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Coexpression of Anticipatory and Consummatory Volitional Deficits in Schizophrenia and Their Association With Memory Impairment

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Avolition in schizophrenia has been attributed to the *decoupling* between emotion and motivation rather than an inability to perceive or distinguish emotions. Hence, goal-directed behavior incentivized by positive or negative reinforcement becomes impoverished and dull. It is further suggested that goal-directed actions directed at future outcomes (*anticipatory* or *representational* response) are preferentially affected, as opposed to actions directed to the current state of affairs (*consummatory* or *evoked* response). Attempts to dissociate them behaviorally using the "anticipatory and consummatory pleasure" (ACP) task have demonstrated deficits in both components, yet some have claimed otherwise. In this replication study, we presented further characterization of the pronounced deficits in valence-dependent consummatory as well as anticipatory responding in 40 subjects with schizophrenia in comparison with 42 healthy subjects. In addition, two novel observations were made. First, the correlation between ratings of emotional intensity and arousal levels of pictures used to motivate responding in the ACP task was markedly attenuated in the schizophrenic (SZ) group, suggesting that the *decoupling* from emotion may be manifested beyond goal-directed behavior in schizophrenia. Second, multiple correlations between ACP performance indices and individual scores in the letter–number span test were uniquely observed in the SZ group, not among healthy controls. The co-emergence of ACP and working memory deficiency in SZ may be linked to common psychopathological processes.

General Scientific Summary
The replication study provided further support that lack of motivation in schizophrenia can lead to a failure to seek (or avoid) pleasurable (or aversive) emotional experiences. However, our data challenged the interpretation of previous studies and suggested that the disconnection of action from emotion may be more extensive. We also clarified that the linkage between this functional disconnection and working memory deficiency was unique in people with schizophrenia.

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Benjamin K. Yee served as lead for data curation, formal analysis, writing–original draft, and writing–review and editing and contributed equally to conceptualization, methodology, validation, and visualization. Joyce Y. T. Lam assumed a leading role in establishing the methodology and project administration, and contributed equally to conceptualization, data curation, investigation, resources management, software, validation, visualization, writing–original draft, and writing–review and editing; she also supported formal analysis of the data. Marcus H. F. Ng contributed equally to formal analysis, writing–original draft, and writing–review and editing. Ivy P. Y. Cheng played a supporting role in resources, writing–original draft, and writing–review and editing. Maritta Välimäki led the acquisition of funding, contributed equally to the supervision of the study, and supported the conceptualization of the study, writing of the original draft, and subsequent review and editing of the manuscript.

The experiment materials are available at https://osf.io/download/kjvxe/

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Avolition is a core negative symptom in the DSM-5 and ICD-10 criteria of schizophrenia. Kraepelin (1920/1974) suggested that the "loss of energy and drive" characteristic in *dementia praecox* is a consequence of "disjointed [rather than loss of] volitional behavior." One interpretation of this *disjunction* refers to the failure of affective experiences to incentivize adaptive, goal-directed behavior (Heerey & Gold, 2007). It is distinct from the failure to experience or register the emotional valence of specific events, as in anhedonia—the inability to feel pleasure. Reports of intact subjective rating and reflexive response to affective stimuli in people with schizophrenia (Aghevli et al., 2003; Curtis et al., 1999) showed that anhedonia is unlikely the primary cause of avolition. Instead, "the loss of mastery over volitional actions" (Kraepelin, 1919/1971) may be more closely linked to executive dysfunction in schizophrenia (Zec, 1995).

Gard et al. (2006, 2007) attempted to differentiate volitional control from emotional experience with the self-report Temporal Experience of Pleasure Scale (TEPS) by parsing pleasure experience into its temporal components. Separate items were designed to tap anticipatory (i.e., to be experienced in the future) or consummatory (i.e., in the moment) pleasure (Klein, 1984). This temporal distinction is expected to mirror the distinction between *wanting* and *liking* central to the incentive theory of motivation (Berridge & Robinson, 2016). The initial study by Gard et al. (2007) showed that the anticipatory (or wanting) component was specifically impaired in schizophrenia, but it was followed by a series of conflicting reports (Frost & Strauss, 2016; Visser et al., 2020). Using TEPS, Strauss et al. (2011) reported a selective reduction in consummatory pleasure instead; and Da Silva et al. (2017) failed to find any difference from healthy controls (HCs).

The consummatory–anticipatory dichotomy was also investigated by Heerey and Gold (2007). Instead of relying on self-report, they developed the "anticipatory and consummatory pleasure" (ACP) task, designed to distinguish two types of emotion-driven response incentivized by positive (desirable), or negative (undesirable) visual affective stimuli. Between two distinct phases, responses either modify the exposure time of affective stimuli *in-the-moment* or the likelihood of being presented with the specific stimuli at some time in the future. They were aptly described as *evoked* and *representational* responses, respectively. In keeping with the parsing of pleasure experiences into consummatory vs anticipatory components by Gard et al. (2006), the key distinction between *evoked* and *representational* responses in the ACP task is the temporal separation between an action and its goal.

In their seminal study, Heerey and Gold (2007) concluded that representational/anticipatory response was preferentially impaired in people with schizophrenia or schizoaffective disorder on the basis of two findings. First, the correlation of response vigor with the perceived valence of the affective images was weaker among schizophrenia subjects (their Figure 4). Second, schizophrenia subjects exhibited excessively inappropriate responses to neutral stimuli (their Figure 3). The first finding has been replicated in people with acute as well as chronic schizophrenia (Chu et al., 2020; Lui, Liu, et al., 2016; Wang et al., 2020; Xie et al., 2017) and is widely taken as evidence for a *decoupling* of behavior from emotional incentive. However, the suggestion of a preferential impairment in representational/anticipatory response in schizophrenia has been challenged by more recent studies. Lui, Liu, et al. (2016) and Xie et al. (2017) both reported a preferential decoupling in evoked/consummatory response, while Chu et al. (2020) observed comparable impairment in both types of response. In addition, Heerey and Gold's (2007) finding concerning inappropriate responding to neutral stimuli by subjects with schizophrenia also appears far from robust. Such disinhibited responding was absent (Chu et al., 2020), comparably observed in both types of response (Lui, Liu, et al., 2016; Lui, Shi, et al., 2016), or more strongly expressed in evoked/consummatory response (Xie et al., 2017).

Heerey and Gold (2007) claimed that their data further indicated a link between the emotion–behavior coupling (specifically for representational/anticipatory response) and working memory function. However, the statistical support presented was far from unequivocal: the crucial correlative analysis was performed with data pooled across patients and controls. The correlation could have been driven by the concomitant deficits in both measures in schizophrenia subjects relative to controls. Moreover, a comparison of ACP performance between patients with and without poor working memory by Lui, Liu, et al. (2016) failed to yield a difference in terms of emotion-behavior decoupling during anticipatory responding. Instead, these authors suggested that preserved working memory was associated with greater decoupling in evoked/consummatory response in schizophrenia.

The present study was undertaken to address the inconsistent outcomes outlined above. Their clarification not only is relevant to how the link of volition to emotion may be disrupted in schizophrenia but also the application of ACP and its variants as a behavioral test to differentiate forms of volitional dysfunction in depression (Wang et al., 2020), schizotypy (Yan et al., 2019), and its potential extension to addiction, obsessive-compulsive disorder, or impulse-control disorder. To this end, Heerey and Gold's (2007) ACP task was faithfully replicated here after translation to the Chinese language (Lui, Liu, et al., 2016) and administered to subjects with schizophrenia spectrum disorders in comparison with a group of age- and gender-matched HCs.

To improve the quantification of specific dependency of responding on stimulus valence, we applied a priori orthogonal trend analysis to facilitate the evaluation of the predicted response profile. The quantification was extended to individual subjects for subsequent correlative analysis between ACP and memory performance. Here, we attempted to broaden working memory evaluation beyond the letter–number span (LNS) task routinely employed in previous ACP studies. Specifically, we opted for a visual recognition test designed to evaluate the load-dependent expression of short-term working memory (J. M. Palva et al., 2010; S. Palva et al., 2011) with minimal retention demand and opportunity for rehearsal. Although viable data were only obtained from half of the subjects with schizophrenia, it provided potential insights into future experimental design in the search for cognitive correlates of emotion–behavior decoupling in schizophrenia.

Method

Subjects

As a replication study, the sample sizes closely matched the seminal study by Heerey and Gold (2007). Full descriptions of recruitment and eligibility criteria are provided in online supplemental material A.

Schizophrenia Group

This cohort comprised adult outpatients recruited from the community, aged between 18 and 60, with a confirmed diagnosis under schizophrenia spectrum disorder of DSM-5 and stable symptoms. Other inclusion criteria included normal corrected vision, the ability to communicate in spoken Cantonese and written Chinese, and the capacity to provide informed consent. Subjects with another comorbid mental disorder, a history of head injury, hemiplegia or other neurological conditions, electroconvulsive therapy in the past 6 months, color blindness, or pregnancy were excluded; 40 eligible schizophrenia (SZ) subjects were recruited.

