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Joyce Y.T. Lam

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ABSTRACT

Lack of motivation (avolition) is a core negative symptom in schizophrenia (SZ) that can lead to a failure to seek pleasurable experiences or avoid aversive ones. This symptom often manifests as an inability to carry out tasks or goal-oriented activities, causing individuals with SZ to be perceived as passive or unwilling to engage in self-care and follow treatment plans. This perception can foster negative attitudes toward the illness and the patients themselves.

This study aimed to deepen the understanding of avolition in SZ and consisted of three phases. Phase I examined the disconnection of behavior from emotion and its relation to working memory impairment using the Anticipatory and Consummatory Pleasure (ACP) task, comparing individuals with SZ (n=40) and healthy adults (n=42). In Phase II, the ACP task was extended to healthy adults (n=91) to evaluate the relationship between the emotion-behavior connection and SZ-like traits. Phase III applied brain imaging methods (fMRI) to explore motivational deficits in relation to brain connectivity among individuals with SZ (n=15) and healthy adults (n=23).

The study revealed that people with SZ experience disconnections in both future-oriented and immediate motivation, despite reporting normal emotional experiences. These disconnections were linked to working memory deficits. Brain imaging results showed unusual connections in brain networks, particularly in the salience network, associated with motivational deficits in SZ. Unexpectedly, healthy individuals with SZ-like traits exhibited stronger motivated behavior toward future rewards compared to those with SZ.

These findings enhance the understanding of motivational deficits in SZ. It is crucial for healthcare professionals to recognize that a lack of motivation can be a symptom of the illness, enabling them to approach patients empathetically and tailor treatment plans effectively.

KEYWORDS: schizophrenia, emotion-behaviour coupling, avolition, anhedonia, motivation, emotion, working memory, schizotypy, Anticipatory and Consummatory Pleasure task, salience network, brain connectivity

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TIIVISTELMÄ

Motivaation puute (avolition) on keskeinen negatiivinen oire skitsofreniassa (SZ). Oire voi johtaa siihen, että henkilö ei hae miellyttäviä kokemuksia tai vältä epä-miellyttäviä kokemuksia. Motivaation puute ilmenee usein kyvyttömyytenä suo-rittaa tehtäviä tai tavoitesuuntautuneita toimintoja, mikä saa skitsofreniaa sairastavat näyttämään passiivisilta tai haluttomilta huolehtimaan itsestään ja noudattamaan hoitosuunnitelmia. Tämä saattaa edistää negatiivisia asenteita sairautta ja potilaita kohtaan.

Tutkimuksen tavoitteena oli syventää ymmärrystä avolitiosta skitsofreniassa. Tutkimus koostui kolmesta vaiheesta. Vaiheessa I tutkittiin käyttäytymisen ja tunteiden välistä erkaantumista sekä sen yhteyttä työmuistin häiriöihin käyttämällä ACP tehtävää (Anticipatory and Consummatory Pleasure task). Kyseisessä vaiheessa vertailtiin skitsofreniaa sairastavia (n=40) ja terveitä aikuisia (n=42). Vaiheessa II ACP-tehtävää laajennettiin terveisiin aikuisiin (n=91). Tehtävässä arvioitiin tunteiden ja käyttäytymisen yhteyttä skitsofrenian kaltaisiin piirteisiin. Vaiheessa III käytettiin aivokuvantamismenetelmiä (fMRI) tutkimaan motivaation puutteita suhteessa aivojen yhteyksiin skitsofreniaa sairastavilla (n=15) ja terveillä aikuisilla (n=23).

Tutkimus osoitti, että skitsofreniaa sairastavat kokevat erkaantumista sekä tulevaisuuteen suuntautuvassa että välittömässä motivaatiossa, vaikka he raportoivat normaaleja tunnekokemuksia. Nämä erkaantumiset olivat yhteydessä työmuistin häiriöihin. Aivokuvantamistulokset osoittivat poikkeavia yhteyksiä aivojen verkos-toissa, jotka liittyivät motivaation puutteisiin skitsofreniassa. Yllättäen terveet henkilöt, joilla oli skitsofrenian kaltaisia piirteitä, osoittivat vahvempaa motivoitu-nutta käyttäytymistä tulevia palkkioita kohtaan verrattuna skitsofreniaa sairastaviin.

Nämä löydökset parantavat motivaation puutteiden ymmärtämistä skitso-freniassa. On tärkeää, että terveydenhuollon ammattilaiset tunnistavat motivaation puutteen sairauden oireeksi. Tämä mahdollistaa empaattisen lähestymistavan potilaisiin ja tehokkaiden hoitosuunnitelmien räätälöinnin.

AVAINSANAT: skitsofrenia, tunteiden ja käyttäytymisen yhdistäminen, anhedonia, motivaatio, tunne, työmuisti, skitsotyyppi

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Abbreviations

ACC	Anterior Cingulate Cortex
ACP task	Anticipatory and Consummatory Pleasure task
Ainsula	Anterior Insula
DMN	Default Mode Network
fMRI	Functional Magnetic Resonance Imaging
FPN	Frontoparietal Network
MPFC	Medial Prefrontal Cortex
LNS	Letter-Number Span
LP	lateral parietal
LPFC	Lateral Prefrontal Cortex
PCC	Posterior Cingulate Cortex
PPC	Posterior Parietal Cortex
RPFC	Rostral Prefrontal Cortex
SMG	Supramarginal Gyrus
SN	Salience Network
SPQ-B	Schizotypal Personality Questionnaire – Brief Version
SZ	Schizophrenia
VWM task	Visual Working Memory Task

List of Original Publications

This dissertation is based on the following original publications, which are referred to in the text by their Roman numerals:

I Lam, J. Y. T., Ng, M. H. F., Cheng, P. Y. I., Välimäki, M., & Yee, B. K. Coexpression of anticipatory and consummatory volitional deficits in schizophrenia and their association with memory impairment. *Journal of Psychopathology and Clinical Science*, 2023; 138(4): 499-513.

II Lam, J. Y. T., Ng, M. H. F., Välimäki, M., & Yee, B. K. The relationship between schizotypal traits and affect-driven volition in healthy adults. *Journal of Psychopathology and Behavioral Assessment*, 2024; *46*(2), 263-276.

III Lam, J. Y. T., Hsu, C. L., Ng, M. H. F., Välimäki, M., & Yee, B. K. Exploring the correlation between resting-state functional connectivity and affect-action coupling in schizophrenia: insights from the ACP task. Manuscript.

1 Introduction

Schizophrenia is a severe and chronic mental disorder that affects approximately 20 million people worldwide, equating to roughly 0.3% of the global population (World Health Organization, 2022), highlighting its significant public health impact. Characterised by distortions in thinking, perception, emotions, and behaviour, schizophrenia profoundly disrupts an individual's ability to function in daily life. Among its diverse symptoms, negative symptoms are particularly debilitating (Marder & Galderisi, 2017). Avolition, defined as a lack of motivation to initiate and sustain goal-directed activities, stands out as a core negative symptom that severely impairs individuals' capacity to engage in essential tasks such as self-care, employment, and maintaining social relationships (Foussias & Remington, 2010). This motivational deficit significantly contributes to the reduced quality of life experienced by those with schizophrenia (Green et al., 2015), making it a critical focus for research and intervention.

Healthcare professionals, including mental health nurses, psychiatrists, psychologists, rehabilitation specialists, and support workers, play a vital role in managing schizophrenia. Yet, avolition poses unique challenges that require specific understanding. Unlike positive symptoms such as hallucinations or delusions, avolition is less visible and often misinterpreted as laziness or disinterest (Kirkpatrick et al., 2006). It is important that clinical staffs recognise that this lack of motivation is not a personal failing but a neurobiologically rooted symptom of the disorder (Barch & Dowd, 2010). This awareness is essential for fostering empathy and implementing effective support strategies, such as breaking tasks into manageable steps, offering consistent encouragement, and establishing structured routines (Kring & Barch, 2014). Equipping staff with this knowledge enhances their ability to provide compassionate and practical care tailored to the needs of individuals with schizophrenia.

Significant progress has been made in schizophrenia research, shedding light on its symptoms, neural mechanisms, and treatment options. Studies have utilised neuroimaging to explore deficits in associated brain regions (Fornito et al., 2012), as well as various instruments to assess the impacts on functional outcomes (Leifker et al., 2011). Therapeutic approaches, including cognitive-behavioural therapy,

motivational interviewing, and antipsychotic medications, have also been investigated for their efficacy in addressing negative symptoms (Aleman et al., 2017). Despite these efforts, critical research gaps remain. Avolition, along with its interplay with other cognitive deficits, such as working memory or emotional processing, remains poorly understood (Strauss et al., 2012). This has limited the development of comprehensive models of the symptom. Additionally, there is a lack of targeted interventions specifically designed for avolition, as most current treatments address schizophrenia broadly rather than focusing on individual symptoms (Fusar-Poli et al., 2015).

To bridge these gaps, this study investigates affective motivation in schizophrenia, with a particular emphasis on emotion-behaviour coupling, by utilising an objective behavioural test, the Anticipatory and Consummatory Pleasure (ACP) task, to differentiate between the enjoyment of immediate experiences and the anticipation of future pleasures. The aim of this study is to gain a deeper understanding of the translation of emotional salience to motivated (volitional) behaviour (i.e., emotion-behaviour coupling) and its association with working memory impairments in individuals with schizophrenia and schizotypal features.

The results from this research could elucidate how deficits in emotion-behaviour coupling contribute to the avolition symptoms of schizophrenia. By understanding the underlying mechanisms and neural basis of the deficits, the findings emerged from this study could contribute to future implications for early detection and treatment, as well as transdiagnostic research.

To address the multifaceted nature of avolition and its wide-ranging impacts, this study adopts an interdisciplinary approach, integrating perspectives and methodologies from mental health nursing, neuroscience, psychology, psychiatry, and rehabilitation sciences for the following reasons. First, patients with schizophrenia, particularly those with chronic conditions, present challenges that require interdisciplinary collaboration. A key example is avolition, where reduced motivation significantly affects cognitive, emotional, social, and daily life functioning (Foussias et al., 2014; Galderisi et al., 2018). Addressing these challenges necessitates a comprehensive understanding that spans multiple disciplines (Kirkpatrick et al., 2006). Second, the relationship between patients and care providers is central to effective treatment and recovery. Nurses and other frontline healthcare professionals, with their direct and continuous contact with patients, are uniquely positioned to observe the daily impact of avolition (McCabe & Priebe, 2004). An interdisciplinary approach enhances these relationships by integrating diverse expertise, promoting holistic care, facilitating communication, and coordinating treatment plans (Hartley et al., 2020). Third, implementing evidence-based and validated interventions requires integrating research findings across disciplines. This framework ensures that care providers are informed by the

latest developments in neuroscience, psychology, and clinical practice, leading to more effective treatment strategies tailored to the complex needs of individuals with schizophrenia (Mueser et al., 2013; Leucht et al., 2017).

2 Review of the Literature

2.1 Schizophrenia

Schizophrenia is a chronic mental disorder characterized by significant disruptions in thought processes, emotional regulation, and behavioural functioning (American Psychiatric Association, 2013). It manifests as a heterogeneous condition with a diverse symptom profile, affecting about 0.3% of the global population (World Health Organization, 2022). Epidemiologically, schizophrenia typically emerges in late adolescence to early adulthood, with onset peaking between the late teens and mid-20s for men and slightly later for women (McGrath et al., 2008). Its prevalence is consistent across diverse cultural and geographic contexts, though environmental factors may influence its course (World Health Organization, 2022). Diagnosis relies on clinical observation of symptom patterns persisting for at least six months, as no definitive biomarker exists (American Psychiatric Association, 2013). Treatment integrates antipsychotic medications, such as risperidone or clozapine, with psychosocial interventions, though complete symptom resolution is uncommon (Leucht et al., 2012). Schizophrenia thus requires a comprehensive approach to understanding its broad implications, paving the way for detailed examination of its symptomatic components.

The symptomatology of schizophrenia is classified into three broad domains: positive, negative, and cognitive (Owen et al., 2016). Positive symptoms encompass excesses or distortions of normal functioning, such as hallucinations and delusions, which add atypical experiences to an individual's perception (American Psychiatric Association, 2013). Negative symptoms involve reductions in typical emotional and behavioural capacities, affecting areas such as motivation and social interaction (Kirkpatrick et al., 2006). Cognitive symptoms include deficits in attention, memory, and executive functioning, impairing information processing and decision-making (Green, 1996). These domains vary in presentation and severity across individuals, contributing to the disorder's diagnostic and clinical complexity.

2.2 Negative symptoms in schizophrenia

Negative symptoms have long been recognised as a core feature of schizophrenia. The early conceptualisation of negative symptoms can be traced back to the late 19th

century. Emil Kraepelin (1919/1971) emphasised the deterioration of emotional and volitional functions in what he termed dementia praecox– which was characterized by early onset and a deteriorating course of illness. This concept later influenced the development of the modern understanding of schizophrenia. Later, Eugen Bleuler (1950) highlighted the lack of emotional expression and drive as part of his concept of schizophrenia. These early observations laid the foundation for understanding negative symptoms as distinct from positive symptoms like hallucinations and delusions, which were more noticeable. Negative symptoms refer to a reduction or absence of normal emotional and behavioural functions, contrasting with positive symptoms that involve the presence of abnormal experiences.

Currently, National Institute of Mental Health (NIMH) made a consensus on the construct of negative symptoms, including: avolition, anhedonia, asociality, blunted affect, and alogia (Kirkpatrick et al., 2006, see Table 1). They further categorised the five negative symptoms into 2-factor model: (1) experiential deficits (avolition-apathy or motivation and pleasure), and expressive deficits (diminished expression). Research showed that negative symptoms present on more than 50% of people with schizophrenia (Bobes et al., 2010; Sicras-Mainar et al., 2014).

Table 1. The definition of negative symptoms.

NEGATIVE SYMPTOMS	DOMAIN	DEFINITION
AVOLITION	MAP	Reduced motivation to initiate and sustain goal-directed activities or behaviours
ANHEDONIA		Inability to experience pleasure or interest
ASOCIALITY		Inability to initiate and sustain social interaction and relations
ALOGIA	XP	Decreased speech output
FLATTEN AFFECT		Reduced emotional expression, including facial expressions, voice tone, and gestures

Note. MAP = experiential deficits in motivation and pleasure, EXP = expressive deficits

Negative symptoms significantly shape schizophrenia's prognosis and quality of life, exerting a profound influence on long-term functioning (Kirkpatrick et al., 2006). Unlike positive symptoms, which are episodic and treatment-responsive, negative symptoms persist, impairing social relationships, occupational performance, and self-care (Foussias et al., 2014). This chronicity marks them as a primary contributor to disability, often exceeding the burden of positive symptoms (Milev et al., 2005).

2.3 Impacts of negative symptoms

"The patients appear lazy and negligent because they no longer have the urge to do anything either of their own initiative or at the bidding of another. They can spend years in bed."

– Eugen Bleuler, 1950

According to Bleuler's description (see quote above), he highlighted a lack of motivation in people with schizophrenia. This isn't a matter of laziness in the traditional sense but rather a symptom of their condition. Individuals lose the urge to initiate or engage in activities, even when prompted by others. This behaviour might be perceived as laziness or negligence by others, but it is, in fact, a core feature of avolition. The inability to act is not due to willful disobedience or apathy but a deeper psychological impairment. Bleuler (1950) also noted the extreme manifestation of this symptom, where individuals might have difficulty to perform daily life and responsibilities. The impacts of negative symptoms in schizophrenia, profoundly disrupt the lives of affected individuals, their communities, and society, creating a cascade of challenges that impair daily functioning, social connections, and economic productivity (Fervaha at al., 2014; Marder & Galderisi, 2017).

At the individual level, negative symptoms profoundly affect one's self-initiating behaviours, resulting in poor daily functioning. Individuals with schizophrenia often struggle with performing basic tasks, such as grooming, preparing meals, or managing finances, as evidenced by their lack of energy and motor retardation (Rocca et al., 2016; Morrens et al., 2007). Studies using ecological momentary assessment (EMA) show that people with schizophrenia spend much of their time alone at home being inactive, which further diminishes their ability to engage in self-care and meaningful activities (Granholm et al., 2020; Strassnig et al., 2021).

Apart from daily tasks, negative symptoms also greatly disrupt social functioning and health behaviour when self-initiating behaviour is hampered. Individuals with schizophrenia exhibit reduced willingness to engage with others, impacting their interpersonal relationships and social performance (Galderisi et al., 2014; Giordano et al., 2024). This social withdrawal often leads to isolation, as they struggle to participate in community activities or maintain relationships, further exacerbating feelings of loneliness and social skill deficit (Robertson et al., 2014; Yu et al., 2024). Additionally, negative symptoms contribute to poor treatment adherence. The lack of motivation to engage in preventive health behaviours or seek professional help results in poor health outcomes, creating barriers to recovery and increasing the severity of symptoms over time (Galderisi et al., 2014; Acosta, 2012). These individual-level impacts highlight the significant challenges that negative symptoms present to everyday functioning, social relationships, and overall well-being.

Negative symptoms extend its impact to the community, affecting social relationships and healthcare services (García-López et al., 2022; Barlati et al., 2022). In terms of social relationships, negative symptoms strain the dynamics between individuals with schizophrenia and various parties. Family members, often acting as caregivers, face significant emotional and physical burdens, taking on variety of responsibilities, such as ensuring medication adherence and managing financial stress (Rahmani et al., 2022). This can lead to caregiver burnout, compounded by feelings of frustration and helplessness (Kokurcan et al., 2015; Shamsaei et al., 2015; Khalil et al., 2022). Family member, intimate partners and friends might find it hard to develop strong emotional connection with persons with schizophrenia due to their diminished ability to express affect and greater interpersonal distance (Budziszewska et al., 2020; Kraus et al., 2024). While employers might face challenges imposed by negative symptoms since it impairs their employees' work performance, as studies revealed that affective flattening and social withdrawal correlate with lower Work Behavior Inventory (WBI) scores (Bell et al., 2003; Marwaha & Johnson, 2004). Indeed, the employment rate among persons with schizophrenia has remained persistently low (often less than 10%) for decades, reflecting a long-lasting challenge (Marwaha & Johnson, 2004; Holm et al., 2021)

In the healthcare service domain, negative symptoms significantly increase the burden on healthcare systems by necessitating greater frontline manpower and resources. Individuals with severe negative symptoms often require long-term, resource-intensive interventions such as psychotherapy, rehabilitation programs, and community-based care, which strain healthcare systems (Weber et al., 2022). Indeed, individuals with one or more negative symptoms require more medical attention for their non-communicable disease (e.g., diabetes, hypertension), averaging 25.8% more specialty care visits and 19.4% more primary care visits than their counterparts without negative symptoms (Sicras-Mainar et al., 2014). The inevitable consequence of this health concern is that additional case managers and rehabilitation staff are required to effectively manage their complex health needs (Health Service Executive, 2019). These community-level impacts indicate the ripple effect of negative on both social and healthcare systems.

For the society, negative symptoms have far-reaching societal impacts, influencing public perception, economic productivity, and social welfare systems. Public perception and awareness are heavily shaped by stigma surrounding schizophrenia, which often leads to marginalization and social exclusion. This stigma contributes to reduced employment opportunities, as public misconceptions (e.g., belief that individuals with schizophrenia are unable to work) limit their reintegration into the workforce (Durand-Zaleski et al., 2012; Taskin et al., 2003). As a result, employment rates among people with schizophrenia are relatively low (Marwaha & Johnson, 2004; Holm et al., 2021). To address this, anti-stigma

campaign has been proposed as a societal intervention, for instance, the UK's 'Time to Change' programme has shown success in reducing discrimination and improving public attitudes toward mental illness (Thornicroft et al., 2016).

The societal cost of negative symptoms is also evident in the increased dependency on social welfare systems. Individuals with schizophrenia often rely on disability benefits and welfare programs due to unemployment and inactivity, placing a financial burden on public resources. Studies estimate annual societal costs per person at USD 63,000 in Sweden (Ekman et al., 2013) and USD 69,000 in England (Knapp et al., 2004), with social security costs alone reaching a minimum of USD 19,232 per person annually in Norway (Evensen et al., 2016). Furthermore, negative symptoms exacerbate social exclusion, as individuals have 50% fewer social contacts and support networks compared to the healthy population, perpetuating cycles of isolation and poverty (Gayer-Anderson & Morgan, 2013; Lavelle, Healey & McCabe, 2014). These societal impacts highlight the urgent need for broader interventions to mitigate the economic and social consequences of negative symptoms.

In summary, negative symptoms of schizophrenia create a cascade of effects, starting with the individual's daily struggles, extending to community-level challenges in relationships and the healthcare system, and culminating in significant societal burdens related to stigma, economic loss, and welfare dependency (see Figure 1). Understanding the mechanisms behind these symptoms is crucial for effective treatment and support. For instance, avolition—a key negative symptom that is driven by deficits in anticipatory pleasure, where individuals struggle to experience motivation or enjoyment in anticipating future activities (Gard et al., 2007). This mechanism underscores the need for targeted interventions that address motivational deficits to improve engagement in daily life, social interactions, and treatment adherence. By comprehensively addressing negative symptoms at all levels, the recovery outcome can be enhanced and benefit individuals, communities, and society.

