PCN Psychiatry and Clinical Neurosciences

REVIEW ARTICLE

Understanding source monitoring subtypes and their relation to psychosis: a systematic review and meta-analysis

Stefano Damiani, MD [1]*, Alberto Donadeo, MD,[1] Nicola Bassetti, MD,[1] Gonzalo Salazar-de-Pablo, MD [2,3], Cecilia Guiot, MD,[1] Pierluigi Politi, MD, PhD[1] and Paolo Fusar-Poli, MD, PhD[1,2,4]

Aims: Source monitoring (SM) is the metacognitive ability to determine the origin of one's experiences. SM is altered in primary psychiatric psychosis, although relationships between SM subtypes, other cognitive domains and symptoms are unclear. Our aims were to synthesize evidence comparing psychosis -with and without hallucinations- and healthy controls classifying SM subtypes by source discrimination (internal/external/reality monitoring) and stimulus modality (visual/auditory/imagined/performed).

Methods: This systematic review adopted Preferred Reporting Items for Systematic Reviews and Meta-Analyses, Meta-analyses Of Observational Studies in Epidemiology and Population, Intervention, Comparison and Outcomes guidelines. Core demographical and clinical parameters were extracted. Newcastle-Ottawa Scale was used as quality check. SM differences between (i) psychosis patients *versus* healthy controls and (ii) patients with *versus* without hallucinations were investigated *via* random-effect model meta-analysis. The primary effect size measure was standardized mean difference (SMD) in each SM subtype performance (error or accuracy). Heterogeneity, publication biases and meta-regressions were assessed.

Results: Five thousand two hundred and fifty-six records were screened to finally include 44 studies (1566 patients, 1175 controls). Mean Newcastle-Ottawa score was 7.41 out of 9. Few studies measured SM associations with cognition (n = 9) and symptoms (n = 19), with heterogeneous findings. SM performance across all measures was reduced in psychosis *versus* healthy controls (SMD = 0.458). Internal SM (SMD: errors = 0.513; accuracy = 0.733) and imagined stimuli (SMD: errors = 0.688; accuracy = 0.978) were specifically impaired. Patients with *versus* without hallucinations showed SM deficits only for externalizing (SMD = 0.410) and imagined/auditory (SMD = 0.498/0.277) errors.

Conclusion: The proposed classifications highlight specific SM deficits for internal/imagined stimuli in psychosis, providing evidence-based indications to design and interpret future studies.

Keywords: *externalizing bias, meta-analysis, psychosis, schizophrenia spectrum, source monitoring.*

http://onlinelibrary.wiley.com/doi/10.1111/pcn.13338/full

Source monitoring (SM) definition encompasses all the mental activities involved in making attributions about the origin of past or current subjective experiences (source memory or online SM, respectively).[1] A first classification based on source discrimination identifies three main SM subtypes: (i) internal SM (ISM) discriminates mental experiences originating from the subject, such as imagined or performed actions; (ii) external SM (ESM) discriminates between externally-generated stimuli (for instance, whether an action was presented *via* written or spoken words); (iii) reality monitoring (RM) differentiates whether the origin of an experience was internal or external (world/self differentiation). RM errors can be internalizing (RMi) when external stimuli are confused as internally-generated, or externalizing (RMe) when internally-generated stimuli are attributed to an external source.

A second classification depends on the way in which stimuli are presented to or encoded by the subject, that is, the *stimulus modality*. Internal stimuli can be imagined or performed, while external stimuli are usually visual or auditory. Different stimulus modalities engage perceptual channels that could be more subject than others to SM errors.

The possible source discriminations and stimulus modalities subtypes for SM are schematized in Fig. 1.

Source monitoring and psychosis

SM shows a clear relationship to the whole psychosis spectrum, a cluster of mental conditions characterized by impaired reality testing and world/self differentiation[2] operationalized as hallucinations and/or delusions.[3] As neurological and psychiatric psychosis are separate nosological entities,[4] the present work focuses on psychoses stemming from primary psychiatric disorders. From here on, we will hence refer to psychosis within the context of primary, non-organic psychotic disorders within the "schizophrenia spectrum and other psychotic disorders" (such as brief psychotic episodes, schizophrenia, schizoaffective disorder)[5,6] or "bipolar disorder with psychotic

[1] Department of Brain and Behavioral Sciences, University of Pavia, Pavia, Italy
[2] Early Psychosis: Interventions and Clinical-detection (EPIC) Lab, Department of Psychosis Studies, Institute of Psychiatry, Psychology & Neuroscience, King's College London, London, UK
[3] Child and Adolescent Mental Health Services, South London and the Maudsley NHS Foundation Trust, London, UK
[4] OASIS service, South London and Maudsley NHS Foundation Trust, London, UK
* Correspondence: Email: stefano.damiani@unipv.it

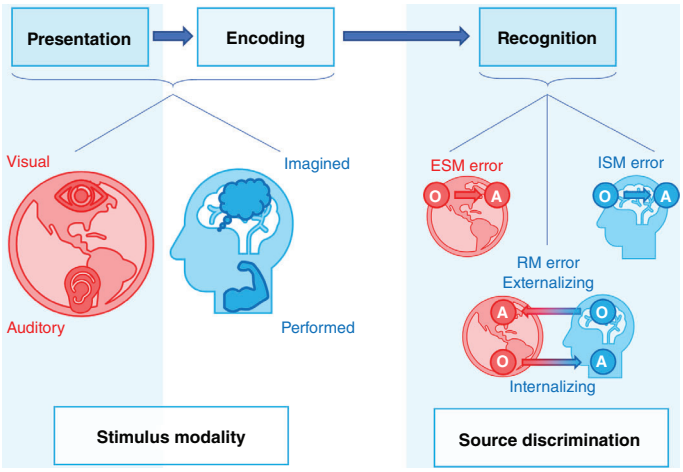

Fig.1 Source monitoring subtypes and stimulus modalities. In the first phase of source monitoring tasks, a stimulus (eg. a written or recorded sentence) is presented and encoded by the subject (eg. sentence read in mind or aloud). In the recognition phase, the stimulus is presented again, and the subject has to discriminate whether its original source was internal/self (blue) or external/non-self (red). Arrows directions (O = original source → A = answered source) represent the four possible types of source discrimination errors. ESM: external source monitoring; ISM: internal source monitoring; RM: reality monitoring.

features"[7] domain as classified in the International Statistical Classification of Diseases (ICD) and Diagnostic and Statistical Manual of Mental Disorders (DSM) criteria.[8]

SM impairments are typical of psychosis[9] and likely increase in severity when hallucinations are present.[10] However, contrasting findings and heterogenous designs in the SM studies make it difficult to synthesize the evidence in an univocal interpretation, lacking an updated synthesis.[11]

The present study aims to systematically review and meta-analyze the SM literature on psychosis to test three main hypotheses: (i) Source discrimination type (operationalized as ISM, ESM, RMe or RMi) influences SM performance in psychosis compared to healthy individuals (ii) SM is more impaired in individuals experiencing hallucinations than in those not experiencing hallucinations (iii) Stimulus modality (operationalized as auditory, visual, imagined or performed) can be an important factor to explain differences in SM performance between psychosis and healthy individuals.

Methods

This Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020[12]) (eTables 1 and 2) and Meta-analyses Of Observational Studies in Epidemiology checklist (MOOSE[13]) (eTable 3)-compliant systematic review was registered in PROSPERO (CRD42020221300).

Literature search and eligibility criteria

Articles were identified on MEDLINE and Web of Knowledge (all databases) in from inception until June 31, 2021. Two researchers (AD and SD) conducted a computerized search using the following search string: "(source OR reality) AND monitoring) AND (psych* OR schizophreni*)." Endnote X9 version was used to organize and collect data. A manual search was conducted on the relevant studies and additional references were included. Inclusion/exclusion criteria were applied following the Population, Intervention, Comparison and Outcomes and Study tool (PICOS)[14] and are listed in Fig. 2A. Inclusion criteria were: (i) diagnosis of schizophrenia spectrum and other psychotic disorders or bipolar disorder with psychotic features according to DSM-III/IV/5 or ICD-10/11; (ii) investigation of at least one source monitoring type among internal source monitoring, external source monitoring, and reality monitoring; (iii) the presence of a control group (healthy individuals with no past or present psychosis or patients with no hallucinations); (iv) the possibility to measure either accuracy or error scores; (v) case-control or cross-sectional studies; and (vi) Full-text in English. Exclusion criteria were: (i) organic/neurological psychosis; and (ii) the presence of potentially distracting conditions (EEG, PET or MRI) that may have influenced the task performance differently in the two groups. A major aim of this study was to differentiate SM performance according to stimulus modality. Neuroimaging studies were excluded as they produce stimuli (mainly auditory and tactile) that may be especially distressing or confounding for the group with psychosis. This may excessively reduce their performance when compared to healthy controls; and (iii) the use of measures that mix accuracy and error scores (signal detection measures).