Healthy Control Group

Healthy Chinese-speaking adults with good or corrected vision were recruited by advertisements and word of mouth from the community. Potential subjects with any physical disabilities, chronic diseases, neurological conditions, pregnancy, and a personal/familial history of mental disorders were excluded. Out of the 105 eligible volunteers, we first selected those who matched the gender and age to one of the 40 subjects in the SZ group. Next, additional same-sex healthy volunteers whose age was ± 1 year of the remaining SZ subjects were also selected. This yielded a total of 42 healthy participants. There remained five female SZ subjects without a control fulfilling the above matching criteria, but their age never deviated >7 years from a female HC subject.

Procedures

Following informed consent, all subjects completed a demographic questionnaire and the TEPS. Current diagnosis and medication, and the age of the first approach for psychiatric service were obtained from medical records. The ACP task and the Visual Working Memory (VWM) test were then administered in a counterbalanced order, followed by the LNS test. The three tests were performed in a quiet room and were separated by at least 5 min. Additional 1–2 min breaks were permitted during the ACP and VWM tests at the subjects' request. Each subject received a HK$200 shopping voucher as gratitude for participation. All experiments were conducted in accordance with the Declaration of Helsinki, with prior approvals by institutional review boards (The Hong Kong Polytechnic University, and the Hong Kong Hospital Authority).

Anticipatory and Consummatory Pleasure Task

The ACP task was identical to the original task (see Figure 1 in Heerey & Gold, 2007) except for translation into Chinese. The implementation and instructions (see online supplemental material B) used closely followed that obtained from Lui, Liu, et al. (2016). It was implemented in E-Prime®2.0 (PA, USA) on a laptop PC. A set of 42 visual stimuli (14 positive, 14 neutral, and 14 negative) were used. Each stimulus was constructed by the juxtaposition of three images of the same valence categories taken from the International Affective Picture System (IAPS; Lang et al., 2005). Full descriptions of the task, including pretraining and instructions, are provided in online supplemental material B. Briefly, the two phases of the task comprised multiple discrete trials. In each trial of Phase 1, following the presentation of the stimulus, the subjects first rated the stimulus' pleasantness and then arousal on a 9-point Likert-like scale. Next, they were instructed to decrease/increase the likelihood of seeing the just presented stimulus according to how unpleasant/pleasant (undesirable/desirable) they rated the stimulus. They were told that actual change achieved would depend on the designated key presses registered within a 2-s window, and also explicitly instructed to refrain from responding to stimuli they considered neither pleasant nor unpleasant. In Phase 2, the subjects were presented with a pseudorandom subset of the visual stimuli (10 positive, 10 neutral, and 10 negative) that appeared previously in Phase 1. The subjects were instructed to shorten or lengthen the viewing time of undesirable and desirable stimuli on the screen in each trial by repeatedly pressing the designated keys. Subjects were again instructed to refrain from responding to stimulus considered as neutral. Each trial ended with the disappearance of the stimulus from the screen (minimum 3 s, maximum 10 s). The vigor of *representational/anticipatory* and *evoked/consummatory* response was indexed by response rates expressed in Hz from valid trials (i.e., key presses congruent with subjective unpleasantness–pleasantness ratings) recorded in Phase 1 and Phase 2, respectively.

Visual Working Memory Test

The test was implemented on a desktop PC running the STIM^2 (Compumedics, Australia). All stimuli were composed of an array of (2, 4, or 6) uniquely colored squares (with a palette of seven colors), displayed against a white arena on the screen with a permanent fixation point (+) drawn in the middle. Each trial began with a 100-ms presentation of the sample stimulus, followed by 1-s retention interval, and a 500-ms presentation of the test stimulus (see Figure C1 in online supplemental material C). The sample and test stimuli were identical in half of the trials but differed in the color of a single square in the other half. The subjects were instructed to press the "yes" key if they detected a change in the test stimulus from the sample, or the "no" key if not, within 2.5 s after the test stimulus appeared. Late responses were counted as nonresponse, and a total of 540 discrete trials were administered. Accuracy and memory capacity ($L_m \times (H - FA)/(1 - FA)$, where $L_m = 2$, 4, or 6; $H =$ hit rate and $FA =$ false alarm rate) at successive higher memory loads (L_m; Pashler, 1988).

Letter–Number Span

The LNS task (Gold et al., 1997) was identical to that in previous ACP studies in schizophrenia (Chu et al., 2020; Heerey & Gold, 2007; Lui, Liu, et al., 2016; Xie et al., 2017). After listening to a string of unique alphanumeric characters, subjects needed to restate the numbers in ascending order followed by the letters in alphabetical order. The alphanumeric strings increased sequentially from two to nine characters. Four distinct strings were evaluated at each length. The task was terminated if all four attempts failed. The total correct responses and maximum length reached were scored.

Temporal Experience of Pleasure Scale

The 20-item Chinese version of the TEPS was used. Its internal consistency (Cronbach's $\alpha = 0.83$) and test–retest reliability ($r = .79$) have been validated (Chan et al., 2012, 2016). Subjects responded to each item on a 6-point Likert-like scale (from 1 = *very false for me* to 6 = *very true for me*).

Statistical Analysis

All data analyses were performed with SPSS® v26. Variables derived from independent assessments were analyzed separately. Following examination of data distribution of individual variables for gross departure from normality (Shapiro–Wilk test), evaluation of group differences was performed using parametric analysis of variance (ANOVA) with between-subject factor, Group (SZ vs. HC), and appropriate within-subject factors (e.g., Valence, Phases in the ACP task, or Memory Loadings in the VWM test). Planned polynomial trend analysis was applied to dissect the response pattern in the ACP task, by partitioning the within-subject factor, Valence, into orthogonal linear and quadratic components (including interaction terms). The quadratic component of the individual response profile was also calculated by curve fitting. The association between ACP performance indices and memory performance in the LNS and VWM tests was examined by Pearson's correlation and partial correlation. Fisher's *z*-transformation was applied to correlation coefficients calculated for individual subjects before group comparison using to ANOVAs. Deviation of individual group's average performance indices from chance level was evaluated by a one-sample *t* test. Group comparisons of demographic and clinical data were evaluated by independent *t* test or Fisher's exact test (FET).

Transparency and Openness

Every effort has been made to comply with APA Style Journal Article Reporting Standards and transparency and openness (TOP) requirements at Level 2. Access to the original data is obtained from the corresponding author (B. K. Y.) upon reasonable requests. Data analytics, including statistical software employed, are fully described, and no custom-made code is needed for their reproduction. Request for the E-Prime® script of the Chinese version of the ACP task used here should be made after prior approval from its originator (Lui, Liu et al., 2016). The script for the VWM test and the online supplemental materials included in this report are available from the OSF repository (https://osf.io/w5nst/). Neither the study plan nor the analysis plan had been preregistered.

Results

Demographic and Clinical Characteristics

The SZ ($n = 40$) and HC ($n = 42$) groups did not differ in terms of age, $t(80) = 1.00$, $p = .32$, or gender ratio ($\chi^2 = 0.41$, $df = 1$, $p = .52$). Significant group differences in the stratification of three socioeconomic factors were identified (online supplemental material D). The SZ group had a higher proportion of never-married subjects, yet a higher number of divorcees (FET: $p < .001$). The education level was generally lower in SZ subjects (FET: $p < .001$). The proportion of unemployment and reliance on government allowances was higher in the SZ group (FET: $p < .001$). These were consistent with the known demographic characteristics of schizophrenia.

The diagnostic composition in the SZ group included primarily schizophrenia (87.5%) and schizoaffective disorder (12.5%)—the two most common diagnoses of schizophrenia spectrum disorders in the Chinese adult population. Moreover, 23 had their first contact with psychiatric services at or under 25 years of age (mean ± SD: 25.1 ± 9.2). The average number of years past since the first psychiatric contact was 20.6 ± 10.0 years; and it was under one decade in five subjects. Symptoms were well controlled. Adverse psychotic symptoms were not observed during the study. All but two SZ subjects were maintained on antipsychotic drugs: clozapine, olanzapine, or risperidone, with a mean chlorpromazine-equivalent dosage of 622.0 ± 470.8 mg daily. Furthermore, 19 subjects were also prescribed antidepressants (fluoxetine, sertraline, or amitriptyline), anxiolytics, and/or hypnotic agents.

Anticipatory and Consummatory Pleasure Task

Subjective Pleasantness and Arousal Ratings

Individuals' average subjective pleasantness and arousal ratings of the visual stimuli according to IAPS valence categories (negative, neutral, positive emotional valence) obtained in Phase 1 were subjected to separate 2 × 3 (Group × IAPS categories) mixed ANOVAs.

