

Efficacy of psychological interventions targeting cognitive biases in schizophrenia: A systematic review and meta-analysis

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Introduction

Schizophrenia and related psychoses (SZ&RP) significantly impacts psychosocial functioning, quality of life and well-being (Yanos & Moos, 2007). SZ&RP is primarily characterized by positive (i.e., hallucinations and delusions) and negative (e.g., affective flattening, avolition, and anhedonia) symptoms as well as pervasive cognitive impairments (Tandon, Nasrallah, & Keshavan, 2009). In addition to these cardinal characteristics, individuals with SZ&RP show systematic cognitive biases, which are not deficits per se but rather tendencies to treat information differently or adopt an alternative thinking style (Moritz & Woodward, 2007b). Formally, cognitive biases are conceptualized as a systematic and preferential orientation toward appraising, processing, selecting and remembering certain information (Grisham, Becker, Williams, Whitton, & Makkar, 2014; Lester, Mathews, Davison, Burgess, & Yiend, 2011). On the other hand, cognitive deficits refer to reduced cognitive capacity for which the following seven domains have been found to be impaired and potentially malleable via treatment in SZ&RP: speed of information processing, attention/vigilance, working memory, verbal learning and memory, visual learning and memory, reasoning and problem solving and social (Nuechterlein et al., 2004). Although associations have been found between cognitive biases and cognitive deficits, principal component analyses have shown that they are separable constructs (Eifler et al., 2015; Moritz, Veckenstedt, et al., 2010). Also, correlations with positive symptoms have been consistently reported for cognitive biases, but are less evident for cognitive deficits (McLean, Mattiske, & Balzan, 2017; Moritz, Heeren, Andresen, & Krausz, 2001). Further, cognitive biases are common in the general population and often addressed in psychological therapies via cognitive restructuring, but tend to be exacerbated and generalized in psychosis/mental illness, and may contribute to symptoms. Research shows they are related to, but generally distinguishable from, cognitive deficits, such as attention and memory impairments (Eisenacher & Zink, 2017). While cognitive biases are equally observed in non-clinical subjects and across psychiatric diagnoses (e.g., obsessive-compulsive disorder; Grisham et al., 2014), some (e.g. jumping to conclusions which is defined later on) have been specifically associated with psychotic symptoms in individuals with SZ&RP (McLean et al., 2017), at-risk groups (Eisenacher et al., 2016), and healthy individuals with sub-clinical delusional ideation (Balzan, Delfabbro, Galletly, & Woodward, 2013; Menon et al., 2013; Woodward, Buchy, Moritz, & Liotti, 2007). This suggests they may be a cognitive marker of psychosis and/or psychosis proneness (Eisenacher & Zink, 2017; Lepage, Sergerie, Pelletier, & Harvey, 2007; Moritz, Vitzthum, Randjbar,

Veckenstedt, & Woodward, 2010; Moritz & Woodward, 2007b). The ones that have been most systematically observed in SZ&RP patients are presented next.

Cognitive biases

Among biases specifically implicated in SZ&RP, **‘jumping to conclusions’ (JTC)** has perhaps received the greatest amount of attention (Savulich, Shergill, & Yiend, 2012) and refers to the tendency to collect very little information before reaching a conclusion or making a decision (Garety & Freeman, 2013a; Ross, McKay, Coltheart, & Langdon, 2015). A recent meta-analysis (Dudley, Taylor, Wickham, & Hutton, 2016) reported JTC in approximately 60% of SZ&RP patients, but only in 38% of individuals with other psychiatric diagnoses and 29% of healthy controls. JTC is measured using a probabilistic reasoning task, such as the traditional “beads task” (or its variant, the “fish task”). In the beads task, a coloured bead is drawn from one of two jars, which have different colour ratios (e.g., 85% white, 15% black) and participants are required to determine which of the two is being drawn from (Huq, Garety, & Hemsley, 1988). After each drawn bead, participants are asked whether they have made a decision (i.e., from which jar the beads are being drawn from) and how confident they are in their decision. The most common outcome measure of this task is the ‘draws to decision’ (DTD) index, which is simply the number of beads drawn before a decision was reached. Most often, JTC is operationalized as making a decision after drawing one or two beads (Moritz et al., 2013; Ross, Freeman, Dunn, & Garety, 2011; So et al., 2015). JTC is hypothesized to underlie the formation of delusions in SZ&RP, as it can influence the likelihood of adopting a belief with very little evidence (Broyd, Balzan, Woodward, & Allen, 2017).

The **bias against disconfirmatory evidence (BADE)** refers to the tendency to disregard evidence that contradicts one’s beliefs (Moritz, Vitzthum, et al., 2010; Sanford, Veckenstedt, Moritz, Balzan, & Woodward, 2014; Speechley, Moritz, Ngan, & Woodward, 2012). This bias is commonly assessed using short three-sentence vignettes where each sentence provides additional information about the situation (Sanford et al., 2014; Speechley et al., 2012; Woodward et al., 2007). After each sentence, participants rate and re-rate four interpretations of the story, which become more or less plausible as more information is given. BADE is defined as a decreased tendency to downrate interpretations that become implausible as the story progresses, that is, a tendency not to incorporate evidence that contradicts a belief. In contrast to JTC, which may contribute to the formation of delusions, BADE is hypothesized to underlie delusion maintenance, in that an unwillingness to integrate disconfirmatory evidence may

prevent delusional beliefs from being challenged (Broyd et al., 2017). A related class of cognitive bias frequently observed in individuals with SZ&RP is called **overconfidence in errors** and refers to having unreasonably heightened confidence in one's judgement, inferences and predictions (Balzan, 2016; Köther et al., 2017; Moritz, Goritz, et al., 2015).