Discrepancies were resolved through consensus. Corresponding authors were contacted for papers that lacked sufficient statistical data (i.e. mean and SD) and, when available, further data were included.

Data extraction

Two independent authors (AD and NB) worked independently and in duplicate to read full text and collected the following data: groups characteristics and diagnosis, number of subjects, gender (males %), age, IQ (scale and score), education years, clinical scale used to measure psychotic symptoms, antipsychotic medication (chlorpromazine equivalents), illness duration and presence of old/new recognition tasks (ONRT, see methods section). Task descriptions and main SM findings from each study were collected and systematically reviewed. For the review purposes, we systematically collected and reported data concerning associations between SM performance and several parameters: positive and negative symptoms severity, cognition, emotional content of stimuli, and degree of confidence in the given answers.

Quality assessment

The quality of included studies was evaluated with the Newcastle-Ottawa Scale (NOS), considering selection, comparability, and exposure as items (maximum score = 9).[15]

Meta-analysis: groups definition

For individuals with psychotic disorders (PSY), the included diagnostic categories were either "schizophrenia spectrum and other psychotic disorders" or "bipolar disorder with psychotic features" as classified by ICD/DSM criteria. "Brief psychotic episodes" and "acute and transient psychotic disorders" were also included, while psychoses induced by other organic or medical conditions were excluded (see Fig. 2a for full PICOS criteria). Healthy controls (HC) were screened for psychosis (except for n = 5 studies which did not report how psychosis was excluded in the HC group) and not diagnosed with any psychiatric condition. Whenever possible, PSY with or without current hallucinations (PSY-H and PSY-NH respectively) were also collected as separate groups and compared.

Meta-analysis: Outcome measures of SM performance – Source discrimination *versus* stimulus modality

Mean number/proportion of correct (accuracy) or incorrect (errors) source recognitions quantitatively determined SM performance. For source discrimination classification of outcome measures, it was possible to classify accuracy measures as either ISM or ESM. SM measures that did not differentiate between ISM and ESM sources were excluded by the meta-analysis. Errors allowed a more fine-grained classification as ISM, ESM, RMe and RMi. For this reason, errors and accuracy measures were tested separately. For stimulus modality classification, external sources were classified as auditory or visual, while internal sources were classified as imagined or performed (for instance, whether a displayed word was read silently or aloud).

PCN Psychiatry and Clinical Neurosciences

(a) PICOS criteria

Parameter	Inclusion	Exclusion
Participants	Diagnosis of Schizophrenia Spectrum and Other Psychotic Disorders or Bipolar Disorder with Psychotic Features according to DSM-III/IV/5 or ICD-10/11 Any age, with or without hallucinations	Organic/neurological psychosis
Intervention	Investigation of at least one source monitoring type among internal source monitoring, external source monitoring, and reality monitoring	Source monitoring tasks performed under potentially distracting conditions (EEG, PET, or MRI)
Comparator	i) Healthy individuals without past or present psychosis ii) Patients subgroup without hallucinations	
Outcomes	Accuracy and/or errors in source monitoring	Signal detection measures of source monitoring mixing accuracy and error parameters Unclear source distinctions
Study design	Observational studies (case-control, cross sectional)	Reviews, abstracts, posters, conferences
Language	Full-texts published in English	

(b) PRISMA flow chart

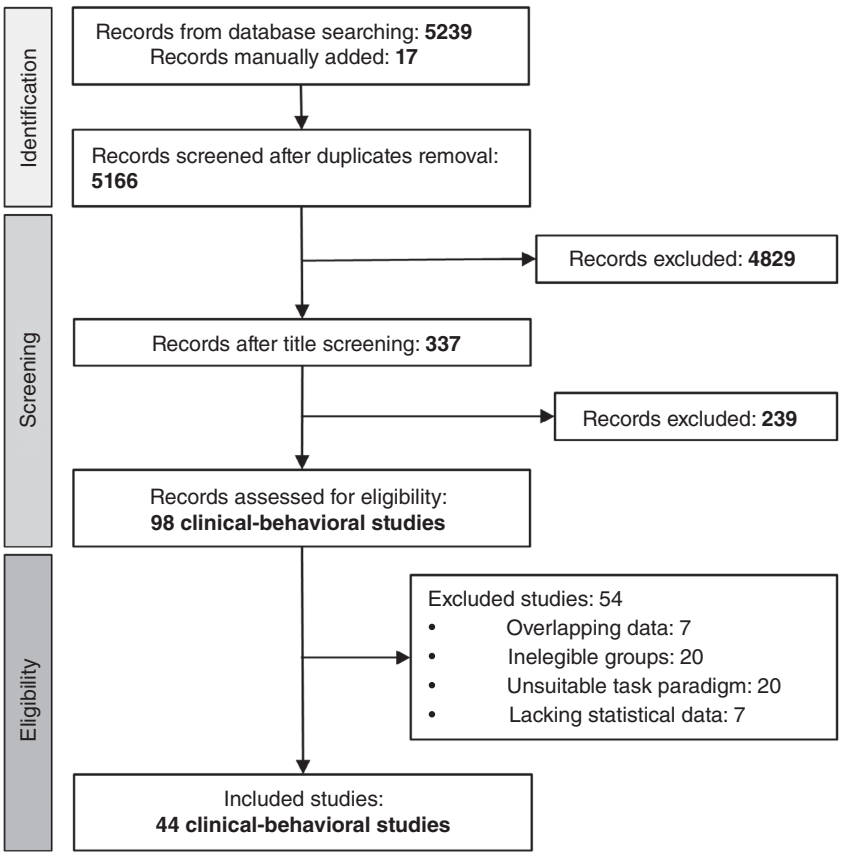

Fig.2 Study selection criteria and flow-chart. (a) Population, Intervention, Comparison and Outcomes and Study (PICOS) tool; (b) Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow chart.

Strategy for data synthesis

Our primary aim was to evaluate differences in SM performance between PSY and HC for each SM discrimination subtype. Differences were tested as source discrimination errors and accuracy scores. Additionally, we tested differences in source discrimination performance between PSY-H and PSY-NH.

The abovementioned analyses were conducted after re-classifying the outcome measures of SM performance for each study according to the stimulus modality.

Standardized mean difference (SMD) was used as the main effect size metric for the analyses.[16] When multiple measures investigated the same source monitoring subtype within a single study, a

merged effect size was computed prior to inclusion in the main analysis. Only clear source distinctions were included (for instance, accuracy/error measures where original voices were distorted were not considered). Since the studies were expected to be heterogeneous, meta-analytic random-effects models were used, and three different values of within-study correlations of SM measures (r = 0.3; r = 0.5; r = 0.7) were compared to test the possible influence of this parameter on SMD.[17]

Subgroup analyses for (i) source discrimination (Error: ESM, ISM, RMe and RMi; Accuracy: ESM and ISM) and (ii) stimulus modality (auditory, visual, imagined and performed) classification were carried out. Heterogeneity among study point estimates was assessed with the Q statistic. The I^2 index evaluated the magnitude of heterogeneity with $I^2 > 50\%$ and $P < 0.10$ indicating significant heterogeneity.[18] Egger's test for funnel plot asymmetry was implemented to assess a possible publication bias[19] in the main group of analyses (source discrimination). The trim-and-fill method was applied when t-value for Egger's test was significant in order to correct for asymmetry bias.[20] All analyses were two-sided, with $\alpha = 0.05$.

Meta-analytical regression was conducted to evaluate the percentage of PSY individuals with hallucinations. This was performed when ≥10 studies per outcome were available in accordance with Cochrane guidelines.[21]

A second control analysis was performed to account for old/new recognition task (ONRT) effect. ONRTs measure the ability to recognize previously presented stimuli (old items) from items not shown before (new items). When ONRT did not imply the presence of a source monitoring process, the measure was discarded and not meta-analyzed. When both the original and the answered sources were clearly identifiable, new items were always considered as external sources as they were not self-generated, thus allowing a certain degree of overlap between ONRT and SM. In these instances, it may be argued that SM performance could be more related to the actual remembering of the source rather than to a source discrimination process. The overall SM performance was thus meta-analyzed separately for measures involving and not involving ONRT to test this potential bias.

