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REVIEW

The Relationship Between Schizophrenia and Interoceptive Accuracy and Sensitivity: A Systematic Review and Meta-Analysis

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Abstract: Interoception is the ability of a person to perceive, integrate, interpret and regulate signals from within the body. The progression of the disease in schizophrenic patients affects their interoceptive function, producing large differences regarding interoceptive accuracy and sensibility when compared with the healthy controls. However, empirical work has produced mixed results. The study used Rev Man 5.4 software to analyse the accuracy and sensitivity of interoception in schizophrenia and healthy controls. Six studies were included in this study with 190 patients and 399 healthy controls. A systematic literature search was conducted based on The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. It was pre-registered under CRD420251028401. Meta-analysis showed that there was a statistically significant difference between schizophrenic patients and healthy controls in terms of interoceptive accuracy and sensitivity (interoceptive accuracy: I^2=78%, SMD=−0.54, 95% CI:-1.03, −0.05; and interoceptive sensitivity: I^2=75%, SMD=0.19,95% CI:-0.00,0.39). The results found a statistically significant difference in the lower accuracy and sensibility of interoception in patients with schizophrenia compared to normal subjects.

Keywords: schizophrenia, interoception, heartbeat counting task, MAIA

Introduction

Interoception refers to the process by which the nervous system senses, interprets, and integrates internal bodily signals, providing continuous monitoring of the body's physiological state across both conscious and unconscious levels.[1] This fundamental biological process has gained increasing attention in psychiatric research, particularly in relation to anxiety disorders, autism spectrum conditions, and mood disorders, where studies have demonstrated robust associations between interoceptive dysfunction and symptom manifestation.[2–4] Contemporary research conceptualizes interoception as a multidimensional construct comprising three distinct but interrelated components: (1) interoceptive accuracy:refers to an individual's ability to actually perceive and accurately report internal body signals. This is a performance-based, objective dimension that does not depend on an individual's subjective beliefs or emotions, (2) interoceptive sensitivity: The intensity, frequency, and strength of an individual's subjective beliefs about internal body sensations. It is based solely on the individual's subjective report of how much they think they feel rather than how accurately they actually perceive it, and (3) interoceptive awareness:refers to an individual's metacognitive awareness of the correspondence between inner feeling accuracy and inner feeling sensitivity. Simply put, it is whether or not a person is aware of the accuracy of his or her inner feelings.[5] While early meta-analytic work yielded mixed findings regarding the relationship between cardiac interoceptive accuracy and anxiety, more recent investigations employing standardized assessment protocols have identified more consistent patterns of association.[6,7]

In schizophrenia spectrum disorders (SSDs), accumulating evidence suggests significant impairments in interoceptive functioning, though the precise neural mechanisms remain incompletely understood.[8] Schizophrenia is characterised by

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significant perceptual disturbances and behavioural changes, and symptoms may include persistent delusions, hallucinations, highly disturbed thinking, behaviour, or abnormal mood swings.[9] Modern conceptualizations of schizophrenia increasingly emphasize disturbances in bodily self-awareness as core features of the disorder, with neuroimaging studies implicating dysfunction in the anterior insular cortex and associated salience network regions.[10,11] Recent longitudinal research has demonstrated that interoceptive deficits often emerge during the prodromal phase and may predict illness progression.[12] Notably, specific patterns of interoceptive dysfunction appear differentially associated with symptom clusters: diminished interoceptive awareness correlates with positive symptoms, while altered interoceptive sensitivity shows stronger links to negative symptoms.[13] When the intense physical reactions of schizophrenia are not rationally explained, one may develop a sense of paranoia that an adverse event is imminent.[14] Furthermore, emerging evidence suggests that abnormalities in interoceptive-affective integration may contribute to the development of anomalous self-experiences characteristic of schizophrenia.[15]

The empirical literature on interoception in schizophrenia has employed diverse methodological approaches, including both behavioral paradigms and self-report measures. Recent relevant articles have highlighted the wide variation between the results of different studies, which may be due to factors such as disease duration, medication status and assessment methods. Particularly noteworthy is the growing recognition of cultural influences on interoceptive awareness, with cross-cultural studies revealing substantial variation in both behavioral performance and subjective reports.[16] The current meta-analysis builds upon these developments by incorporating six multinational studies that collectively represent diverse patient populations and assessment approaches. These studies vary along several potentially important dimensions, including patient age, educational background, illness chronicity, and cultural context - all factors that recent research suggests may moderate interoceptive functioning.

Recent advances in interoception research have introduced novel assessment approaches that may enhance measurement precision. These include the CARdiac Elevation Detection (CARED) task, which improves measurement accuracy,[17] and the MAIA-2 questionnaire, which provides enhanced differentiation between adaptive and maladaptive interoceptive attention styles.[18] These developments underscore the importance of systematic evaluation of existing evidence to clarify the nature and magnitude of interoceptive abnormalities in schizophrenia.

In light of these considerations, this pre-registered systematic review and meta-analysis (CRD420251028401) aims to: (1) quantify differences in interoceptive functioning between individuals with schizophrenia and healthy controls across multiple assessment modalities; (2) examine potential moderators of these differences, including clinical characteristics and methodological factors; and (3) integrate these findings with contemporary neurobiological models of schizophrenia. By synthesizing evidence from diverse geographical regions and assessment approaches, this study seeks to provide a comprehensive characterization of interoceptive dysfunction in schizophrenia while predicting key directions for future research and clinical application.

Method

Search Strategy

The systematic literature search was conducted in accordance with The PRISMA 2020 statement: an updated guideline for reporting systematic reviews and was pre-registered.[19] The PRISMA checklist and extracted data can be found in Supplementary Material 1. The screening process was carried out by six authors independently. We searched PubMed and Web of Science for relevant studies on schizophrenia interoception from the time of the library's inception until 3 April 2025 for the following search terms:"Schizophrenia(s)", "Dementia Praecox", "Schizophrenic Disorders", "Disorder(s), Schizophrenic", "Schizophrenic Disorder" and "Interoception","Alliesthesia(s)", "Alliesthesias". A total of 158 articles were found and 51 duplicate studies were manually removed using EndNote, resulting in 107 studies.