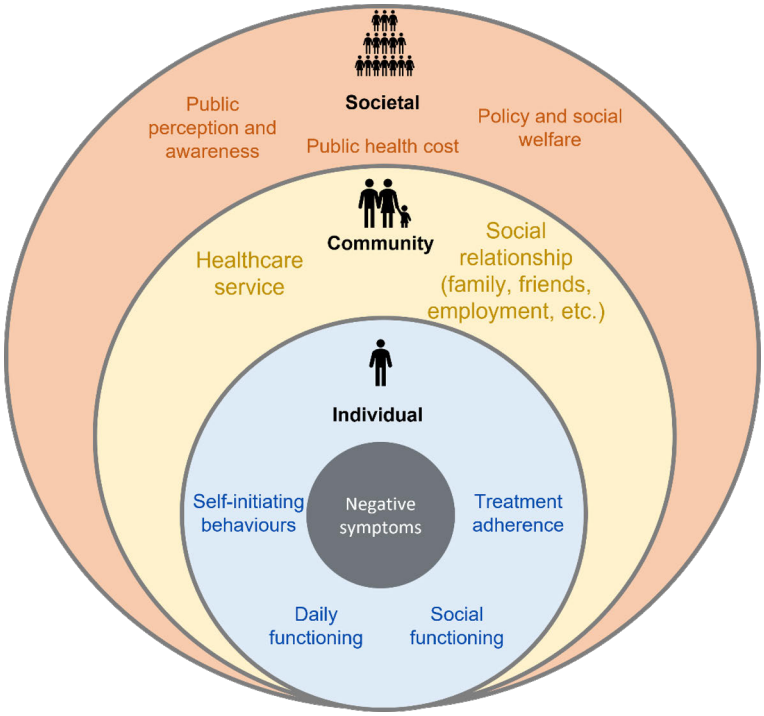


Figure 1. The multi-level impact of negative symptoms from individuals to society. The layer demonstrates that negative symptoms not only affect individuals but also extend their impact to the community and society.

2.4 Motivational deficits in schizophrenia

Motivational deficits or disturbances in schizophrenia have drawn attention and interest from researchers and clinicians over the past decades (Najas-Garcia et al., 2018). Historically, it was believed that individuals with schizophrenia struggled with goal-directed activities due to *anhedonia*, a perceived inability to derive pleasure from such activities, establishing it as a core negative symptom (Strauss, 2013; Strauss et al., 2014; Visser at al., 2020). However, emerging evidence challenges this notion, suggesting that impairments in anticipatory pleasure—the expectation of future rewards—better explain the inability to pursue goals than deficits in consummatory pleasure, which involves immediate enjoyment (Gard et al., 2007; Foussias & Remington, 2010; Foussias et al., 2014). Furthermore, the concept of emotion-behaviour decoupling, where emotional experiences fail to initiate corresponding actions, provides a unifying framework for understanding these deficits (Chan et al., 2025). Klein (1984) introduced a distinction between ***consummatory pleasure*** (or 'liking'), which is derived from immediate affective experiences, and ***anticipatory pleasure*** (or 'wanting'), which relies on the expectation of future rewards. This framework has been pivotal in reframing

avolition in schizophrenia (Gard et al., 2007; Strauss et al., 2011). For example, one may enjoy watching a movie (i.e., intact consummatory pleasure) but fail to plan to watch another due to a lack of anticipatory drive, reflecting avolition rather than anhedonia (Gard et al., 2007). Thus, anhedonia is more closely linked to deficits in consummatory pleasure, while avolition is driven by disruptions in anticipatory pleasure.

2.4.1 Emotion-behaviour decoupling

> *"a weakening of those emotional activities which permanently form the mainspring of volition, emotional dullness, failure of mental activities, loss of mastery over volition, of endeavour, and of ability for independent action."*
>
> ***– Emil Kraepelin, 1919/1971, pp.74***

Avolition, characterized by a profound reduction in initiating and sustaining goal-directed activities, is a prominent, persistent, and disabling negative symptom of schizophrenia, posing a significant hurdle to rehabilitation (Galderisi et al., 2018). Kraepelin (1920/1974) proposed that the "loss of energy and drive" arises from a *decoupling* between affective experiences and willed, goal-directed behaviour, rather than an inability to experience emotions, as seen in anhedonia. He suggested that this decoupling may lead to maladaptive, inappropriate, or disorganised behaviour and impairments in social functioning. It manifests as an inability to act on recognized intentions, such as planning to attend a community class but fail to enroll despite valuing the experience, or express enthusiasm for gardening but never plant a seed (Foussias & Remington, 2010). Distinct from disinterest or fatigue, avolition reflects a specific failure to translate goals into actions, often described by patients as an intangible barrier (Kring & Barch, 2014). This symptom significantly contributes to functional impairments, with unemployment rates among individuals with schizophrenia reaching approximately 80%, largely due to disrupted motivation (Marwaha & Johnson, 2004). Avolition is also linked to poorer quality of life and reduced intrinsic motivation, the internal drive to engage in activities for their inherent satisfaction (Saperstein et al., 2011; Strauss et al., 2013).

One interpretation of this motivational (or volitional) deficit refers to ***emotion-behaviour decoupling*** – the failure of emotional experiences to initiate corresponding actions, serving as a unifying framework for understanding avolition in schizophrenia (Heerey & Gold 2007). In healthy individuals, emotions drive behaviours (e.g., excitement about a hobby prompts practice). In schizophrenia, however, individuals may feel pleasure or interest but fail to act, resulting in disengagement despite intact emotional capacity (Barch & Dowd, 2010). This decoupling is evident in the **'anhedonia paradox'**, where patients report intact

consummatory pleasure (enjoying stimuli in the moment) but impaired anticipatory pleasure, reflecting low anticipatory motivation (Gard et al., 2007; Kring & Elis, 2013). Experimental tasks demonstrate that while individuals with schizophrenia rate stimuli as pleasant, they perform fewer actions to sustain rewarding experiences, such as pressing keys to extend exposure (Heerey & Gold, 2007, Gold et al., 2008; Strauss & Gold, 2012). This suggests that while consummatory motivation may be subtly impaired, anticipatory motivation is the primary deficit driving avolition (Figure 2). Avolition extends beyond hedonic deficits to include non-hedonic drives, such as social interest, impacting symptoms like asociality (Strauss et al., 2014). For instance, individuals might enjoy a social event but fail to plan another due to diminished anticipatory drive. Thus, while the anhedonia paradox informs emotion-behaviour decoupling, the framework encompasses broader motivational impairments, including social and goal-directed engagement.

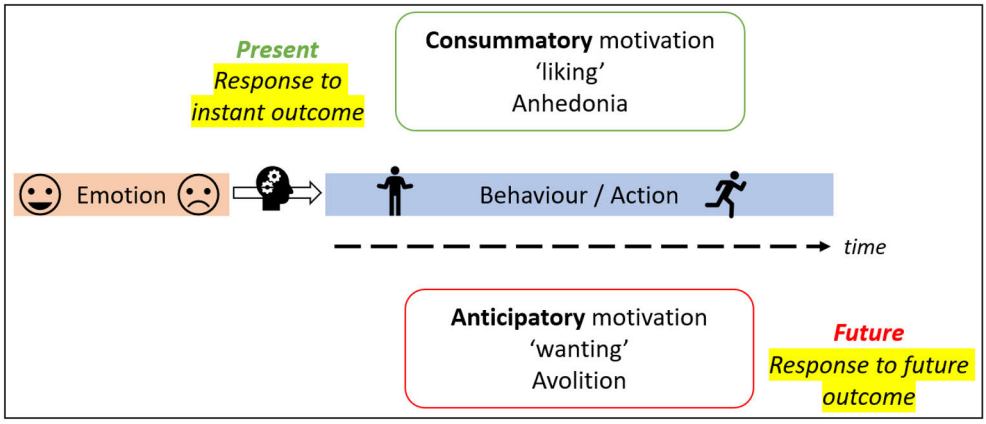


Figure 2. An illustration of the emotion-to-action process.

Anticipatory pleasure, often described as "wanting", involves cognitive and emotional processes that motivate goal pursuit (Sherdell et al., 2012). In schizophrenia, impaired anticipatory pleasure directly contributes to avolition by reducing motivation to initiate rewarding activities, as patients struggle to envision future enjoyment (Gard et al., 2007). This deficit in anticipating rewards, rather than experiencing them, drives the lack of goal-directed behaviour. Avolition creates a self-reinforcing cycle: reduced self-initiated behaviour leads to deteriorated functioning across personal, social, and occupational domains, limiting positive experiences and further entrenching avolition (Foussias & Remington, 2010; see Figure 3). This cycle underscores avolition's pervasive impact and its distinction from anhedonia, which plays a related but distinct role in motivational impairments.

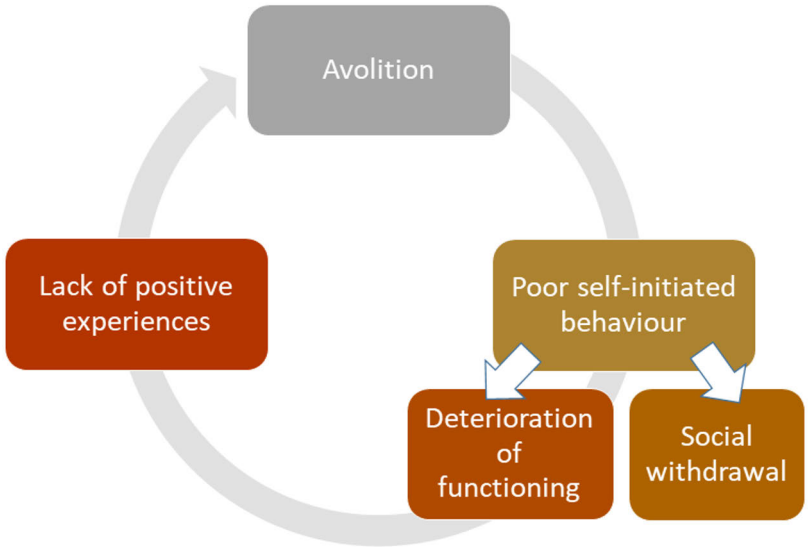


Figure 3. The vicious circle of avolition in schizophrenia.

2.4.2 Potential factors contributing to avolition

The persistence of avolition in schizophrenia is driven by neurobiological, cognitive, and psychological factors, particularly disruptions in anticipatory and consummatory motivation:

- Neurobiological factors: Dopamine dysregulation in mesolimbic pathways, which are critical for anticipatory motivation (Berridge & Robinson, 1998). Reduced ventral striatal dopamine signaling impairs the drive to pursue future rewards, mirroring anticipatory deficits in the anhedonia paradox (Juckel et al., 2006). Functional MRI studies reveal lower striatal activation during reward anticipation tasks in people with schizophrenia compared to controls, correlating with avolition severity (Juckel et al., 2006). Disrupted connectivity between the dorsolateral prefrontal cortex (DLPFC) and limbic regions further hinders action planning, preventing emotions from translating into behaviour (Strauss et al., 2014). However, these findings are limited by an overemphasis on dopamine, as other neurotransmitters, such as serotonin and glutamate, may also play a role but remain less studied. Moreover, the impact of antipsychotic medications complicates interpretations, as they suppress dopamine signaling, necessitating longitudinal studies to isolate primary deficits (Heinz & Schlagenhauf, 2010).
- Cognitive factors: Cognitive impairments, particularly in reward prediction and effort valuation, contribute to avolition (Gold et al., 2013). Individuals with schizophrenia often overestimate the effort required for tasks, for instance perceiving simple chores as overwhelming, which reduces anticipatory

motivation (Gold et al., 2013). In addition, reward prediction errors, where patients misjudge reward likelihood, disrupt anticipatory pleasure, undermining goal pursuit (Heerey & Gold, 2007). Working memory deficits further impair the ability to maintain goals, preventing sustained action toward emotionally salient outcomes (Barch, 2005; Green, 1996).

- Psychological factors: Impaired integration of emotions into behaviour is central to the anhedonia paradox (Kring & Barch, 2014). Gard et al. (2007) argue that low anticipatory motivation, driven by weakened reward expectation, prevents planning (even when the capacity to experience pleasure remains intact). Negative expectations, such as the belief that actions will not receive rewards, further suppress both anticipatory and consummatory motivation, perpetuating avolition (Foussias & Remington, 2010). Emotional ambivalence, such as experiencing mixed feelings about goals, may also reduce motivational drive, although evidence supporting this explanation is limited (Trémeau, 2006).

Given the complex psychopathology of avolition, it remains unclear how the aforementioned factors interact to disrupt anticipatory and consummatory motivation in schizophrenia, ultimately preventing the translation of affective experience into motivated behaviour (Heerey & Gold, 2007; Kring & Elis, 2013). This uncertainty regarding emotion-behaviour decoupling underscores the persistence of avolition and highlights the need for comprehensive approaches to better understand and investigate motivational deficits in schizophrenia (Foussias et al., 2014). Failing to understand how neurobiological, cognitive, and psychological factors drive avolition in schizophrenia may result in ineffective treatments, persistent disability, and increased societal burdens. Unclear mechanisms behind motivational deficits could perpetuate poor functioning, social isolation, and economic costs, while stalling research progress and missing transdiagnostic insights, urging the need for integrated studies to develop targeted interventions.

2.5 Treatment and support for people with schizophrenia

2.5.1 Antipsychotic treatment

Antipsychotic medication is a cornerstone in the management of schizophrenia since the serendipitous discovery of chlorpromazine in the early 1950s, shifting treatment from invasive methods, such as lobotomy and insulin-coma therapy to pharmacological interventions. This evolution reflects significant advancements in psychiatric care, yet challenges remain, particularly in effectively treating negative symptoms (e.g., avolition, anhedonia) and cognitive deficits (Sampogna et al., 2023). A summary of pharmacological treatment for schizophrenia is shown in Figure 4.

The antipsychotic effect is linked to antidopaminergic properties, specifically D2 receptor[1] antagonism (Carlsson & Lindqvist, 1963), leading to the dopamine hypothesis of schizophrenia (Appendix 1). Initially, this hypothesis suggested overall dopamine hyperactivity (Davis et al., 1991), but later iterations introduced regional specificity, linking excess dopamine in subcortical regions to positive symptoms and deficits in cortical areas to negative symptoms and cognitive impairments (Howes & Kapur, 2009). Following chlorpromazine, other first-generation antipsychotics (FGAs) like fluphenazine and haloperidol were developed (Janssen et al., 1960; Ramachandraiah et al., 2009). FGAs work through non-selective D2 receptor antagonism, reducing dopamine neurotransmission and suppressing positive symptoms (Zhang et al., 2013; Monteleone et al., 2021). However, this widespread blockade leads to side effects like extrapyramidal symptoms and hyperprolactinemia, etc. (Grace & Uliana, 2023). In addition, FGAs may exacerbate severe negative symptoms and cognitive deficits by further reducing dopamine activity in the mesocortical pathway (Abi-Dargham & Laruelle, 2005). These significant side effects adversely affect the quality of life for people with schizophrenia, prompting the development of antipsychotic drugs with improved tolerability.

Clozapine, the prototype of second-generation antipsychotics (SGAs; Hippius, 1989), introduced in the 1970s, showed efficacy in improving both positive and negative symptoms (Tandon et al., 1993) with fewer EPS (Gerlach et al., 1996; Miller et al., 1998; Sykes et al., 2017). Subsequent SGAs, such as risperidone and olanzapine, and amisulpride are characterized by dual antagonism of D2 and 5-HT2A receptors[2], potentially improving negative symptoms and cognitive deficits (Li et al., 2016; de Bartolomeis et al., 2013). However, SGAs have varied side effects, including metabolic issues (Kirk et al., 2009; Makary et al., 2023) and hyperprolactinemia (Stojkovic et al., 2022; Peuskens et al., 2014). Other side effects, such as clozapine-specific agranulocytosis (Mijovic & MacCabe, 2020), prolonged QT interval, orthostatic hypotension, and sleep disturbance, have also been reported with SGAs (Mortimer et al., 2023; Tandon et al., 2020; Khasawneh & Shankar, 2014). Moreover, the efficacy of SGAs in improving negative and cognitive symptoms in schizophrenia is still unclear. A meta-analysis (Fusar-Poli et al., 2015) revealed that although SGAs do not exacerbate negative symptoms as some FGAs do, they exhibit only a subtle, non-significant improvement in negative symptoms. Similarly, reports on the improvement of cognitive deficits by SGAs are frequently modest in their effect (Meltzer & McGurk, 1999; Meltzer & McGurk, 2001).

[1] D2 dopamine receptor, a brain protein that regulates movement, motivation, and hormone release by inhibiting neuronal activity in response to dopamine.

[2] 5-HT2A receptor, a serotonin receptor in the brain that plays a major role in mood, perception, and cognition.

Third-generation antipsychotics (TGAs), starting with aripiprazole (FDA-approved in 2002), act as "dopamine system stabilizers" (Kikuchi et al., 2021), modulating dopamine activity to improve positive and negative symptoms, as well as cognitive functioning (Chen et al., 2022). Subsequent TGAs, such as brexpiprazole and cariprazine, also act as partial agonists at D2 and D3 receptors (Frankel & Schwartz, 2017). TGAs generally have reduced metabolic side effects but may cause other issues like nausea and akathisia (Skidmore-Roth, 2024). While some studies suggest TGAs may be more effective for negative symptoms (Earley et al., 2019; Krause et al., 2018), recent findings report no significant improvement, warranting further investigation (Hsu et al., 2017; Tsapakis et al., 2024).

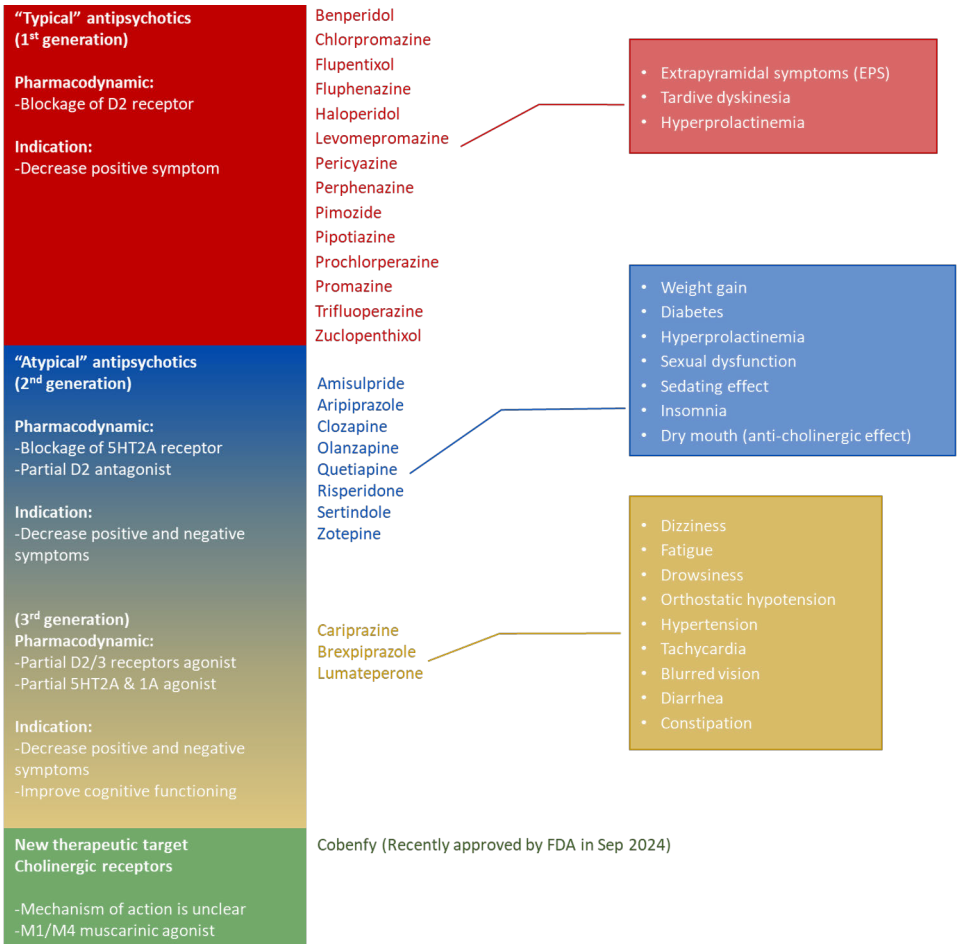


Figure 4. Classes of medication for schizophrenia treatment. The classes of medication are represented by the text box on the left. Each colour indicates different class of drugs: First-generation antipsychotics (FGA) (Red); Second-generation antipsychotics (SGA) (Blue); Third-generation antipsychotics (TGA) (Yellow); Add-on medication (Green). Their corresponding side effects are shown by the text box on the right.

Over the past seven decades, antipsychotics development has become more sophisticated, with improvements in mechanism of action aimed at enhancing efficacy and tolerability. However, negative symptoms and cognitive functioning remain significant unmet needs in the treatment of schizophrenia, as existing antipsychotics yielded mixed results regarding their effectiveness. This underscores the need for novel therapeutic approaches targeting pathways beyond dopamine, for example:

- The *glutamate hypofunction hypothesis* posits that the hypofunction of glutamatergic signalling via NMDA receptors (NMDARs) contributes to schizophrenia symptoms (Olney et al., 1999). This hypothesis is supported by observations that healthy individuals exhibit schizophrenia-like symptoms after exposure to NMDAR antagonists such as ketamine and phencyclidine (Lahti et al., 2001). Enhancing glutamatergic signalling at NMDARs has been explored as a potential therapeutic strategy, especially for negative and cognitive symptoms, with targets such as metabotropic glutamate receptors (mGluRs) and glycine modulators currently under investigation (Dogra & Conn, 2022; Harvey & Yee, 2013; Pei et al., 2021).
- The *cholinergic system* has been proposed in playing a critical role in the pathophysiology of schizophrenia (Raedler & Tandon, 2006). The FDA approved Cobenfy™ in September 2024, the first antipsychotic targeting muscarinic receptors in the cholinergic system (instead of drugs directly targeting the dopamine receptors), offering a new approach for negative and cognitive symptoms (Hasan & Abid, 2024).
- *Neuroinflammation* is involved in the pathophysiology of schizophrenia (Müller, 2018). Elevated levels of cytokines such as IL-6 and TNF-α in blood and cerebrospinal fluid have been observed in patients with schizophrenia (Gallego et al., 2018). Some studies have further found that anti-inflammatory medication could be beneficial in schizophrenia (Sommer et al., 2012).

Taken together, these alternative pathways offer promising directions for the development of novel treatments. Yet, drug development is often a long process. It remains a journey to overcoming the unresolved challenges in treating schizophrenia's negative symptoms and cognitive deficits.

2.5.2 Non-pharmacological interventions

Non-pharmacological interventions are crucial in managing schizophrenia, particularly for drug-resistant negative symptoms and social withdrawal, which significantly impair quality of life and are often inadequately addressed by antipsychotics (Mueser et al., 2013; Fusar-Poli et al., 2015; Galderisi et al., 2018).