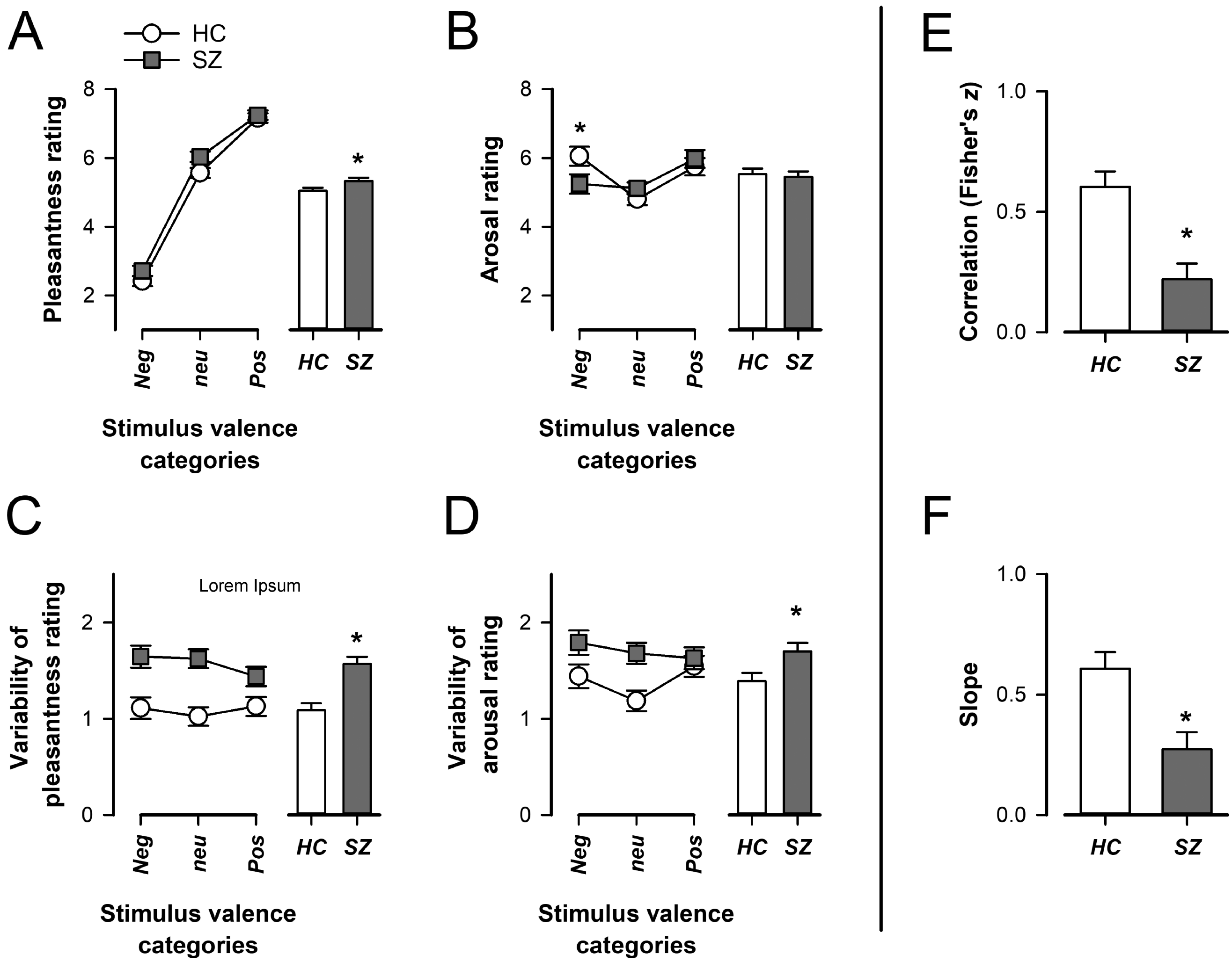
Pleasantness ratings conformed closely to the IAPS valence categories in both groups (Figure 1A). The ANOVA yielded a significant effect of IAPS categories, $F(2, 160) = 588.87$, $p < .001$, $\eta_p^2 = 0.88$, and Group, $F(1, 80) = 4.88$, $p < .05$, $\eta_p^2 = 0.06$. The Group effect emerged because SZ subjects generally gave a higher rating, (i.e., toward more pleasant; mean ± *SE*: 5.33 ± 0.09) than HC subjects (5.05 ± 0.09). This was seen regardless of IAPS valence, and the interaction term was far from significance ($F < 1$).

Across the three IAPS valence categories, positive and negative stimuli received higher arousal ratings than neutral ones (Figure 1B). This expected effect of IAPS categories was highly significant, $F(2, 160) = 9.24$, $p < .001$, $\eta_p^2 = 0.10$. Polynomial contrast analysis confirmed that the effect stemmed primarily from its quadratic component: V-shape profile; $F(1, 80) = 50.56$, $p < .001$, $\eta_p^2 = 0.39$; cf. the linear component: $F < 1$. The quadratic trend was, however, less prominent in the SZ group, yielding a significant interaction, $F(2, 160) = 4.07$, $p < .05$, $\eta_p^2 = 0.05$; quadratic component: $F(1, 80) = 7.34$, $p < .01$, $\eta_p^2 = 0.08$. Compared with HC subjects, SZ subjects were less aroused by the negative images ($p < .05$), whereas positive and neutral images were rated similarly by the two groups.

We also examined the variability of individual subjective pleasantness and arousal ratings. The standard deviation of stimulus ratings of each IAPS valence category was subjected to separate two-way ANOVAs. In general, ratings of pleasantness (Figure 1C) and arousal (Figure 1D) were both more variable in the SZ group, as evidenced by the significant Group effect in the respective ANOVAs, $F(1, 80) = 21.07$, $p < .001$, $\eta_p^2 = 0.21$; $F(1, 80) = 6.31$, $p < .05$, $\eta_p^2 = 0.07$. Rating variability appeared stable across IAPS valence categories. Neither the main effect of IAPS categories nor its interaction with the Group achieved statistical significance.

Next, we examined whether the departure of the pleasantness rating from neutrality (defined as deviation from a rating of 5) predicted higher arousal ratings. To this end, the correlation coefficient between the two ratings was computed for each subject followed by Fisher's *z*-transformation before comparison between groups. A positive correlation was evident in both SZ and HC groups, but it was significantly lower in the SZ group, $F(1, 80) = 17.58$, $p < .001$,

Figure 1
Subjective Pleasantness and Arousal Ratings



Note. Average individual pleasantness (A) and arousal (B) ratings of the visual stimuli presented in the first phase are illustrated by the line plots, as a function of the IAPS stimulus valence categories: *Neg*: negative, *neu*: neutral, *Pos: positive* emotional valence. Average ratings across the three valence categories are shown in the accompany bar plots. The variability of pleasantness (C) and arousal (D) ratings were indexed by the standard deviation of individual ratings. Correlation between deviation of pleasantness rating from 5 (indicating complete emotional indifference) and the arousal rating computed for each subject was lower in SZ (E). Evaluation of the slope obtained by linear regression in each subject yielded the same conclusion (F). * indicates a significant difference ($p < .05$) between groups. SZ: $n = 40$, HC: $n = 42$. IAPS = International Affective Picture System; HC = healthy control; SZ = schizophrenia.

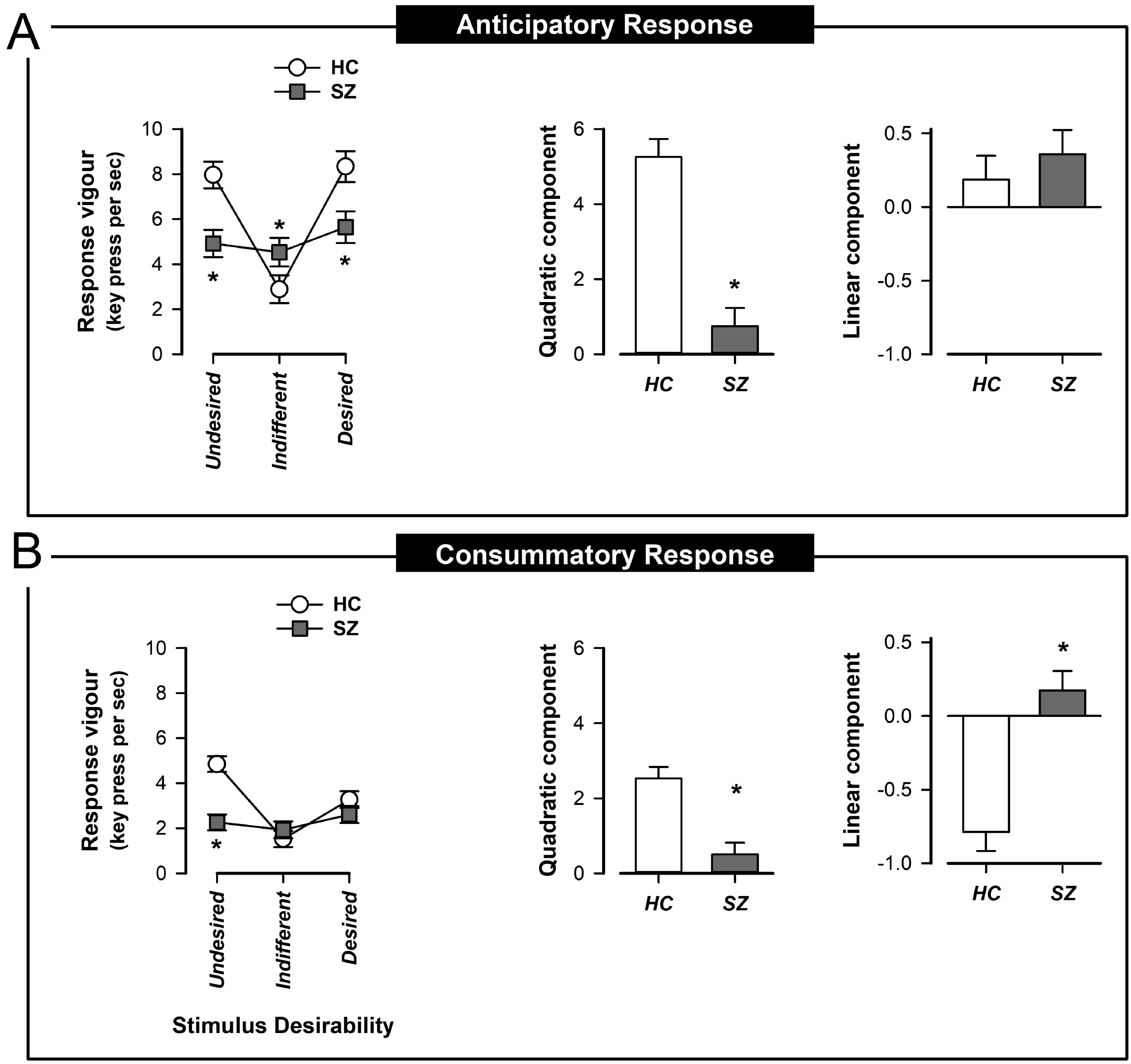
$\eta_p^2 = 0.18$; Figure 1E. The slope of the linear regression line was further computed as it represented the linear dependency of arousal ratings on the deviation of pleasantness/unpleasantness from neutrality (Figure 1F), and it was less steep in the SZ group, $F(1, 80) = 11.45$, $p < .001$, $\eta_p^2 = 0.13$.