All effect size calculations and statistical analyses were carried out using Comprehensive Meta-Analysis version 3.[22]

Results

Systematic review

The literature search yielded 5239 records. Seventeen additional studies were manually added (total n = 5256). After removing duplicates, we screened the title of 5166 citations: 337 abstracts were selected and 98 of them were assessed for eligibility as full texts. After excluding 54 studies, a final set of 44 clinical/behavioral randomized controlled trials were finally included for meta-analysis and, therefore, data extraction (Fig. 2b).[9,23–66] A detailed description of the exclusion reasons of the 54 excluded studies is available in eTable 4.

Sample characteristics and study designs

The age range was 19.9–52.6 for PSY and 21.1–53.3 for HC. Males were more prevalent than females, but equally represented across groups (65.9% in PSY and 65.6% in HC). The most assessed domains were clinical symptoms (88.6% of the studies), followed by education years (63.6%), IQ (59.1%), illness duration (59.1%) and chlorpromazine equivalents (47.7%). A total of eight clinical scales were adopted for psychotic symptoms. Similarly, cognitive scales were heterogeneous (14 different scales measuring IQ in 26 studies). Full details for each study are collected in Table 1.

Concerning source memory tasks, the classical separation of presentation and recognition phases was always respected. Online SM was tested in six tasks only, and usually implemented either a visual feedback (control of an object) or an auditory feedback (self/alien voice distorted to increase the difficulty of recognition).

In the included studies, PSY group participants were diagnosed with schizophrenia in 27 studies, with schizophrenia spectrum in 14 studies, and with either schizophrenia spectrum or bipolar disorder with psychotic features in three studies.

The overall quality of the studies was high (mean NOS score 7.4 over 9, see eTable 5).

Relationship between SM, clinical symptoms and other factors

eTable 6 schematizes tasks designs and findings.

Nineteen studies measured the association between SM performance and clinical symptoms, but only seven showed negative correlations between SM performance and the severity of at least a category of symptoms. Of note, one study[53] found a negative and selective association between SM performance and core-self disturbances using the Examination of Anomalous Self-Experience interview.[67]

Relationship to cognition was investigated by only nine studies, with heterogeneous measures. Social cognition showed a positive correlation with SM performance. Executive functions and IQ showed mixed findings. SM performance showed no association with memory in PSY in two studies (one of them found a positive correlation between memory and SM performance in HC instead), and a positive correlation with long-term recall memory was found in one study. The negative emotional valence of stimuli impacted on SM, reducing performance in both PSY and HC.

When the original source was altered in pitch or distorted, SM performance was significantly reduced in all groups. Two studies conducted by Johns and colleagues showed that this reduction was greater in PSY-H, followed by PSY-NH and, finally, HC.

Meta-analysis

A total of 44 studies including 1566 PSY and 1175 HC were meta-analyzed.

Main outcome: source discrimination error and accuracy in PSY *versus* HC

PSY performed worse than HC across all measures, with higher error and lower accuracy scores (Table 2). Overall, a moderate effect size was reported when considering all source discrimination measures in PSY *versus* HC (SMD = 0.458; CI = 0.401–0.514). Seventy-two of the 74 considered error measures for ESM, ISM, RMe and RMi (12, 12, 24 and 26, respectively) reported increased SM errors in PSY, with a solid statistical significance ($P < 0.001$). When comparing errors in SM subtypes, PSY committed more errors than HC. Mean effect sizes were slightly lower for original external sources (ESM SMD = 0.398; CI = 0.226–0.570; RMi SMD = 0.374; CI = 0.270–0.477) than internal ones (ISM SMD = 0.513; CI = 0.315–0.711; RMe SMD = 0.407; CI = 0.307–0.507). Heterogeneity was significant for ESM ($I^2 = 51.660$; $P = 0.019$) and ISM ($I^2 = 57.180$; $P = 0.007$) errors, while no publication bias was found by Egger's tests.

As for SM error measures, accuracy was better in HC when compared to PSY, with moderate effect sizes. Again, PSY showed a higher impairment for internal sources (ISM SMD = 0.733; CI = 0.623–0.844) than for external ones (ESM SMD = 0.454; CI = 0.343–0.566). Heterogeneity and publication bias tests were not significant.

Effect size did not change when using different within-study correlations of SM measures (eTable 7).

Source discrimination - PSY-H *vs*. PSY-NH

Twelve studies compared PSY-H (n = 234) with PSY-NH (n = 217) for a total of 451 subjects. Differences between these two groups were less consistent, showing small and non-significant effect sizes for both errors and accuracy measures: RMe was the only exception (SMD = 0.410; CI = 0.173–0.647) and it was investigated by a higher number of studies (10 *vs*. 3–7 for the other outcome measures)