These psychological and social interventions, bridge treatment gaps by y fostering motivation, interpersonal skills, and community integration, creating structured, supportive environments that promote cognitive, social, and emotional engagement critical for recovery (Kern et al., 2009; Nibbio et al., 2020), Through structured and supportive settings, they enhance motivation and functional outcomes. Complementing pharmacological treatments, they enhance long-term outcomes (Leucht et al., 2012; Bighelli et al., 2018), mitigate isolation and stigma, and align with clinical guidelines (American Psychiatric Association, 2020; Gaebel et al., 2011). Their effectiveness depends on personalized approaches, innovative patient-centred strategies, and overcoming systemic barriers like resource limitations and access disparities (Mueser et al., 2013; Asher et al., 2017), ultimately fostering independence (Dixon et al., 2015) and reducing reliance on medical systems (Jung & Newton, 2009).

Psychological interventions aim to regulate cognition, emotion, and behaviour to improve symptom management and functioning. These interventions can be categorised into Cognitive and Symptom-Focused Therapies and Interpersonal Functioning Interventions. Examples include psychoeducation, cognitive behavioural therapy (CBT), and cognitive remediation, which enhance understanding and cognitive processes in schizophrenia (Table 2).

Psychoeducation delivers information on symptoms and relapse prevention via sessions, workshops, or multimedia, reducing stigma and improving adherence (Bäuml et al., 2006), and it improves individuals' social and global functioning (Xia et al., 2011). CBT uses cognitive restructuring to alleviate distress induced by positive symptoms (Beck & Rector, 2005), and it contributes to the reduction of delusion and hallucination (Jauhar et al., 2014). Cognitive Remediation employs cognitive exercises to improve attention and memory (Wykes et al., 2011), and it has a better recovery effect when paired with other rehabilitations (van Duin et al., 2019). While these three interventions contribute to the improvement of positive symptoms and cognitive functioning in general, but their impact on negative symptoms is limited, possibly due to the complex neural mechanisms underlying these symptoms (Klingberg et al., 2011; Ventura et al., 2019; Mäkinen et al., 2008). In addition, common barriers for implementations include limited impact on patients with severe symptoms, and also resource consuming (Cella et al., 2017; Ince et al., 2016).

Interpersonal Functioning Interventions, such as Family Intervention and Social Skills Training, enhance social competence and reduce relational stress. Family Intervention fosters communication and supportive networks, integrating CBT and motivational techniques, while Social Skills Training improves interaction skills through role-playing (Pharoah et al., 2010; Almerie et al., 2015). Both reduce relapse and improve relationships, with Social Skills Training modestly addressing social withdrawal (Turner et al., 2018; McDonagh et al., 2017). Meta-analysis (Kurtz &

Mueser, 2008) revealed that interpersonal functioning interventions generally achieve a moderate effect (d = 0.47) on reducing negative symptoms in schizophrenia, and their effectiveness depends on family or group participation, which logistical barriers or patient disengagement may hinder the therapeutic progress. These interventions are adaptable but require sustained effort, limiting outcomes in low-resource settings or for isolated patients (American Psychiatric Association, 2020).

A summary of different psychological interventions is described in Table 2.

Table 2. Common psychological interventions for schizophrenia.

Type	Intervention	Description	Benefit	Barrier
Cognitive & symptom-focused	Psychoeducation	Provides information about schizophrenia to patients and families to improve understanding of the illness.	Promotes treatment adherence, reduces stigma, and helps prevent relapse.	May not address deeper psychological or functional issues; effectiveness depends on the participant's willingness to engage.
	Cognitive behavioural therapy	Targets maladaptive thoughts and behaviours to improve coping and reduce symptoms like delusions and hallucinations.	Improves symptom management, enhances coping mechanisms, and reduces distress.	Requires trained therapists; not all patients respond equally; may not address cognitive deficits.
	Cognitive remediation	Focuses on improving cognitive skills such as memory, attention, and problem-solving through structured exercises.	Enhances cognitive functioning, which can improve daily life and social outcomes	Time-intensive; effects may take weeks or months to manifest; requires consistent participation.
Interpersonal functioning	Family intervention	Engages family members in supporting the patient through education, emotional support, and problem-solving training.	Reduces relapse rates, improves family relationships, and lowers caregiver stress.	Requires family commitment and participation; can be emotionally taxing for participants.
	Social skill training	Uses role-playing, modelling, and real-world practice to improve social and interpersonal skills.	Enhances social functioning, reduces isolation, and fosters community integration.	May not generalize well to real-life situations; requires repeated practice for lasting benefits.

Social interventions promote community integration, autonomy, and empowerment by addressing social, vocational, and self-management needs, including Supported Employment Services (SES), Coordinated Specialty Care (CSC), and Self-Management and Recovery-Focused Interventions (Mueser et al., 2013; Dixon et al., 2015; Table 3).

SES supports vocational self-sufficiency through competitive job placement, job coaching, and ongoing assistance, enhancing employment outcomes, social connectedness, and mental health, with modest benefits for negative symptoms like social withdrawal (Becker & Drake, 2003; Frederick & VanderWeele, 2019; Luciano et al., 2014). Its alignment with career goals is a key strength, but employer stigma and limited resources pose barriers, particularly for patients with severe avolition (Tsang et al., 2010).

Coordinated Specialty Care (CSC) and Self-Management and Recovery-Focused Interventions provide holistic case management with distinct approaches to enhance recovery in schizophrenia. CSC employs multidisciplinary teams, including caseworkers, psychiatrists, and therapists, to deliver integrated services such as psychotherapy, medication management, family education, and vocational support, achieving significant reductions in symptoms and improved social and occupational functioning, particularly in early psychosis (Kane et al., 2016; Correll et al., 2018). Self-Management empowers clients through personalised goal-setting, coping skill development, and peer-led support groups, fostering autonomy, self-efficacy, and quality of life by encouraging active participation in recovery (Lean et al., 2019; Thomas et al., 2018). Both interventions reduce relapse rates, with CSC's strength lying in its structured, team-based coordination and Self-Management's in its client-centred focus that promotes long-term engagement. The success of both interventions varies due to challenges in addressing negative symptoms like avolition, which require sustained patient motivation, as well as factors such as resource availability, access to trained caseworkers, and the scalability of programs in underfunded or rural healthcare settings (Mueser et al., 2013; Rosenheck et al., 2017; Kidd et al., 2014).

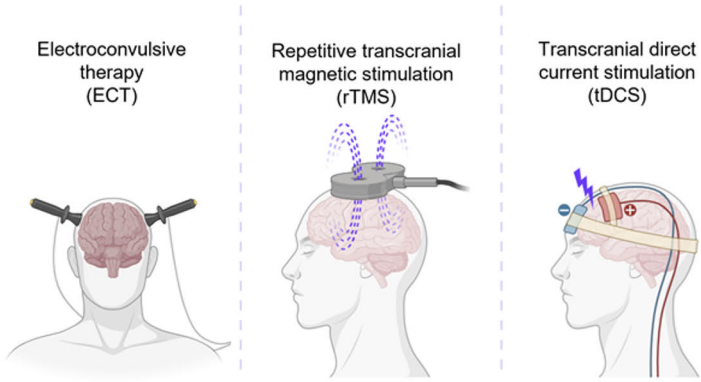
A summary of different social interventions is described in Table 3.

Table 3. Common social interventions for schizophrenia.

Intervention	Description	Benefit	Barrier
Supported employment service	Helps individuals find and maintain meaningful employment through vocational training, job placement, and workplace support.	Promotes self-sufficiency, improves quality of life, and fosters a sense of purpose.	Jobs may be difficult to secure or sustain in competitive markets; stigma in the workplace can be a barrier.
Coordinated specialty care program	Team-based approach, integrating therapy, medication, family support, and education/employment assistance.	Improves clinical outcomes, enhances functional recovery, and reduces long-term disability	Requires significant resources and multidisciplinary staff; accessibility may be limited in low-resource areas.
Self-management & recovery-focused interventions	Empowers individuals to manage their care through goal setting, symptom tracking, and coping strategies.	Fosters autonomy, builds resilience, and supports long-term recovery.	Relies heavily on patient engagement, which may be challenging for individuals with severe symptoms or low motivation.

2.5.3 Neurostimulation

Neurostimulation techniques are being explored for schizophrenia, particularly for treatment-resistant cases, targeting positive, negative, and cognitive symptoms by modulating dysfunctional neural circuits (Dokucu, 2015). These methods offer alternatives or complements to pharmacotherapy, with varying mechanisms and applications (Figure 5).



Invasiveness	Invasive	Non-invasive	Non-invasive
Mechanism	Induces generalized seizures via electrical currents	Uses magnetic pulses to stimulate specific brain regions	Applies a weak electrical current to the scalp
Side Effects	Confusion, memory problems	Mild headaches, scalp discomfort	Mild skin irritation, headaches
Neuro-navigation	Limited	Limited, if without neuro-navigation systems	Limited
Efficacy in reducing negative symptoms	Limited	Improvements in depressive symptoms can reduce associated negative symptoms	Mixed results

Figure 5. An overview of the characteristics of neurostimulation modalities for schizophrenia. *Created using BioRender.com.*

Electroconvulsive therapy (ECT), introduced in 1938 by Ugo Cerletti and Lucio Bini, involves passing controlled electrical currents through the brain to trigger brief seizures (Gazdag & Ungvari, 2019). Initially used for schizophrenia, it was largely replaced by antipsychotics in the 1950s (de Mangoux et al., 2022). ECT is thought to alter neurotransmitter levels, enhance neuroplasticity, and modulate neural circuits involved in mood, psychosis, and cognition (Singh & Kar, 2017). It is highly effective for positive symptoms like hallucinations and delusions, particularly in treatment-resistant schizophrenia (Chanpattana & Andrade, 2006; Matheson et al., 2010; Zervas et al., 2012). However, side effects such as temporary memory loss and learning impairment limit its use (Porter et al., 2020). Modern ECT, administered under anesthesia with muscle relaxants, is safer but has limited efficacy for negative symptoms, with some studies showing modest improvements (Remington et al., 2017; Tan et al., 2022).

Since the 1990s, non-invasive brain stimulation (NIBS) techniques like transcranial magnetic stimulation (TMS) and transcranial direct current stimulation (tDCS) have emerged as less invasive alternatives to traditional neurostimulation, avoiding surgical implants (Bhattacharya et al., 2022). NIBS modulates neural

activity in brain regions linked to cognitive, affective, and motivational deficits in schizophrenia (Aleman et al., 2018; Osoegawa et al., 2018).

TMS uses electromagnetic induction to generate electric currents in targeted brain regions, with a scalp-placed coil delivering magnetic pulses to excite or inhibit cortical neurons (Barker et al., 1985). Repetitive TMS (rTMS), involving multiple pulses per session, is widely studied for psychiatric disorders (George et al., 1995; Lefaucheur et al., 2014). It shows moderate efficacy for negative symptoms, with effect sizes of 0.53-0.63 (Shi et al., 2014). A meta-analysis (Lorentzen et al., 2022) indicated that rTMS reduces negative symptoms, particularly motivational deficits. Variants like intermittent theta burst stimulation (iTBS) and deep TMS (dTMS) are also promising (Cheng et al., 2023; Kishi et al., 2024; Poorganji et al., 2023), with a study highlighted that iTBS significantly reduced negative symptoms after 20 sessions (Bation et al., 2021). TMS is safe, well-tolerated, and has minimal side effects, making it a viable option for schizophrenia (Blyth et al., 2025).

tDCS applies a weak electrical current (1-2 mA) through scalp electrodes, with anodal stimulation enhancing neuronal firing and cathodal stimulation reducing it (Nitsche et al., 2008; Stagg & Nitsche, 2011). This bidirectional modulation targets dysfunctional neural circuits in schizophrenia, particularly in the dorsolateral prefrontal cortex (DLPFC) and temporoparietal junction (TPJ), which associate to cognitive deficits and hallucinations (Gomes et al., 2018). A recent meta-analysis found small-to-moderate effects across these domains, with greater consistency for positive symptoms when paired with cognitive training (Kim et al., 2019). Negative symptom improvements vary, often requiring multiple sessions (10-20) over weeks (Valiengo et al., 2020). Cognitive benefits, like improved attention, are promising but depend on standardized protocols. tDCS is portable, cost-effective, and safe, with minor side effects like scalp tingling or redness (Brunoni et al., 2011). Unlike TMS, tDCS devices are compact and suitable for outpatient or supervised home use (Charvet et al., 2015). However, its weaker stimulation may limit efficacy for deeper brain structures or severe symptoms (Esmaeilpour et al.,

Current neurostimulation techniques show mixed efficacy for reducing negative symptoms in schizophrenia. ECT is effective for positive symptoms but has negligible effects on negative symptoms (e.g., avolition) due to its non-specific neural circuits (Tan et al., 2022). rTMS and iTBS demonstrate moderate potential for negative symptoms by enhancing DLPFC activity, though effects are inconsistent and short-lived (Lorentzen et al., 2022; Bation et al., 2021). tDCS offers small benefits for avolition when targeting motivational circuits, but results are varied (Kim et al., 2019). While TMS and tDCS are the most promising, no modality consistently reduces negative symptoms, highlighting the need for refined protocols and larger clinical trials (Aleman et al., 2018).

2.6 Assessments for negative symptoms

2.6.1 Clinical assessments

The assessment of negative symptoms is a critical component in the diagnosis and management of schizophrenia (Marder & Kirkpatrick, 2014). Negative symptoms, are often subtle and internalized, making them challenging for individuals to self-identify (Correll & Schooler, 2020). Clinical assessments, conducted by trained clinicians, provide valid and reliable evaluations through observations and structured or semi-structured interviews, typically lasting 15 to 45 minutes, depending on the instrument (Table 4). These assessments are essential for evaluating symptom severity, developing treatment plans, and monitoring progress.

Since the 1960s, well-validated clinical instruments have been developed to measure negative symptoms, many of them remain in global use. Early assessments primarily evaluate a broad range of schizophrenia symptoms, limiting specific and detailed evaluation of negative symptoms. For instance, the Brief Psychiatric Rating Scale (BPRS; Overall & Gorham, 1962), was one of the first tools to assess both positive symptoms (e.g., hallucinations, grandiosity) and negative symptoms (e.g., blunted affect, uncooperativeness) alongside general psychopathologies (e.g., anxiety, depression). Building on the construct of the BPRS, the Positive and Negative Syndrome Scale (PANSS; Kay et al., 1987) expanded to 30 items, offering a more comprehensive evaluation of schizophrenia symptoms. These assessments provided a broad mental health profile but lacked specificity for negative symptoms.

In the 1980s, a paradigm shift recognized negative symptoms as a distinct domain, leading to the development of clinical tools targeting negative symptoms. The Scale for the Assessment of Negative Symptoms (SANS; Andreasen, 1982) marked a significant advance by focusing on the characteristics of the five core negative symptoms. The Negative Symptom Rating Scale (NSRS; Iager et al., 1985) incorporated cognitive tasks (e.g., word recall) and decision-making prompts (e.g., spending gift cash) to assess judgment and attention, though it remained behaviour-focused. These tools provided clinicians with structured frameworks to observe and track visible signs of negative symptoms. Later, the Negative Symptom Assessment-16 (NSA-16; Alphs et al., 1989) addressed the overreliance on observable behaviours by incorporating semi-structured interviews to probe subjective states, such as future-plans and motivation, offering deeper insights into internal experiences.

The proliferation of diverse measurement tools has provided varied definitions of negative symptoms, advancing clinicians' understanding of patients' mental conditions and daily challenges in managing schizophrenia. However, this diversity has also created inconsistencies in clinical assessments, complicating efforts to standardize diagnosis and treatment (Kirkpatrick et al., 2006). The 2006 NIMH-MATRICS consensus unified

negative symptoms into five core domains, leading to the development of the Brief Negative Symptom Scale (BNSS; Kirkpatrick et al., 2011) and Clinical Assessment Interview for Negative Symptoms (CAINS; Horan et al., 2011).

The BNSS (Kirkpatrick et al., 2011) distinguishes between anticipatory and consummatory anhedonia, as well as internal experience versus behaviour, providing a nuanced assessment. The CAINS (Kring et al., 2013) categories negative symptoms into two factors: motivation and pleasure (MAP; e.g., expected pleasure from work, family) and expression (EXP; e.g., vocal prosody). The MAP subscale evaluates independent living and family functioning, enabling clinicians to assess patients' desires for relationships and community engagement (Blanchard et al., 2017). Both BNSS and CAINS reduce reliance on observable behaviours, offering more objective measures of avolition and achieving satisfactory internal consistency and convergent validity (Kring et al., 2013).

The key clinician-rated assessments are described in Table 4.

Table 4. Clinician-rated assessments for negative symptoms in schizophrenia.

INSTRUMENT	MODE OF ADMINISTRATION	SUBSCALES	NUMBER OF ITEMS, SCALE
Brief Psychiatric Rating Scale (BPRS, Overall & Gorham, 1962)	Clinical observation and semi-structured interview (15-30 mins)	• Positive symptoms (6 items) • Negative symptoms (6 items) • Other psychopathologies (6 items)	18 items 8-point Likert scale
Positive and Negative Syndrome Scale (PANSS, Kay et al., 1987)	Semi-structured interview with observation (30-40 mins), often incorporating informant questionnaire	• Positive symptoms (7 items) • Negative symptoms (7 items) • General psychopathology (16 items)	30 items 7-point Likert scale
Scale for the Assessment of Negative Symptoms (SANS, Andreasen, 1982)	Primarily clinical observation, with optional brief interview	• Affective Flattening (8 items) • Alogia (5 items) • Avolition/Apathy (4 items) • Anhedonia/Asociality (5 items) • Attention (3 items)	25 items 7-point Likert scale
Negative Symptom Rating scale (NSRS, Iager et al., 1985)	Combining observation and structured tasks (20-30 mins), including cognitive and decision-making prompts	• Thought processes (2 items) • Cognition (3 items) • Volition/motivation (3 items) • Affect/Relatedness (2 items)	10 items 7-point Likert scale

INSTRUMENT	MODE OF ADMINISTRATION	SUBSCALES	NUMBER OF ITEMS, SCALE
Negative Symptom Assessment -16 (NSA-16, Alphs et al., 1989)	Semi-structured interview with observational components (15-25 mins)	• Communication (4 items) • Emotional/Affect (3 items) • Social involvement (3 items) • Motivation (4 items) • Retardation (2 items)	16 items 7-point Likert scale
Clinical Assessment Interview for Negative Symptoms (CAINS, Horan et al., 2011)	Semi-structured interview (15-20 mins) with minimal observation	• Motivation and Pleasure (9 items) • Expression (4 items)	13 items 5-point Likert scale
Brief Negative Symptom Scale (BNSS, Kirkpatrick et al., 2011)	Semi-structured interview (15-20 mins) using a manualized protocol	• Anhedonia (3 items) • Lack of normal distress (1 item) • Asociality (2 items) • Avolition (2 items) • Blunted affect (3 items) • Alogia (2 items)	13 items 7-point Likert scale

2.6.2 Self-reported questionnaires

Self-report instruments, though less reliable than clinician-rated assessments, uniquely capture the subjective experiences of individuals with schizophrenia, such as diminished motivation and emotional disconnection. These tools offer critical insights into internal states often overlooked by observation or interviews, complementing behavioural assessments (Kirkpatrick et al., 2006). They are essential for understanding core negative symptoms and their impact on patients' lives (see Table 5 for instrument details).

Starting in the 1980s, self-report scales were developed to assess negative symptoms efficiently. Early tools, such as the Subjective Deficit Syndrome Scale (SDSS; Jaeger et al., 1990), Self-Evaluation of Deficit Scale (SEDS; Liddle & Barnes, 1988), and Community Assessment of Psychic Experience (CAPE; Stefanis et al., 2002), took a broad approach, measuring multiple symptom domains. For example, SDSS targets motivation and anhedonia but includes unrelated constructs like insomnia, reducing its specificity (Jaeger et al., 1990). CAPE, adapted from the Scale for the Assessment of Negative Symptoms (SANS), assesses anhedonia and asociality but shows weak correlations with clinician-rated PANSS scores, particularly for avolition and blunted affect, highlighting discrepancies between patient and clinician perspectives (Stefanis et al., 2002). These broad scales, while

time-efficient, struggle to distinguish specific negative symptom domains, limiting their precision.

To address the limitations of global scales, newer instruments target specific negative symptom domains. The Subjective Experience of Negative Symptoms (SENS; Selten et al., 1993), an interview-based tool derived from SANS, was an early attempt to assess subjective deficits, including attention and memory (Selten et al., 1993). More recent tools, such as the Motivation and Pleasure Scale–Self-Report (MAP-SR; Llerena et al., 2013), Self-Evaluation of Negative Symptoms (SNS; Dollfus et al., 2016), and Negative Symptoms Inventory–Self-Report (NSI-SR; Raugh et al., 2023), adopt a two-factor model focusing on motivation/pleasure deficits and diminished expression. MAP-SR, adapted from the Clinical Assessment Interview for Negative Symptoms (CAINS), emphasizes motivation and pleasure due to the poor reliability of expression items (Llerena et al., 2013). A systematic review highlights MAP-SR and SNS for their comprehensive assessment of motivation and anhedonia, though NSI-SR's limited validation reduces its reliability (Métivier & Dollfus, 2025).

Parallel to schizophrenia-specific tools, subdomain-focused instruments assess specific negative symptom aspects across disorders. Early scales, like the Physical and Social Anhedonia Scale (PAS/SAS; Chapman et al., 1976), and SAS's revision, the Revised Social Anhedonia Scale (RSAS; Eckblad et al., 1982), targeted physical and social anhedonia. The Snaith-Hamilton Pleasure Scale (SHAPS; Snaith et al., 1995), originally for depression, was adapted for schizophrenia to measure impaired pleasure (Jarratt-Barnham et al., 2020). Building on the two-factor model (Blanchard & Cohen, 2006), the Temporal Experience of Pleasure Scale (TEPS; Gard et al., 2006) and Anticipatory and Consummatory Interpersonal Pleasure Scale (ACIPS; Gooding & Pflum, 2014) distinguish anticipatory and consummatory pleasure, with TEPS focusing on perceptual aspects and ACIPS on social interactions (Gard et al., 2006; Gooding & Pflum, 2014). These distinctions clarify the role of pleasure anticipation in avolition, enhancing mechanistic understanding (Gard et al., 2007).