Anticipatory and Consummatory Response

The proportion of valid trials in both phases of the ACP task exceeded 90%. It was generally lower in Phase 2 of the experiment, and lower in the SZ groups. The group difference appeared more pronounced in Phase 2 (SZ: 93.25 ± 1.18% vs. HC: 98.41 ± 1.15%) than in Phase 1 (SZ: 96.96 ± 0.75%; 98.75 ± 0.73%). A 2(Group) × 2(Phases) ANOVA of the proportion of valid trials yielded a main effect of Group, $F(1, 80) = 9.95$, $p < .005$, $\eta_p^2 = 0.11$, Phases, $F(1, 80) = 6.04$, $p < .05$, $\eta_p^2 = 0.07$, and their interaction, $F(1, 80) = 4.18$, $p < .05$, $\eta_p^2 = 0.05$.

The vigor of both anticipatory and consummatory effortful responses obtained in valid trials was quantified by key-press rate and classified according to the perceived pleasantness (i.e., valence or desirability) assigned by individual subjects to the images presented in the trial into the following: *Undesirable* (ratings: 1–3), *Indifferent* (ratings: 4–6), or *Desirable* (ratings: 7–9). As expected, *anticipatory* responding to increase/decrease the probability of seeing a stimulus in the future and *consummatory* response to shorten/lengthen the viewing in-the-moment was higher for undesirable/desirable images in comparison to indifferent images. This ability to translate perceived emotional valence to willed action was

Figure 2
ACP Key-Press Responses as a Function of Perceived Emotional Valence (or Desirability) of the Visual Stimuli



Note. Key-press rate was used to index behavioral effort exerted to increase/decrease the probability of future viewing in panel (A), and to shorten/lengthen in-the-moment viewing time in panel (B), of images classified according to subjective desirability (*Undesired*, *Indifferent*, or *Desired*). The profile of key-press rate against stimulus desirability is plotted on the left. The quadratic and linear components of the profile were separately shown in the accompany histograms (middle and right plots, respectively). SZ: $n = 40$, HC: $n = 42$. * indicates a significant difference ($p < .05$) between groups. ACP = anticipatory and consummatory pleasure; HC = healthy control; SZ = schizophrenia.

strongly expressed in HC subjects but substantially weakened in the SZ subjects (Figure 2).

The HC group exhibited a highly symmetric, V-shaped, anticipatory response profile. By comparison, the SZ group responded with less vigor in desirable and undesirable trials and showed stronger response in indifferent trials (Figure 2A). The HC group's consummatory response followed a V-shaped profile, albeit asymmetric, with more vigorous responding in undesirable trials than desirable ones (Figure 2B). Hence, the flattening of the response profile in the SZ group was associated with a more prominent deficiency in undesirable trials.

These impressions were confirmed by the 2(Group) × 2 (Phases) × 3(Desirability) ANOVA of key-press rate. First, the V-shaped response profile was confirmed by the significant effect of Desirability, $F(2, 160) = 50.73$, $p < .001$, $\eta_p^2 = 0.39$, that primarily stemmed from its quadratic component, $F(1, 80) = 73.73$, $p < .001$, $\eta_p^2 = 0.48$, accounting for 99.61% of the sum-of-square partitioned to Desirability. Second, the aberrant valence-driven responding in the SZ group and its differential expression between the two phases led to the significant Group × Desirability interaction, $F(2, 160) = 63.44$, $p < .001$, $\eta_p^2 = 0.44$, and the three-way interaction, $F(2,160) = 14.69$, $p < .001$, $\eta_p^2 = 0.16$. These two interaction terms were again more prominent in their quadratic components, $F(1, 80) = 45.07$ and 17.06, both p's $< .001$, $\eta_p^2 = 0.36$ and 0.18, respectively. The quadratic component of desirability-dependent responding thus most effectively captured the aberrant behavior in the SZ group, as depicted in Figure 2. The respective effect size (η_p^2) of the Group × Desirability$_{\text{(quadratic)}}$ interaction term computed from separate ANOVAs restricted to the *anticipatory* or *consummatory* phase was 0.35 and 0.25, respectively.

Considering the substantial flattening of the response profile in the SZ group across both phases, we further evaluated if the predicted V-shape profile was completely abolished. One-sample *t* test showed that the mean quadratic component of the anticipatory and consummatory response profiles both significantly exceeded zero at the one-tailed criterion, $t(39) = 1.95$, $p_{\text{one-tailed}} = .029$; $t(39) = 3.06$, $p_{\text{one-tailed}} = .002$, respectively. Hence, valence (desirability) had maintained some control over key presses in the SZ group in accordance with the ACP task.

Responding was generally higher during the anticipatory than the consummatory phase, $F(1, 80) = 78.21$, $p < .001$, $\eta_p^2 = 0.50$. Examination of the linear components confirmed the stronger consummatory responding in undesirable trials by HC subjects (Figure 2B). Finally, consistent with our interpretation, the overall ANOVA yielded a significant main effect of Group, $F(1, 80) = 4.08$, $p < .05$, $\eta_p^2 = 0.05$, and the Phase × Desirability interaction, $F(2, 160) = 23.54$, $p < .001$, $\eta_p^2 = 0.23$.

Emotion-Effort and Arousal-Effort Coupling

Next, we examined how individual's own rating of pleasantness predicted the vigor of response across stimuli. This was quantified by computing the product-moment correlation coefficient for valid trials in each of the three categories of desirability from each phase of the ACP task. Thirteen SZ subjects and 20 HC subjects had yielded sufficient valid trials for the computation of all six correlation coefficients (2 Phases × 3 perceived levels of desirability). Omissions of subjects were due to the requirements for at least three valid trials spanning across at least two ratings in each and every defined range of ratings assigned to the three categories of subjective valence: undesirable (ratings: 1, 2, 3), indifferent (ratings: 4, 5, 6) and desirable (ratings: 7, 8, 9).

The coefficients were submitted to a 2(Group) × 2(Phases) × 3 (Desirability) ANOVA after Fisher's *z*-transformation. As expected, the pleasant rating scores correlated negatively and positively with response vigor to undesirable and desirable images, respectively, while the correlation was near zero for indifferent images. For both anticipatory and consummatory responding, this coupling between stimulus-perceived desirability and response vigor was clearly seen in the HC group (Figure 3A). By contrast, the coupling was attenuated in the SZ group. These interpretations were supported by the emergence of a significant effect of Desirability, $F(2, 62) = 27.13$, $p < .001$, $\eta_p^2 = 0.47$, and the Group × Desirability interaction, $F(2, 62) = 4.00$, $p < .05$, $\eta_p^2 = 0.11$. Neither the main effect of Phase nor its interactions approached statistical significance.

A similar analysis was performed to examine the coupling between arousal ratings and responding. This was again quantified by correlation coefficients, except that no distinction was made with respect to stimulus desirability. One coefficient with respect to anticipatory responding, and one for consummatory responding could be computed in 39 SZ and 41 HC subjects. Decoupling was evident in the SZ group regardless of response types (Figure 3B). The 2(Group) × 2(Phases) ANOVA of Fisher's *z*-transformed correlation coefficients yielded only a Group effect, $F(1, 78) = 13.88$, $p < .001$, $\eta_p^2 = 0.15$.