Table 1. List of demographic variables and meta-regressors

Author Year	Diag.	N subjects PSY (H)	HC	PSY-H (%)	males % PSY	males % HC	Age PSY	Age HC	IQ scale	IQ PSY	IQ HC	Education years PSY	Education years HC	Clinical scales	CPZeq.	Illness duration	ONRT
Achim 2011[23]	SCH-s	25	25				23.6 (3.4)	23.4 (3.6)	Shipley	108.4 (15.4)	120.8 (7.7)	12.7 (2.5)	15.6 (1.9)	PANSS		3.1 (1.8)	0
Allen 2004[24]	SCH	28 (15)	15	53.6	89.3	86.7	33.7 (9.3)	33.1 (10.4)	NART	106.4 (7.8)	112 (7.1)			SAPS/SANS		10.4 (11.1)	0
Anselmetti 2007[9]	SCH	45	54		46.7	42.6	33.5 (11.4)	32.2 (12.5)				12.5 (2.5	13.6 (3.7)	PANSS		8.8 (7.9)	0/1
Arguedas 2012[25]	SCH-s	26	27	100	53.8	58.3	43.3 (10.1)	46.0 (11.7)	WTAR	101.5 (10.0)	111.9 (8.4)	12 (2.8)	14.2 (2.6)	SAPS/SANS		19.6 (10.2)	0
Bendall 2011[26]	FEP	43 (20)	26	46.5	52.7	38.0	21.0 (3.4)	21.2 (2.4)	NART	106.4 (6.7)	109.4 (3.6)			PANSS			0
Bentall 1991[27]	SCH-s	38 (22)	22	55.0	72.5	45.4	39.1 (10.7)	35.4 (10.8)						clinical judgment			1
Brebion 1998[29]	SCH	40	40		70.0	65.0	34.1 (11.1)	37.1 (9.9)				12.1 (2.4)	13.2 (1.9)		339 (346)	11.7 (10.2)	0
Brebion 2008[28]	SCH	41 (17)		41.5										SAPS/SANS			1
Brunelin 2006[30]	SCH	61 (30)		49.2	60.0	80.0	33.3 (8.4)					10.8 (2.7)		PANSS	509 (221)	7.9 (9.3)	1
Brunelin 2007[31]	SCH	15	15				28.6 (7.5)	29.1 (7.3)	Raven PM			11.1 (2.4)	12.5 (1.8)	PANSS	629 (692)		0
de Sousa 2016[32]	SCH-s	80	30		72.5	70.0	39.3 (11.6)	38.4 (13.3)	Quick Test	98.4 (10.6)	109.5 (8.3)	11.2 (1.9)	12.7 (2.3)	PANSS	469 (389)	15.2 (10.9)	0
Dondé 2019[33]	SCH	29	29		72.4	79.3	37.3 (11.4)	34.4 (12.6)				10.9 (3.3)	15.7 (3.6)	PANSS	1113 (997)	14.0 (9.4)	1
Drakeford 2006[34]	SCH	16	14		71	31	41.9 (11.5)	38.1 (15.1)	NART	106.3 (7.7)	114.9 (7.6)			BPRS		12.7 (7.3)	1
Fairfield 2016[35]	SCH	24	24				42.4 (6.8)	40.6 (6.7)	WAIS-R			10.5 (3.4)	11.1 (2.8)	BPRS	380		0
Fisher 2008[36]	SCH	91	30		75.0	67.0	39.9 (11.4)	39.7 (13.9)	WAIS-R	96 (12)	108 (12)	13 (2)	15 (2)				0/1
Franck 2000[37]	SCH	17 (7)	17	47.1	82.4	88.2	29.8	28.4 (5.2)	Raven PM			9.5 (2.4)	13.8 (3.7)	BPRS	473 (371)	8.8 (8.1)	0/1
Gaweda 2013[38]	SCH-s	54 (28)	34	51.9	72.2	52.9	35.2 (10.4)	33.2 (11.3)				11.6 (1.0)	11.9 (1.3)	PANSS		10.9 (8.6)	0/1
Gaweda 2018[39]	SCH-s	25	33	88.0	60.0	50.0	20.4 (2.2)	20.3 (2.1)				12.0 (0.2)	11.8 (0.4)	BPRS	406 (175)		0/1
Harvey 1985[40]	SCH	20	10		30.0	30.0	32.6 (8.4)	30.9 (1.5)	CAPPS	3.5 (1.1)	3.6 (0.8)	12.7	12.8				0/1
Harvey 1988[41]	SCH	26	25		54.0	44.0	32.2 (8.1)	30.6 (10.2)				11.8 (2.2)	13.1 (1.3)	SAPS/SANS	710 (270)		0
Henquet 2005[42]	SCH	15	15		93.3	73.3	26.7 (6.4)	26.6 (8.4)	GIT	96.1 (10.2)	113.5 (13.2)			PANSS			0
Hommes 2012[43]	SCH-s	42	49		67.0	32.7	33.5	34.8	WAIS-III	95.6	114.2			PANSS			0
Ilankovic 2011[44]	SCH	23	23	100	47.8	47.8	33.3 (9.3)	33.8 (9.3)	Wort-schatz	104.9 (13.3)	110.6 (12.0)	11.9 (2.4)	12.5 (2.5)	SAPS/SANS		4.7 (5.1)	0
Johns 2006[46]	SCH-s	45 (15)	20	33.3	78.0	60.0	34.9	33.7	NART	104	110			SAPS/SANS		9.1	0
Johns 2001[45]	SCH-s	18 (10)	20	55.6	83.0	80.0	39.1	36.7	NART	106.1	112.0	12.8	14.2	case-notes self-reports		16.8 (8.3)	0
Lavallé 2020[47]	SCH	38	29		52.6	31.0	41.0 (6.6)	40.4 (9.3)				12.2 (3.2)	14.2 (2.9)	PANSS		13.5 (7.8)	0/1
Mammarella 2010[48]	SCH-s	26	26		84.6	53.8	39.2 (8.5)	39.2 (8.6)	BIT	102.2 (7.5)	115.3 (2.8)	9.1 (2.5)	14.5 (2.5)	BPRS	384 (158)	15.4 (6.3)	0
Moritz 2003[49]	SCH	30	21		70.0	52.4	31.1 (8.3)	27.0 (10.7)	MWT	112.7 (12.8)	112.9 (14.0)	12.0 (1.8)	11.53 (1.7)	BPRS	253 (190)	4.48 (6)	0/1
Moritz 2005[50]	SCH	30	15		63.3	53.3	37.3 (10.2)	37.7 (12.5)	NART	102.0 (9.4)	110.6 (6.8)			SSPI	672 (494)	12.7 (7.3)	0/1
Moritz 2006[51]	SCH	31	61	45.0	71.0	50.8	33.8 (9.9)	31.1 (8.8)				11.6 (1.7)	12.0 (1.5)	PANSS	687 (864)		0
Morrison 1997[52]	SCH-s	30 (15)	15	100	79.0	73.3	44.1 (13.0)	39.6 (17.1)	NART	101.9 (14.5)	107.7 (13.6)			KGV-R		14.8 (9.6)	0
Nelson 2020[53]	FEP	39	34		46.0	29.0	19.9 (3.2)	21.1 (1.8)	WASI	111.5 (15.9)	107.5 (9.1)			BPRS CAARMS SANS			0/1
Nienow 2004[54]	SCH	52	52		55.8	48.1	36.2 (8.4)	37.5 (7.2)	WAIS-R	87.8 (12.2)	105.6 (8.4)	12.4 (1.7)	14.6 (1.7)	SAPS/SANS			1
Ragland 2006[55]	SCH	16	15		87.5	86.6	34.8 (7.7)	32.2 (7.0)				13.2 (2.6)	13.9 (1.9)	SAPS/SANS	250	14.2 (9)	0/1
Serrone 2019[56]	PSY	37 (24)	40	100	59.4	47.5	44 (11)	40 (12)						PANSS		18.5 (11.9)	0
Stephane 2010[90]	SCH-s	39 (31)	26	79.5	92.0	96.1	52.6 (9.7)	53.3 (10.2)	NART	102.2 (8.8)	106 (8.0)	14 (3.3)	14.5 (2.5)	BPRS SAPS/SANS	309 (171)	24.3 (12.8)	0/1
Szczepanowski 2020[58]	SCH	39	50		64.1	26.0	38.4 (14.1)	29.2 (8.1)						SAPS/SANS	826 (1176)	15.6 (10.5)	0
Szoke 2009[59]	SCH	54	37		72.2	48.7	33.8 (9.5)	45.6 (12.6)						SSPI			0
Versmissen 2007[60]	PSY	41	52	100	76.0	36.5	32.3 (10.4)	47.0 (7.6)	GIT	111.3 (20.6)	124.5 (17.0	4.6 (1.2)	5.6 (0.8)	PSE			0
Vinogradov 1997[66]	SCH	26	21	100	54.0	43.0	40.2 (9.6)	38.5 (7.6)	Shipley	98.9 (12.8)	111.1 (5.9)	13.9 (1.7)	14.9 (1.4)	BPRS	360		1
Waters 2004[62]	SCH	43	24	58.5	81.4	83.3	36.7 (8.4)	34.7 (8.8)	NART	100.2 (9.3)	103.6 (4.8)	11 (2)	11.8 (1.9)	PANSS	942 (445)	13.6 (8.1)	1
Waters 2009[63]	SCH-s	41	20	44.2			35.6 (9.6)	42.0 (10.4)	NART	96.7 (11.0)	100.2 (6.4)	11.0 (1.6)	11.3 (1.3)	SAPS/SANS	642 (439)	13 (8.8)	1
Werner 2014[64]	SCH	20	18		75.0	72.2	37.1 (7.8)	36.7 (8.9)	BACS	256.8 (40.8)	285.3 (23.3)			SAPS/SANS	321 (334)		0
Woodward 2007[65]	SCH-s	51	20	31.4	73.0	45.0	37.2 (9.4)	40.0 (11.4)		98.2 (8.6)	110.2 (8.8)			SSPI	663 (546)	16.2 (8.4)	0

Results are always reported as means (standard deviation).

Groups: H, patients with hallucinations; HC, healthy control; FEP, First Episode Psychosis; PSY, patients with psychosis (diagnosis of either schizophrenia spectrum or bipolar disorder with psychotic features); SCH, schizophrenia; SCH-s, schizophrenia spectrum.

Headlines: Diag., Diagnosis; CPZ, eq antipsychotic dosages (chlorpromazine equivalents); IQ, intelligence quotient; ONRT, Old new recognition task (0 = no, 1 = yes, 0/1=).

Questionnaires: BACS, Brief Assessment of Cognition in Schizophrenia; BIT, Brief Intelligence Test; BPRS, Brief Psychiatric Rating Scale; CAPPS, Current and Past Psychopathology Scales; CAARMS, Comprehensive Assessment of At Risk Mental States; GIT, Groninger Intelligence Test; KGV-R, Krawiecka, Goldberg, Vaughan psychosis scale; MWT, multiple choice vocabulary text; NART, National Adult Reading Test; PANSS, Positive and Negative Syndrome Scale; PSE, Present State Examination; Raven PM, Raven's Progressive Matrices; SANS, Scale for the Assessment of Negative Symptoms; SAPS, Scale for the Assessment of Positive Symptoms; SSPI, Signs and Symptoms of Psychotic Illness Rating Scale; WAIS, Wechsler Adult Intelligence Scale; WASI, Wechsler Abbreviated Scale Intelligence; WTAR, Wechsler Test of Adult Reading.

(Table 2). A publication bias was observed at the Egger's test. However, the corrected RMe effect size after applying a trim-and-fill method did not vary (SMD = 0.368; CI = 0.105–0.631; Q Value: 16.371).