Self-report instruments engage individuals with schizophrenia in their assessment, fostering a patient-centred approach. They reveal subjective challenges that clinician-rated evaluations may overlook, improving diagnostic precision. The two-factor model in domain-specific and subdomain-focused tools provides a multidimensional perspective, refining clinical insights. Combining self-report and clinician-rated measures balances objective observations with patients' lived experiences, optimizing the evaluation of negative symptoms (Métivier & Dollfus, 2025).

A list of self-reported instruments is outlined in Table 5.

Table 5. Examples of self-reported instruments assessing negative symptoms.

Instrument (short name, author(s), year)	Subscales	Total number of items, scale
Subjective experience of deficits in schizophrenia (SEDS, Liddle & Barnes, 1988)	• Thinking (6 items) • Emotion (4 items) • Drive (3 items) • Perception (4 items) • Strain (3 items) • Miscellaneous (1 item)	21 items (6 for negative symptoms) 5-point Likert scale
Subjective deficit syndrome scale (SDSS, Jaeger et al, 1990)	• Amotivation • Anhedonia • Blunted affect	19 items (3 for negative symptoms) Dichotomous questions 4-point Likert scale for rating existing symptoms
Community Assessment of Psychic Experiences (CAPE, Stefanis et al., 2002)	• Positive symptoms (20 items) • Negative symptoms (14 items) • Depressive symptoms (8 items)	42 items 4-point Likert scale
Subjective experience of negative symptoms (SENS, Selten et al., 1993)	• Affective flattening (7 items) • Alogia (4 items) • Avolition-apathy (5 items) • Anhedonia-asociality (8 items) • Attention (2 items)	24 items Interview-based self-rating 5-point Likert scale
Motivation and pleasure scale—self-report (MAP-SR, Llerena et al, 2013)	• Social pleasure (3 items) • Recreational or work pleasure (9 items) • Motivation & effort to engage in activities (6 items)	18 items 5-point Likert scale
Self-evaluation of Negative Symptoms (SNS, Dollfus et al, 2016)	• Social withdrawal (4 items) • Avolition (4 items) • Anhedonia (4 items) • Diminished emotional range (4 items) • Alogia (4 items)	20 items 3-point Likert scale
Negative Symptoms Inventory Self-Report (NSI-SR, Raugh et al., 2023)	• Behavioural items (9 items) • Internal experience (8 items) (Anhedonia, Avolition, Asociality, Lack of normal distress)	17 items Frequency (days/week) for behavioural items; 10-point Likert scale for internal experience
Physical and Social Anhedonia Scale (PAS/SAS, Chapman et al., 1976)	• Physical and Social Anhedonia	PAS: 61 items SAS: 40 items Dichotomous (true/false)

Instrument (short name, author(s), year)	Subscales	Total number of items, scale
Revised Social Anhedonia Scale (RSAS, Eckblad et al., 1982)	• Social Anhedonia	40 items Dichotomous (true/false)
Snaith–Hamilton-Pleasure-Scale (SHAPS, Snaith et al., 1995)	• Pleasure	14 items 4-point Likert scale
Self-Assessment Anhedonia Scale (SAAS, Olivares et al., 2005)	• Anhedonia	27 items 3-point Likert scale
Apathy Evaluation Scale (AES, Marin et al., 1991)	• Apathy	18 items 4-point Likert scale
Temporal Experience of Pleasure Scale (TEPS, Gard et al., 2006)	• Anticipatory and consummatory pleasure	18 items 6-point Likert scale
Anticipatory and Consummatory Interpersonal Pleasure Scale (ACIPS, Gooding & Pflum, 2014)		17 items 6-point Likert scale

2.6.3 Behavioural experiments

Assessing avolition is challenging due to the specificity of its complex psychological processes (Green & Horan, 2015). Several behavioural paradigms have been employed to investigate volitional deficits, but most fall short in capturing the nuanced distinction between anticipatory and consummatory pleasure. For instance, the Effort-Expenditure for Rewards Task (EEfRT) evaluates effort-based decision-making by asking participants to choose between high-effort, high-reward and low-effort, low-reward tasks, focusing on reward sensitivity and cost-benefit analysis (Treadway et al., 2009). Similarly, the Progressive Ratio Task measures motivation by increasing the effort required to obtain a reward, assessing the breakpoint at which participants cease responding (Barch et al., 2014). However, these tasks primarily gauge general motivational effort and do not specifically disentangle the temporal aspects of pleasure (anticipatory vs. consummatory).

The debate on volitional deficits in schizophrenia, which stems from the impairment in anticipatory pleasure but not in in-the-moment (consummatory) pleasure, has not been fully resolved. Initial empirical evidence relying on self-report questionnaire (e.g., Temporal Experience of Pleasure Scale, TEPS) yielded inconsistent results (Da Silva et al., 2017; Frost & Strauss, 2016; Visser et al., 2020),

but the development of an objective behavioural assessment named the Anticipatory and Consummatory Pleasure (ACP) task has addressed this limitation (Heerey & Gold, 2007). The task was designed to measure the vigour of motivated behavioural response driven by affective stimuli (Figure 6). It indexes two key aspects of emotion–behaviour coupling (i.e., anticipatory vs. consummatory motivation). By differentiating these components, it tests the hypothesis that schizophrenia impairs anticipatory but not consummatory pleasure, offering a precise and reliable tool to elucidate volitional deficits. Its real-time, behavioural- focus minimises reliance on subjective reports, making the ACP task superior for dissecting the complex motivational impairments in avolition and strengthening the understanding of negative symptoms in schizophrenia.

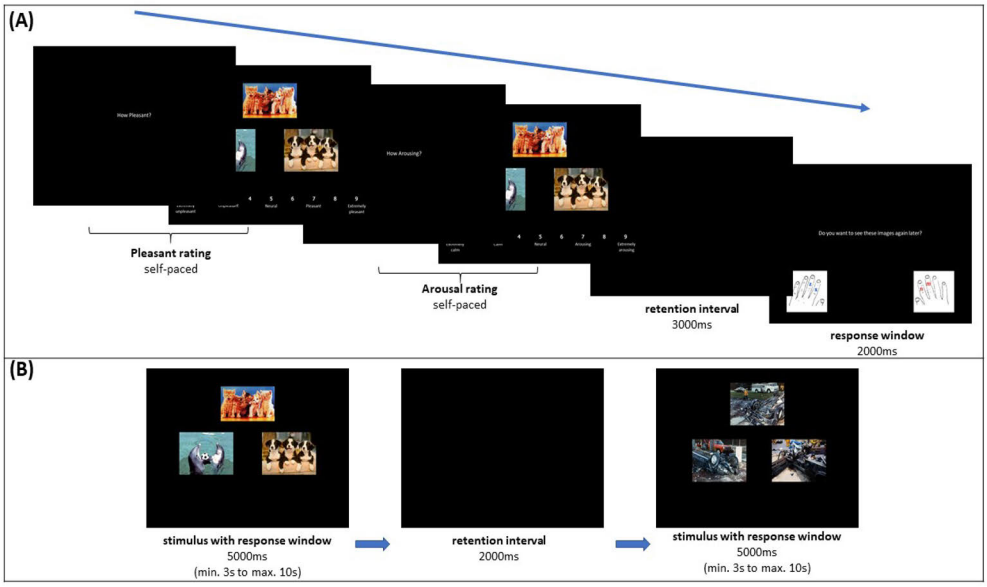


Figure 6. The task paradigm of ACP task, showing the Anticipatory Phase (A) and the Consummatory Phase (B).

2.7 Current research on emotion-behaviour decoupling in schizophrenia

2.7.1 ACP studies in schizophrenia

In the seminal study, Heerey and Gold (2007) concluded that people with schizophrenia demonstrated a preferential impairment in the regulation of anticipatory emotion-behaviour coupling by two findings:

1. Affect-driven effortful behaviour was weaker (i.e., emotion-behaviour decoupling) among people with schizophrenia (their Figure 4).
2. People with schizophrenia exhibited responses to neutral stimuli that were excessively inappropriate (their Figure 3).

The first finding has been consistently confirmed in individuals with acute or chronic schizophrenia (Chu et al., 2020; Lui et al., 2016a; Wang et al., 2020; Xie et al., 2017) and is commonly regarded as evidence for decoupling between affective experience and motivated behaviour. However, the notion of a specific impairment in anticipatory responses in schizophrenia has been challenged by more recent research. Lui et al. (2016a) and Xie et al. (2017) both identified a preferential deficit in consummatory responses, while Chu et al. (2020) found similar impairments in both responses. The latter finding regarding inappropriate reactions to neutral stimuli by individuals with schizophrenia seems to lack consistency. Such disinhibited responses were not present (Chu et al., 2020), observed similarly in both response types (Lui, et al., 2016a; Lui, et al., 2016b), or more prominently expressed in evoked or consummatory responses (Xie et al., 2017). Taken together, the above ACP findings do not agree the conclusion that anticipatory emotion-behaviour coupling is selectively or preferentially impaired in SZ (Table 6).

In previous ACP studies, a computational approach was used to measure the alignment between subjective pleasantness ratings and motivated behaviour, referred to as "correspondence" (see Table 6). This method involved calculating the correlation between pleasantness ratings and the frequency of key presses per second within two valence categories: Undesirable (ratings: 1–3) and Desirable (ratings: 7–9). To meet the assumption of normality required for subsequent analyses, Fisher's transformation was applied to convert the correlation coefficients into z-scores, which were then analysed using a 2 (Group) × 2 (Phase) ANOVA. However, this computational approach has significant limitations that may result in information loss. First, the "correspondence" method excludes the indifference category (ratings: 4–6), which Heerey and Gold (2007) identified as crucial for detecting selective emotion-behaviour decoupling in anticipatory responses among individuals with schizophrenia. Second, it considers only three ratings per valence category (1–3 for undesirable and 7–9 for desirable), which can lead to substantial data loss if participants provide limited subjective ratings (e.g., consistently rating 8). These limitations may explain mixed findings across studies. For instance, Lui et al. (2016a) reported a significant Group × Phase interaction using this method, though their results contradicted those of Heerey and Gold (2007). Conversely, Xie et al. (2017) and Wang et al. (2020) found non-significant results, while Lui et al. (2016b) and Chu et al. (2020) did not report correlations between subjective valence ratings and response vigour. These findings highlight the need for alternative computational

approaches that capture the full spectrum of valence ratings to better index emotion-behaviour coupling.

A summary of previous ACP studies on schizophrenia is presented in Table 6.

2.7.2 The relationship between emotion-behaviour coupling and working memory

The relationship between emotion-behaviour coupling and working memory

ACP studies have also explored the effect of working memory in emotion–behaviour coupling in schizophrenia. The initial findings from Heerey and Gold (2007) highlighted the relationship between emotion–behaviour decoupling (particularly in anticipatory responses) and working memory impairment in schizophrenia. However, the reported results were unclear, as the correlation analysis combined data from both the schizophrenia and healthy control groups. This approach might have been influenced by the concurrent deficits observed in both emotion–behaviour coupling and working memory among people with schizophrenia compared to healthy controls. Subsequent ACP studies by Lui et al. (2016a) found no difference in emotion–behaviour decoupling during anticipatory responses when comparing participants with and without poor working memory in schizophrenia. Instead, they proposed that intact working memory was linked to stronger consummatory emotion-behaviour decoupling in schizophrenia. Chu et al. (2020) also did not identify any effect of working memory on emotion–behaviour coupling, although they noted a loss of the 3-way interaction (i.e., motivational salience).

Table 6. A summary of ACP studies (in chronological order).

Authors (year)	Sample group (with healthy controls)	Clinical & intelligence assessments[a]	Other assessments[b]	Motivational salience* 3-way interaction	Correspondence** 2-way interaction	Main findings***
Heerey & Gold (2007)	41 SZ	BPRS, SANS	CPAS, CSAS, LNS, SS	+	+	ANT>CON
Lui et al. (2016a)	72 first-episode SZ	PANSS, WAIS-R	LNS	-	+	CON>ANT
Lui et al. (2016b)	25 chronic SZ	SCID-I. PANSS, WAIS-R	-	-	N/A	Con>ANT
Lui et al. (2016b)	27 early SZ			+	N/A	
Xie et al. (2017)	65 SZ	DSM-IV, PANSS, WAIS-R	LNS	-	-	CON>ANT
Chu et al. (2020)	26 SZ inpatients	PANSS, SANS, WAIS-R	EEfRT, LNS	-	N/A	ANT~CON
Chu et al. (2020)	27 SZ outpatients			-	N/A	
Wang et al. (2020)	42 SZ	PANSS. SANS, HRSD-17, MDQ, WAIS-R	CPAS, RCSAS, ACIPS, TEPS, LNS	+	-	ANT>CON
Lui et al. (2023)	127 first-episode SZ	PANSS, CAINS, WAIS-R, SAPS, MADRS	TEPS, EES, SOFAS, PAS	N/A	+	ANT>CON

Note. *The 3-way interaction refers to Desirability × Group × Phase. **The 2-way interaction refers to Group × Phase. '+' indicates a statistically significant interaction effect ($p < 0.05$), while '-' indicates a non-significant effect ($p > 0.05$). N/A = data unavailable. ***The main findings summarize the emotion-behaviour decoupling in the schizophrenia group. '>' indicates stronger emotion-behaviour decoupling, and '~' indicates a comparable deficit across both phases. ANT = anticipatory affective motivation; CON = consummatory affective motivation.

[a] Clinical and intelligence assessments: BPRS = Brief Psychiatric Rating Scale, SANS = Scale for the Assessment of Negative Symptoms, PANSS = Positive and Negative Syndrome Scale, WAIS-R = Wechsler Adult Intelligence Scale-Revised, SCID-I = Structured Clinical Interview for DSM-IV Axis I Disorders, HRSD-17 = 17-item Hamilton Rating Scale for Depression, MDQ = Mood Disorder Questionnaire, CAINS = Clinical Assessment Interview for Negative Symptoms, SAPS = Scale for the Assessment of Positive Symptoms, MADRS = Montgomery-Åsberg Depression Rating Scale.

[b] Other assessments: CPAS = Chapman Physical Anhedonia Scale, RCSAS = Revised Chapman Social Anhedonia Scale, LNS = Letter-Number Span, SS = Spatial Span, EEfRT = Effort Expenditure for Rewards Task, ACIPS = Anticipatory and Consummatory Interpersonal Pleasure Scale, TEPS = Temporal Experience of Pleasure Scale, EES = Emotion Expressivity Scale, SOFAS = Social and Occupational Functioning Assessment Scale, PAS = Premorbid Adjustment Scale.

2.7.3 Transdiagnostic ACP studies in people with schizotypal traits

Transdiagnostic research examining the ability of ACP task to detect early psychosis and identify individuals at risk has provided some evidence that ACP deficits may serve as a behavioural endophenotype of schizophrenia. For example, Xie et al. (2017) found schizophrenia-like deficits in the ACP task among unaffected first-degree relatives of people with schizophrenia. However, findings on the task's sensitivity to schizotypal personality traits in the general population have been inconsistent. While Xie et al. (2017) reported ACP deficits in individuals with strong schizotypal traits, Lui et al. (2016b) found no such impairments. The generalisation of ACP findings from schizophrenia spectrum disorder to schizotypal traits would represent a significant extension, reinforcing the concept of schizotypy as "a unifying construct for linking a broad continuum of clinical and subclinical manifestations" (Kwapil & Barrantes-Vidal, 2015). This is particularly relevant to the negative schizotypy dimensions, namely 'interpersonal' and 'disorganisation' latent factors. However, current evidence supporting this hypothesis is currently limited, with data available from only two studies conducted by Lui et al., (2016b) and Xie et al. (2017). Notably, both studies employed an extreme group approach in college student samples.

The first study by Lui et al. (2016b) compared high negative schizotypy and low negative schizotypy group (n = 31 vs. 28). These groups were defined as scoring one standard deviation (SD) above or below the mean of the Scales for Physical and Social Anhedonia (Chapman et al., 1976) from a sample of 1,863 college students. The result found no significant differences between the two groups and ACP performances. In a subsequent study, Xie et al. (2017) used a stringent criterion for the high negative schizotypy group, formed by 1.96 SD above the mean score on the Chapman's Social Anhedonia Scale (SAS) from a larger sample of 2,994 college students. However, the criterion for the comparison control group was flexible, consisting of individuals with below-average SAS scores. This design revealed significant group differences, resulting a weaker emotion-behaviour coupling in the high negative schizotypy group. Xie et al. (2017, pp1480) believed that negative schizotypy, as assessed by severe social anhedonia, was related to emotion-behaviour decoupling. They also suggested that the failed observation in Lui et al. (2016b) was due to insufficient extreme criteria for defining the high schizotypy group.

Xie et al.'s (2017) conclusions with ignorance of Lui et al.'s (2016b) findings, remain controversial. The reliance on an extreme group approach in these studies has been increasingly criticized (e.g., Cohen, 1983; Irwin & McClelland, 2003; MacCallum et al., 2002; Preacher et al., 2005). A major limitation of this approach is its inability to provide a dimensional perspective on the relationship between

schizotypal traits and emotion-behaviour decoupling across the schizotypy continuum in general population. By focusing only on the extremes, Lui et al. (2016b) and Xie et al. (2017) excluded about 97–98% of their initial sample, overlooking the centrally located data that are essential for capturing variability within the most representative segment of the population.

In summary, the ACP task has provided valuable insights into emotion-behaviour decoupling in schizophrenia. Yet, the existing evidence remains inconsistent, particularly regarding whether volitional deficits are confined to anticipatory responses or are also manifest in consummatory responses. Methodological limitations, including narrow computational approaches and extreme group sampling, have obscured the interpretation of the precise nature of these deficits and their association with working memory and schizotypal traits. These ambiguities underscore the need for further research to elucidate the complex relationships underlying emotion–behaviour decoupling and their broader implications in schizophrenia.

2.8 Summary and research gaps

The literature review highlights the significant impact of negative symptoms in schizophrenia, particularly avolition, which significantly impairs motivation, daily functioning, social relationships, and quality of life. Avolition, characterized by deficits in anticipatory pleasure and emotion-behaviour decoupling, contributes to chronic disability, straining individuals, communities, and societal systems through increased healthcare demands, caregiver burden, and economic costs. While antipsychotic medications, psychosocial interventions, and neurostimulation techniques have advanced schizophrenia management, their efficacy in addressing negative symptoms, especially avolition, remains limited. Clinical and self-reported assessments have evolved to better capture the subjective and cognitive dimensions of negative symptoms, yet inconsistencies in measurement tools persist. The Anticipatory and Consummatory Pleasure task provides an objective and reliable behavioural approach to studying emotion-behaviour decoupling. However, findings are mixed regarding the specificity of anticipatory versus consummatory deficits and their links to working memory and schizotypal traits. Research gaps include the need for standardized assessment frameworks, a clearer understanding of the neural and cognitive mechanisms underlying avolition, and the development of targeted interventions to address motivational deficits, particularly across the schizophrenia spectrum and in transdiagnostic populations. Addressing these gaps will empower mental healthcare professionals, especially frontline nurses, to deliver holistic care that not only mitigates symptoms but also promotes sustained recovery and enhances the quality of life for individuals with schizophrenia and related disorders.

3 Aims

The overall aim of this study was to gain a deeper understanding of the disconnection of volitional behaviour from emotional processing and its association with working memory deficits in individuals with schizophrenia. This issue is critical in daily practice for managing avolition symptoms (Foussias & Remington, 2010). The study focused on two temporal components of pleasure experience: anticipatory and consummatory responses. Three cross-sectional experiments (Phase I–III) were conducted to examine emotion-behaviour coupling in people with schizophrenia and schizotypal traits.

The specific study objectives are as follows:

1) To evaluate the deficits in anticipatory and consummatory emotion-behaviour coupling in individuals with schizophrenia (Phase I).
2) To examine whether working memory performance influences the coupling in anticipatory and consummatory emotion-behaviour coupling (Phase I).
3) To evaluate the deficits in anticipatory and consummatory emotion-behaviour coupling in individuals with schizotypal traits (Phase II).
4) To explore the relationship between anticipatory and consummatory emotion-behaviour coupling and neural functional connectivity in individuals with schizophrenia (Phase III).

4 Materials and Methods

4.1 Study Design

In this study, three experiments were conducted to capture emotion-behaviour coupling in people with schizophrenia (Papers 1 and 3) and schizotypal traits (Paper 2). Experiment design was adopted in this study for its reliability, validity, and objectivity, minimizing biases and enhancing the accuracy of the findings compared to self-report measures (Hole, 2020, pp.181-216).

In **Phase I and III**, a matched pairs design (*schizophrenia vs. healthy controls*) was used to maximize the power and validity of the findings by controlling for confounding variables, such as sex and age (Bai et al., 2022; Kapelner & Krieger, 2023) (Paper 1 and 3). In **Phase II**, a within-subject design with clustering (*higher vs. lower schizotypy*) was used to enhance the robustness and interpretability of the findings (Paper 2). Measuring the same subjects across different conditions allows for control over individual differences, reducing error variance and enhancing sensitivity to treatment effects (May & Hittner, 2012). Additionally, clustering manages inherent correlations in grouped data, improving the accuracy of statistical analyses (Nahum-Shani & Dziak, 2018). These designs allowed for a comprehensive examination of the differences between groups or clusters across various measures (Jackson, 2016).

4.2 Study population, setting, and sampling

This study focused on people diagnosed with schizophrenia, a complex mental health disorder that affects approximately 0.3% of people worldwide, causing significant disruptions to individuals' ability to lead fulfilling lives (Ayano, 2016). In Hong Kong, there were about 50,400 people diagnosed with schizophrenic spectrum disorder[3] in the Hospital Authority as of 31 December, 2020 (The Government of HKSAR, 2021). The community-dwelling adults with schizophrenia are generally mentally stable with fewer (or controlled) psychotic

[3] This number does not include people who consult private psychiatrists.

symptoms, yet many still exhibit significant residual negative symptoms (Madianos & Economou, 1988).