Visual Working Memory

Nine SZ subjects were unable to complete the VWM test, and the number of nonresponded trials by the remaining SZ subjects ($37.37 \pm 4.64\%$, $n = 31$) far exceeded the HC group (2.69 ± 3.98, $n = 42$; $F(1, 71) = 32,19$, $p < .001$, $\eta_p^2 = 0.31$. To avoid confounding differences in the number of trials, we only included the first 120 responded trials at each memory load and excluded subjects (12 SZ and 1 HC) who failed the criterion. One additional SZ subject was dropped because she always responded "yes" despite completing all 560 trials, as this prevented the computation of memory capacity scores. The final 2 × 3 (Group × Memory Loads) ANOVA of all variables included 18 SZ and 41 HC subjects.

Analysis of correct rate showed a clear reduction with increasing load, $F(2, 114) = 166.87$, $p < .001$, $\eta_p^2 = 0.75$, and the SZ group was clearly impaired, $F(1, 57) = 33.45$, $p < .001$, $\eta_p^2 = 0.37$. The magnitude of the SZ deficit was largely stable across memory loads ($F < 1$; Figure 4A). Accuracy dropped from 91% to 69% in the HC group, while a drop from 79% to 57% was seen in the SZ group. One-sample test showed that the SZ group had maintained performance above chance (>50%) at the highest load, $t(17) = 3.26$, $p < .005$.

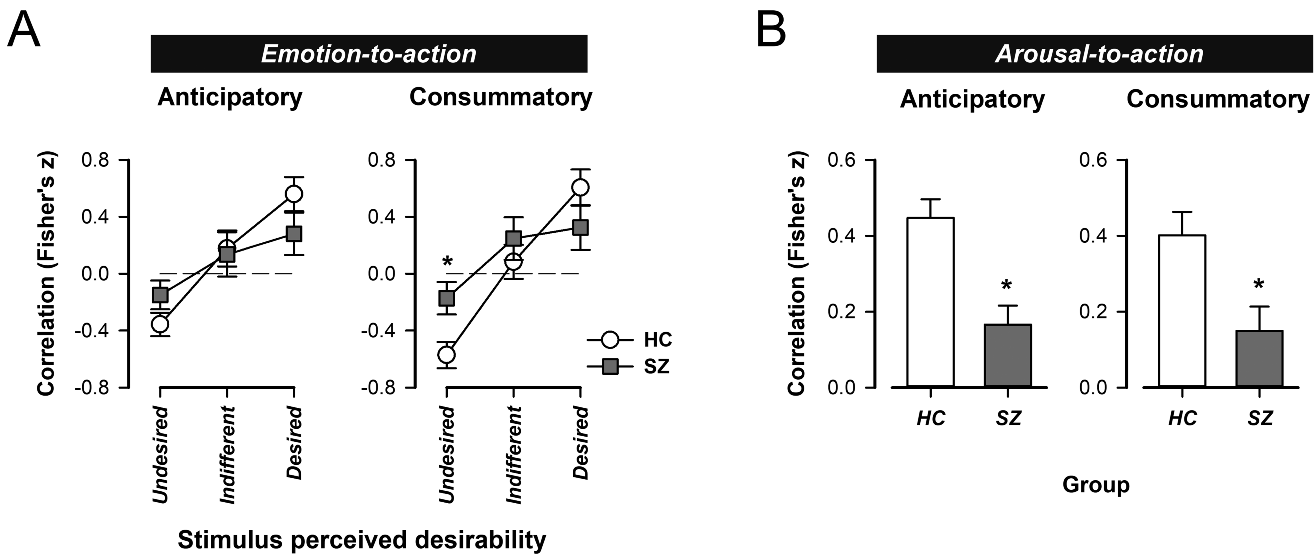
The SZ group was also deficient in terms of memory capacity, $F(1, 57) = 31.43$, $p < .001$, $\eta_p^2 = 0.36$. While increasing memory loads induced higher memory capacity in the HC group, a decrease was observed in the SZ group. This led to a significant interaction, $F(2, 114) = 13.19$, $p < .001$, $\eta_p^2 = 0.19$, and the impression that the capacity deficiency in the SZ group was magnified with increasing loadings (Figure 4B).

Finally, reaction time showed a clear increase with increasing memory loads, $F(2, 114) = 38.77$, $p < .001$, $\eta_p^2 = 0.41$, but the rate of increase was lower in the SZ group (Figure 4C). The latter led to a significant interaction, $F(2, 114) = 6.70$, $p < .005$, $\eta_p^2 = 0.11$, although the average reaction time was comparable between groups ($F < 1$).

Given that a significant proportion of SZ subjects was excluded from the VWM analysis, we conducted additional analysis (see online supplemental material E) to examine if SZ subjects included ($n = 18$) and those excluded ($n = 22$) might exhibit systematic difference in their ACP performance. Specifically, it is imperative to decide if the substantial ACP deficit in the SZ group described before could have been primarily driven by SZ subjects whose general engagement in psychological testing was markedly impaired. If so, it would undermine the validity of our conclusion. To this end, we directly contrasted ACP performance between the two subsets SZ

Figure 3

Correlation Between Behavioral Efforts and Subjective Ratings in Stimulus Pleasantness (Desirability) and Arousal Levels



Note. (A) Individual correlation coefficients between key-press rate and stimulus desirability of the associated stimuli (*Undesired*, *Indifferent,* and *Desired*) based on subjective pleasantness ratings (1–3, 4–6, and 7–9, respectively) were computed separately for *anticipatory* and *consummatory* response across valid trials in 13 SZ and 20 HC subjects. (B) Individual correlation coefficients between key-press rate and stimulus arousal ratings were computed separately for valid trials in the two phases (*anticipatory* and *consummatory*) of the ACP task. SZ: $n = 39$, HC: $n = 41$. * indicates a significant difference ($p < .05$) between groups. HC = healthy control; SZ = schizophrenia; ACP = anticipatory and consummatory pleasure.

subjects in an analysis of press rate as a function of subjective stimulus valence (negative, neutral, positive) across the two phases (anticipatory vs. consummatory response) of the ACP task. There was no statistical evidence suggesting that their ACP response profile might differ significantly from each other (see Figure E1 in the online supplemental materials). In addition, we also compared the demographic and clinical features between two subsets of SZ subjects, which yielded only a difference in sex ratio with ($p = .005$ by FET). While the *VWM-able* subset had a bias for males (14M:4F), the *VWM-unable* subset had a bias for females (7M:15F). The two subsets, however, did not differ in terms of age, age at first psychiatric contact, years since first psychiatric contact, medication expressed in chlorpromazine-equivalent dosage, diagnosis, marital status, education levels, or employment. They also cannot be differentiated by their TEPS or LNS performance. Relevant descriptive and interpretative statistics are listed in Table 2 in online supplemental material E.

Letter–Number Span

The SZ group was substantially impaired. Significant group effects of comparable effect size were obtained from separate one-way ANOVAs of LNS correct score, $F(1, 80) = 98.07$, $p < .001$, $\eta_p^2 = 0.55$, and maximum alphanumeric string length completed, $F(1, 80) = 101.79$, $p < .001$, $\eta_p^2 = 0.56$; Figure 5.

Temporal Experience of Pleasure Scale

A 2 (Group) × 2 (Subscores) ANOVA including anticipatory and consummatory TEPS subscores failed to yield any significant group difference. A nonsignificant numerical reduction of TEPS scores was just discernible in the SZ group (Figure 6). Consummatory subscores were notably higher than anticipatory subscores across both groups, $F(1, 80) = 77.42$, $p < .001$, $\eta_p^2 = 0.49$.

Correlation Between ACP and Memory Variables

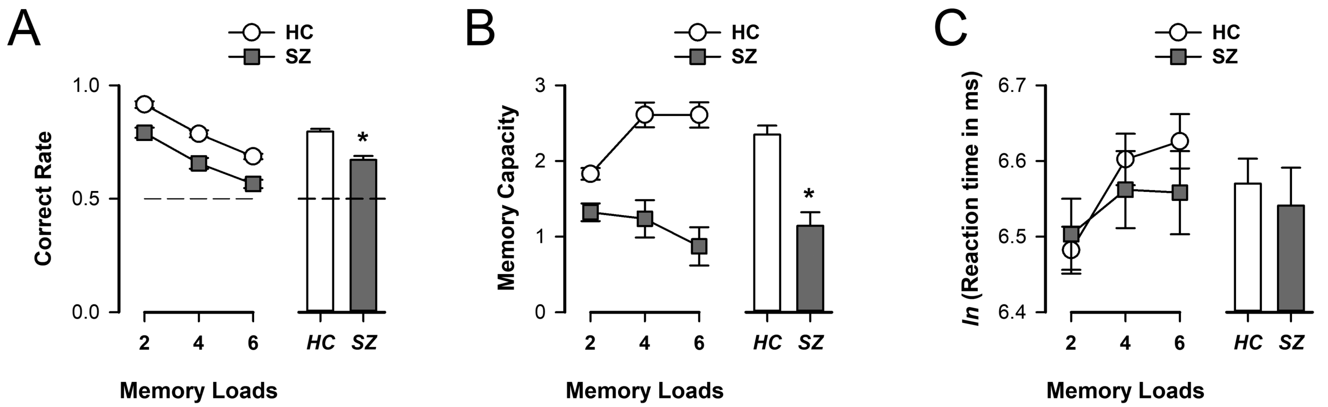
Five ACP performance variables correlated significantly with LNS scores, but these correlations were uniquely observed in the SZ subjects (Figure 7). The five variables were (a) correlation of subjective pleasantness and arousal ratings (Figure 1D), (b) and (c) the quadratic components computed from the anticipatory and consummatory response profiles (Figure 2A, B), (d) and (e) the correlations of arousal ratings against anticipatory, and consummatory responding (Figure 3B). By contrast, none of the five ACP variables correlated with individual performance in the VWM test. Interpretation of these null results, however, is limited by the reduced sample size ($n = 18$). It is therefore worth noting that the correlation between arousal-anticipatory response coupling and VWM correct rate yielded an effect size ($r = .37$, $p = .14$, $R^2 = 0.13$, $df = 16$) approaching those ACP–LNS correlations shown in Figure 7. Otherwise, the coefficients of determination of other ACP–VWM correlations were all below 0.05.