Study Selection and Extraction

Article screening was done by three members of the team, and no errors were found. For questionable research, the subject matter is discussed and eventually agreed upon by the members of the group. The criteria for inclusion in the study were as follows: (1) the full text is available; (2) the study was conducted on people with schizophrenia and had

a relevant diagnosis; (3) the study used interoception measures, including a research paradigm and an assessment questionnaire; (4) there was a clear study design and interoception data on people with schizophrenia were available, and the results were publicly available;and (5) the language of the article is English. In order not to miss all the studies on interoception in schizophrenia, the literature was screened to include all the studies that had measurements of interoception, including heartbeat counting tasks and similar tasks such as the heart rate discrimination task, the heartbeat perception task, etc.; as well as the Multidimensional Assessment of Multidimensional Assessment of Interoceptive Awareness(MAIA), and so on. The Heartbeat Counting Task included in the literature involves asking subjects to estimate the number of heartbeats in 25s, 35s, and 45s, counting their heartbeats silently when they hear the "start" signal until they receive the "stop" signal, and reporting the number of heartbeats in the interval just ended verbally to the main subject at the time of each "stop" signal. At each "stop" signal, the subject had to report verbally to the master the number of heartbeats during the interval just ended. For detailed information and reasons for exclusion, see specifically Figure 1.

Of the six included studies, five of them used the Heartbeat Counting Tasks or similar experiments, and three used the MAIA to assess the interoceptive abilities of the study participants. Two of these studies used both the Heartbeat Counting Task (or similar experiments) and the MAIA. Two studies included only patients with schizophrenia, and four other studies recruited patients with diagnoses of other mental disorders in addition to those with schizophrenia. However, all six of these studies reported differences in interoceptive abilities between schizophrenic patients and normal controls. The basic characteristics of the included literature are shown in Table 1.[13,20–24]

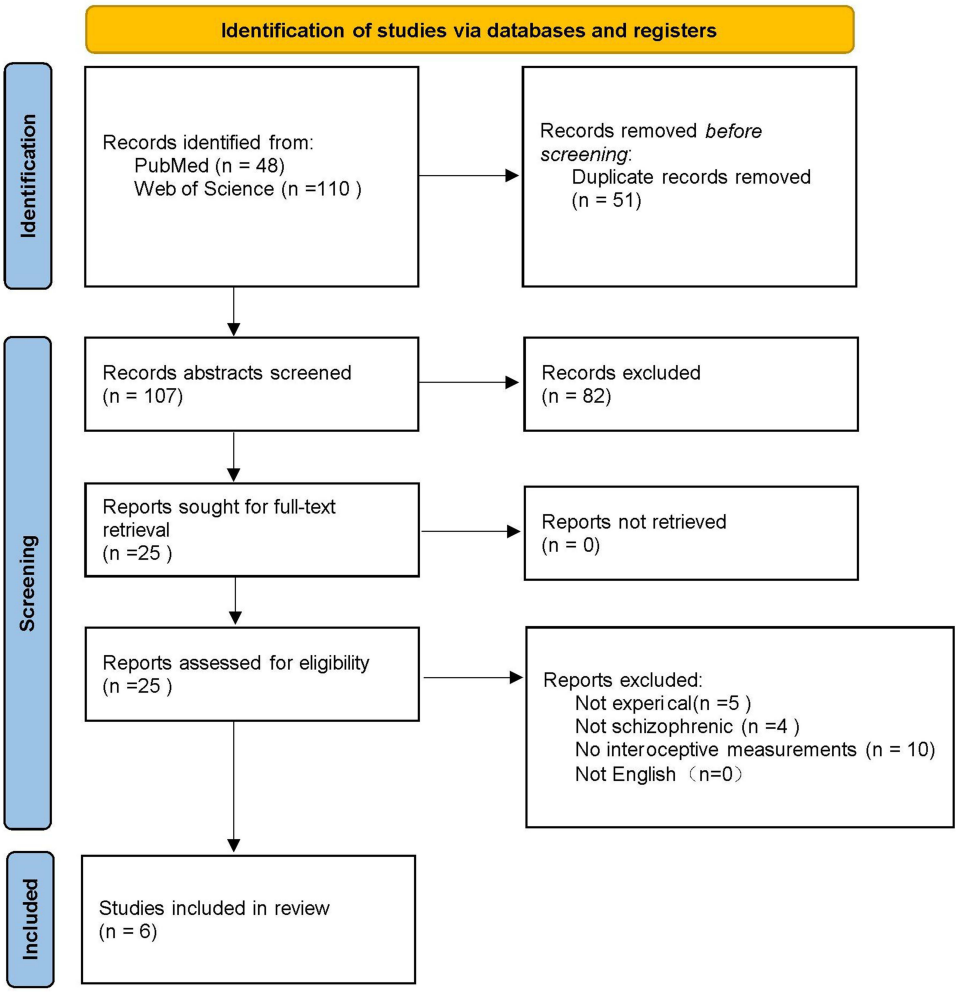

Figure 1 A flow diagram demonstrating the number of studies identified and the number of studies excluded at each screening stage.

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Table 1 Basic Characteristics of the Included Literature

Author	N		Area	Interoception Task	Questionnaire
	SCZ	*HC*			
Hugo D.2023[13]	19	67	Europe	Heartbeat Tracking Task Heartbeat Discrimination Task	BPQ
Martina 2016[17]	23	23	Europe	Heartbeat Counting Task	No.
Damiani S2024[18]	36	210	Europe	No.	MAIA
Lénie 2021[19]	30	28	North America	Heartbeat Counting Task	MAIA
Akihiro 2023[20]	42	30	Asia	Heartbeat Counting Task	MAIA
Jayson 2024[21]	40	41	Australasia	Heart rate Discrimination Task	No.

