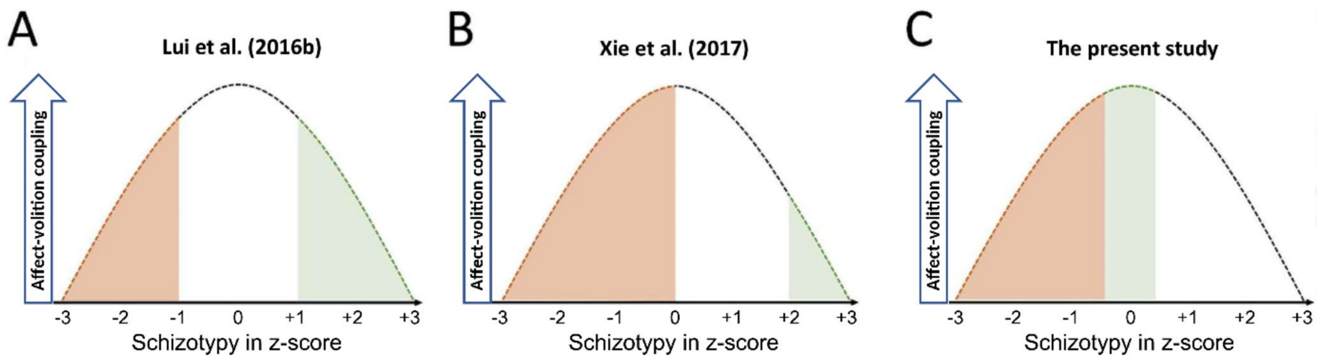

Fig. 3 A synthesis of inconsistent findings on the relationship between schizotypy and affect-volition coupling. (The model speculates that the relationship follows an inverted U-shaped profile can accommodate the disagreement between Lui et al., (2016b) and Xie et al. (2017), as well as the present study)

their elected measure (Lui et al., 2016b; Xie et al., 2017, respectively), but the construction of the comparison group was no less different. Lui et al. (2016b) had constructed their non-schizotypy comparison group by selecting subjects scoring 1 SD below the pooled mean. Xie et al. (2017), on the other hand, selected a matching number of "control" subjects whose scored were below the pooled mean by some unknown method.[1] With the reasonable assumption that the optimal intermediate level of schizotypy resides close to the population mean and the inverted-U profile was roughly symmetrical at its maximum, the model could readily accommodate the null difference between groups in Lui et al. (2016b), and the weaker coupling reported by Xie et al. (2017) in their schizotypy (social anhedonia) group. This account disagrees with Xie et al.'s (2017) interpretation that the less stringent criterion adopted by Lui et al. (2016b) for their negative schizotypy group was responsible for their null results. Xie et al. (2017) was in effect suggesting that their more stringent criterion at 1.96 SD above mean had yielded an effect size sufficiently large for its robust detection, i.e., less prone to Type II error. Our model, instead, attributes the inconsistent outcomes between these two studies to the inconsistent construction of their comparison groups. Indeed, inspection of Lui et al. (2016b, see their Fig. 4b) "non-schizotypy" comparison group showed markedly weaker affect-volition coupling than Xie et al.'s (2017, see their Fig. 3b) "control" comparison group, although this was primarily seen in their consummatory response. Moreover, both high-schizotypy and *non*-schizotypy groups of Lui et al. (2016b) showed almost equivalently poor affect-volition consummatory response.

Where would our data fit into this model? Unlike the extreme group approach, the correlation approach should retain sensitivity to variation around the centre of the distribution as well as any tail enders. However, our sample mean schizotypy score (SPQ-B total: mean = 4.95, SD = 4.2) was notably lower than recent normative SPQ-B scores reported in Chinese: mean = 6.37, SD = 3.46, N = 4,907 (Fonseca-Pedrero et al., (2018) including Taiwanese Chinese: mean = 6.32, SD = 4.2, N = 1,188 (Ma et al., 2015). We suspect that the lower SPQ-B score in our samples might stem from recruitment from a wider community base, with full-time students accounting for ~20% of our sample space. By contrast, the two aforementioned normative data sets were solely or predominately obtained from college students. Lui et al. (2016b) and Xie et al. (2017) also conformed to this bias. As pointed out by an anonymous reviewer, the low levels of schizotypy observed in our subjects might imply that they were "super normal". This could be partly attributed to the stringent exclusion criteria applied here whereby three subjects with a psychiatric history (beyond psychotic disorders) in themselves or in their first-degree relatives had been excluded. Although we also planned to exclude subjects due to the presence of chronic disorders and medications, no one was excluded on this basis. We also suspect the explicit referral to healthy subjects during recruitment could have inadvertently biased against potential subjects who felt that they were not in *excellent* health. Consequently, the possibility that the majority of subjects here had "super normal" health status must be considered.

Hence, our sample would be mapped to the left-side of the normative distribution based on college students.[2] As a consequence, our sample straddles over the rising portion of the inverted-U shaped function (Fig. 3C) and increasing schizotypy within this domain is associated with stronger affect-volition coupling. The model may further predict that

[1] We assumed that Xie et al. (2017) had selected their 32 control subjects randomly from roughly half of the subjects in the initial pool of 2,994 subjects that scored below the sample mean.

[2] Unfortunately, we cannot ascertain this speculation because both studies relied on Champman SAS for identification of subjects with extreme negative schizotypy traits, and we may not transform the 74-item SPQ scores reported by Lui et al. (2016b) for a direct comparison with our SPQ-B scores here. Nevertheless, we believe that the overall lower levels of schizotypy in our sample could be crucial to the emergence of our unexpected finding.

this effect would become relatively weak as the function passes the inflexion (i.e., optimal coupling) point.

Regarding the novel observation that higher CP schizotypal trait was associated with stronger affect-arousal coupling (Table 2), it may stem from enhanced attention to emotional cues as suggested by Kerns (2005). However, it is uncertain why it was selectively seen in response to images perceived as pleasant (i.e., in the positive valence domain). Additionally, we did not observe a similar effect when comparing affect-arousal coupling between people with schizophrenia and healthy controls (Lam et al., 2023). Further comparison between patients with predominantly positive vs. negative symptoms would be warranted. Nonetheless, our findings here support the hypothesis that positive and negative schizotypy dimensions exert distinct influence over dissociable affective processes. Finally, the emergence of a correlation between LNS memory scores and q_C (affect-volition coupling of consummatory ACP response) here (Table 2) conformed to a trend first reported by Heerey and Gold (2007), which we later showed was primarily observed among people with schizophrenia but not in the age-and-gender matched healthy controls (Lam et al., 2023).

In summary, although the limited variability and the bias for low schizotypy in our sample would restrict the applicability of our unexpected findings to a small segment of the general population (as depicted in Fig. 3), the unexpected and serendipitous insights emerged from the present study show that the modulation of affect-volition coupling is likely more complex than previously envisaged (Xie et al., 2017). This includes the possibility that the low end of schizotypy personality may also harbour a deficiency in affect-volition coupling. A large cross-sectional sample capable of capturing an extended spectrum of variation in schizotypy representative of the non-clinical population would be most instructive in any future attempts to test the predictive power of our hypothetical model (Fig. 3) presented here.

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Data Availability Access to the original data is obtained from the corresponding author upon reasonable requests.

Declarations

Conflict of Interest The author(s) declared that there were no conflicts of interest with respect to the authorship or the publication of this article.

Ethical Standards This study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board of The Hong Kong Polytechnic University (HSEARS20210524002).

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