Stimulus modality

Although all categories showed significant reductions in SM performance between PSY and HC, the outcome measures re-classification yielded to a wider distribution of effect sizes: accuracy-related effect sizes were higher than errors, and differences between PSY and HC peaked for imagined stimuli (SMD error = 0.688; CI = 0.490–0.885; SMD accuracy = 0.978; CI = 0.688–1.268) followed by auditory, performed and visual stimuli (Table 3). This pattern was also observed in PSY-H *versus* PSY-NH comparisons, but the number of studies per stimulus type was small (n = 1–7) and differences were significant for imagined

Table 2. Meta-analysis of source monitoring performance divided by source discrimination type

Source Disc.	No. of Studies	N PSY	N HC	SMD (r = 0.5)† Mean	95% CI		z value	p-value	Test for Heterogeneity Q	I^2	*P*	Egger's test t value	*P*
PSY *vs* HC													
Error													
ESM	12	438	355	0.398	0.226	0.570	4.263	<0.001	22.755	51.660	0.019	0.698	0.519
ISM	12	419	353	0.513	0.315	0.711	5.079	<0.001	25.689	57.180	0.007	0.375	0.716
RMe	24	906	672	0.407	0.307	0.507	7.274	<0.001	23.014	0.061	0.460	0.478	0.641
RMi	26	946	758	0.374	0.270	0.477	6.611	<0.001	28.624	12.661	0.280	1.279	0.142
Accuracy													
ESM	23	705	631	0.454	0.343	0.566	7.608	<0.001	28.191	21.961	0.169	0.577	0.540
ISM	20	673	545	0.733	0.623	0.844	12.504	<0.001	18.407	<0.001	0.495	0.186	0.801
ALL	42	1566	1175	0.458	0.401	0.514	15.789	<0.001					
PSY-H *vs* PSY-NH													
Error													
ESM	4	91	79	0.083	−0.188	0.353	0.600	0.548	0.183	<0.001	0.980	1.272	0.331
ISM	3	65	62	0.291	−0.040	0.621	1.725	0.085	1.804	<0.001	0.406	24.253‡	0.026
RMe	10	186	180	0.410	0.173	0.647	3.387	0.001	11.893	24.326	0.219	3.075§	0.015
RMi	7	149	144	0.169	−0.053	0.390	1.493	0.135	2.909	<0.001	0.820	0.260	0.806
Accuracy													
ESM	5	119	99	0.235	−0.007	0.477	1.902	0.057	1.012	<0.001	0.908	0.232	0.832
ISM	4	89	68	0.267	−0.040	0.573	1.706	0.088	1.860	<0.001	0.602	1.838	0.207

ESM, External Source Monitoring; HC, Healthy Controls; ISM, Internal Source Monitoring; PSY, Patients with psychosis; PSY-H, Patients with Hallucinations; PSY-NH, Patients without Hallucinations. RMe, Reality Monitoring externalizing bias; RMi, Reality Monitoring internalizing bias.
†SMD (Standardized Mean Differences) are computed assuming a within-study source monitoring measures correlation of 0.5.
‡No trim-and-fill modifications.
§Trim-and-fill modification to SMD = 0.368; 95%CI = 0.105–0.631; Q Value: 16.371.

Table 3. Meta-analysis of source monitoring performance divided by stimulus modality

Stimulus Modality	No. of Studies	N PSY	N HC	SMD (r = 0.5)† Mean	95% CI		z value	*P* value	Test for Heterogeneity Q	I^2	*P*
Error PSY *vs* HC											
Auditory	14	459	439	0.420	0.286	0.553	6.156	<0.001	13.409	3.052	0.417
Visual	18	655	593	0.372	0.271	0.474	7.195	<0.001	16.543	0.000	0.486
Imagined	11	393	326	0.688	0.490	0.885	6.829	<0.001	17.040	41.314	0.073
Performed	24	918	647	0.383	0.275	0.490	6.992	<0.001	27.002	14.822	0.256
Accuracy PSY *vs* HC											
Auditory	13	402	323	0.676	0.475	0.876	6.611	<0.001	21.183	43.351	0.048
Visual	16	593	485	0.358	0.190	0.527	4.172	<0.001	32.332	53.606	0.006
Imagined	7	209	178	0.978	0.688	1.268	6.613	<0.001	11.872	49.463	0.065
Performed	16	560	423	0.578	0.407	0.748	6.639	<0.001	24.657	39.166	0.055
Error PSY-H *vs* PSY-NH											
Auditory	7	131	126	0.277	0.031	0.523	2.203	0.028	6.585	8.888	0.976
Visual	3	69	63	0.042	−0.252	0.336	0.278	0.781	0.231	<0.001	0.891
Imagined	3	65	62	0.489	0.155	0.823	2.868	0.004	1.622	<0.001	0.444
Performed	6	124	106	0.202	−0.042	0.446	1.622	0.105	4.156	<0.001	0.527
Accuracy PSY-H *vs* PSY-NH											
Auditory	3	61	42	0.209	−0.169	0.587	1.081	0.279	1.782	<0.001	0.410
Visual	3	82	70	0.162	−0.122	0.446	1.118	0.264	1.568	<0.001	0.457
Imagined	1	28	26	0.359	−0.179	0.897	1.307	0.191	0.000	<0.001	1.000
Performed	4	89	68	0.202	−0.145	0.549	1.142	0.253	3.486	13.947	0.323

HC, Healthy Controls; PSY, Patients with psychosis; PSY-H, Patients with Hallucinations; PSY-NH, Patients without Hallucinations.
†SMD (Standardized Mean Differences) are computed assuming a within-study source monitoring measures correlation of 0.5.

(SMD = 0.489; CI = 0.155–0.823) and auditory (SMD = 0.277; CI = 0.031–0.523) errors only.

Control analyses

The three different values of within-study correlations of SM measures we tested exerted no effect on SMD (eTable 7). Twenty-two studies reported the percentage of PSY-H, even though some of them did not compare SM performance between PSY-H and PSY-NH groups. No influence of the percentage of PSY-H was detected, (eTable 8). Twenty studies did not involve ONRT, while in 24 ONRT was present in at least one SM measure. Overall effect size of SM performance differences between PSY and HC was similar in studies involving (SMD = 0.457; CI = 0.377–0.538) and not involving (SMD = 0.486; CI = 0.404–0.569) ONRT.

Discussion

Our study is the first to systematically classify SM measures in order to separately meta-analyze the different SM subtypes. The extent of SM impairment was qualitatively and quantitatively measured in psychosis, finding moderate to high effect sizes in all the outcome measures that compared these PSY with HC. Less clear results emerge when confronting PSY with and without hallucinations, as PSY-H showed a worse SM performance only for externalizing errors, with a moderate effect size.

Being SM a basic function of the self,[68,69] it interacts with a plethora of subjective and environmental factors (cognition, age, prior beliefs, and expectancies, etc.).[52,70,71] SM deficits in psychosis appeared quite separate from the dimensions of positive and negative symptoms. Only seven over 19 studies found an association between SM deficits and increased symptoms severity, and this association was often detected only in one of the two clusters. Discussion on the specific relationship between SM and hallucinations is deepened in the following section. A somehow closer relationship can be inferred from the nine studies directly investigating associations between SM and other cognitive domains. Positive correlation of SM performance and several subsets of cognitive skills were found, but with very few replications (including memory). Besides, it must be noted that >60% of the included studies matched PSY and HC by IQ and yet found important differences in SM between groups, in line with the view that SM and cognition are only partially overlapping constructs.[72]

Source discrimination and stimulus modality: does the difference lie in the source?

Of the two SM classifications adopted for the main analysis, source discrimination-based comparisons were similar in terms of effect sizes, although slightly increased differences between PSY and HC were present for internal stimuli sources (ISM and RMe). When considering the classification based on stimulus modality, differences between PSY and HC were more prominent for stimuli that were only imagined, that is, detached from any objective factor that could mediate world/self-relationship. Previous studies conducted on the general population suggested that imagined stimuli may be more subject to SM errors than perceived ones.[73] However, the SM deficit for internal/imagined stimuli observed in HC is even more prominent in psychosis. This suggests that the absence of reliable and concrete information coming from external inputs (auditory/visual) or proprioceptive feedbacks (performed) may dramatically contribute to deconstructing these patients' world/self-boundaries. In our previous work, we defined this weakening of boundaries between world and self "world/self-ambivalence."[74] This phenomenon highlights the critical role of the encoding phase, coherently with the predictive coding hypothesis which poses unreliable prior beliefs or perceptions as pivotal features of psychosis.[75] Without a reference to compare the unstable priors to, the correct processing of information would be less efficient, as the only option would be to rely exclusively on the priors.[76]

Source monitoring and hallucinations

But what happens when an active psychosis is present? Externalizing errors may be more frequent than internalizing ones, especially for patients with past or current hallucinations.[10,77,78] Our findings support this theory, as SM performance in PSY-H did not differ from PSY-NH in none of the considered measures except for RMe which showed an effect size comparable to the one observed between PSY and HC. The selective tendency to commit externalizing errors goes along with the increased internal pressure and shifted world/self-boundary we described.[74] The hypothesized link between externalizing biases and hallucinations, both characterized by the confusion of internal contents with external ones, is thus further supported by the present findings.