The article used the risk of bias assessment tool provided by the Cochrane Handbook to assess the literature for risk of bias. The analysis of bias consisted of seven areas of evaluation: "Random sequence generation","Allocation concealment", "Blinding of participants and personnel", "Blinding of outcome assessment", "Incomplete outcome data", "Selective reporting ", and "other biases '. Each section was evaluated by the authors in terms of 'unknown risk','low risk", and "high risk" of the literature. The included studies did not selectively report risks and other unknown risks. The results of the literature quality evaluation are shown in Figure 2.

Interoceptive Accuracy

Academics are inconclusive about the measurement of interoception, but the Heartbeat Counting Tasks are more widely used in measuring interoceptive accuracy. The Heartbeat Counting Task required subjects to count the number of heartbeats they felt during the measurement period and to report the number of heartbeats at the end of each end quiz. Two of six included

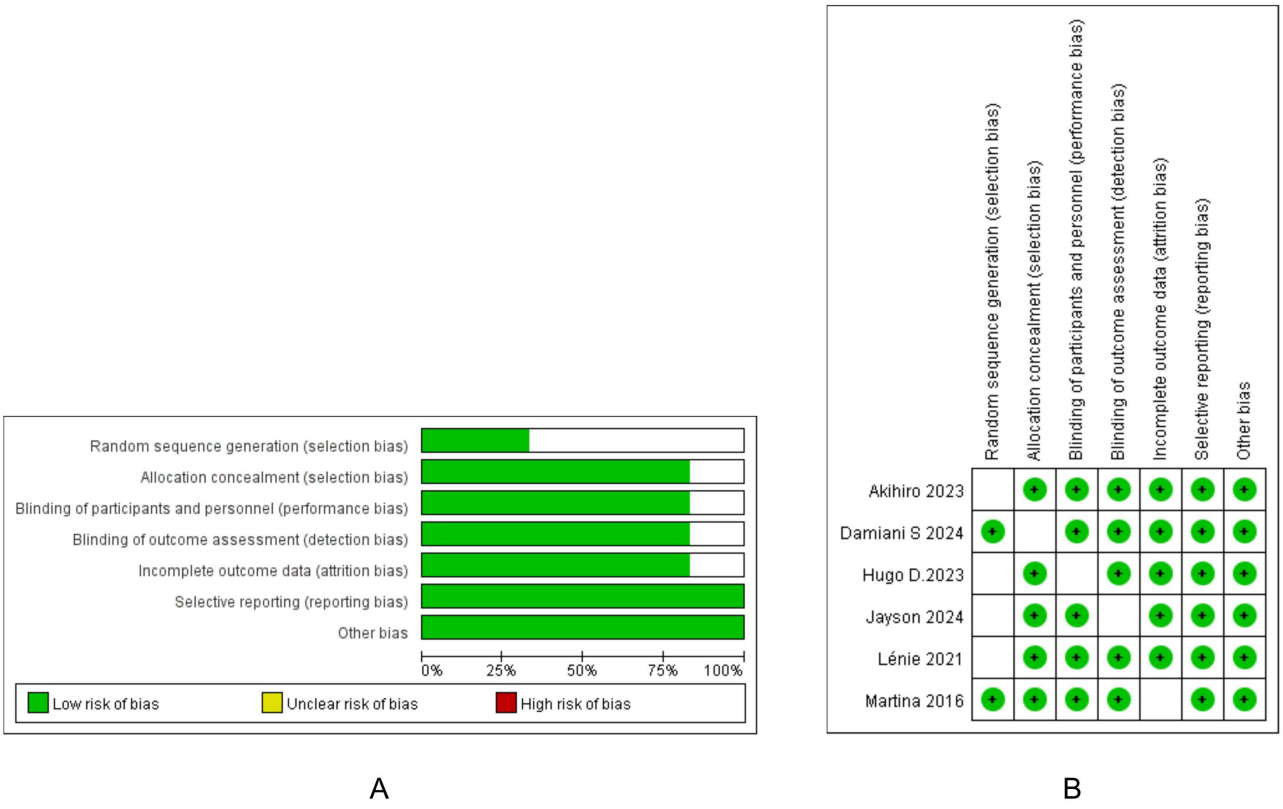

Figure 2 (**A**) Proportion of risk of bias for included studies graph; (**B**) Summary chart of risk of bias for included studies.

studies used similar variations of the Heartbeat Counting Task, which also required subjects to feel the frequency of their heartbeat for a defined period of time, and involved a similar process, so they were also included in the study. By comparing the subjects' estimated number of heartbeats with the actual number, it was possible to determine whether there has interoception difference between the schizophrenics and the normal controls. It has been shown that the Heartbeat Counting Task performance remains stable during task repetition and does not change with increasing familiarity.[25,26] Purposeful perception of one's own heartbeat is not a habitual behaviour, and thus the results of the Heartbeat Counting Task have a certain stability that can effectively account for the problem of interoceptive accuracy.

Multidimensional Assessment of Interoceptive Awareness (MAIA)

The MAIA is a self-administered questionnaire that assesses interoceptive sensitivity. The MAIA consists of 32 items, including "Noticing", "Not-distracting", "Not-worrying", "Attention regulation", "Emotional awareness", "Self-regulation", "Body listening" and "Trusting".[27] Three of the six included studies used the MAIA to measure interoceptive sensitivity, and one used the Porges Body Perception Questionnaire (BPQ), a subscale of the BPQ that assesses a subject's sensitivity to his or her own body, quantifies interoceptive sensations, and also serves as a questionnaire for assessing interoception.[28]

Clinical Diagnosis

In the studies included in the meta-analysis, patients with schizophrenia were recruited from local hospital outpatient clinics and all met the DSM-5 diagnosis of schizophrenia. Two of the five included studies used the Negative and Positive Symptom Scale (PANSS),which further explored and refined the interoceptive sensitivities of patients with schizophrenia, in order to compare which dimension of the PANSS scale had the greatest impact on patients' interoceptive functioning.