The study population consisted of two sub-groups: (1) People with Schizophrenia (SZ; Paper 1 and 3) and (2) Healthy Control (HC; Paper 1 and 2) in the community. To further understand the extent of deficits in emotion-behaviour coupling in SZ, HCs were included as a reference group, along with transdiagnostic conditions (i.e., schizotypal traits). The inclusion and exclusion criteria for both groups are outlined in Table 7.

Table 7. The inclusion and exclusion criteria of study participants (Phases I-III).

	INCLUSION CRITERIA	**EXCLUSION CRITERIA**
ALL PARTICIPANTS	(1) Aged 18-60 years (2) Literacy in Chinese (Cantonese or Mandarin); (3) Normal or corrected vision; and (4) The ability to provide informed consent	(1) Pregnancy [a] (2) Any contraindications for MRI [b]
GROUP 1: PEOPLE WITH SCHIZOPHRENIA	(1) Clinical diagnosis under schizophrenia or schizoaffective disorder of DSM-5 (APA, 2013); and (2) stable symptoms (i.e., mentally stable)	(1) Comorbid mental disorders [c] (2) a history of head injury, hemiplegia or other neurological/cerebrovascular conditions; and (3) received electroconvulsive therapy (ECT) in the past 6 months
GROUP 2: HEALTHY CONTROLS	(1) Without personal and familial (first-degree relatives only) history of mental disorders [c]	(1) A history of mental disorders or neurological (brain) damage; (2) any physical disabilities that may interfere with performance in any tests; (3) the use of psychoactive drugs in the past 6 months; and (4) chronic diseases [d]

[a]Pregnant women were not covered by insurance.

[b]This criterion adopted in Phase III only. MRI contraindications include, but are not limited to, individuals with cardiac pacemakers, metal implants, restlessness behaviour, claustrophobia, and pregnant women.

[c]Mental disorders include, but are not limited to, schizophrenia spectrum disorders, major depression, anxiety disorders, impulse control disorders, neurodevelopmental disorders, and substance use disorders.

[d]This criterion adopted in Phase I and II only. Chronic diseases include, but are not limited to, diabetes, autoimmune diseases, chronic inflammatory diseases, chronic pain, cardiopulmonary diseases, cancer, and other chronic conditions that require long-term medications. DSM-5 = The Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition.

Regarding study setting, the SZ group was recruited from day hospitals, community psychiatric units, private residential care homes, and halfway houses in Hong Kong (Paper 1 and 3). The HC group consisted of non-psychiatric adults, were recruited via advertisements and word of mouth in the local community as controls (Paper 1 and 2). In Hong Kong, people with schizophrenia reside in diverse living arrangements that significantly influence their quality of life and recovery outcomes (Chan et al., 2003). These include hospitals for acute or long-term care, long-stay care homes (including private residential care homes) for chronic cases, halfway houses for transitional support, supported hostels or housing for semi-independent living, and community settings where individuals live with family or alone (Yeung & Chan, 2006). Studying community-living people with schizophrenia is crucial to understand their unique challenges and support needs, which can inform the development of accessible and effective community-based mental health services.

A convenience sampling method was employed (Paper 1 – 3), whereby participants were selected based on their availability and willingness to participate (Jackson, 2016). Considering that schizophrenia is a low-incidence disorder and that the study population consisted of community-dwelling adults diagnosed with schizophrenia, this sampling method would be the most suitable approach for recruitment (Emerson, 2015; Golzar et al., 2022).

4.3 Participant recruitment

In **Phase I**, potential participants with schizophrenia (SZ) were identified by healthcare providers who screened medical records against predefined inclusion and exclusion criteria. If they fulfilled these criteria, they were formally approached, given a leaflet explaining the present study, and invited to a briefing session. Following the briefing session, those expressing an interest in participating were provided with an information sheet detailing the study requirements. Any further queries were addressed, and those who decided to volunteer were requested to sign an informed consent form. To ensure their eligibility, SZ participants completed a series of self-report questionnaires (including demographic and clinical characteristics) for screening before the experiment (Paper 1). Eligible SZ participants were invited to join the experiment, for those who were accepted to undergo fMRI scans, were also enrolled in **Phase III** (Paper 3).

In **Phases I – III**, HC participants were registered online via Google Forms. Following registration, their eligibility was screened by the researcher, and invitations to join the experiment were sent. On the day of the experiment, the researcher provided an information sheet and verbally explained the details.

Written consent was then sought from the participants before proceeding with the experiment (Paper 1 – 3).

Figure 7 illustrated the recruitment and screening process for the two sub-groups. In **Phase I**, HC were first selected to match the gender and age of the 40 subjects in the SZ group. Additional same-sex HC within ±1 year of the remaining SZ participants were then selected, resulting in a total of 42 HC. Five female participants in the SZ group did not have corresponding controls that met the matching criteria; however, their ages did not deviate by more than 7 years from a healthy control of the same gender. In **Phase II**, the final data analyses were conducted in 91 HCs, as 14 participants were dropped. In **Phase III**, 15 SZ participants and 23 HC participants were included in the analysis after excluding 5 and 2 participants (due to invalid data) from each group.

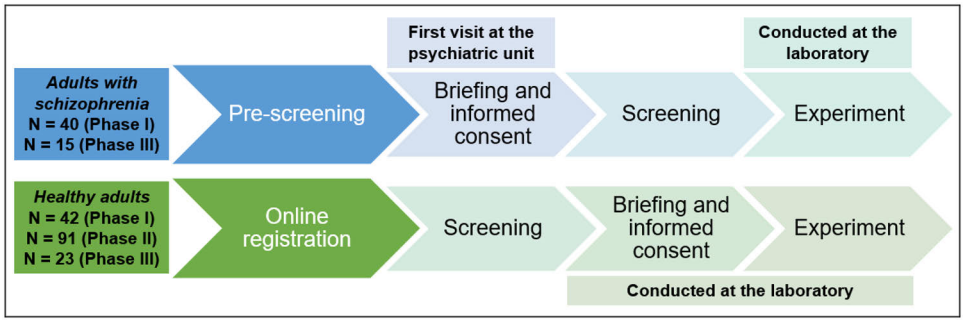


Figure 7. The recruitment and screening process.

4.4 Measures

Demographic data, including gender, age, education level, occupation, and marital status, were obtained from all participants across three phases. Additional clinical information, including diagnosis, first contact with psychiatric services, and medication records, was sought from individuals with schizophrenia. The description of each assessment (see Appendix 2.).

- Anticipatory and consummatory Emotion-behaviour coupling, a behavioural paradigm, Anticipatory and Consummatory Pleasure (ACP) task (Heerey & Gold, 2007; Lui et al., 2016a) was adopted in all phases (Paper 1 – 3).
- Working memory were assessed by Visual Working Memory (VWM) Task modified from previous studies (Palva et al., 2010, 2011; Figure 8) and Letter-Number Span (Gold et al., 1997) (Paper 1).
- Schizotypal traits were evaluated by the brief version of Schizotypal Personality Questionnaire (SPQ-B; Ma et al., 2010, 2015) (Paper 2).

- Neural connectivity was assessed using resting-state functional magnetic resonance imaging (rs-fMRI). The rs-fMRI scans were performed using a 3-Tesla scanner with 32-head coil. T1-weighted structural images were acquired (TR = 2500 ms, TE = 3 ms, and FA = 8°, FOV = 230 mm, resolution of 1×1×1 mm). T2-weighted gradient echo planar imaging (EPI) sequence was used to acquire rs-fMRI data (TR = 2,000 ms, TE = 30 ms, FA = 90°, FOV = 230 mm, and 32 slices with a resolution of 3×3×4 mm) (Paper 3).

  A summary of assessments used in each original paper is described in Table 8.

Table 8. A summary of assessments used in each original paper.

Assessments	Outcomes	Administration	Paper 1	Paper 2	Paper 3
Anticipatory and Consummatory Pleasure (ACP) task[#] (Heerey & Gold, 2007; Lui et al., 2016a)	Emotion-behaviour coupling	Behvioural	X	X	X
Visual Working Memory (VWM) Task[#] (Palva et al., 2010, 2011)	Working memory	Cognitive	X	-	-
Letter-Number Span (LNS) (Gold et al., 1997)	Working memory	Cognitive	X	-	-
Schizotypal Personality Questionnaire-Brief (SPQ-B) (Ma et al., 2010, 2015)	Schizotypal traits	Self-reported	-	X	-
Neuroimaging	Functional neural connectivity	Resting-state fMRI	-	-	X

Note. [#]conducted using computer. [*]Assessment for people with schizophrenia only

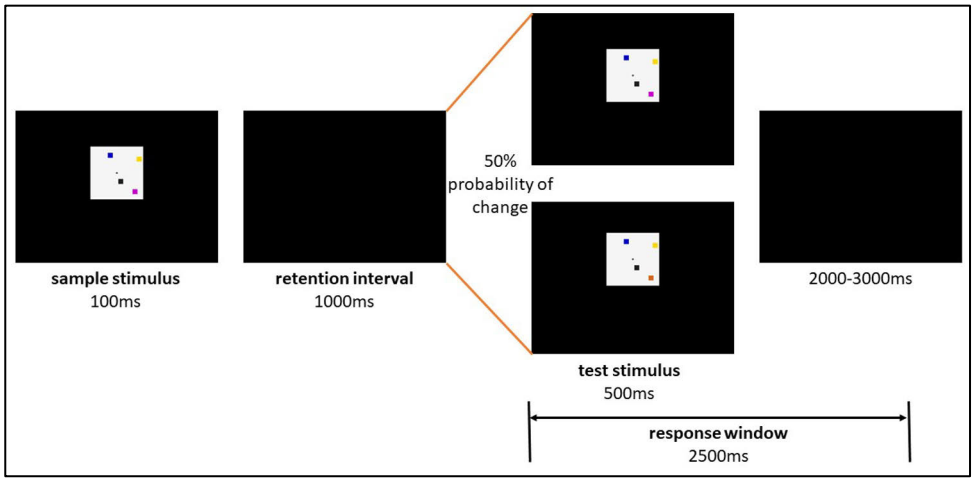


Figure 8. A schematic depiction of a trial in the Visual Working Memory (VWM) Test (from left to right).

4.5 Data collection

To facilitate participation, the researchers escorted participants to the laboratory (point-to-point for people with schizophrenia and pick up in the campus for healthy participants). On-site support was provided for all participants.

In **Phase I and II**, participants were reported their demographic and clinical characteristics[4] (Paper 1 and 2). After that they completed a working memory task (Paper 1) and a behavioural task on the computer, followed by a working memory test (Paper 1 and 2). The entire experiment takes about 60-90 minutes at the University Research Facility in Behavioral and Systems Neuroscience (UBSN) at The Hong Kong Polytechnic University.

In **Phase III**, subjects with SZ who were willing to undergo fMRI scans in Phase I were enrolled in this phase. Healthy controls (HCs) were asked to provide their demographic information after registration. Following baseline data collection, appointments for fMRI scans were confirmed. The fMRI scans were conducted using a 3T MRI scanner at the MR Imaging Unit, Department of Diagnostic Radiology at the University of Hong Kong for SZs, and at the University Research Facility in Behavioral and Systems Neuroscience (UBSN) at The Hong Kong Polytechnic University for HCs. All participants were informed about the MRI scan procedure beforehand. They were then asked to complete an MRI safety screening form and provide informed consent. After the scan, participants completed a behavioural task on the computer (Paper 3).

4.6 Data processing and analysis

4.6.1 Data processing

Demographic information, medical records and LNS were collected using a paper form. Data entry and initial data processing of computerised assessments (i.e., ACP task and VWM task) was performed using Microsoft Excel before statistical analysis.

4.6.1.1 Computation of ACP performance indies

In **Phase I**, polynomial orthogonal contrasts were utilized to capture the predicted V-shaped response profile. This computation method highlights an enhanced response to both negative and positive valence relative to neutral, in which trials grouped into three valence categories: *Undesired* (rated 1-3), *Indifferent* (rated 4-

[4] SZ participants were assessed during the first visit.

6), and *Desired* (rated 7-9). A one-sample test of the mean quadratic component was conducted against the null hypothesis (H_0: $\mu_{\text{(quadratic component)}} = 0$). The steeping or flattening V-shaped response profile suggests better or poorer emotion-behaviour coupling (see Figure 9A). Any trial (except those rated as *Indifferent*, 4–6) that registered more than four incongruent key presses (i.e., the responses did not align with the subjective pleasantness ratings) was deemed invalid (Lui et al., 2016b, pp.677) and from the final analysis (Paper 1).

In **Phase II and III**, the profile of response vigour was expressed as a function of valence ratings, ranging from 1 to 9 (from *very unpleasant* to *very pleasant*). Using the least squares method, a quadratic polynomial equation was fitted to each subject's response profile. The convexity of the fitted curve was captured by the quadratic coefficient. A positive value suggests a U-shaped profile, with larger values indicating a steeper response rate increase as perceived valence becomes more extreme (moving away from neutral). By comparing responses across all valence ratings, it allows for a more nuanced representation of variations within each category (see Figure 9B). Trials were considered invalid if incongruent key presses constituted 20% or more of the total key presses. This criterion did not apply to trials with *Indifferent* ratings (4–6), in which all key presses were included. Participants with more than 20% invalid trials were excluded from the final analysis (Paper 2 and 3).

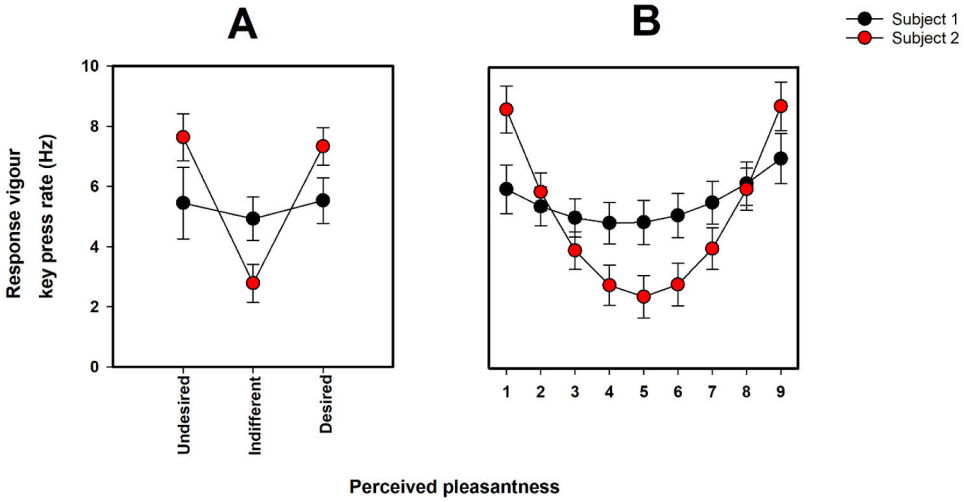


Figure 9. Interpretation of ACP findings. A sample presentation of emotion-behaviour coupling by computation based on the perceived pleasantness of the pooled valence categories (A) and all valence ratings (B). Subject 1 exhibited a flatter shape in comparison to Subject 2, revealing poorer emotion-behaviour coupling.

4.6.1.2 Computation of VWM test

Response accuracy and reaction time were measured for each level of memory load. Individual memory capacity was estimated using Pashler's method (Pashler, 1988), as described by Palva et al. (2010). This method calculates memory capacity based on the number of items (2, 4, or 6) and evaluates how well participants detected changes in the test stimulus. The hit rate refers to correctly identifying a change, while the false alarm rate indicates incorrectly thinking a change occurred when it did not. Thus, the change in the test stimulus is considered a signal according to signal detection theory.

4.6.1.3 Pre-processing for fMRI data

The pre-processing of fMRI data were performed using CONN toolbox v.22.a (www.nitrc.org/projects/conn) and SPM v.12.7771 (http://www.fil.ion.ucl.ac.uk/spm) in MATLAB R2023a (MathWorks, Inc., USA). The fMRI pre-processing pipeline included realignment, susceptibility distortion correction, outlier detection, normalization to MNI space, and spatial smoothing (Nieto-Castanon, 2020). Functional images were coregistered to the first scan, realigned with 6 degrees of freedom, and resampled to correct for motion (Andersson et al., 2001; Friston et al., 1995). Outliers were identified using CONN Artifact Detection Tools with thresholds based on framewise displacement and BOLD signal changes (Power et al., 2014). Images were normalized into MNI space, segmented into tissue classes, and resampled to 2 mm isotropic voxels using SPM's unified segmentation (Ashburner & Friston, 2005; Ashburner, 2007; Calhoun et al., 2017). Smoothing was performed with an 8 mm Gaussian kernel. Functional data were denoised using component-based noise correction (CompCor), addressing potential confounding effects from white matter and CSF timeseries, motion parameters, and outliers (Friston et al., 1996; Behzadi et al., 2007; Chai et al., 2012; Power et al., 2014). Finally, bandpass filtering between 0.008 Hz and 0.09 Hz was applied (Hallquist et al., 2013). First-level analysis computed seed-based connectivity maps and ROI-to-ROI connectivity matrices using the 164 HPC-ICA network template and Harvard-Oxford atlas (Desikan et al., 2006). A priori selection was conducted within triple network model (i.e., default mode network, salience network, and frontoparietal network) due to its relevance to schizophrenia dysfunction. A total of 33 connectivity pairs across 15 brain regions were included to explore functional connectivity and its associations with Emotion-behaviour coupling in schizophrenia.

4.6.2 Data analysis

All statistical analyses were performed using IBM SPSS Statistics (versions 26–29; IBM Corp, USA). Descriptive statistics were used to report demographic and clinical data. To assess group differences, independent t-tests, Fisher's exact tests, and chi-square tests were utilized as appropriate. Effect sizes were reported using R^2 for correlational analyses and η_p^2 for analyses of variance (ANOVA). A two-tailed significance level of $p < 0.05$ was maintained throughout all analyses.

In **Phase I**, parametric ANOVAs were performed to evaluate differences in anticipatory and consummatory emotion-behaviour coupling and VWM performance between individuals with schizophrenia and healthy controls. These analyses employed a between-subjects factor, Group (schizophrenia vs. healthy controls), and appropriate within-subjects factors, Valence and Phases in the ACP task, or memory loadings in the VWM test. To dissect the response patterns in the ACP task, planned polynomial trend analysis was conducted, partitioning the within-subject factor Valence into orthogonal quadratic components, including interaction terms. This approach aimed to capture the anticipated V-shaped response profile, reflecting increased response vigour for both negative and positive valences relative to neutral stimuli. Specifically, the quadratic component quantified the convexity of individual response profiles, serving as an index of emotion-behaviour coupling. One-way ANOVA was then used to compare Letter-Number Span (LNS) performance between groups. To examine the influence of working memory performance on emotion-behaviour coupling, Pearson's correlations and partial correlations were calculated to assess the relationships between ACP performance indices and LNS performance for each group. To ensure the normality of correlation coefficients for group comparisons, Fisher's *z*-transformation was applied to individual correlation coefficients prior to statistical analysis (Paper1).

In **Phase II**, Pearson's correlations were calculated to evaluate the relationship between schizotypal traits and emotion-behaviour coupling in ACP task, R^2 were used to indicate the effect size. The influence of schizotypal traits on emotion-behaviour coupling was further investigated by dividing participants into high and low schizotypal trait groups. K-means clustering (k = 2, *a priori*) was employed to create these distinct groups based on normalized SPQ-B subscores: (CP, IP, and DO). The initial centroids were determined by SPSS, and the clustering solution was validated for robustness against variations in initial centroids to confirm cluster stability. Subsequent comparisons of emotion-behaviour coupling between the two cluster groups were performed using parametric ANOVAs with between-subjects factor Cluster and within-subjects factors Phases and Valence in the ACP task. Significant interactions from the ANOVAs were further explored with post-

hoc tests, utilizing the pooled error variance to pinpoint specific group differences (Paper 2).

In **Phase III**, the relationship between emotion-behaviour coupling and neural functional connectivity was examined in individuals with schizophrenia and in age- and sex-matched healthy adults. Pearson's correlation analyses were performed separately for the schizophrenia and healthy control groups to assess the correlation between ACP indices and functional connectivity pairs within the triple network. To ensure robust significance testing without assuming normality, p-values were determined using a permutation method with 10,000 resamplings (Good, 2013; LaFleur & Greevy, 2009). False Discovery Rate (FDR; Benjamini & Hochberg, 1995) with a q-value threshold of 0.05 was applied to adjust for multiple comparisons (Paper3).

4.7 Ethical considerations

Ethical approval from the Institutional Review Board of The Hong Kong Polytechnic University (#HSEARS20210211005, #HSEARS20210524002, #HSEARS20231212005) and the Hong Kong Hospital Authority (HKECREC-2019-041) were obtained. All phases were conducted in compliance with the Declaration of Helsinki (World Medical Association, 2013), and strict adherence to the British Psychological Society Code of Human Research Ethics (Oates et al., 2021) was maintained throughout the study:

- Given that individuals with mental health conditions are a vulnerable population, it was crucial to ensure their capacity to provide informed consent (Beck & Ballon, 2020; Dunn, 2006).
- All participants received comprehensive information about the study both in writing and verbally before consenting (Anderson & Mukherjee, 2007; Yanos et al., 2009).
- Privacy rights were upheld at every stage of the research process, from data collection to publication, with participants assured of anonymity and no identifying information included in any publications (World Health Organization, 2005).
- Data were securely stored with encryption and were accessible only to authorized research personnel (Wilms, 2019).
- Participants were not required to disclose any information they wished to keep private and could withdraw from the study at any time if they felt distressed or uncomfortable (Anderson & Mukherjee, 2007).

- In case there are any adverse events, they will be reported during the research (World Health Organization, 2005).
- As a token of gratitude for their participation, incentives were provided to all completers (Gelinas et al., 2018).

The guidelines for using IAPS images in research were strictly followed in all phases (University of Massachusetts Amherst, 2024). In addition, the Transparency and Openness Promotion (TOP) Guidelines – Level 2 (Nosek et al., 2015) were followed to support open research. All original data can be obtained from the corresponding author upon reasonable request. Supplemental materials from this research are available at the OSF repository (Study I: https://osf.io/w5nst/; Study II: https://osf.io/cjfye/; Study III: https://osf.io/n968s/).