Discussion

The present study reexamined the power of the ACP task to detect and quantify emotional decoupling in the behavioral expression of goal-directed action incentivized by affective stimuli in schizophrenia. First, we consolidated the presence of robust impairment in both types of response in schizophrenia when the subjective rating of emotional content was apparently normal. Second, our data

Figure 4

Performance in the Visual Working Memory (VWM) Test



Note. The memory deficit in the SZ group (*) was evident in terms of correct rate (A) and memory capacity (B) in the first 120 trials at each memory load. (C) The overall reaction time was comparable between groups, but its rate of increment with increasing memory loads was lower in the SZ group. SZ: $n = 18$, HC: $n = 41$. HC = healthy control; SZ = schizophrenia.

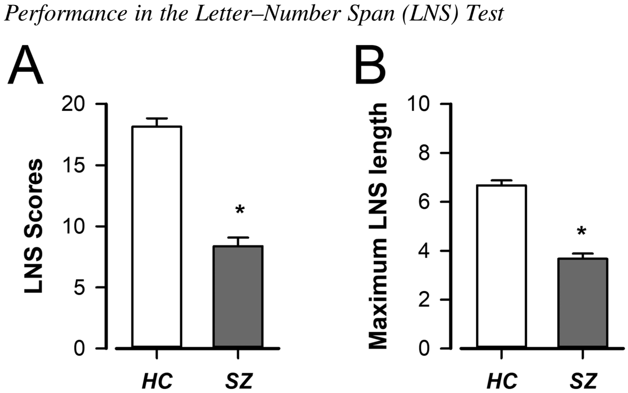
suggested that interpretation for a preferential emotional decoupling in *anticipatory* goal-directed action in schizophrenia based on the ACP paradigm (here and elsewhere) may be untenable (see further discussion below based on planned orthogonal contrasts analysis). Third, we provided new evidence for emotional decoupling beyond goal-directed behavior. Stimuli whose affective valence was perceived as more extreme (pleasantness scale) were less effective in driving higher arousal ratings in the SZ group. Fourth, there were grounds for a more refined interpretation of the potential link between emotional decoupling and working memory deficiency in schizophrenia, first alluded to by Heerey and Gold (2007). The comprehensive association between indices of emotional decoupling derived from the ACP task and LNS memory scores (Figure 7) has clarified concerns raised in the Introduction. One critical qualification was that the association was unique to the SZ group, highlighting that the linkage between volitional and cognitive deficits may be pathological. Although the failure to generalize the correlative findings to the VWM test could partly be attributed to reduced statistical power, it highlights the possibility that not all working memory tests are equally linked to the emergence of emotional decoupling in schizophrenia—hence, the need for further dissection.

ACP Versus TEPS

The ACP task is a behavioral paradigm to dissociate consummatory and anticipatory goal-directed action incentivized by emotion that mirrors the temporal separation between actions and outcomes emphasized in the TEPS (Gard et al., 2006). Here, ACP was superior in differentiating our SZ and HC subjects while TEPS essentially failed (Figure 6). The critical Group × Desirability interaction across the two phases of the ACP task yielded an impressive effect size of $\eta_p^2 = 0.44$. The limited robustness of TEPS, however, was not unprecedented (Frost & Strauss, 2016; Visser et al., 2020). The

Figure 5

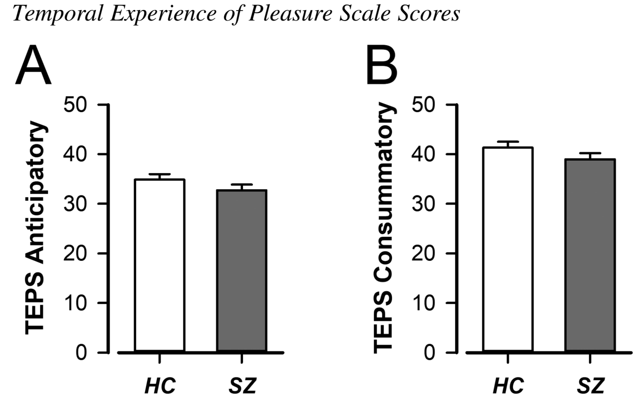
Performance in the Letter–Number Span (LNS) Test



Note. LNS performance was grossly impaired in the schizophrenia group in terms of (A) total correct scores and (B) maximum length achieved. SZ: $n = 40$, HC: $n = 42$. * denotes significant group difference at $p < .05$. HC = healthy control; SZ = schizophrenia.

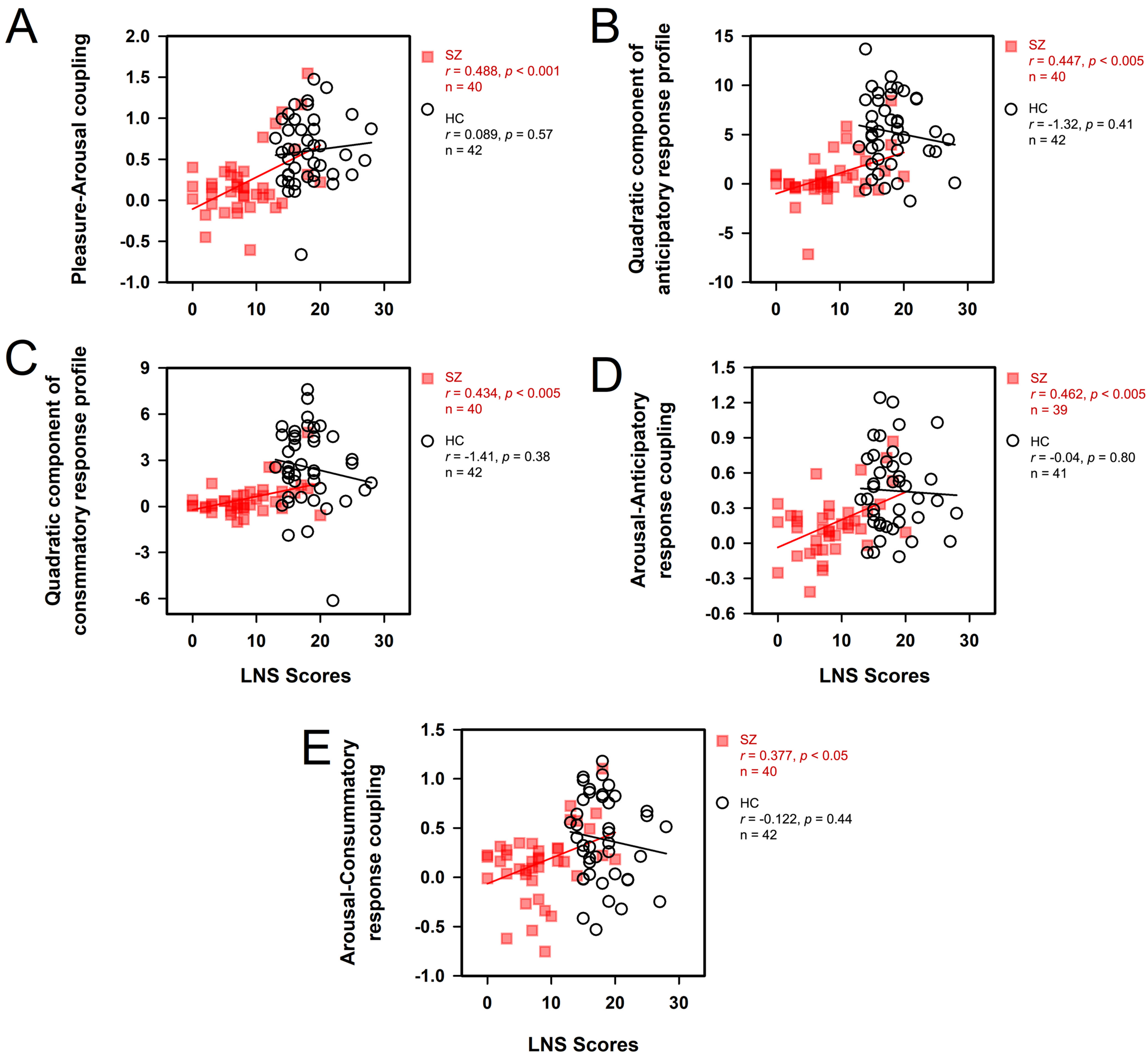
Figure 6

Temporal Experience of Pleasure Scale Scores



Note. No significant group difference was obtained in the (A) anticipatory and (B) consummatory subscales of TEPS. SZ: $n = 40$, HC: $n = 42$. TEPS = Temporal Experience of Pleasure Scale; HC = healthy control; SZ = schizophrenia.