Concerning stimulus modalities, imagined stimuli stand out again as the category better distinguishing the presence of hallucinations, but are the least represented in terms of sample sizes and studies (3 for errors and 1 for accuracy), leaving open questions concerning the effective validity of this finding. Preliminary results from Gaweda and colleagues[79] suggest that the association of hallucinations and imagined stimuli extends beyond primary psychosis. In fact, alcoholic patients with a history of hallucinations were more prone to confuse imagined with performed stimuli than patients without hallucinations and healthy controls.

Auditory stimuli also showed marginal SM deficits in PSY-H compared to PSY-NH. Auditory hallucinations are more frequent than visual ones (70% *vs*. 27%) in primary psychiatric psychosis,[80,81] tentatively suggesting an association of SM performance reductions and alterations in auditory pathways.

In summary, SM performance differences between PSY-H and PSY-NH are less clear-cut compared to the sharp gap between PSY and HC. This questions whether SM deficits may relate more to self-disturbances than to hallucination proneness.[82]

Applications and future opportunities

Taken together, the bulk of evidence we considered suggests that SM is a relatively independent domain from the clinical and cognitive criteria that are routinely used to define psychosis. More importantly, our study introduces a novel perspective according to which SM deficits are specifically selective for imagined stimuli, which are paradoxically the least investigated by literature (see Table 3).

To redirect future lines of research towards the SM subtypes which more clearly differentiate PSY from HC may allow to further disentangle the specific and unspecific features of the SM dimension and, ultimately, to design clinically-oriented tasks with diagnostic and follow-up valence. Novel approaches suggest that SM may be an objective measure of deeply subjective disorders such as anomalous self-experiences[53,83] by testing the very notion of self as a "principle of identity."[69] Based on our findings, we pose that the internal/imagined category of stimuli may be the primary proxy on which the subject relies on when determining its separate existence from the surrounding world, and that this dynamic is fundamentally altered in psychosis. This hypothesis is supported by the fact that reduced SM performance is lower not only in psychosis, but also in at risk mental states,[84] autism[72] and Alzheimer's disease[85] which are conditions where self-disturbances are relevant. Conversely, no SM deficits have been reported for conditions where self is preserved, such as major depressive disorder.[34] However, deficits in ISM, but not RM, have been also encountered in patients with obsessive-compulsive disorder,[47] requiring caution in interpreting SM findings as specific for self-disturbances until replicated results from cross-diagnostic studies are available.

Analyzing the presented literature allows to draw several indications for the design of future SM studies: (i) errors allow a more fine-grained exploration of SM performance than accuracy measures. This is especially relevant in subjects with hallucinations, as externalizing errors are the most significant proxy to discriminate them from subjects without hallucinations. (ii) Very few studies directly compared

different SM subtypes. The collected evidence suggests that it is important to monitor this aspect in order to select reproducible SM task with high discriminative power between PSY and HC. (iii) Specifically, future research may focus on exploring deficits in the differentiation of internal processes, which showed greater impairments in PSY but have not been sufficiently explored in the active phases of psychosis. (iv) When considering these phases, comparisons have mostly been conducted between patients with and without hallucinations. As of now, only a handful of studies compared presence and absence of other core symptoms such as delusions, self-disturbances or active phases of illness. It would be enticing to widen our knowledge by exploring these aspects. (v) No ONRT-differences on SM performances differences between PSY and HC were detected, proving that new stimuli can be considered on the same level of external, non-self-sources. (vi) Clinical and cognitive evaluations should be performed in SM studies in order to better quantify the degree of association/independence of these domains. For symptoms, adopting widely used scales that also allow to score different sensory modalities such as the Scale for Assessment of Positive Symptoms (SAPS)[86] would greatly enhance the resolution of SM findings. For cognition, a uniform and easy-to-collect proxy of general intelligence is education years,[87] which we thus recommend to collect. (vii) Leveraging these novel findings, pharmacological studies may analyze which medications are more beneficial for SM, thus allowing to offer more tailored interventions for psychosis.

Limitations

This work is not without limitations: first, several studies used specific signal detection measures of SM that mixed accuracy and error parameters, so that it was not possible to include these outcomes in the review or meta-analysis. Second, our classification did not consider categories defined as important by previous studies, such as verbal *versus* non-verbal presentation of stimuli,[39] emotional valence[88] or delusions.[89] Third, the heterogeneity of clinical symptoms and cognitive functioning assessment instruments prevented to draw reliable conclusions concerning the associations between SM and these two domains. Furthermore, the majority of studies comparing patients used hallucinations as the main symptom of reference, leaving other domains that may importantly contribute to SM (i.e. thought disorders, negative symptoms, etc.) underexplored. Fourth, accuracy measures showed increased magnitude of effect sizes, even though the pattern of effect sizes was similar throughout SM subtypes. The reasons for this phenomenon are yet unclear, but it confirms that accuracy and error measures are not exactly complementary and should be addressed separately, as we did in the present study.

Conclusion

Although all SM subtypes share a moderate impairment in psychosis, the performance gap increases for internal sources and imagined stimuli, suggesting that these can be efficiently used as proxies for world/self ambivalence when comparing healthy controls, silent and active phases of illness. The proposed classifications highlight specific SM deficits for internal/imagined stimuli in psychosis and confirm previous theories linking externalizing biases to hallucinations, providing new evidence-based indications to design and interpret future studies.

Acknowledgments

Open Access Funding provided by Universita degli Studi di Pavia within the CRUI-CARE Agreement. [Correction added on May 18, 2022, after first online publication: CRUI-CARE funding statement has been added.]

Disclosure statement

Dr. Salazar de Pablo reports honoraria from Janssen-Cilag and grants from the Alicia Koplowitz Foundation and consulting fees from Angelini Pharma outside the submitted work. Dr. Fusar-Poli reports research fees from Lundbeck and honoraria from Lundbeck, Angelini Pharma, Menarini, Sunovion and Boehringer Ingelheim outside the submitted work.

Author contributions

SD designed the study. AD, NB and CG reviewed the literature and extracted data. GSP and SD conducted data-analysis. SD, PP and PFP wrote the first draft of the manuscript. PP and PFP coordinated the research team.