5 Results

5.1 Sociodemographic and clinical characteristics of participants

In **Phase I**, the schizophrenia (SZ) and healthy controls (HC) participants were matched in age and sex ratio. The SZ group had more single and divorced individuals, lower education levels, and higher rates of unemployment and reliance on government assistance (all *P*s < .001), consistent with known schizophrenia demographics. The SZ group consisted of individuals with schizophrenia and schizoaffective disorder. Many had approached psychiatric services by the age of 25. Almost all participants were on antipsychotic medications (Paper 1).

In **Phase II**, healthy male and female adults in the community, aged 18-59, were included. The average age is 39, with a balanced sex ratio and marital status. Most of them were well-educated, with stable. No history of psychiatric or chronic illness was reported. No significant differences were found in all sociodemographic characteristics after cluster-split (Paper 2).

In **Phase III**, the SZ and HC groups were matched in age and sex ratio. Similar to the profile of Phase I, the SZ group also showed significant differences in levels of education, marital status, and employment status (all *P*s < .001) compared to the HC group. As the SZ participants are a subset of Phase I, the clinical characteristics of the participants are comparable to those of the parent sample (Paper 3).

Table 9 shows the sociodemographic and clinical characteristics of participants in three phases.

Table 9. Sociodemographic and clinical characteristics of participants in each study.

	Phase I		Phase II	Phase III	
	Schizophrenia Patients (n=40)	Healthy Controls (n=42)	Healthy Adults (n=91)	Schizophrenia Patients (n=15)	Healthy Controls (n=23)
Age (year)					
Mean ± SD	45.7 ± 9.9	43.3 ± 11.8	39.0 ± 12.2	45.3 ± 11.5	44.9 ± 9.77
Range	22 – 60	21 – 59	18 – 59	29 – 60	29 – 60
Sex					
Male	21 (52.5%)	25 (59.5%)	45 (49.5%)	9 (60%)	13 (56.5%)
Female	19 (47.5%)	17 (40.5%)	46 (50.5%)	6 (40%)	10 (43.5%)
Marital Status					
Single (never married)	27 (67.5%)	17 (40.5%)	46 (50.5%)	9 (60%)	11 (47.8%)
Married	5 (12.5%)	24 (57.1%)	44 (48.4%)	2 (13.3%)	12 (52.2%)
Divorced or widowed	8 (20.0%)	1 (2.4%)	1 (1.1%)	4 (26.7%)	0 (0.0%)
Education					
Secondary or below	18 (45.0%)	1 (2.4%)	13 (14.3%)	8 (53.3%)	0 (0.0%)
High school or vocational training	17 (42.5%)	7 (16.6%)	4 (4.4%)	6 (40%)	6 (26.1%)
Undergraduate or above	5 (12.5%)	34 (81.0%)	74 (81.4%)	1 (6.7%)	17 (73.9%)
Employment					
Employed	12 (30.0%)	26 (61.9%)	62 (68.1%)	5 (33.3%)	19 (82.6%)
Student	0 (0.0%)	7 (16.7%)	18 (19.8%)	0 (0.0%)	2 (8.7%)
Unemployed	11 (27.5%)	2 (4.7%)	4 (4.4%)	4 (26.7%)	1 (4.3%)
Government allowances*	15 (37.5%)	0 (0.0%)	0 (0.0%)	5 (33.3%)	0 (0.0%)
Homemaker/retired	2 (5.0%)	7 (16.7%)	7 (7.7%)	1 (6.7%)	1 (4.3%)
Diagnosis					
Schizophrenia	35 (87.5%)	N/A	N/A	N/A	N/A
Schizoaffective disorder	5 (12.5%)				
Age of first contact of psychiatric service	n=39**			n=14**	
Mean ± SD	25.1 ± 9.2	N/A	N/A	25.9 ± 11.54	N/A
Median	23			21.5	
Range	11 – 49			13 – 56	
Years since first contact of psychiatric service	n=39**				
Mean ± SD	20.6 ± 10.0	N/A	N/A	N/A	N/A
Median	19				
Range	2 – 45				
Antipsychotic medication					
Chlorpromazine (CPZ)-equivalent					
Mean (±SD) in mg/day	622.0 ± 470.8	N/A	N/A	599.8 ± 390.3	N/A
Median	560.0			600	
Range	0 – 2,332			56.25 – 1,716	
Schizotypal traits (SPQ-B), Mean ± SD			5.15 ± 4.24		
Cognitive-perceptual (CP)			1.96 ± 1.73		
Interpersonal (IP)	N/A	N/A	2.32 ± 2.10	N/A	N/A
Disorganisation (DO)			0.88 ± 1.26		

Note. *Eligible for Comprehensive Social Security Assistance and/or Disability Allowance from the Social Welfare Department of the Hong Kong Government. **Relevant data could not be ascertained in one SZ subject. SPQ-B = Brief version of Schizotypal Personality Questionnaire.

5.2 Emotion-behaviour coupling in people with schizophrenia

The response vigour (key presses per second) as a function of subjective affective valence (undesired, indifferent, desired) associated with the IAPS images was recorded during the Anticipatory Phase (Figure 10A) and the Consummatory Phase (Figure 10B), respectively. In contrast to the V-shaped response profile observed in the HC group, the SZ group's response profile was substantially flatter in both phases. These observations were confirmed by a significant three-way interaction (Desirability × Group × Phase) in

quadratic components, $F(1, 80) = 17.06$, $p < .001$, $\eta_p^2 = 0.18$. Compared to HC subjects, the SZ group's flatter response profile indicated a stronger impairment in anticipatory responses than in consummatory responses. However, this impression was largely influenced by the stronger quadratic trend in anticipatory responses among HC group. A 2 (Phases) × 3 (Desirability) ANOVA did not yield a significant two-way interaction in the SZ group, $F(2, 78) = 1.11$, $p = .033$, $\eta_p^2 = 0.03$. This suggests the co-existence of significant deficits in both anticipatory and consummatory responses in people with SZ (i.e., similar responses across both phases), despite seemingly normal subjective ratings of affective stimuli compared to the International Affective Picture System (IAPS) normative data ($p < 0.001$). Hence, the interpretation of preferential anticipatory emotion-behaviour decoupling in SZ, based on ACP task performance (Paper 1), may not be justified. More detailed results are reported in original Paper 1.

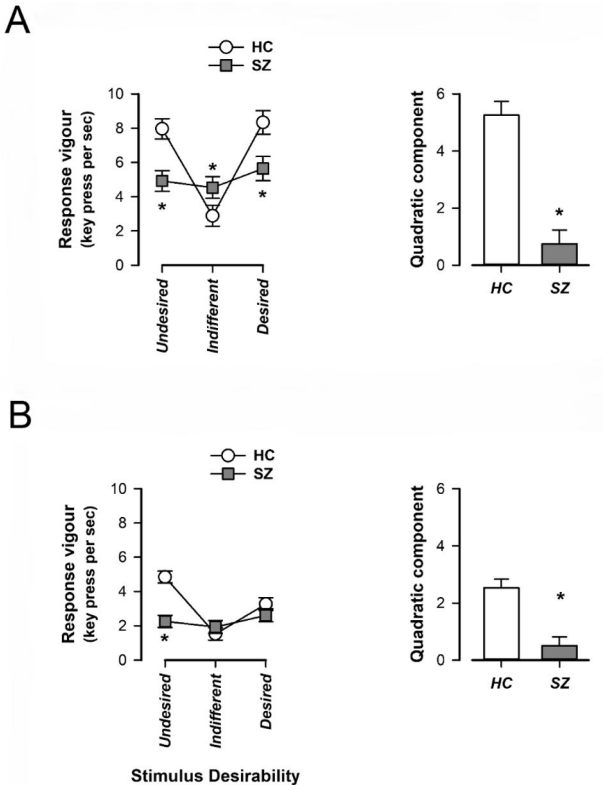


Figure 10. ACP response profile between people with schizophrenia and healthy controls. ACP key-press responses as a function of perceived emotional valence (or desirability) of the visual stimuli. Key-press rate was used to index behavioural effort exerted to increase/decrease probability of future 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 component of the profile was shown in the accompany histograms. SZ: n=40, HC: n=42. * indicates a significant difference (p<0.05) between groups. HC = healthy control; SZ = schizophrenia. Modified from Figure 2 in original Paper 1.

5.3 Emotion-behaviour coupling and working memory

The association between the two forms of emotion-behaviour coupling and working memory (i.e., LNS scores) was evaluated. Both anticipatory and consummatory emotion-behaviour coupling were significantly correlated with LNS scores in the SZ group ($r = 0.45$ and 0.43, respectively; $p < 0.005$), but not in the HC group ($r = -0.32$ and -0.41, respectively; $p > 0.05$; see Figure 11). This means that the lower the LNS scores, the weaker the emotion-behaviour coupling, indicating better cognitive performance is associated with stronger volitional responses. Notably, those with low LNS scores also showed weaker emotion-behaviour coupling, as captured by the quadratic components derived from both anticipatory and consummatory response profiles. This unique pattern among people with SZ highlights a pathological link between volitional and cognitive deficits (see Paper 1, Figure 8). Despite robust ACP-LNS correlations were identified, no association was found between ACP performances and the Visual Working Memory (VWM) test ($p > 0.05$). This reveals the possibility that not all working memory components are equally related to the emergence of emotion-behaviour decoupling in SZ. More detailed results are reported in original Paper 1.

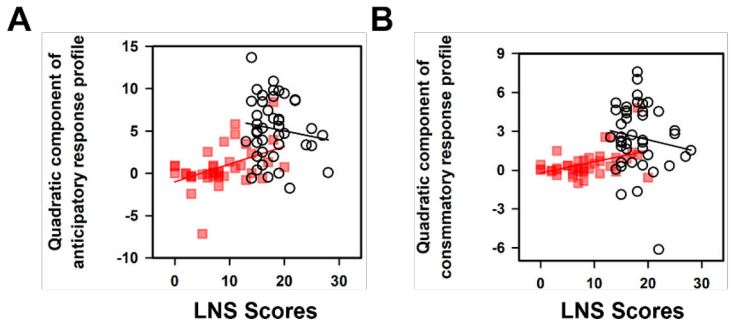


Figure 11 Correlation and Scattered Plots between ACP variables and LNS Memory Scores. Pearson's correlation coefficients were computed separately for the SZ (n=40) and HC (n=42) group. Two ACP variables, (A) anticipatory and (B) consummatory responding are plotted against the total scores in the LNS test. Two regression lines (SZ: red, HC: black) are fitted to each scattered plot. HC = healthy control; SZ = schizophrenia. Modified from Figure 7 in original Paper 1.

5.4 Emotion-behaviour coupling in people with schizotypal traits

Each of the three SPQ-B sub-scores—cognitive-perceptual (CP), interpersonal (IP), and disorganisation (DO)—was analysed for its association with two ACP indices:

anticipatory emotion–behaviour coupling (q_A) and consummatory emotion-behaviour coupling (q_C), respectively. Anticipatory emotion-behaviour coupling was positively correlated with the IP and DO sub-scores of the SPQ-B ($p = 0.001$, $R^2 = 0.11–0.12$), indicating that higher negative and disorganised schizotypal traits were associated with stronger anticipatory affective motivation. In contrast, no significant associations were observed between consummatory emotion–behaviour coupling and any of the SPQ-B sub-scores, nor between anticipatory coupling and the positive schizotypal trait (CP). To evaluate the effect of schizotypal traits on ACP performance, k-means clustering yielded two clusters (higher schizotypy vs. lower schizotypy) in accordance with the standardized SPQ-B sub-scores. The "higher schizotypy" cluster had higher scores, while the "lower schizotypy" cluster had lower scores across all three schizotypal traits. Comparison between the two clusters revealed significant differences in all three schizotypal traits (all p-values < 0.0001, $\eta_p^2 = 0.296 – 0.75$). The clusters also differed in the emotion-behaviour coupling for anticipatory response (q_A) [$p < 0.002$, $\eta_p^2 = 0.103$], but not consummatory response (q_C) [$p = 0.95$, $\eta_p^2 = 0.000041$].

It has been hypothesised that schizotypy may represent a behavioural endophenotype of schizophrenia; however, the current study did not support the hypothesis that higher schizotypy in nonclinical adults exhibit similar ACP deficits as those in people with SZ, who demonstrate weaker emotion-behaviour coupling. Findings indicated that response vigour for anticipatory responses significantly increased as subjective valence deviated from a neutral rating of 5 in the higher schizotypy cluster (Figure 12A), while response vigour for consummatory responses was seemingly driven by unpleasant images (Figure 12B). A significant 3-way interaction (Clusters × Phases × Valence rating), $F(8, 712) = 9.76$, $p < 0.0001$, $\eta_p^2=0.099$ confirmed these observations, with significant main effects for clusters ($p < 0.05$, $\eta_p^2=0.067$) and interactions with valence ($p < 0.0001$, $\eta_p^2=0.050$) and phase ($p < 0.05$, $\eta_p^2=0.071$). Thus, this suggests that nonclinical populations with schizophrenia-like traits does not necessarily exhibit the same degree of emotional and behavioral impairments seen in SZ (Paper 2). More detailed results are reported in original Paper 2.

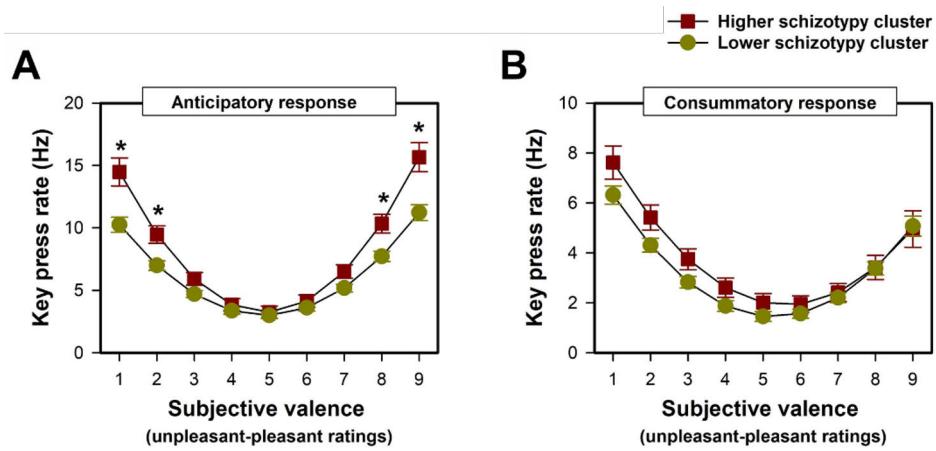


Figure 12. Comparison of ACP performance of the two clusters of subjects obtained by k-mean clustering. The response profile of anticipatory key press response rate (A) and of consummatory key press response rate (B) as a function of subjective valence based on individual quadratic regression. * indicates significant difference between the two clusters. Modified from Figure 2 in original Paper 2.

5.5 Emotion-behaviour coupling and resting state neural connectivity

In the SZ group, the quadratic components of emotion–behaviour coupling were 0.13 (SD = 0.25) for anticipatory and 0.07 (SD = 0.15) for consummatory emotion–behaviour coupling. In contrast, the HC group exhibited stronger emotion–behaviour coupling, with quadratic components of 0.44 (SD = 0.21) for anticipatory and 0.25 (SD = 0.13) for consummatory phases.

Pearson's correlations examined the associations between ACP performances and 33 intra-network ROI-to-ROI functional connectivity pairs for SZ and HC groups independently. There were approximately 57% (12 out of 21) of SN connections in the SZ group showed significant positive correlations with either anticipatory and/or consummatory emotion–behaviour coupling (q_A and q_C), as determined by permutation testing (R^2 = 0.27–0.49) before FDR correction (see Table 10B). In contrast, only about 20% (4 out of 21) of SN-q_C correlations were identified in the HC group, with no significant association between anticipatory emotion–behaviour coupling and SN connections in the HC group. This suggests that SN connectivity may serve as an indicator of affect-driven motivation in SZ.

Although the number of significant correlations reduced after FDR correction, five SN connections remained significantly associated with q_C in the SZ group, while none persisted for q_A. This selective preservation indicates that SN connectivity is more robustly linked to consummatory volition than to anticipatory processes in SZ. Notably, some correlations that did not survive FDR correction still had *p*-values <

0.1. The overlap in q_C-related associations across groups may reflect shared neural substrates supporting consummatory emotion–behaviour coupling, suggesting potential trends for further exploration. Additionally, the lack of significant correlations for q_A underscores the need for caution in interpreting anticipatory connections.

The correlative analysis also revealed that two pairwise connections within the DMN and one within the FPN showed significant correlations with ACP performance in HC but not in SZ (see Table 10A and 10C). The connection between the right lateral parietal (LP-R) region and the medial prefrontal cortex (MPFC) was positively linked to consummatory responses, while the connection with the posterior cingulate cortex (PCC) was negatively linked to anticipatory responses. In the FPN, the connection between the lateral prefrontal cortex (LPFC) and the posterior parietal cortex (PPC) in the right hemisphere was positively associated with consummatory responses, although none remained significant after FDR correction.

In summary, a notable distinction emerged in the correlations between salience network (SN) connections and ACP indices (q_A and q_c) among SZ and HC participants. These findings provide initial evidence of specific neural connectivity patterns associated with avolition symptoms in SZ, suggesting that enhanced SN connectivity may be linked to improved consummatory volitional processes (Paper 3). More detailed results are reported in original Paper 3.

Table 10 summarises the correlations between intra-network connectivity and two ACP indices among SZ and HC groups.

Table 10. Key correlation findings of ROI-ROI connectivity within triple network among people with schizophrenia and healthy controls.

		ANTICIPATORY PHASE						CONSUMMATORY PHASE					
		SZ (n=15)			HC (n=23)			SZ (n=15)			HC (n=23)		
Source ROI	**Target ROI**	*r*	*p*	*p-FDR*	*r*	*p*	*p-FDR*	*r*	*p*	*p-FDR*	*r*	*p*	*p-FDR*
(A) DEFAULT MODE NETWORK													
MPFC	LP-R	-0.382	0.157	0.646	-0.073	0.745	0.920	-0.238	0.392	0.904	0.455	0.031	0.184
LP-R	PCC	0.281	0.323	0.646	-0.413	**0.049**	0.291	0.025	0.930	0.930	-0.001	0.996	0.996
(B) SALIENCE NETWORK													
ACC	AInsula-L	0.613	**0.017**	0.130	0.197	0.374	0.715	0.273	0.330	0.364	0.145	0.515	0.645
ACC	RPFC-L	0.367	0.180	0.259	0.262	0.223	0.715	0.695	**0.006**	**0.034**	0.593	**0.004**	0.082
ACC	RPFC-R	0.443	0.092	0.243	0.309	0.148	0.715	0.541	**0.037**	0.085	0.529	**0.010**	0.068
Ainsula-L	AInsula-R	0.560	**0.031**	0.130	-0.208	0.340	0.715	0.366	0.176	0.231	0.002	0.993	0.993
Ainsula-L	RPFC-L	0.424	0.116	0.243	0.237	0.272	0.715	0.558	**0.030**	0.078	0.262	0.229	0.343
Ainsula-R	RPFC-L	0.403	0.141	0.259	0.353	0.099	0.715	0.701	**0.003**	**0.034**	0.441	**0.034**	0.144
Ainsula-R	RPFC-R	0.557	**0.031**	0.130	0.341	0.116	0.715	0.561	**0.028**	0.078	0.551	**0.007**	0.075
Ainsula-R	SMG-R	0.520	**0.049**	0.172	0.119	0.590	0.826	0.497	0.063	0.120	0.300	0.162	0.283
RPFC-L	RPFC-R	0.285	0.309	0.331	0.176	0.418	0.732	0.567	**0.028**	0.078	0.395	0.064	0.160
RPFC-L	SMG-R	0.585	**0.020**	0.130	0.230	0.287	0.715	0.678	**0.006**	**0.034**	0.253	0.237	0.645
RPFC-R	SMG-R	0.584	**0.021**	0.130	0.131	0.551	0.826	0.701	**0.005**	**0.034**	0.244	0.268	0.645
SMG-L	SMG-R	0.350	0.207	0.259	-0.049	0.823	0.909	0.671	**0.009**	**0.037**	0.112	0.612	0.645
(C) FRONTOPARIETAL NETWORK													
LPFC-R	PPC-R	0.398	0.144	0.432	0.454	**0.030**	0.180	0.395	0.150	0.449	0.391	0.064	0.386

Note. Correlations of ROI-to-ROI connectivity within (A) Default Mode Network, (B) Salience Network, and (C) Frontoparietal Network and two ACP performance indices (anticipatory and consummatory responding) in the SZ and HC groups, respectively. Abbreviations: MPFC = Medial Prefrontal Cortex, PCC = Posterior Cingulate Cortex, LP = lateral parietal, PPC = posterior parietal cortex, LPFC = lateral prefrontal cortex, ACC = Anterior Cingulate Cortex, AInsula = Anterior Insula, RPFC = Rostral Prefrontal Cortex, SMG = Supramarginal Gyrus, and suffixes "-L" and "-R" refer to the left and right hemisphere, respectively, HC = healthy control, SZ = schizophrenia. *p-FDR = False-Discovery Rate p-values.* Modified from Table 4 in original Paper 3.

6 Discussion

6.1 Summary of main results

6.1.1 Co-expression of anticipatory and consummatory volitional deficits in schizophrenia

The present study confirmed significant impairments in goal-directed actions despite normal emotional ratings in individuals with schizophrenia (SZ), highlighting co-existing anticipatory and consummatory volitional deficits (Paper 1). Previous ACP studies do not support the hypothesis that anticipatory emotion-behaviour coupling is selectively or preferentially impaired in people with SZ (see Section 2.7). Instead, the evidence suggests a more pervasive decoupling across both anticipatory and consummatory responses. A controversial question is whether the differential expression of anticipatory versus consummatory emotion-behaviour decoupling in the SZ group can be interpreted as evidence for stronger emotional decoupling in anticipatory responses. An affirmative conclusion, however, risks overinterpreting the sharper V-shaped anticipatory response profile (i.e., the quadratic component) observed in the healthy control (HC) group as evidence of greater attenuation in the SZ group. There are three reasons to approach this with caution:

First, subsequent studies following Heerey and Gold's seminal work (2007) have failed to replicate the critical three-way interaction (Desirability × Group × Phase), except for Lui et al. (2016b, study 2), Wang et al. (2020), and the present study (Paper 1).