Statistical Methods

Meta-analysis was done based on Rev Man 5.4 software. Differences in continuous variables due to measurement units were assessed using standardised mean difference (*SMD*) combined with *95% CI*. Heterogeneity between studies was determined by the χ^2-test. Heterogeneity was determined by the χ^2-test: if heterogeneity was low ($I^2 \leq 50\%$ and $P > 0.1$), a fixed-effects model was used to combine the data; if heterogeneity was significant ($I^2 \geq 50\%$ or $P < 0.1$), a random-effects model was used. If the heterogeneity was significant ($I^2 \geq 50\%$ or $P < 0.1$), a random-effects model was used. The sensitivity of the findings was tested using the method of removing data from 1 study document at a time.

Results

Interoceptive Accuracy

Aggregate Analysis Discussion

The 5 studies included in the analysis systematically assessed differences in the interoceptive accuracy in schizophrenics and normal subjects. Heterogeneity tests showed high heterogeneity ($I^2=78\%, P=0.001$), and combining effect sizes using a random-effects model. The results showed that the total effect sizes for the meta-analyses ranged from −1.03, −0.05. Out of 5 studies, 2 data were found to show significant differences between the interoceptive accuracy of schizophrenics and that of normal individuals. Both studies showed that in the heartbeat counting task, schizophrenics scored lower than normal controls. The results are shown in Figure 3. A funnel plot was drawn for this metric, and the scatter distribution was generally symmetrical across studies, suggesting that no significant publication bias was found in this study, see Figure 4.

Subgroup Analysis

Heartbeat Counting Task

Three studies used the Heartbeat Counting Task to measure interoceptive accuracy. Heterogeneity tests showed higher heterogeneity ($I^2=77\%,P=0.01$),so a random effects model was used. The results showed that the schizophrenic patients scored significantly lower than the control group ($SMD=-0.80,95\%\ CI:-1.46\sim-0.14,Z=2.37,\ P=0.02$), as shown in Figure 5.

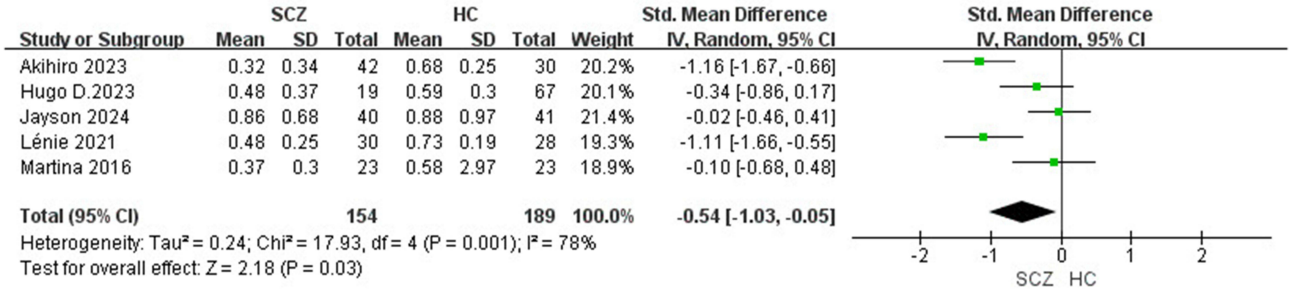

Figure 3 Forest plot comparing interoceptive accuracy within SCZ and HC.

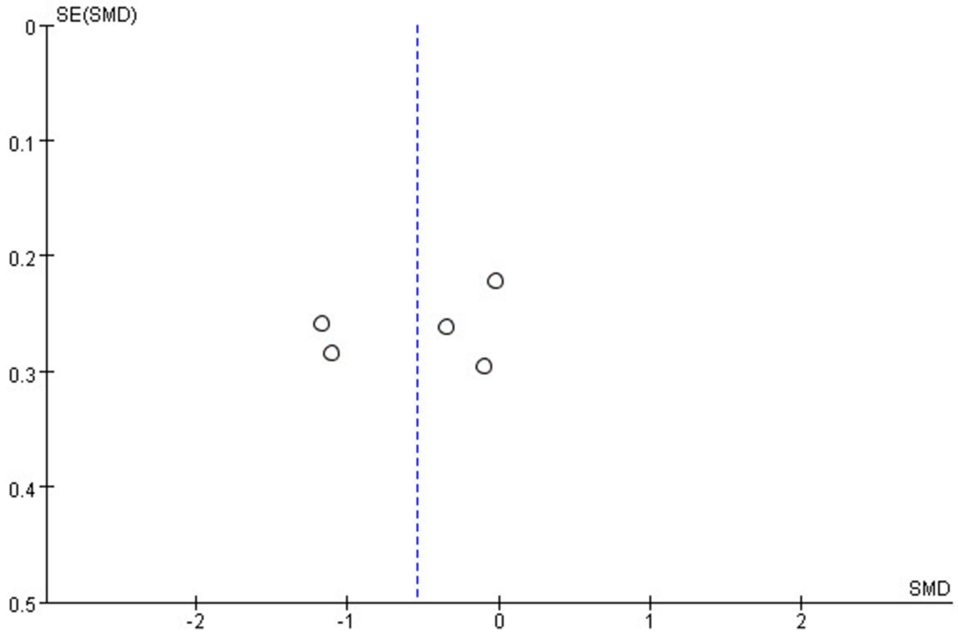

Figure 4 Funnel plot comparing interoceptive accuracy within SCZ and HC.