References

1. Mitchell KJ. Definition: Source monitoring. *Cortex* 2017; **96**: 129–129.
2. Guloksuz S, van Os J. The slow death of the concept of schizophrenia and the painful birth of the psychosis spectrum. *Psychol. Med.* 2018; **48**: 229–244.
3. Arciniegas DB. Psychosis. *Continuum* 2015; **21**: 715.
4. Dilsaver S. Differentiating organic from functional psychosis. *Am. Fam. Physician* 1992; **45**: 1173–1180.
5. Voss M, Chambon V, Wenke D, Kühn S, Haggard P. In and out of control: Brain mechanisms linking fluency of action selection to self-agency in patients with schizophrenia. *Brain* 2017; **140**: 2226–2239.
6. Qin P, Wang M, Northoff G. Linking bodily, environmental and mental states in the self–a three-level model based on a meta-analysis. *Neurosci. Biobehav. Rev.* 2020; **115**: 77–95.
7. Woodward ND, Heckers S. Brain structure in neuropsychologically defined subgroups of schizophrenia and psychotic bipolar disorder. *Schizophr. Bull.* 2015; **41**: 1349–1359.
8. Demjaha A, Morgan K, Morgan C *et al*. Combining dimensional and categorical representation of psychosis: The way forward for DSM-V and ICD-11? *Psychol. Med.* 2009; **39**: 1943–1955.
9. Anselmetti S, Cavallaro R, Bechi M *et al*. Psychopathological and neuropsychological correlates of source monitoring impairment in schizophrenia. *Psychiatry Res.* 2007; **150**: 51–59.
10. Waters F, Woodward T, Allen P, Aleman A, Sommers I. Self-recognition deficits in schizophrenia patients with auditory hallucinations: A meta-analysis of the literature. *Schizophr. Bull.* 2012; **38**: 741–750.
11. Nelson B, Whitford TJ, Lavoie S, Sass LA. What are the neurocognitive correlates of basic self-disturbance in schizophrenia?: Integrating phenomenology and neurocognition part 2 (aberrant salience). *Schizophr. Res.* 2014; **152**: 20–27.
12. Page MJ, McKenzie JE, Bossuyt PM *et al*. The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ*; 2021; **372**: n71.
13. Stroup DF, Berlin JA, Morton SC *et al*. Meta-analysis of observational studies in epidemiology: A proposal for reporting. *JAMA* 2000; **283**: 2008–2012.
14. Amir-Behghadami M, Janati A. Population, intervention, comparison, outcomes and study (PICOS) design as a framework to formulate eligibility criteria in systematic reviews. *Emerg. Med. J.* 2020; **37**: 387.
15. Wells GA, Shea B, O'Connell D *et al*. *The Newcastle-Ottawa Scale (NOS) for Assessing the Quality of Nonrandomised Studies in Meta-Analyses*. Ottawa, Ottawa Hospital; 2000.
16. Andrade C. Mean difference, standardized mean difference (SMD), and their use in meta-analysis: As simple as it gets. *J. Clin. Psychiatry* 2020; **81**: 1–4.
17. DerSimonian R, Laird N. Meta-analysis in clinical trials. *Control. Clin. Trials* 1986; **7**: 177–188.
18. Huedo-Medina TB, Sánchez-Meca J, Marín-Martínez F, Botella J. Assessing heterogeneity in meta-analysis: Q statistic or I^2 index? *Psychol. Methods* 2006; **11**: 193–206.
19. Egger M, Smith GD, Schneider M, Minder C. Bias in meta-analysis detected by a simple, graphical test. *BMJ* 1997; **315**: 629–634.
20. Duval S, Tweedie R. Practical estimates of the effect of publication bias in meta-analysis. *Austral. Epidemiol.* 1998; **5**: 7–14.
21. Higgins JP, Thomas J, Chandler J *et al*. *Cochrane Handbook for Systematic Reviews of Interventions*. Hoboken, New Jersey: John Wiley & Sons, 2019.
22. Borenstein M, Hedges L, Higgins J, Rothstein H. *Comprehensive Meta-Analysis Version 3*. Biostat, Englewood, NJ, 2013.
23. Achim AM, Lefebvre A-A, Cellard C, Bouchard R-H, Roy M-A, Tremblay S. The role of recollection in source memory: An examination of schizophrenia patients and their first-degree relatives. *Brain Cogn.* 2011; **75**: 147–153.

24. Allen PP, Johns LC, Fu CHY, Broome MR, Vythelingum GN, McGuire PK. Misattribution of external speech in patients with hallucinations and delusions. *Schizophr. Res.* 2004; **69**: 277–287.
25. Arguedas D, Stevenson RJ, Langdon R. Source monitoring and olfactory hallucinations in schizophrenia. *J. Abnorm. Psychol.* 2012; **121**: 936–943.
26. Bendall S, Jackson HJ, Hulbert CA. What self-generated speech is externally misattributed in psychosis? Testing three cognitive models in a first-episode sample. *Schizophr. Res.* 2011; **129**: 36–41.
27. Bentall RP, Baker GA, Havers S. Reality monitoring and psychotic hallucinations. *Br. J. Clin. Psychol.* 1991; **30**: 213–222.
28. Brebion G, Ohlsen RI, Pilowsky LS, David AS. Visual hallucinations in schizophrenia: Confusion between imagination and perception. *Neuropsychology* 2008; **22**: 383–389.
29. Brébion G, Smith MJ, Amador X, Malaspina D, Gorman JM. Word recognition, discrimination accuracy, and decision bias in schizophrenia: Association with positive symptomatology and depressive symptomatology. *J. Nerv. Ment. Dis.* 1998; **186**: 604–609.
30. Brunelin J, Combris M, Poulet E *et al*. Source monitoring deficits in hallucinating compared to non-hallucinating patients with schizophrenia. *Eur. Psychiatry* 2006; **21**: 259–261.
31. Brunelin J, d'Amato T, Brun P *et al*. Impaired verbal source monitoring in schizophrenia: An intermediate trait vulnerability marker? *Schizophr. Res.* 2007; **89**: 287–292.
32. de Sousa P, Sellwood W, Spray A, Bentall RP. The affective reactivity of psychotic speech: The role of internal source monitoring in explaining increased thought disorder under emotional challenge. *Schizophr. Res.* 2016; **172**: 189–194.
33. Donde C, Mondino M, Leitman DI *et al*. Are basic auditory processes involved in source-monitoring deficits in patients with schizophrenia? *Schizophr. Res.* 2019; **210**: 135–142.
34. Drakeford JL, Edelstyn NM, Oyebode F, Srivastava S, Calthorpe WR, Mukherjee T. Auditory recognition memory, conscious recollection, and executive function in patients with schizophrenia. *Psychopathology* 2006; **39**: 199–208.
35. Fairfield B, Altamura M, Padalino FA, Balzotti A, Di Domenico A, Mammarella N. False memories for affective information in schizophrenia. *Front. psychiatry* 2016; **7**: 191.
36. Fisher M, McCoy K, Poole JH, Vinogradov S. Self and other in schizophrenia: A cognitive neuroscience perspective. *Am. J. Psychiatry* 2008; **165**: 1465–1472.
37. Franck N, Rouby P, Daprati E, Dalery J, Marie-Cardine M, Georgieff N. Confusion between silent and overt reading in schizophrenia. *Schizophr. Res.* 2000; **41**: 357–364.
38. Gaweda L, Woodward TS, Moritz S, Kokoszka A. Impaired action self-monitoring in schizophrenia patients with auditory hallucinations. *Schizophr. Res.* 2013; **144**: 72–79.
39. Gaweda L, Li E, Lavoie S, Whitford TJ, Moritz S, Nelson B. Impaired action self-monitoring and cognitive confidence among ultra-high risk for psychosis and first-episode psychosis patients. *Eur. Psychiatry* 2018; **47**: 67–75.
40. Harvey PD. Reality monitoring in mania and schizophrenia - the association of thought-disorder and performance. *J. Nerv. Mental Dis.* 1985; **173**: 67–73.
41. Harvey PD, Earleboyer EA, Levinson JC. Cognitive deficits and thought-disorder - a retest study. *Schizophr. Bull.* 1988; **14**: 57–66.
42. Henquet C, Krabbendam L, Dautzenberg J, Jolles J, Merckelbach H. Confusing thoughts and speech: Source monitoring and psychosis. *Psychiatry Res.* 2005; **133**: 57–63.
43. Hommes J, Krabbendam L, Versmissen D, Kircher T, van Os J, van Winkel R. Self-monitoring as a familial vulnerability marker for psychosis: An analysis of patients, unaffected siblings and healthy controls. *Psychol. Med.* 2012; **42**: 235–245.
44. Ilankovic LM, Allen PP, Engel R *et al*. Attentional modulation of external speech attribution in patients with hallucinations and delusions. *Neuropsychologia* 2011; **49**: 805–812.
45. Johns LC, Rossell S, Frith C *et al*. Verbal self-monitoring and auditory verbal hallucinations in patients with schizophrenia. *Psychol. Med.* 2001; **31**: 705–715.
46. Johns LC, Gregg L, Allen P, McGuire PK. Impaired verbal self-monitoring in psychosis: Effects of state, trait and diagnosis. *Psychol. Med.* 2006; **36**: 465–474.
47. Lavalle L, Bation R, Donde C, Mondino M, Brunelin J. Dissociable source-monitoring impairments in obsessive-compulsive disorder and schizophrenia. *Eur. Psychiatry* 2020; **63**: e54.
48. Mammarella N, Altamura M, Padalino FA, Petito A, Fairfield B, Bellomo A. False memories in schizophrenia? An Imagination Inflation Study. *Psychiatry Res.* 2010; **179**: 267–273.
49. Moritz S, Woodward TS, Ruff CC. Source monitoring and memory confidence in schizophrenia. *Psychol. Med.* 2003; **33**: 131–139.
50. Moritz S, Woodward TS, Whitman JC, Cuttler C. Confidence in errors as a possible basis for delusions in schizophrenia. *J. Nerv. Mental Dis.* 2005; **193**: 9–16.
51. Moritz S, Woodward TS, Rodriguez-Raecke R. Patients with schizophrenia do not produce more false memories than controls but are more confident in them. *Psychol. Med.* 2006; **36**: 659–667.
52. Morrison AP, Haddock G. Cognitive factors in source monitoring and auditory hallucinations. *Psychol. Med.* 1997; **27**: 669–679.
53. Nelson B, Lavoie S, Gaweda L *et al*. The neurophenomenology of early psychosis: An integrative empirical study. *Conscious. Cogn.* 2020; **77**: 102845.
54. Nienow TM, Docherty NM. Internal source monitoring and thought disorder in schizophrenia. *J. Nerv. Mental Dis.* 2004; **192**: 696–700.
55. Ragland JD, McCarthy E, Bilker WB *et al*. Levels-of-processing effect on internal source monitoring in schizophrenia. *Psychol. Med.* 2006; **36**: 641–648.
56. Serrone D, Parnanzone S, Pizziconi G *et al*. Source monitoring task in a sample of in-patients with verbal auditory hallucinations compared to control sample. *Riv. Psichiatr.* 2019; **54**: 90–94.
57. Stephane M, Kuskowski M, McClannahan K, Surerus C, Nelson K. Evaluation of speech misattribution bias in schizophrenia. *Psychol. Med.* 2010; **40**: 741–748.
58. Szczepanowski R, Cichon E, Pasieczna AH, Gaweda L, Rosinczuk J. Monetary incentives increase metacognitive confidence in source memory performance in patients with schizophrenia. *Front. Psychiatry* 2020; **11**: 725.
59. Szoke A, Meary A, Ferchiou A, Trandafir A, Leboyer M, Schuerhoff F. Correlations between cognitive performances and psychotic or schizotypal dimensions. *Eur. Psychiatry* 2009; **24**: 244–250.
60. Versmissen D, Janssen I, Johns L *et al*. Verbal self-monitoring in psychosis: A non-replication. *Psychol. Med.* 2007; **37**: 569–576.
61. Vinogradov S, Poole JH, WillisShore J, Ober BA, Shenaut GK. The relationship of IQ to source monitoring errors in schizophrenia. *Schizophr. Res.* 1997; **24**: 127–127.
62. Waters FAV, Maybery MT, Badcock JC, Michie PT. Context memory and binding in schizophrenia. *Schizophr. Res.* 2004; **68**: 119–125.
63. Waters FAV, Badcock JC. Memory for speech and voice identity in schizophrenia. *J. Nerv. Mental Dis.* 2009; **197**: 887–891.
64. Werner J-D, Trapp K, Wuestenberg T, Voss M. Self-attribution bias during continuous action-effect monitoring in patients with schizophrenia. *Schizophr. Res.* 2014; **152**: 33–40.
65. Woodward TS, Menon M, Whitman JC. Source monitoring biases and auditory hallucinations. *Cogn. Neuropsychiatry* 2007; **12**: 477–494.
66. Vinogradov S, WillisShore J, Poole JH, Marten E, Ober BA, Shenaut GK. Clinical and neurocognitive aspects of source monitoring errors in schizophrenia. *Am. J. Psychiatry* 1997; **154**: 1530–1537.
67. Parnas J, Møller P, Kircher T *et al*. EASE: Examination of anomalous self-experience. *Psychopathology* 2005; **38**: 236–258.
68. Mishara AL, Lysaker PH, Schwartz MA. Self-disturbances in schizophrenia: History, phenomenology, and relevant findings from research on metacognition. *Schizophr. Bull.* 2014; **40**: 5–12.
69. Zahavi D. Phenomenology of self. *Self Neurosci. Psychiatry* 2003; **56**: C75.
70. Dennis NA, Hayes SM, Prince SE, Madden DJ, Huettel SA, Cabeza R. Effects of aging on the neural correlates of successful item and source memory encoding. *J. Exp. Psychol. Learn. Mem. Cogn.* 2008; **34**: 791–808.
71. McDonough IM, Gallo DA. Illusory expectations can affect retrieval-monitoring accuracy. *J. Exp. Psychol. Learn. Mem. Cogn.* 2012; **38**: 391–404.
72. Damiani S, Guiot C, Nola M *et al*. Two faces of a coin? A systematic review of source monitoring and its relationship with memory in autism. *Brain Sci.* 2021; **11**: 640.
73. Henkel LA, Franklin N, Johnson MK. Cross-modal source monitoring confusions between perceived and imagined events. *J. Exp. Psychol. Learn. Mem. Cogn.* 2000; **26**: 321–335.
74. Damiani S, Fusar-Poli L, Brondino N *et al*. World/self ambivalence: A shared mechanism in different subsets of psychotic experiences? Linking symptoms with resting-state fmri. *Psychiatry Res. Neuroimag.* 2020; **299**: 111068.
75. Sterzer P, Adams RA, Fletcher P *et al*. The predictive coding account of psychosis. *Biol. Psychiatry* 2018; **84**: 634–643.