Second, the report of a stronger V-shaped profile in anticipatory compared to consummatory responses in the previous ACP studies might be an artifact of the task design. Both anticipatory and consummatory responses were quantified by key presses per second; however, the response windows differed significantly. For anticipatory responses, the window was fixed at 2 seconds, with no immediate feedback provided. By contrast, the response window for consummatory responses was variable and directly dependent on key presses. During desirable trials, appropriate key presses not only extended the viewing time (as desired) but also prolonged the response window. However, as viewing time approached the upper limit of 10 seconds, the potential reward for additional key presses diminished,

causing the key-press rate to decelerate and lowering the average press rate. Conversely, in undesirable trials, the response window was shorter (less than 5 seconds), potentially inflating the average key-press rate. This temporal asymmetry may explain the stronger V-shaped consummatory response observed in HC subjects. The design of ACP task is described in original Paper 1 and its supplemental material.

Third, there is no a priori rationale for predicting whether anticipatory or consummatory responses should exhibit a sharper V-shaped profile in healthy individuals. While ACP studies consistently report a stronger anticipatory profile, the expected outcomes for anticipatory and consummatory responses are qualitatively different. Anticipatory responses are linked to changes in the future probability of viewing a specific stimulus, whereas consummatory responses reflect "in-the-moment" viewing time. This qualitative difference complicates direct application of the delayed discounting function (Frederick et al., 2002), which would otherwise predict weaker anticipatory responses relative to consummatory ones.

6.1.2 Working memory impairment and its role in emotion-behaviour decoupling

The potential link between emotion-behaviour decoupling and working memory deficiency in SZ, initially suggested by Heerey and Gold (2007) – a correlation between the concordance of anticipatory response with subjective valence and working memory (i.e., LNS) performance. However, their analysis pooled data from both schizophrenia and healthy subjects, leaving it unclear whether group differences drove the observed correlation, as they did not perform a scatter plot or within-group correlation analysis. The present findings align with observations that ACP performance in SZ with near-normal LNS performance was better than in those with a clear working memory deficit, although still poorer than in healthy controls (Lui et al., 2016a). Chu et al. (2020) also found that variations in working memory alone could not statistically account for emotion–behaviour decoupling in SZ. The effect sizes of correlations (see Paper 1, Figure 7) support this conclusion, suggesting that emotion–behaviour decoupling in SZ likely involves dysfunction in other cognitive processes. In other word, the link between diminished emotion-behaviour coupling and memory dysfunction was more pervasive than previously described.

The VWM test was adopted due to its "minimal rehearsal, temporal retention, and manipulation demand, and its focus on memory buffer capacity" (Palva et al., 2010). However, its implementation as a two-alternative forced choice task was too demanding for half of the SZ subjects in the present study. The inability to observe a comparable ACP–VWM correlation in the SZ group could be partly due to the insufficient statistical power. Therefore, the distinction between LNS and VWM

warrants careful interpretation, as it may suggest that short-term memory capacity is not relevant to the strong 'pathological' ACP–LNS correlation. Thus, it remains uncertain to what extent the ACP task performance correlates with specific facets of working memory functions. More detailed discussions are reported in original Paper 1.

6.1.3 Reconciling conflicting evidence in schizotypy and emotion-behaviour coupling

The present study extended the ACP task to non-clinical adults, revealing that higher schizotypal traits, particularly in interpersonal and disorganization dimensions, were associated with stronger anticipatory emotion-behaviour coupling, with cluster analysis further indicating that individuals with higher schizotypy were more motivated by anticipatory than consummatory processes (Paper 2).

As proposed by Meehl (1962), schizotypal traits would reflect schizophrenia-like psychopathology, however, contrary to this expectation, the findings revealed the opposite pattern. Notably, people with higher schizotypal scores were associated with stronger, but not weaker, emotion-behaviour coupling. This observation was particularly evident in anticipatory motivation rather than consummatory motivation (Klein, 1984; Heerey & Gold, 2007). Results emerged from the present study are difficult to align with the two previous studies that explored the association between schizotypal traits and emotion-behaviour coupling in Chinese population: Lui et al. (2016b) found that schizotypy was largely unrelated to ACP performance, while Xie et al. (2017) reported that higher schizotypy scores were associated with weaker emotion-behaviour coupling. One potential explanation may involve accounting for differences in sample characteristics, which arise from the inconsistent and somewhat arbitrary formation of comparison groups in previous studies (Lui et al., 2016b; Xie et al., 2017). A plausible and inclusive model can be proposed based on the hypothesis that the relationship between schizotypy and emotion-behaviour coupling follows an inverted U-shaped curve (see Paper 2, Figure 3). This model suggests that deviations—either lower or higher—from an intermediate level of schizotypy are associated with a decline in the strength of emotion-behaviour coupling. Within this framework, emotion-behaviour coupling would be strongest at moderate levels of schizotypy, while extreme scores in either direction would result in weaker coupling.

Assuming the optimal intermediate level of schizotypy lies near the population mean and that the inverted U-shaped relationship is roughly symmetrical, this model can accommodate the null findings in Lui et al. (2016b) as well as the weaker emotion-behaviour coupling observed in Xie et al.'s (2017) high schizotypy (social anhedonia) group. This interpretation diverges from Xie et al.'s (2017) explanation,

which attributed Lui et al.'s null results to a less stringent criterion for defining their high schizotypy group. Xie et al. (2017) argued that their stricter criterion of 1.96 SD above the mean produced an effect size large enough to detect a robust difference, making their results less susceptible to a Type II error. In contrast, the proposed model attributes the inconsistencies between the two studies to differences in how their comparison groups were constructed. A closer examination of the data supports this interpretation. For example, the "non-schizotypy" comparison group in Lui et al. (2016b; see their Fig. 4b) revealed a markedly weaker emotion-behaviour coupling compared to the "control" comparison group in Xie et al. (2017; see their Fig. 3b). This difference was particularly evident in the consummatory response. Moreover, both the high schizotypy and non-schizotypy groups in Lui et al. (2016b) demonstrated similarly poor emotion-behaviour consummatory responses. These observations reinforce the idea that methodological differences in group construction, rather than the stringency of criteria for defining schizotypy, may underlie the conflicting findings across studies. More detailed discussions are reported in original Paper 2.

6.1.4 Potential neural connectivity for emotion-behaviour coupling

The present study explored the brain-behaviour relationship with resting-state functional connectivity within the triple network and emotion-behaviour coupling in schizophrenia (SZ). The findings may indicate that altered salience network (SN) connectivity—particularly for consummatory emotion-behaviour coupling—is linked to motivational deficits in schizophrenia, with patterns suggesting compensatory engagement in some individuals rather than a uniform dysfunction. Although these interpretations require caution given methodological and statistical constraints, they highlight the value of network-specific frameworks for understanding volitional processes in SZ (Paper 3).

The SN—consists of two key nodes—anterior insula (Ainsula) and anterior cingulate cortex (ACC)—coordinates internal and external salience signals to initiate and sustain motivated behaviour (Menon et al., 2023; Seeley et al., 2007). A key result was that weaker resting-state SN connection was associated with greater emotion-behaviour decoupling, raising the possibility of compensation. One interpretation is that enhancing SN connectivity may help counteract emotion-behaviour coupling, potentially alleviating broader deficits in incentive salience (Gradin et al., 2013) given the SN is primarily responsible in detecting salient stimuli, directing attention, and prioritizing information (Menon & Uddin, 2010). Yet, greater SN connectivity may also be maladaptive in some individuals, contributing to aberrant salience and positive symptoms (Corlett & Fraser, 2025;

Gray et al., 1991; Kapur, 2003) or inefficient allocation of cognitive–affective resources (McCutcheon et al., 2023), in line with models emphasising the dynamic, context-dependent role of SN (Menon et al., 2023). In addition, the correlational patterns suggest rostral prefrontal cortex (RPFC)-centred interconnections to ACC and AInsula, associated with both anticipatory and consummatory volition in ACP task. This aligns with the known role of the RPFC in reward processing and avolition symptoms in SZ (Bartoli et al., 2024; Namkung et al., 2017; Olney et al., 2018; Palaniyappan & Liddle, 2012). By contrast, anterior insula connections with ACC and supramarginal gyrus related more to anticipatory motivation but did not survive FDR, suggesting more diffuse or state-dependent neural associations compared to consummatory processes. Further investigation is warranted to confirm the robustness of SN connections involved in the anticipatory response.

Apart from SN connections, a few DMN and FPN connections were identified only in healthy controls and were not FDR-robust, though they are consistent with DMN involvement in simulating future outcomes (Wang et al., 2015) and FPN roles in decision-making and goal-directed control (Tu et al., 2013; Vincent et al., 2008). Hence, any suggestion that reduced engagement of these connections drives motivational deficits in SZ must be interpreted cautiously.

Taken together, SN dysregulation may be central in SZ, both compensatory and dysfunctional patterns across networks are evident. Notably, the data do not support a preferential or selective impairment of anticipatory volition (Heerey & Gold, 2007); rather, a co-expression of anticipatory and consummatory volition in SZ (Chu et al., 2020; Wang et al., 2020; and Paper 1). Given the modest sample and the intrinsic weakness of rs-fMRI data, it is prudent to conclude that the neural correlates of anticipatory and consummatory affect-driven motivated behaviours cannot be clearly distinguished. More detailed discussions are reported in original Paper 3.

6.2 Validity and reliability of the study

The present study significantly advanced the understanding of emotion-behaviour decoupling in schizophrenia through methodological refinements and practical insights that build upon prior research. First, it introduced polynomial contrasts to derive novel indices for interpreting ACP task responses, providing a precise measure of emotion-behaviour coupling. This refined analysis resolved inconsistencies in previous studies, improving the interpretability of ACP task performance and establishing a robust framework for future research (Paper 1). Second, expanding the application of ACP task to a non-clinical population with schizotypal traits demonstrated its sensitivity to detect the strength of emotion-behaviour coupling in healthy adults, broadening its relevance to the high-risk population (Paper 2). Third, the study pioneered the integration of behavioural data

with resting-state functional connectivity, linking behavioural deficits to specific neural circuits, particularly within the salience network. This multimodal approach grounded behavioural observations in neurobiological evidence, significantly enhancing the study's robustness (Paper 3).

The matched-pairs design (Paper 1 and 3) enhanced internal validity by controlling for confounding variables through participant matching, ensuring that observed effects are attributable to the independent variable. By pairing participants based on relevant characteristics (e.g., age, sex), this design minimizes selection bias and extraneous variability (Campbell & Stanley, 2015). This approach strengthens causal inferences by focusing on the effect of the independent variable, making it a robust method for experimental research (Shadish et al., 2002). Due to potential site effects, Paper 3 did not include direct group comparisons; nevertheless, the preliminary findings from the schizophrenia and matched healthy control cohorts offer valuable guidance for subsequent validation. A replication study incorporating an a priori power analysis specific to brain–behaviour correlations would help determine appropriate sample sizes and other design parameters.

The extreme group approach adopted by the two previous studies (Lui et al., 2016b; Xie et al., 2017) illustrates the methodological inconsistencies that may underlie the discrepancies in their findings. Both studies recruited substantially larger initial subject pools (20 to 32 times larger than the current study), but their methods of forming comparison group (i.e., non-schizotypy) were seemingly different, for example Lui et al. (2016b) selected 1.96 SD above the mean schizotypy score; while Xie et al. (2017) selected subjects who scored below the pooled mean using an unspecified method. Considering the external validity, the present study included diverse sample (Paper 2), ensuring that the research findings could be generalized to a broader population. By including participants with varied demographic characteristics, a diverse sample reflects the real-world target population, reducing sampling bias and capturing natural variability in outcomes (Cook et al., 1979). This increases the likelihood that results will apply across different groups and settings, making findings more robust and relevant outside the study's specific context (Shadish et al., 2002).

A low level of schizotypy in Phase II, potentially due to stringent exclusion criteria and recruitment of healthy subjects, may indicate a "super normal" group, limiting variation in schizotypal traits (SPQ-B mean = 4.95, SD = 4.2) compared to normative Chinese samples, e.g., Fonseca-Pedrero et al., (2018): mean = 6.37, SD = 3.46, N = 4,907, and Ma et al. (2015): mean of 6.32, SD = 4.2, N = 1,188. It is suspected that the lower SPQ-B scores in the present study may reflect recruitment from a broader community base, as full-time students accounted for only approximately 20% of the sample. By contrast, the normative datasets mentioned above were derived entirely or predominantly from college student populations, as

were the samples used in Lui et al. (2016b) and Xie et al. (2017). Nonetheless, the present study retains sensitivity to variations across the entire distribution, suggesting that the sample is situated on the rising portion of the hypothesised inverted U-shaped function (see Paper 2, Figure 3C), where higher schizotypy is associated with stronger emotion-behaviour coupling.

The exploratory nature of Phase III was explicitly acknowledged, and findings were framed as provisional to avoid overinterpretation and to contextualise effect size uncertainty. Nonetheless, statistical analyses followed rigourous approaches. First, false discovery rate was applied to mitigate Type I error arising from multiple testing. Second, resampling method was used to derive empirical *p*-values for Pearson correlations, reducing reliance on parametric distributional assumptions and decreasing sensitivity to extreme values relative to conventional parametric tests. This is a methodologically sound approach for maintaining sensitivity to magnitude relationships while eliminating concerns about normality and outlier. The constraints related to sample size and resting-state fMRI are discussed in section 6.3 *Potential pitfalls*.

These methodologies ensured both the validity and reliability of the results. Overall, the present study provided a solid foundation for future investigations into emotion-behaviour decoupling and inform psychiatric nursing and rehabilitation practices, offering actionable insights to improve patient care.

6.3 Potential pitfalls

Inherent to the study design, there are few potential pitfalls that would warrant attention and further explanation or justifications.

- **Potential bias in the recruitment of schizophrenia participants:** In Phase I and Phase III, the SZ group was largely comprise chronic, medicated patients with stable symptoms (due to the requirement to perform fMRI scan), and this may limit generalisation to a wider spectrum of schizophrenia patients, such as positively-symptomatic and drug-resistant patients, and first episode and acute schizophrenic patients. Previous ACP findings indicated that the characteristics of both anticipatory and consummatory emotion-behaviour coupling in schizophrenia may vary depending on the stage of the illness (Appendix 3). Emotion-behaviour coupling is apparently stronger during the early stage of schizophrenia. Specifically, anticipatory motivation seems to be intact compared to consummatory motivation. Notably, emotion-behaviour coupling becomes weaker in both anticipatory and consummatory motivation as the illness progresses (i.e., deterioration in the chronic stage). Besides, Chu et al. (2020) evaluated the ACP deficits between hospitalised and community-dwelling patients (i.e., inpatients vs. outpatients). They concluded that emotion-behaviour

decoupling is comparable between patients with or without long-term hospitalisation, however, they speculated that hospitalised patients may exacerbate the severity of decoupling. Future studies should include a more diverse sample that represents various stages of the illness, making it crucial to interpret the findings within this context.

- **Ability to perform behavioural task:** People with schizophrenia are well recognised for having cognitive dysfunction and poor psychomotor speed. The implementation and instructions used in the ACP task closely followed those employed by Lui and colleagues (i.e., Chan's group). In fact, the ACP task, including all instructions, was directly obtained from them. Only very minor corrections were carried out solely to conform with the use of Chinese in Hong Kong, and to ensure that all on-screen texts were in traditional (rather than simplified) Chinese characters. There was no gross discrepancy. A full description of the implementation and instructions (including verbal instructions by the experiment) is included (see Paper 1, Supplementary Material C). It is evident that all participants had comprehended the requirements of the tasks, as they were explicitly asked to express their understanding during explanation and practice. They were also given the opportunity to request further explanation at multiple junctures and to repeat practice trials as desired. Lui et al. (2016b) demonstrated a more severe deficit that led to complete insensitivity to valence in the context of emotion-behaviour coupling. In their Study 3, they showed a complete loss of expected V-shaped profile (see their Figure 4B) in non-clinical subjects identified either as "negative schizotypy" or "non-schizotypy" (as controls) whose understanding of task instructions should not be a concern. Provision of these details together with the statistical evidence for the presence of the basic V-shape response profile in SZ group should adequately addressed concerns regarding participants' ability to complete ACP task.
- **Intrinsic limitation of resting-state fMRI (rs-fMRI):** The present findings highlight the functional connectivity within salience network might influence the strength of emotion-behaviour coupling in schizophrenia, while the associations between the other two brain networks (i.e., the default mode network and the frontoparietal network) and ACP performances appear weak (Paper 3). These observations, however, cannot decide if anticipatory and consummatory emotion-behaviour decoupling effectively dissociable at the neuropsychological levels. Therefore, a rigorous approach is warranted to further dissect neural correlates underlying anticipatory and consummatory responding during the ACP task. rs-fMRI signals do not reflect real-time brain activity during consummatory or anticipatory responses in the ACP task, even though they correlate with subsequent ACP performance.

- **Limitations of dichotomous grouping:** In Phase II, clustering analysis was performed to classify participants into two schizotypy groups. This approach was initially chosen to allow comparison with previous studies that used high and low schizotypy groups. However, dichotomous grouping can lead to significant loss of information and statistical power. This method reduces the variability inherent in the data, potentially obscuring meaningful differences and relationships. It may also introduce arbitrary cut-off points, which can bias results and limit the generalisability of findings. Furthermore, dichotomous grouping can inflate the risk of Type I and Type II errors, making it harder to detect true effects. In contrast, retaining the schizotypy score in its continuous form preserves the richness of the data and allows for more nuanced and accurate analyses. Given that the sample in the present study may be 'super normal' (i.e., positively skewed), future studies are recommended to employ recruitment strategies that ensure a broader and more representative range of schizotypy scores. This could involve reaching out to more diverse populations and using methods that maximise variability in the sample, thereby enhancing the validity and interpretability of future findings.
- **Interpretation cautions for underpowered and premature findings:** Given the exploratory nature with a limited sample in Phase III, the results should be interpreted with caution and regarded primarily as hypothesis-generating rather than conclusive. The modest sample size increases the risk of reduced statistical power and unstable or inflated effect-size estimates. In addition, connectivity analyses were confined to ROI-ROI connectivity within the triple network, broader network dynamics and cross-network interactions were not captured. Complementary approaches (e.g., seed-to-voxel mapping or graph-theoretic analyses) could provide a more comprehensive understanding of the distributed mechanisms underlying brain-behaviour relationship, but these methods typically require substantially larger samples to yield stable and interpretable results. Future replication studies should include an a priori power calculation (based on conservative or pooled effect-size estimates) and adopt practices such as multi-site harmonization, targeted recruitment, and robust estimation methods (e.g., bootstrap confidence intervals or Bayesian approaches) to improve reliability and generalisability.

6.4 Implications and recommendations

The ACP task demonstrated high sensitivity in detecting and quantifying the translation of affective experience into motivated behaviour (i.e., emotion-behaviour coupling) in people with schizophrenia. Emotion-behaviour decoupling is a potential transdiagnostic marker of avolition (Lui et al., 2023). The dissection of emotion-

behaviour coupling in the ACP task, focusing on the temporal separation between an action and its goal. It mirrors the differentiation of 'liking' and 'wanting' behaviours, is posited to be analogous to anhedonia and avolition in schizophrenia, respectively. The co-expression of anticipatory and consummatory emotion-behaviour decoupling in schizophrenia challenged the initial hypothesis that anticipatory affective motivation is selectively or preferentially impaired in individuals with schizophrenia (Heerey and Gold, 2007). To address this parsimonious account, recommendations for further investigations and methodological refinement of the ACP task are outlined below:

1. The use of a quadratic polynomial across the full spectrum of subjective ratings provides a sensitive index that captures subtle variations in both anticipatory and consummatory responses. This approach enhances the interpretation of motivated behaviour and offers a robust method for studying avolition via the ACP task. Including ACP indices in screening processes may enable clinicians to identify motivational deficits earlier than traditional methods, which often prioritise cognitive impairments and subjective reports, thereby facilitating timely interventions. Future studies may also clarify the extent of the V-shaped profile in both clinical and healthy populations. Such a response profile would allow researchers and clinicians to interpret the severity of volitional deficits more readily and visually (Paper 1).
2. The key presses (motivated behaviour or effort) in both anticipatory and consummatory phases of the ACP task are actions intended to achieve specific outcomes, are arguably volitional. Self-reported valence ratings for affective images may reflect 'liking', as suggested by Lui et al. (2016a). A limitation of this approach is the uncertainty about whether these ratings are based on experiential or semantic perspectives. Semantic valence, or "factual knowledge about the valence of an object or event", can differ from experiential affective valence (Itkes & Kron, 2019; Kron et al., 2013, 2015). This distinction is important for understanding emotion-behaviour decoupling as a psychopathological concept in schizophrenia. Future ACP studies could consider measuring facial expressions, orienting responses, and autonomic responses (e.g., electrodermal activity) as more objective indicators of arousal to better capture experiential affects (Hamzani et al., 2020; Itkes et al., 2017).
3. To dissect the cognitive underpinnings of avolition symptoms in SZ (e.g., Strauss & Gold, 2012) and other conditions with similar affective symptoms (Heinz et al., 1994; Lambert et al., 2018; Wang et al., 2020), future ACP studies may incorporate tests that selectively engage specific components of executive and working memory function.
4. An inverted U-shaped model attempts to integrate the existing evidence across ACP-schizotypy studies; however, previous studies (Lui et al., 2016b; Xie et al.,

2017) and Phase II adopted dichotomous grouping, which may attenuate the representation of the schizotypy continuum. It may be worthwhile to re-evaluate these two previous reports, as they included a substantial number of participants. In addition, a longitudinal design with adequately powered, balanced samples would enable continuous modelling of schizotypy and evaluation of the proposed U-shaped model. This approach would allow for the use of multi-level modelling, which offers a superior alternative to EGA and avoids dichotomous or extreme grouping of participants.