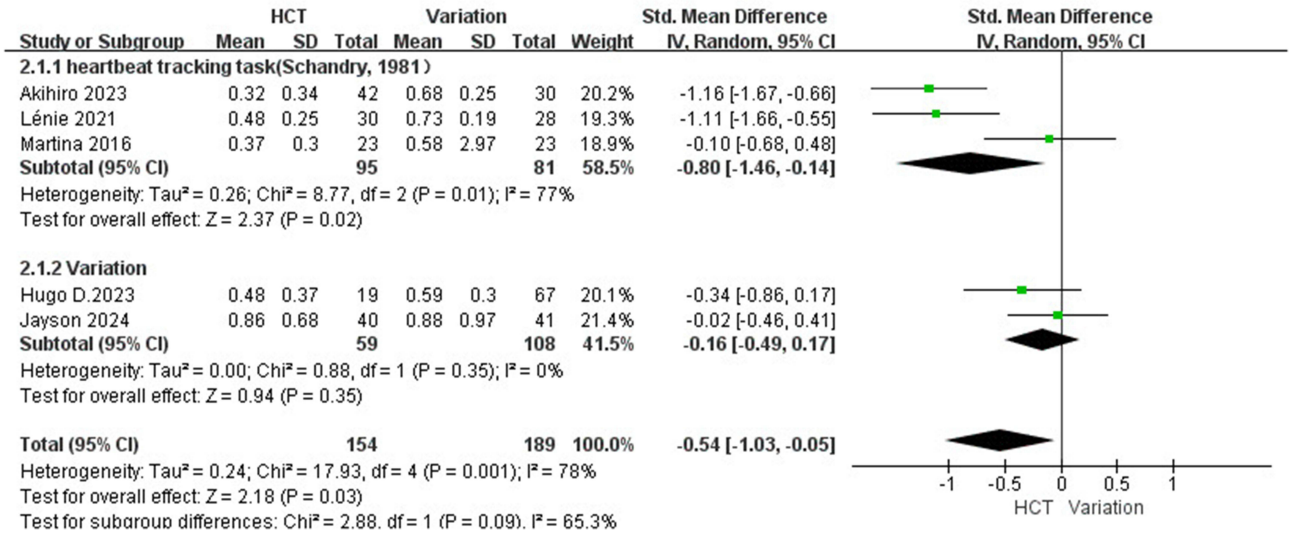

Figure 5 Subgroup comparative forest plot of SCZ and HC interoceptive accuracy.

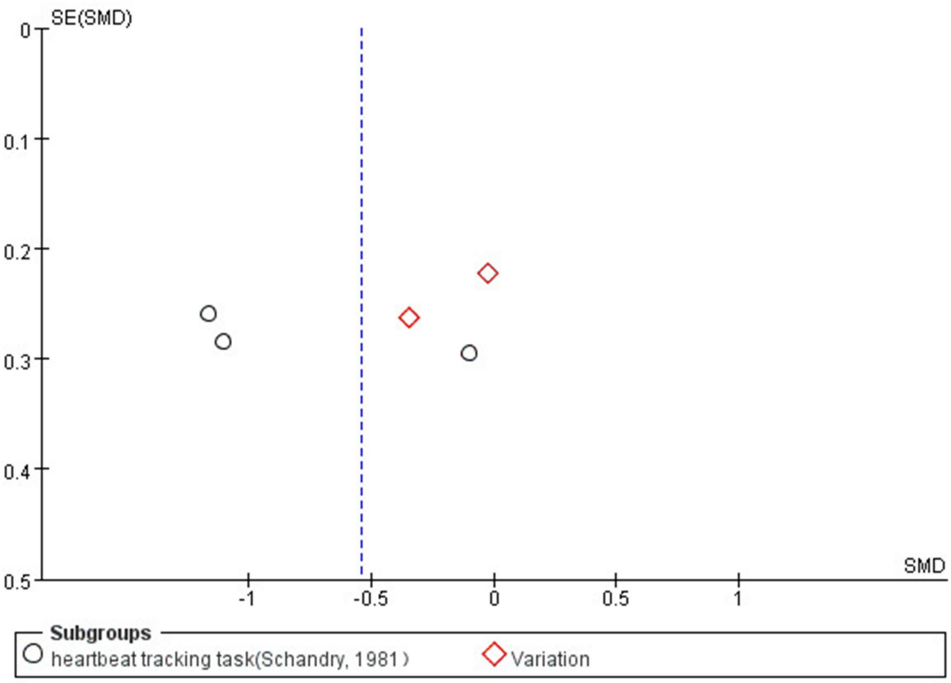

Figure 6 Subgroup comparative funnel plot of SCZ and HC interoceptive accuracy.

Heartbeat Counting Task Variations

2 studies used heartbeat counting task variants, Heartbeat Tracking Task and Heartbeat Discrimination Task. Comparison between the two groups (*SMD=−0.16,95% CI:-0.49~-0.17,Z=0.94, P=0.35*), did not show statistical differences. The results are shown in Figure 5. A funnel plot was drawn for this metric, and the scatter distribution was generally symmetrical across studies, suggesting that no significant publication bias was found in this study, see Figure 6.

Sensitivity Analysis

Sensitivity analyses were conducted on the remaining four studies by progressively removing individual original studies and testing whether the overall effect size would be affected by using the overall validity rate as a control (SMD = −0.54, 95% CI: −1.03, −0.05). The results showed no significant changes in the outcome indicators, suggesting that the results of the Meta-analysis were relatively stable, and the detailed data are shown in Table 2.

Maia

Aggregate Analysis

The 2 studies included in the analyses used the MAIA to assess interoception differences between SCZ and HC. The heterogeneity test showed high heterogeneity (I^2=75%,P<0.00001), so the random effects model was used to combine the

Table 2 Comparative Sensitivity Analysis of the Accuracy of Interoception in SCZ and HC

Author	*SMD*	*95% CI*	*I^2 (%)*	*P*
Strike out Martina 2016	−0.65	−1.22, −0.08	81%	0.03
Strike out Lénie J 2021	−0.41	−0.92, 0.11	76%	0.12
Strike out Akihiro 2023	−0.38	−0.85, 0.09	70%	0.11
Strike out Hugo D. 2023	−0.59	−1.21, 0.03	83%	0.06
Strike out Jason 2024	−0.68	−1.20, −0.16	73%	0.01
Total information	−0.54	−1.03, −0.05	78%	0.03

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effect size, and the combined effect size was SMD=0.19 (95% CI: −0.00,-0.39). The difference was statistically significant (*P=0.05*). Meta-analysis showed that schizophrenic had higher MAIA scores than healthy controls, and the distribution of effect size was shown in Figure 7. A funnel plot was drawn for this metric, and the results showed that the scatter distribution was largely symmetrical across studies, suggesting that no significant publication bias was found in this study, as detailed in Figure 8.