Figure 7
Correlation and Scattered Plots Between ACP Variables and LNS Memory Scores



Note. Pearson's correlation coefficients were computed separately for the SZ ($n = 39$–40) and HC ($n = 42$) group. Five ACP variables (A–E) are plotted against the total scores in the LNS test. Two regression lines (SZ: red squares, HC: black circles) are fitted to each scattered plot. ACP = anticipatory and consummatory pleasure; LNS = letter–number span; HC = healthy control; SZ = schizophrenia. See the online article for the color version of this figure.

possibility that its application to Chinese subjects may undermine TEPS seems unlikely. Li et al. (2015) showed that the Chinese TEPS could differentiate Chinese people with chronic schizophrenia from their nonpsychotic first-degree relatives by the abstract components of anticipatory pleasure and consummatory pleasure with very respectable effect sizes (Cohen's $d = 1.57$ and 0.60, respectively) with sample sizes ($n = 45$) not substantially larger than ours. Secondly, the ACP task, being a behavioral paradigm, is less prone to cultural divergence. The use of IAPS images to induce an affective response in Chinese subjects is well supported (Chiang et al., 2012). Another notable advantage of ACP over TEPS is the ability to contrast approach/seeking and escape/avoidance actions driven by positive and negative emotions, respectively. TEPS instead measures exclusively sensitivity to pleasurable experience.

Interpreting ACP Response Profile Through Polynomial Contrasts

Responding under the two opposing affects in contrast to neutral control trials is associated with a prototypical V-shaped profile that can be precisely and conveniently captured by the quadratic trend across the three ordered levels of valence: *negative/undesirable→ neutral/indifferent→ positive/desirable*. The quadratic trend provides a metric to evaluate emotion-behavior coupling and its hypothesized attenuation (i.e., *decoupling*) in schizophrenia. As an orthogonal complement, the linear trend provides a metric for asymmetric coupling as it specifically contrasts response vigor between undesirable and desirable trials (Fisher & Yates, 1963).

The primary statistical support for the differential expression of *anticipatory* vs. *consummatory* response deficit in our SZ subjects was the emergence of the Group × Phases × Desirability interaction in key-press rate (Figure 2). The differential flattening of the response profile in the SZ group was captured by the quadratic trend of this three-way interaction ($\eta_p^2 = 0.18$). In comparison with HC subjects, the flattening was more substantial in terms of anticipatory response than consummatory response (Figure 2). However, it was obvious that this impression was driven primarily by the stronger quadratic trend in anticipatory response by HC subjects. By contrast, SZ subjects responded similarly between the two phases. A posteriori restricted ANOVAs confirmed the presence of a highly significant Phases × Desirability interaction, $F(2, 82) = 22.55$, $p < .001$, $\eta_p^2 = 0.39$, in the HC group but not in the SZ group, $F(2, 78) = 1.11$, $p = .33$, $\eta_p^2 = 0.03$. This raises a concern that our SZ subjects were unable to comprehend or implement the task requirements.[1] Such a barrier of engagement could have potentially accounted for the nonspecific impairment seen in our SZ subjects. However, we showed that the mean quadratic component of the anticipatory and consummatory responding in the SZ group remained significantly above zero.[2] This was in keeping with our records that all subjects indicated their understanding of the task during the practice phase. This concern however resurfaced in the VWM task, which was apparently more demanding and led to the omission of data by a significant proportion of SZ subjects. Yet, this also provided an opportunity to evaluate the contribution of compliance to task demand in general (or the potential lack of it in our SZ subjects) to our main ACP finding. The additional analysis (detailed in online supplemental material E) showed convincingly that the possibility of poor engagement on the VWM task per se could not differentiate the flattening of the ACP valence-dependent key-press profile.[3] We speculate that what appeared to be suggestive of a lack of task engagement/comprehension was indicative of poor psychomotor speed, and this nonspecific effect was not critical to the emergence of the grossly attenuated emotion-response coupling evident in the ACP task. Thus, in comparison with Heerey and Gold (2007), the flattening in our SZ subjects was more pronounced. Yet, a complete loss of expected V-shaped profile is not unprecedented. Lui, Shi, et al. (2016, see their Figure 4) reported a complete loss in nonclinical negative schizotypy subjects whose understanding of task instructions would not be in doubt.

Finally, the linear trend of the significant three-way interaction in the overall ANOVA ($\eta_p^2 = 0.11$) further revealed an asymmetric emotion-behavior coupling specific to consummatory responding in our HC subjects. Heerey and Gold (2007) also reveal a similar bias in HCs for more vigorous responding in undesirable than desirable trials, but it was interpreted as exclusive to anticipatory responding. Our data agreed nonetheless that SZ subjects never displayed such asymmetric responding. Incidentally, we both observed stronger anticipatory responding by SZ subjects in indifferent trials (Figure 2A).

Anticipatory or Consummatory, That Is the Question

The crucial question that arises is whether the differential expression of *anticipatory* vs *consummatory* response deficit in the SZ group may be interpreted as evidence for a stronger emotional *de*coupling in anticipatory response? We contend that an affirmative answer runs the risk of reading into the stronger V-shape (i.e., quadratic) anticipatory response profile seen in the HC group as evidence for its more severe attenuation in the SZ group. There are at least four reasons for our caution. First, multiple attempts since the seminal study by Heerey and Gold (2007) have failed to report the critical three-way interaction (except Wang et al., 2020, and here), yet the two-way (Group × Desirability or Valence) interaction was far more robust (Chu et al., 2020; Lui, Liu, et al., 2016; Lui, Shi, et al., 2016; Xie et al., 2017).

Second, although ACP studies consistently showed a stronger V-shaped profile in anticipatory compared with consummatory responding, this may be an artifact even though both were quantified by key presses per second. The response window for an anticipatory response was fixed to 2 s without any immediate feedback available. On the other hand, the response window for registering consummatory response was variable—in a manner that directly depended on registered key presses. Appropriate key presses during desirable trials prolonged not only the viewing time (as desired) but also the response window. The potential *reward* gained from further key presses diminished as viewing time approached the upper bound of 10 s. The key-press rate would be expected to decelerate and dragged down the average press rate. By contrast, the response during undesirable trials did not suffer from this potential limit. The resultant shorter response window (<5 s) may have inadvertently inflated the average key-press rate. This difference in time windows may explain the asymmetric response exhibited by HC subjects during consummatory responding.

Third, we lack an a priori rationale for predicting whether the V-shape profile of anticipatory or consummatory response should be stronger in healthy people. Although ACP studies consistently showed a sharper profile in anticipatory responding, a brief survey of TEPS studies have demonstrated all possible patterns in healthy subjects (Da Silva et al., 2017; Gard et al., 2007; Strauss et al., 2011). Notably, in the ACP task, the expected outcomes associated with anticipatory and consummatory responses were qualitatively different. They were delivered either as a change in future probability of viewing, or the "in-the-moment" viewing time, of a specific affective stimulus. This prevents the direct application of delayed discounting function (Frederick et al., 2002), which otherwise should predict weaker anticipatory than consummatory responses.

Fourth, our evaluation of the correlation between subjective valence ratings and behavioral response did not yield any statistical support for a preferential attenuation of the correlation in anticipatory responding, but only a general weakening of the correlation (Figure 3A). This concurs with two recent reports in community-dwelling people with schizophrenia and in-patients (Wang et al., 2020; Xie et al., 2017). Moreover, neither Lui, Shi, et al. (2016)

[1] We are grateful to the two reviewers for raising this concern.

[2] Additional indices were computed to more precisely estimate the quadratic trend of the response profile and they all showed that the SZ group were performing significantly above chance.

[3] This additional analysis was performed as recommended by a reviewer.

nor Chu et al. (2020) had reported a significant interaction between group and response phases in their evaluation of ACP performance in schizophrenia. Heerey and Gold (2007) remains the only study to date reporting that the correlation between valence ratings and vigor of anticipatory response was significantly more impaired in schizophrenia compared with the correlation between valence ratings and vigor of consummatory response—with a moderate effect size ($\eta_p^2 = 0.07$). Intriguingly, the exact opposite outcome, of a comparable effect size ($\eta_p^2 = 0.08$), has been reported in first-episode schizophrenia patients, who exhibited a more severe decoupling between valence ratings and consummatory response vigor (Lui, Liu, et al., 2016). Taken together, the majority of ACP studies failed to substantiate the hypothesis that schizophrenia *selectively* undermines willed actions incentivized by anticipatory emotional reinforcement. Instead, evidence for *de*coupling in both anticipatory and consummatory responses are abound. This impression of a more pervasive decoupling from emotion may extend to the link between emotion and arousal we reported here for the first time.