5. Beyond sample size, potential confounders (e.g., year of illness and antipsychotic medication) and the operational definition/inclusion criteria for 'valid' ACP data may partially explain the divergent findings across studies. To enhance transparency and replicability, the present study provides all study materials, including the Cantonese instructions and computation method. Future replications should adhere to these protocols and reporting standards to maintain scientific rigour. In addition, inspection of existing ACP studies would enhance the cumulative knowledge base by identifying methodological sources of heterogeneity, informing standardised inclusion criteria, and enabling robust evidence synthesis (e.g., meta-analysis and bias assessment).
6. The present findings suggest that behavioural readouts alone do not fully capture the subtle differences between anticipatory and consummatory affective motivation in schizophrenia. A common neural dysfunction cannot be ignored, as it remains unclear whether consummatory and anticipatory responses in the ACP task are mediated by dissociable brain processes. Consequently, ACP may not effectively dissect the psychopathology underlying these two expressions of motivated behaviour. Integrating objective behavioural measures with neuroimaging offers a more powerful approach to diagnosing and assessing the severity of avolition. To this end, a shift from resting-state fMRI to task-based fMRI might provide the necessary sensitivity to detect condition-specific activation patterns linked to anticipatory and consummatory motivation, thereby improving the understanding of the neural basis of emotion–behaviour decoupling in schizophrenia. The revised ACP paradigm should also take account of participants' ability to perform the task during MRI scanning. A pilot study using a mock MRI setup would help assess and refine the task to ensure participant competence and comfort.

Before drawing translational implications, the above recommendations warrant further validation through larger, multi-site experimental studies with diverse samples. If substantiated, they could advance the understanding and management of avolition, a core negative symptom of schizophrenia. Table 11 outlines the potential needs across different domains, along with recommendations for translating these findings into practice and the anticipated outcomes, assuming further validation.

Table 11. Summary of potential needs, recommendations, and anticipated outcomes.

Domain	Potential need	Recommendations	Anticipated outcomes
Clinical care & Services	Enhanced diagnostic precision to quantify avolition severity and enable earlier detection in at-risk groups.	Conduct larger, multi-centre ACP-fMRI validation studies (test–retest reliability, sensitivity/specificity) and integrate brief ACP-informed assessment tools into outpatient and community services.	Early identification of motivational deficits, enabling timely interventions to delay or prevent psychosis onset.
	Development of personalised interventions based on identified motivational deficits and neural correlates.	Design and test targeted behavioural interventions and explore neurostimulation (e.g., TMS, tDCS) in controlled clinical trials with defined endpoints (motivation, functioning).	Tailored treatments that enhance motivation and engagement, improving clinical outcomes.
	Improved quality of life through interventions targeting avolition.	Test interventions in pragmatic, real-world settings to evaluate impact on daily functioning, independence, employment, and well-being.	Enhanced patient independence, social participation, and well-being.
	Introduction of objective, clinician-friendly tools (e.g., observational scales) for assessing avolition in clinical settings.	Develop, validate, and pilot simplified ACP task-based tools for outpatient/community nursing services; provide training and structured checklists.	Streamlined monitoring, earlier intervention, and improved patient management in community care.
	Implementation of targeted behavioural strategies (e.g., goal-setting, immediate reinforcement).	Train clinical staff to apply these strategies; evaluate effectiveness through clinical trials and use fidelity checklists to maintain treatment adherence.	Enhanced patient outcomes through precise, motivation-focused support.
	Refinement of early detection programs using multiple assessments to identify at-risk individuals.	Design and test screening protocols in community mental health services and early psychosis programs; adopt ACP indices to assess avolition.	Proactive identification of motivational deficits and reduced transition risk to psychosis.
	Support for rehabilitation programs that redirect resources toward independence and employment, informed by avolition insights.	Pilot rehabilitation initiatives incorporating ACP assessments to tailor interventions; test effectiveness in real-world settings.	Greater social and economic participation and improved functional outcomes.
	Improved resource allocation to community-based rehabilitation programs guided by objective measures of avolition.	Advocate for pilot programs incorporating ACP measures post-validation across diverse settings.	More accurately targeted services and optimized resource use.

Domain	Potential need	Recommendations	Anticipated outcomes
Workforce, Education & Public Engagement	Improved patient understanding of avolition through ACP task-derived biomarkers, fostering engagement in treatment.	Create plain-language psychoeducational materials (leaflets, videos, apps) explaining avolition and its neural bases; co-design with lived-experience contributors.	Increased patient empowerment, engagement, and treatment adherence.
	Reduced stigma through family psychoeducation highlighting neural bases of avolition (negative symptoms).	Provide family education and guidance on supportive communication and care strategies; co-develop materials to avoid biological determinism.	Improved family support, reduced blame and conflict, and enhanced recovery prospects.
	Enhanced staff empathy and care quality through training on avolition's neural underpinnings.	Integrate preliminary ACP insights into training curricula with appropriate caveats about preliminary evidence.	More effective and empathetic care delivery.
	Introduction of objective assessment and monitoring tools for staff (emphasis on training and uptake).	Train staff to use ACP-informed observational scales and monitoring tools in routine care.	Greater uptake of evidence-informed practices and streamlined patient monitoring.
Research	Advanced methodology for examining emotion–behaviour coupling in schizophrenia and beyond.	Adopt the ACP framework through larger, transdiagnostic studies to enhance generalisability (include depression, bipolar disorder).	Robust, versatile tools for behavioural research across conditions.
	Foundation for novel treatment development using ACP task biomarkers and neural correlates.	Screen pharmacological and non-pharmacological interventions in high-risk groups and follow with clinical trials when justified.	Precision therapeutics for avolition, including novel pharmacological agents and non-invasive neurostimulation.
	Progress in neuroimaging research to map ACP task neural correlates.	Conduct task-based fMRI and multimodal imaging studies to clarify mechanisms underlying ACP measures.	Deeper understanding of avolition's neural mechanisms.
	Promotion of interdisciplinary collaboration integrating behavioural and neuroimaging data for schizophrenia research.	Foster cross-disciplinary consortia involving clinicians, neuroscientists, psychologists, and lived-experience groups to harmonise methods and strengthen findings.	Stronger evidence base, accelerated innovation, and improved translation to practice.
	Expanded research to validate ACP task applications and develop therapies related to avolition.	Secure funding and resources for large-scale studies (task-based fMRI, pragmatic trials) to validate findings.	Evidence-based policies supporting innovative interventions for schizophrenia.

Domain	Potential need	Recommendations	Anticipated outcomes
Policy	Potential reduction in public stigma by framing schizophrenia as a brain-informed condition.	Develop cautious public education campaigns while awaiting robust validation; emphasize balanced messaging and co-design with lived-experience groups.	Increased societal empathy and acceptance of individuals with schizophrenia.
	Empirical data to guide policy decisions on resource allocation and intervention strategies.	Develop objective evaluation tools (digital apps, checklists) to assess rehabilitation effectiveness and perform cost-effectiveness analyses focusing on long-term outcomes.	Data-driven mental health policies, reduced healthcare costs, and improved productivity.
	Potential reduction in economic burden through effective avolition interventions.	Evaluate cost-effectiveness of validated interventions in real-world settings with long-term follow-up.	Lower healthcare costs and improved societal productivity.
	Improved resource allocation to community-based rehabilitation and early intervention guided by objective measures.	Advocate for pilot programs and policy briefs that incorporate validated ACP measures to inform service planning and funding decisions.	More targeted services, better matching of clients to interventions, and optimized use of resources.

7 Conclusions

This study offered new insights into the volitional deficits in schizophrenia (SZ) and related traits by leveraging the Anticipatory and Consummatory Pleasure (ACP) task as a reliable, objective behavioural test for characterising avolition. The present study demonstrated the high sensitivity of the ACP task in detecting avolition in people with chronic SZ, revealing significant co-expression of anticipatory and consummatory emotion-behaviour decoupling and its associations with working memory impairment. These findings illuminate the intricate interplay between motivation, emotion, and cognition, underscoring avolition as a multifaceted symptom rooted in neurobiological dysfunction. Beyond clinical populations, the ACP task also proved sensitive to variations in schizotypal traits amongst non-clinical adults, suggesting its potential as a marker for early motivational deficits across the SZ spectrum. In addition, preliminary exploration of the neural correlates identified aberrant resting-state functional connectivity patterns in SZ, particularly within the salience network, providing a foundational link between behavioural deficits and underlying brain mechanisms. The contributions of this study are twofold – It not only refines the interpretations of ACP findings, but also bridges behavioural and neurological insights to offer a more holistic view of volitional deficit in SZ. By highlighting the ACP task's utility in both clinical and non-clinical contexts, the findings emphasise its value for early detection and intervention strategies. These advancements underscore the importance of interdisciplinary collaboration to tackle the complexities of SZ symptoms.

Following the current findings, future research should prioritise high-powered replication studies to validate the results across diverse SZ stages and populations. Task-based functional imaging during ACP performance is also recommended to further elucidate the real-time neural dynamics of emotion-behaviour decoupling. Exploring the applicability of the ACP task to other psychiatric conditions with volitional deficits could establish it as a transdiagnostic tool, paving the way for personalised interventions that enhance quality of life for affected individuals. This study lays a critical foundation for these future endeavours, offering new pathways to effectively understand and address avolition.

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Appendices

Appendix 1. Key dopamine pathways in schizophrenia.

The exploration of the four major dopamine pathways: (i) mesolimbic, (ii) mesocortical, (iii) nigrostriatal, and (iv) tuberoinfundibular pathways, reveals their relationship to different symptom manifestations (Figure A1):

i. The *mesolimbic* pathway, projecting from the ventral tegmental area (VTA) to limbic structures such as the nucleus accumbens, plays a key role in the positive symptoms of schizophrenia. Hyperactivity of dopamine in this pathway was suggested to enhance the salience of external stimuli, leading to hallucinations and delusions (Heinz & Schlagenhauf, 2010; Brisch et al., 2014).

ii. The *mesocortical* pathway, which connects the VTA to the prefrontal cortex, is closely linked to negative symptoms like avolition, apathy, and anhedonia, as well as cognitive deficits, including impaired executive functions, due to its hypoactivity (McCutcheon et al., 2019).

iii. The *nigrostriatal* pathway, which connects the substantia nigra to the dorsal striatum (including the caudate nucleus and putamen), is mainly involved in modulating movement (Moya et al., 2023). Although dysregulation in this pathway is not directly associated with schizophrenia symptoms, dopamine antagonism (a common side effect of antipsychotic medications) in this pathway can lead to motor disturbances, such as parkinsonism and tardive dyskinesia.

iv. The *tuberoinfundibular* pathway, which links the hypothalamus to the anterior pituitary gland, regulates prolactin secretion through dopamine-mediated inhibition. Antipsychotic drugs that block dopamine receptors in this pathway may disrupt this balance, resulting in elevated prolactin levels and associated side effects like galactorrhea, menstrual irregularities, and broader hormonal imbalances (Kwak et al., 2012).

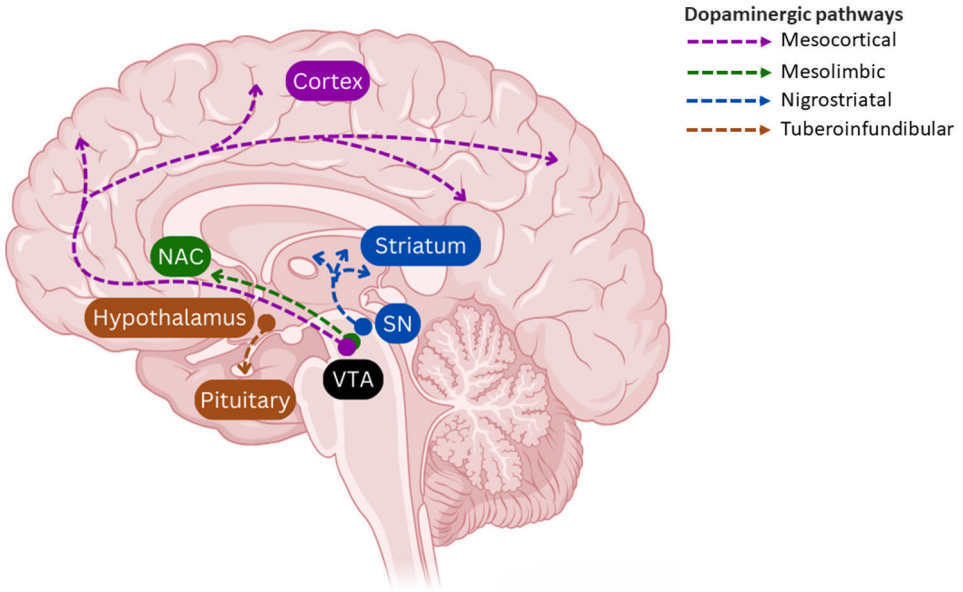

Figure A1. Dopaminergic pathways related to schizophrenia. The colour lines illustrate the four dopaminergic pathways in human brain. The pathways include (i) mesocortical pathway: from ventral tegmental area to cortex (purple); (ii) mesolimbic pathway: from ventral tegmental area to nucleus accumbens (green); (iii) nigrostriatal pathway: from substantia nigra to striatum (blue); and (iv) tuberoinfundibular pathway: from pituitary to hypothalamus (brown), respectively. The figure was modified based on Klein et al. (2019). VTA = ventral tegmental area; NAC = nucleus accumbens; SN = substantia nigra.

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Appendix 2. Brief description of assessments used in each phase

For detailed information, please refer to the original Paper 1 and 2, and their supplementary materials.

Anticipatory and Consummatory Pleasure (ACP)Task.
ACP task is a behavioural paradigm, was conducted using E-Prime® v2.0-3.0 (PA, USA) on a laptop. The full description and instructions of the ACP task are available in Chinese at https://osf.io/w5nst/.
There are two phases (**Anticipatory Phase** and **Consummatory Phase**) in the ACP task (see Figure A2).

- In **Anticipatory Phase**, 42 stimuli were presented randomly, and subjects rated each for pleasantness and arousal on a 9-point Likert scale. Stimuli were categorized as negative, neutral, or positive based on individual ratings. After rating, participants believed they could influence the likelihood of seeing each stimulus again in the next phase by pressing designated keys in a 2-second window: 'x' and 'z' to reduce the likelihood for unpleasant stimuli, and 'n' and 'm' to increase it for pleasant ones.
- In **Consummatory Phase**, a pseudorandom subset of 30 stimuli was presented, and subjects could adjust the viewing time between 3 to 10 seconds by pressing the corresponding keys: 'x' and 'z' to shorten the viewing time, and 'n' and 'm' to lengthen it. If no response was made, the default viewing time was set to 5 seconds. Participants were instructed not to respond to neutral stimuli in both phases.

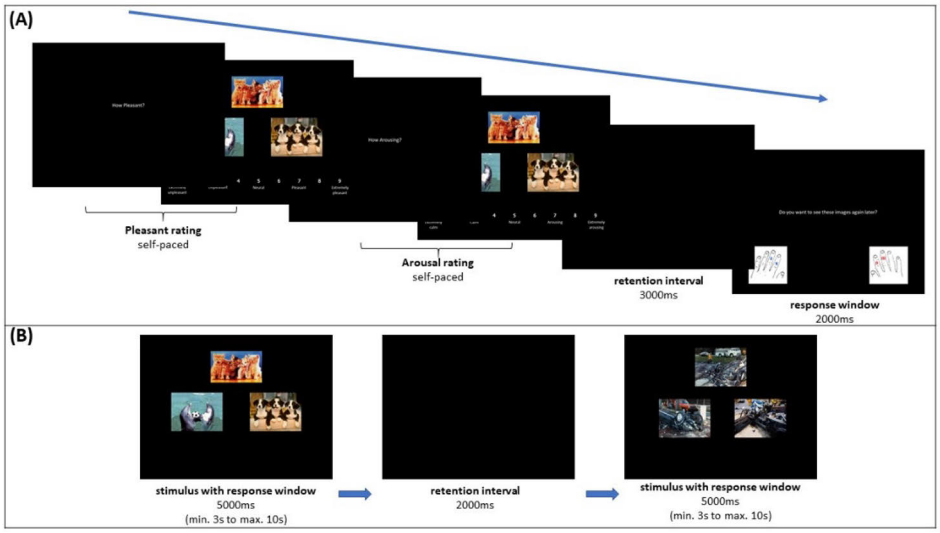

Figure A2. The task paradigm of Anticipatory Phase (A) and Consummatory Phase (B) of the ACP task.

Response rates were calculated for valid trials and represented in Hz (total key presses divided by the time in seconds). Valid and invalid trials were distinguished based on criteria from Lui et al. (2016b). Incongruent key presses were defined as pressing "x" and "z" for unpleasant images (rated 1 to 3) and "m" and "n" for pleasant images (rated 7 to 9). Trials with more than 4 incongruent key presses were considered invalid. Trials with neutral images were always valid, and all key presses in those trials were not incongruent. The response rate per trial was calculated based on all key presses, regardless of their congruence.

Visual Working Memory (VWM) Test.
This task was adapted from an EEG study on loading-dependent dynamics during memory retention (Palva et al., 2010, 2011) and conducted using STIM2™ (Compumedics Ltd., Australia) on a desktop PC with a 23-inch LCD screen viewed from approximately 60 cm. Recognition memory was assessed with visual stimuli consisting of 2, 4, or 6 uniquely colored squares displayed with a central fixation point. Each trial presented a sample stimulus for 100ms, followed by a 1000ms retention interval, and then a test stimulus for 500ms (Figure A3). Half of the trials were "same" (identical stimuli), while the other half were "different" (one square's color changed). Participants used a two-alternative forced choice method via a response pad within a 2500ms window to indicate their responses. A total of 540 trials were conducted across 10 blocks, with fully counterbalanced memory loads and randomized sequences. The interval between the test and subsequent sample stimulus varied from 2.5 to 3.5 s.

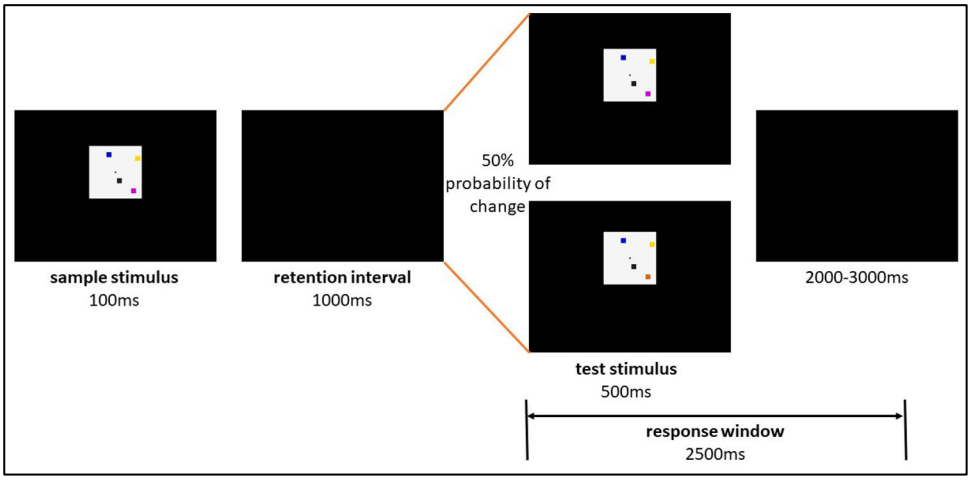

Figure A3. A schematic depiction of a trial in the Visual Working Memory (VWM) Test (from left to right).

Letter–Number Span (LNS).
The LNS task (Gold et al., 1997) measures working memory capacity. Participants listen to unique alphanumeric characters and must verbally repeat the numbers in ascending order, followed by the letters in alphabetical order. The length of the strings increases from two to nine characters, with four strings evaluated at each

length. The task ends if all four attempts fail. The total correct responses and maximum length reached were scored.

Schizotypal Personality Questionnaire-Brief (SPQ-B).
The 22-item Chinese SPQ-B (Ma et al., 2010, 2015) assesses schizotypal traits. It includes three subscores: cognitive-perceptual (CP), interpersonal (IP), and disorganization (DO). Participants respond with Yes (scored 1) or No (scored 0). The CP subscore is the sum of 8 items, the IP subscore is another 8 items, and the DO subscore is from 6 items.

Appendix 3. Variation of anticipatory and consummatory response in different stages of illness

Table A1. Quadratic component of anticipatory and consummatory response in schizophrenia across ACP studies

Authors (year)	Anticipatory response	Consummatory response	Duration of illness (years); mean (SD)
Heerey & Gold (2007)	0.92	1.08	22.75 (7.26)
Lui et al. (2016a)	3.04	1.09	0.38 (0.49)
Lui et al. (2016b) Study 1	2.29	1.88	14.64 (8.77)
Lui et al. (2016b) Study 2	3.95	2.62	1.33 (0.73)
Xie et al. (2017)	2.35	1.57	20.16 (9.26)
Chu et al. (2020) Inpatients	1.19	1.01	36.04 (7.05)
Chu et al. (2020) Outpatients	1.58	1.41	31.96 (10.37)
Wang et al. (2020)	1.63	1.92	2.63 (2.62)
Paper 1 (Lam et al., 2023)	0.75	0.50	25.1 (9.2)

Note. The quadratic component was calculated based on the reported key press rates in each selected study. Comparison between phases (anticipatory and consummatory) in the ACP task was shown. If the value of quadratic component closes to 0, it represents a flatter shape (i.e., stronger emotion-behaviour decoupling).

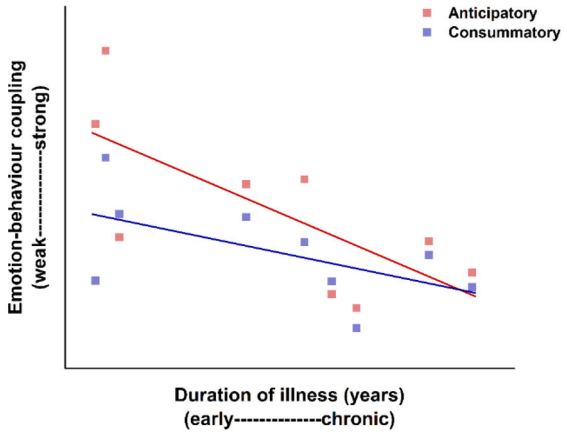

Figure A4. Illustration of the stage of illness affecting the strength of emotion-behaviour coupling. The figure shows the association between anticipatory and consummatory motivation and duration of illness based on the data obtained from Table A1.

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