Subgroup Analysis

Subgroup analyses were conducted in this study according to the eight dimensions of the MAIA scale. It was found that there was a statistical difference between the schizophrenic and healthy controls in the four dimensions of Noticing, Not-worrying, Body listening, and Trusting (*P≤0.05*). Healthy controls scored higher than schizophrenic on the dimension

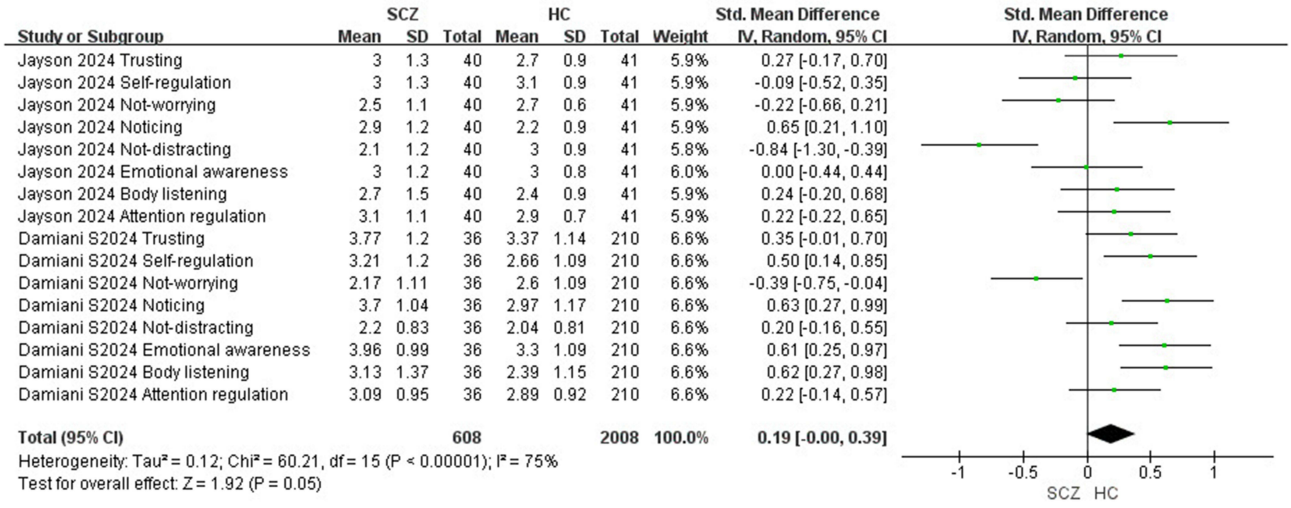

Figure 7 Forest plot comparing MAIA scores for SCZ and HC.

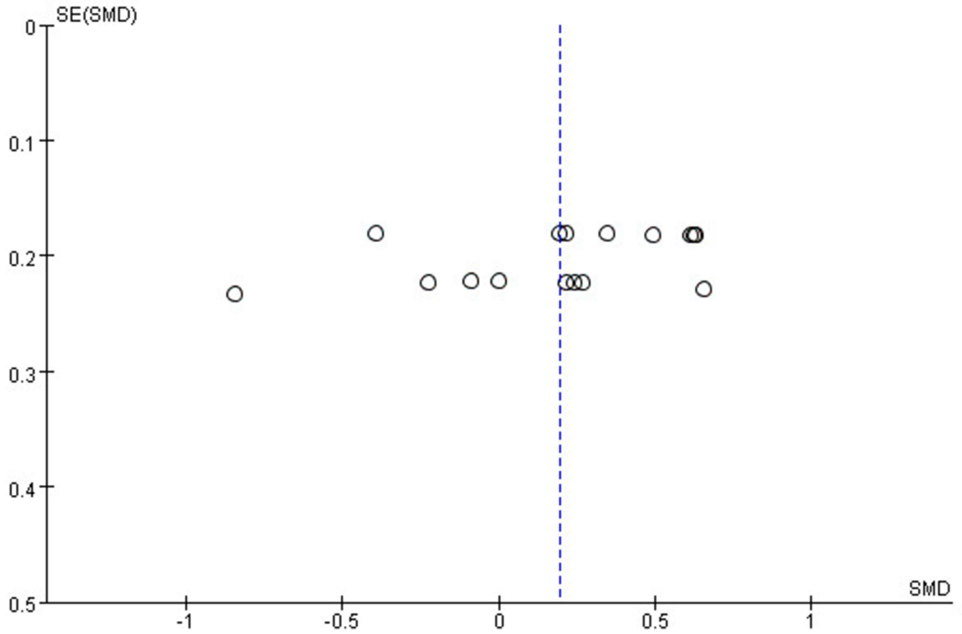

Figure 8 Funnel plot comparing MAIA scores for SCZ and HC.

Not-worrying (*P=0.02*) and lower than schizophrenic on the dimensions Noticing (*P<0.0001*), Body listening (*P=0.02*), and Trusting (*P=0.03*). The results are shown in Figure 9. By plotting the funnel plot, it was found that the scatter of each dimension of MAIA was basically equally distributed on both sides, and no obvious publication bias was found, as detailed in Figure 10.