76. Griffin JD, Fletcher PC. Predictive processing, source monitoring, and psychosis. **In:** Widiger T, Cannon TD (eds). *Annual Review of Clinical Psychology*, Vol. **13**, 2017; 265–289.
77. Brookwell ML, Bentall RP, Varese F. Externalizing biases and hallucinations in source-monitoring, self-monitoring and signal detection studies: A meta-analytic review. *Psychol. Med.* 2013; **43**: 2465–2475.
78. Keefe RSE, Arnold MC, Bayen UJ, Harvey PD. Source monitoring deficits in patients with schizophrenia; a multinomial modelling analysis. *Psychol. Med.* 1999; **29**: 903–914.
79. Gaweda L, Mikula J, Szelenbaum W, Kokoszka A. Towards a cognitive model of hallucinations in the course of alcohol dependence? A source monitoring-based pilot study. *Psychol. Med.* 2014; **44**: 2763–2773.
80. Waters F, Collerton D, Ffytche DH *et al*. Visual hallucinations in the psychosis Spectrum and comparative information from neurodegenerative disorders and eye disease. *Schizophr. Bull.* 2014; **40**: S233–S245.
81. Waters F, Allen P, Aleman A *et al*. Auditory hallucinations in schizophrenia and nonschizophrenia populations: A review and integrated model of cognitive mechanisms. *Schizophr. Bull.* 2012; **38**: 683–692.
82. Garrison JR, Moseley P, Alderson-Day B, Smailes D, Fernyhough C, Simons JS. Testing continuum models of psychosis: No reduction in source monitoring ability in healthy individuals prone to auditory hallucinations. *Cortex* 2017; **91**: 197–207.
83. Nelson B, Whitford TJ, Lavoie S, Sass LA. What are the neurocognitive correlates of basic self-disturbance in schizophrenia?: Integrating phenomenology and neurocognition. Part 1 (source monitoring deficits). *Schizophr. Res.* 2014; **152**: 12–19.
84. Johns LC, Allen P, Valli I *et al*. Impaired verbal self-monitoring in individuals at high risk of psychosis. *Psychol. Med.* 2010; **40**: 1433–1442.
85. El Haj M, Fasotti L, Allain P. Source monitoring in Alzheimer's disease. *Brain Cogn.* 2012; **80**: 185–191.
86. Andreasen NC. *Scale for the Assessment of Positive Symptoms (SAPS)*. Iowa City: University of Iowa, 1984.
87. Matarazzo JD, Herman DO. Relationship of education and IQ in the WAIS—R standardization sample. *J. Consult. Clin. Psychol.* 1984; **52**: 631–634.
88. Costafreda SG, Brebion G, Allen P, McGuire PK, Fu CHY. Affective modulation of external misattribution bias in source monitoring in schizophrenia. *Psychol. Med.* 2008; **38**: 821–824.
89. Keefe RSE, Arnold MC, Bayen UJ, McEvoy JP, Wilson WH. Source-monitoring deficits for self-generated stimuli in schizophrenia: Multinomial modeling of data from three sources. *Schizophr. Res.* 2002; **57**: 51–67.
90. Stephane M, Kuskowski M, McClannahan K, Surerus C, Nelson K. Evaluation of inner-outer space distinction and verbal hallucinations in schizophrenia. *Cogn. Neuropsychiatry* 2010; **15**: 441–450.

Supporting information

Additional Supporting Information may be found in the online version of this article at the publisher's web-site:

Methods S1. Source Monitoring subtypes classification rationale

Table S1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) abstract checklist

Table S2. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist

Table S3. Guidelines for Meta-Analyses and Systematic Reviews of Observational Studies (MOOSE)

Table S4. List of excluded studies

Table S5. Quality check: Newcastle-Ottawa Scale scores

Table S6. Description of tasks and non-meta-analyzed findings related to source monitoring.

Table S7. Comparisons of effect sizes hypothesizing different $r = 0.5$, $r = 0.3$ and $r = 0.7$

Table S8. Meta-regressions