Decoupling Beyond Goal-Directed Behavior

Evidence for a decoupling between valence and arousal ratings was apparent even before the actual key presses for the anticipatory response were registered in Phase 1 of the ACP task. Extensive normative data showed that IAPS images rated as more emotive are also rated higher in arousal (Balsamo et al., 2020). This normative relationship was attenuated in the SZ subjects (Figure 1E). The emotion–arousal connection has received limited attention in the literature, perhaps because arousal bore no programmed consequences and thus considered irrelevant to the types of goal-directed response measured in ACP. However, the motivational significance of arousal has been demonstrated by *ad libitum* viewing time of affective pictures (Kron et al., 2014). Therefore, some discussion is warranted given that our SZ subjects exhibited attenuated coupling between subjective arousal and the vigor of both anticipatory and consummatory responses (Figure 3B).

The attenuation is unlikely simply attributable to a lack of within-subject variability in the two ratings among SZ subjects (Figure 1C, D), or their small (albeit significant) bias for more pleasant ratings (Figure 1A). On the other hand, the failure of SZ subjects to distinguish between neutral and negative categories of images in their arousal ratings (Figure 1B) could have undermined the concordance between perceived valence and arousal ratings (Figure 1F)—which we interpreted as an expression of emotion–arousal decoupling.

Since the ACP task accords no motivational significance to the arousal rating, one may be inclined to interpret emotion–arousal decoupling as a sign of anhedonia rather than avolition. Yet, emotion–arousal decoupling might act as a mediator of the weaker link between subjective arousal and effortful responding observed in the SZ group. When ratings of valence and arousal are tightly correlated, the processing of stimuli of more extreme valence is expected to be modulated by higher arousal. According to the arousal-biased competition theory (Mather & Sutherland, 2011), the affective information therein would be perceived as more salient and represented more strongly in working memory and afforded higher priority in the regulation of behavior—especially behavior incentivized by the prioritized affective information. Hence, strong coupling between valence and arousal can reinforce emotional coupling with behavior. The cognitive processes implicated extend across the diverse supervisory roles of the central executive (Baddeley, 1986), the multifaceted executive dysfunction of which is well documented in schizophrenia (Barch, 2003, 2005). Whether such impairments may differentially contribute to aberrant anticipatory versus consummatory goal-directed behavior that underlies avolition in schizophrenia remains to be further investigated. Nonetheless, our data suggested that both types of motivated behavior were grossly affected in our SZ subjects (Figure 3B). A complementary impression also emerges when the association between deficits in ACP and working memory is considered.

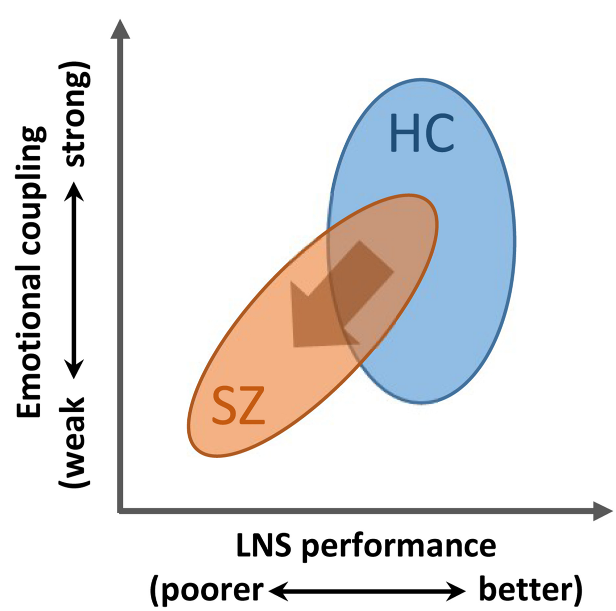
The ACP–LNS Correlation Is Intrinsic to Schizophrenia Psychopathology

A correlation between the concordance of anticipatory response with subjective valence and LNS performance was first reported by Heerey and Gold (2007), but it was based on a pooled analysis across both schizophrenia and healthy subjects. It remains uncertain if it was simply driven by group differences in the two variables because neither a scatter plot nor within-group correlation was performed. Here, we clarified this uncertainty and provided some critical qualifications.

Five ACP variables that were indexing some form of emotional *de*coupling identifiable in the SZ subjects correlated with LNS scores, but only in the SZ group (Figure 7). Notably, SZ subjects scoring low in LNS also exhibited weaker emotion–behavior coupling captured by the quadratic components derived from both anticipatory and consummatory response profiles. Their unique

Figure 8

The Concomitant Attenuation of Emotional Coupling and Working Memory Impairment in Schizophrenia (SZ)



Note. A representation that attributes our correlative findings depicted in Figure 7 as pathological in nature, while the two traits largely varied independently in healthy controls (HCs). See the online article for the color version of this figure.

emergence among SZ subjects suggests a pathological link between diminished emotional coupling and working memory dysfunction (Figure 8). Our data agree with the observation that ACP performance in schizophrenia patients with near-normal LNS performance was better than patients with clear working memory deficit, although it remained poorer than HCs (Lui, Liu, et al., 2016). Chu et al. (2020) also reported that the variation in working memory alone could not statistically account for the presence of emotion–behavior decoupling in schizophrenia. Examination of the effect sizes of correlation shown in Figure 7 has led to the same conclusion. Hence, the emotion–behavior decoupling in schizophrenia likely involves dysfunction of other cognitive processes. Indeed, the link between diminished emotional coupling and memory dysfunction here was more pervasive here than pervasively described. The attenuated concordance related to arousal in schizophrenia also correlated with LNS scores, including emotion–arousal decoupling (Figure 7A) and arousal–behavior decoupling (Figure 7D, E).

Unlike Heerey and Gold (2007), we were unable to generalize the ACP–LNS correlation to a visual-spatial working memory paradigm.[4] The VWM task was selected as an attempt to minimize rehearsal, temporal retention, and manipulation demand, and for its focus on memory buffer capacity (J. M. Palva et al., 2010). However, its implementation as a two-alternative forced choice task proved to be too demanding for half of our SZ subjects. As a consequence, the loss of statistical power might contribute to our failure to observe comparable ACP–VWM correlation in the SZ group. The contrast between LNS and VWM here must therefore be interpreted with caution, although it may point to the irrelevance of short-term memory capacity in the emergence of the robust "pathological" ACP–LNS correlation. Nevertheless, the VWM data had highlighted the possibility that not all working memory components are perhaps equally linked to the emotion–behavior decoupling in schizophrenia. Further dissection is worth attempting to isolate more precisely the cognitive underpinnings of avolition symptoms in schizophrenia (e.g., Strauss & Gold, 2012) as well as other conditions with similar affective symptoms (Heinz et al., 1994; Lambert et al., 2018; Wang et al., 2020). Future ACP studies are encouraged to incorporate tests that can selectively engage specific components of executive and working memory function.

Some Theoretical Considerations

The parsing of reinforced behavior with respect to it consummatory and anticipatory intent in the ACP task is designed to mirror the distinction between *liking* and *wanting* (see Heerey & Gold, 2007, p. 269). Their respective deficiency has been mapped onto anhedonia and avolition, respectively; and by extension, the Kraepelinian expectation of a preferential anticipatory impairment in schizophrenia. However, it may not be fundamentally refuted by our contention that deficiency in both consummatory and anticipatory behavior can be robustly demonstrated in schizophrenia. The key presses recorded in both phases of the ACP task are behavior intended for some specific outcomes. Hence, both consummatory and anticipatory responses are arguably volitional in nature. A closer approximation to *liking* is perhaps the self-reported valence ratings given to affective images—a view explicitly favored by Lui, Liu, et al. (2016). A caveat of this view, however, is that we cannot be certain if the subjective ratings are made primarily from an experiential or semantic perspective. Semantic valence—as "factual knowledge about the valence of an object or event," is dissociable from experiential affective valence (Itkes & Kron, 2019; Kron et al., 2013, 2015). This distinction would be crucial to the conceptualization of emotion-behavior *de*coupling as a psychopathological construct in schizophrenia, and specifically the interpretation of valence-arousal decoupling in schizophrenia demonstrated here. Future ACP studies may consider measuring overt facial, orienting, and autonomic (e.g., electrodermal) responses as more objective readouts of arousal to approximate experiential affects (Hamzani et al., 2020; Itkes et al., 2017).

Conclusion

We demonstrated here the power of the ACP paradigm to capture deficiencies in affective processing for adaptive purposeful behavior through the wealth of data one may extract and analyze. Further dissection is certainly possible: not only to further untangle the underlying psychological processes but also to enrich the application of the ACP task (including its modification) in the study of avolition, apathy, and anhedonia in schizophrenia as well as within a transdiagnostic framework (Yan et al., 2019).

[4] If we were to perform correlation by pooling both SZ and HC subjects together, as Heerey and Gold (2007) did, multiple significant ACP-VWM correlations would also unsurprisingly emerge ($r \asymp 0.3$, $df = 57$, $p < .05$).

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