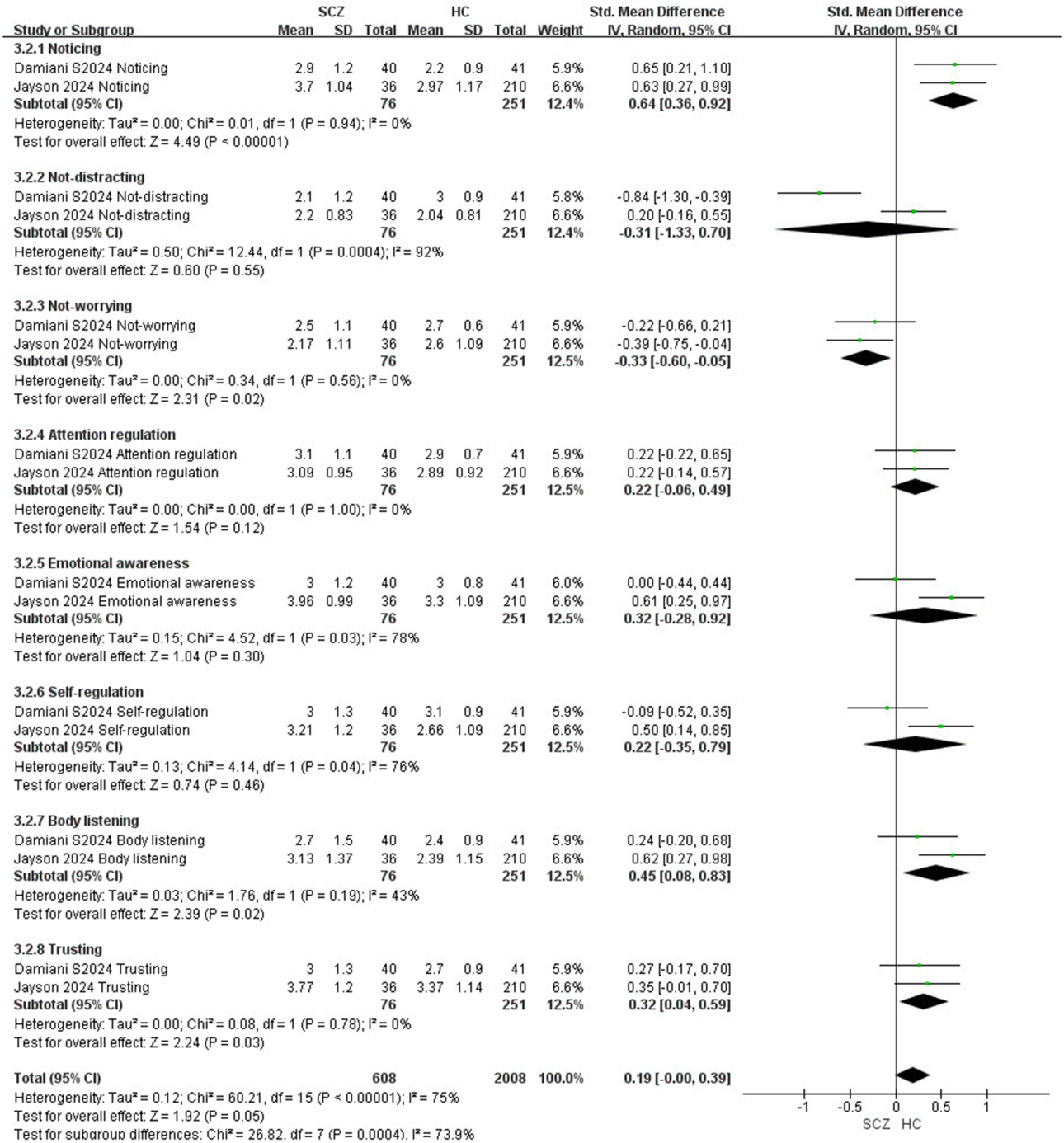

Figure 9 Forest plot of subgroup analyses of MAIA scores for SCZ and HC.

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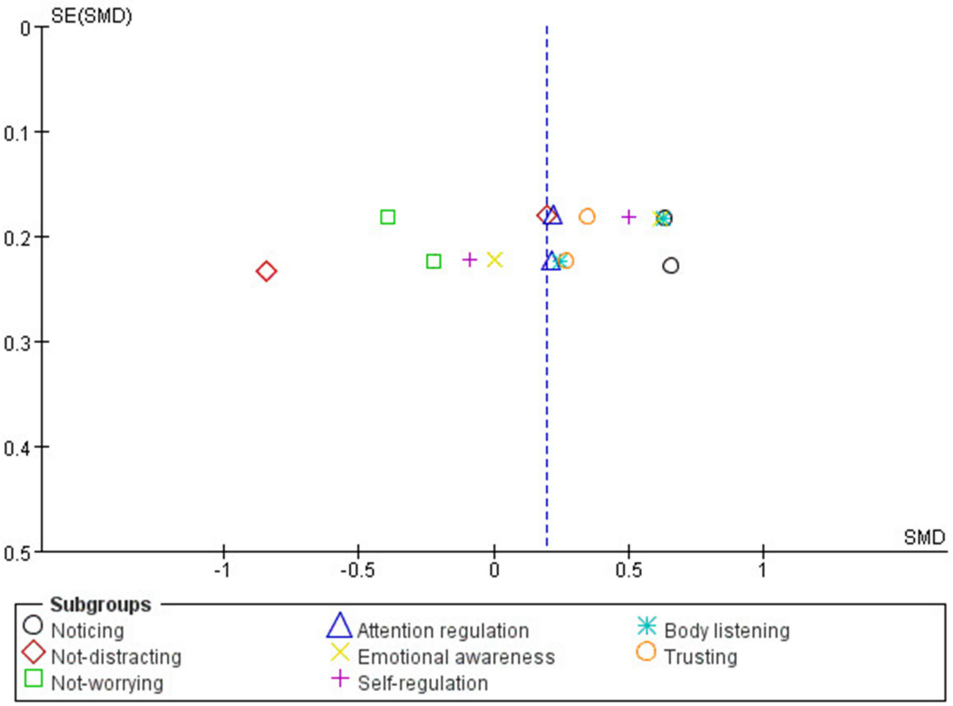

Figure 10 Funnel plot of subgroup analyses of MAIA scores for SCZ and HC.

Conclusion

This pre-registered systematic review and meta-analysis aimed to investigate potential differences in interoceptive accuracy and sensitivity between schizophrenia and healthy controls. Our comprehensive analysis revealed a statistically significant, though modest, difference in interoceptive accuracy between groups ($P = 0.03$), with healthy controls demonstrating superior performance compared to schizophrenia. However, in terms of interoceptive sensitivity, schizophrenics had higher MAIA scores than healthy controls. These findings align with the majority of existing literature in this field, supporting the hypothesis of interoceptive impairment in schizophrenia spectrum disorders.

Heartbeat Counting Task

Our meta-analysis revealed that schizophrenia demonstrated significantly lower accuracy on the standard Heartbeat Counting Task compared to healthy controls. However, this effect was attenuated when examining task variants, likely due to two key limitations: (1) the small number of included studies (n=3 for the Heartbeat Counting Task, n=2 for variations), which reduces statistical power; and (2) substantial methodological heterogeneity among variant protocols, potentially obscuring true effects. These findings suggest that while basic cardiac interoception appears impaired in schizophrenia, the robustness of this deficit may depend on specific task parameters.

MAIA

Among the three studies administering the Multidimensional Assessment of Interoceptive Awareness (MAIA), only two provided analyzable data due to unavailable primary data from one research group.[21,23] Contrary to expectations, the results of the Meta-analysis showed a trend towards higher MAIA scores in schizophrenics than in healthy controls, a trend that was limited by the unequal group sizes (3:1 ratio of healthy controls to patients) and the very small number of included studies. Of note is the fact that subgroup analyses revealed that schizophrenia scored higher than healthy controls on three sub-scales of the MAIA: "Noticing", "Body listening", and "Trusting", while scoring lower than healthy controls on the "Not worrying" dimension. In general, we believe that patients with schizophrenia have deficits in interoceptive functioning and should have lower MAIA scores than healthy controls, but in conjunction with the results,

this is the opposite of what we expected. We speculate that the stage of the disease may be one of the causes of increased interoceptive sensitivity in schizophrenics. In fact, patients with active psychosis are more likely to make certain judgements, even if those judgements they make do not correspond to reality.[29] Thus, the increased capacity for interoceptive sensitivity in schizophrenics might be explained by their over-reliance on maladaptive processes of internal thoughts or perceptions.[21] The results of the meta-analysis are consistent with the findings of Damiani and Akihiro.

Patients with schizophrenia tend to have poorer healing due to the high relapse rate and the persistence of residual states, and patients may continue to have impaired functioning, affecting their recovery of social functioning.[30,31] In recent years, the direction of clinical research has prioritised reducing the severity of positive symptoms in patients with schizophrenia, with less attention paid to quality of life issues for patients. When a second- or third-generation antipsychotic is used, the quality of life improves. In addition, the use of long-acting injectable antipsychotics has been associated with a steady improvement in the level of quality of life.[32] In general, pharmacological treatments should be combined with non-pharmacological interventions, and targeted interventions that address these specific aspects of interoceptive awareness, such as positive thinking training or biofeedback programmes, may be promising therapeutic avenues.[33,34] Future studies should use larger, more balanced samples and examine potential relationships between these interoceptive deficits and specific symptom domains to guide clinical applications.

The meta-analysis found that patients with schizophrenia were lower than healthy controls in interoceptive accuracy but higher than healthy controls in interoceptive sensitivity scores. The consistent finding of reduced interoceptive accuracy in SCZ supports theories linking the disorder to disrupted bodily self-awareness. This aligns with models of schizophrenia as a "self-disorder" where impaired integration of internal signals may contribute to symptoms like depersonalization and hallucinations.[35] Despite mixed results, this meta-analysis underscores interoceptive deficits in SCZ, advocating for standardized measures in future research to clarify neural mechanisms and therapeutic targets. In summary, while schizophrenia is associated with interoceptive dysfunction, the magnitude and specificity of this relationship require further investigation.

Overall, this study systematically integrates evidence on the relationship between schizophrenia and interoceptive function through meta-analysis methods, highlighting the important role of interoceptive deficits in the disorder. The results suggest that interoception may be associated with clinical features such as positive symptoms and recovery of social functioning, providing a theoretical basis for the development of targeted psychological and physiological interventions. As mentioned above, positive thinking training, biofeedback. The present study assessed both interoceptive accuracy and sensitivity and found a dissociation between the two in schizophrenia, decreased accuracy and increased sensitivity, suggesting that patients may have an abnormal pattern of interoception "over-perception but misinterpretation".

Limitations

While this meta-analysis provides some evidence for a relationship between schizophrenia and interoceptive accuracy, we must acknowledge that there are a number of limitations. The analysis included only six studies, and certain subgroups included only two studies. This limits statistical power and increases the risk of Type II errors. Future studies should include larger, more diverse samples to validate these findings. The second is methodological heterogeneity and task variability. The included studies used different measures of interoception, which may capture different aspects of interoceptive abilities. This methodological diversity may have contributed to the high degree of heterogeneity ($I^2 > 75\%$). The third area is questionnaire differences. While the MAIA is the most common interoception measure, one study used the BPQ, which assesses broader body awareness rather than specific internal perceptual abilities. This inconsistency complicates direct comparisons. The BPQ was not included in the analysis because of the dimensional differences in the questionnaire. In addition to this, demographics and clinical variability also had an impact on the results. The SCZ cohort varied in disease duration, symptom severity, and treatment status, all of which may affect patients' interoception abilities. Finally, there are cultural and regional differences. Studies spanning multiple continents may introduce cultural bias in self-report measures. It has been shown that East Asians and West Africans report higher levels of interoceptive sensitivity but lower levels of interoceptive accuracy than European Americans.[36] This may be one of the reasons for the high heterogeneity of the included literature.

Together, these limitations suggest that the current evidence is insufficient to support strong conclusions. High heterogeneity suggests the presence of uncontrolled confounding variables, and small samples and cultural differences reduce the reproducibility of results; while methodological inconsistency challenges the uniformity of construct validity. Therefore caution is needed in the interpretation of the results. At the same time, because of the small sample size, the generalisability of the study is severely limited, and the conclusions may only apply to specific cultural contexts, specific clinical subgroups, or specific measures, and not to general features of the schizophrenia population.

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Disclosure

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