Finally, **attributional biases** represent a family of cognitive biases wherein patients unjustly and uniquely blame others or external circumstances for negative personal events (Salvatore et al., 2012; Savulich et al., 2012). Attributional biases may contribute to positive symptoms, especially persecutory delusions, by distorting neutral events in a negative manner (Bentall, Corcoran, Howard, Blackwood, & Kinderman, 2001); although this hypothesis requires further empirical validation according to Garety and Freeman (2013b)

Interventions targeting cognitive biases

As key factors in the formation and maintenance of positive symptoms, cognitive biases are being increasingly targeted by novel manualized psychological interventions for SZ&RP. One of the earliest and most influential interventions targeting cognitive biases is *metacognitive training* (MCT; Moritz & Woodward, 2007b), which teaches individuals about cognitive biases, how they contribute to the positive symptoms of psychosis, and how they can affect daily life. Several MCT variants and novel interventions drawing from the tenets of MCT have emerged since MCT was first introduced, and these are reviewed below. Previous meta-analyses on MCT-specific interventions have demonstrated small to moderate effects on positive symptoms (Eichner & Berna, 2016; Philipp et al., 2018); however, the first meta-analysis conducted on MCT (Van Oosterhout et al., 2016) did not report significant effects on symptoms or data-gathering bias, though this may have been influenced by overly conservative exclusion criteria, according to Eichner and Berna (2016). They notably criticize that 3 positive studies were excluded from the Van Oosterhout et al. (2016) study because of alleged unavailable data, which they argue could have been obtained otherwise by statistical calculations or via corresponding authors; given the already small number of studies (7 for data-gathering bias and 9 for symptoms), this could indeed have an important impact on the study's conclusions.

There exist several cognitive interventions other than MCT that target cognitive biases, which have not been included in previous meta-analyses focusing on MCT alone. Moreover, previous investigations have used

symptoms as the major outcome variable and have not systematically validated that these interventions positively affected cognitive biases as is their intention. Interventions targeting cognitive biases may also exert positive effects on lack of clinical (unawareness of being ill) and cognitive (self-reflectiveness and self-certainty) insight (Andreou et al., 2017; Favrod et al., 2015). Poor clinical insight is frequently observed in SZ&RP (50-80%) and broadly refers to the failure of acknowledging the signs of one's illness because of a difficulty to reflect on one's own thinking (Amador & Kronengold, 2004; Poyraz et al., 2016; Vohs, George, Leonhardt, & Lysaker, 2016). Similarly, poor cognitive insight is also widely documented in SZ&RP and is defined as the ability to reflect upon one's own thoughts and adopt a critical stance toward the validity of one's beliefs (Beck, Baruch, Balter, Steer, & Warman, 2004; Nair, Palmer, Aleman, & David, 2014). The importance of metacognition (i.e., thoughts about thoughts) in clinical and cognitive insight suggests that it may be an important secondary target/outcome variable for interventions addressing cognitive biases, the majority of which train metacognition. An increasing number of independent studies on these interventions have shown promising results in reducing cognitive biases and positive symptoms as well as improving clinical and cognitive insight in SZ&RP; however, a systematic evaluation of their efficacy has yet to be published. Hence, the aims of the present article were (1) to conduct a systematic review of literature on psychological interventions developed to address cognitive biases in SZ&RP and (2) to evaluate via meta-analysis their efficacy in reducing cognitive biases and psychotic symptoms, and in improving insight (clinical and cognitive). We hope this synthesis and quantitative examination of these evidence-based techniques will provide clinicians and researchers alike with insight into these techniques and their efficacy as well as provide directions for future research on interventions targeting cognitive biases in schizophrenia.

Methods

The review protocol for the current study was registered in the PROSPERO database (CRD 42017065218) and the PRISMA guidelines for systematic and meta-analysis studies were followed (Moher, Liberati, Tetzlaff, Altman, & Group, 2009). The literature search was conducted using the MEDLINE, PsycInfo and EMBASE databases on May 10th, 2019 with no restriction regarding the year of publication. The following keywords were used: (schizophreni* OR psychosis OR psychoses OR psychotic*) AND (cogniti* OR think* OR reason*) AND (bias* OR error* OR distort* OR style). The search was limited to articles written in English or French. Additionally, the reference lists of

all articles included in the review were searched for additional studies. The MCT developers, Steffen Moritz and Todd Woodward, were also consulted to obtain any unpublished data.

The flowchart of study selection is presented in Figure 1. A total of 7,844 references were initially retrieved, another two articles were identified through other sources (by reference list and unpublished data). Following the removal of duplicates ($n = 2,366$), an initial selection by G.S. and G.P. based on articles' titles reduced the number of relevant abstracts to 599. Abstracts of these selected articles were screened according to the following criteria: (a) peer-reviewed (e.g., books and conference abstracts were excluded); (b) included individuals with a schizophrenia-spectrum diagnosis (e.g., schizoaffective diagnoses were included); (c) reported on interventions addressing cognitive biases irrespective of study design (randomized controlled trial or naturalistic study); and (d) evaluated effects on cognitive biases, positive symptoms, and/or insight (clinical and/or cognitive). Notably, because cognitive-behavioral therapies, such as the 'Cognitive-Behavioral Therapy for psychosis' (CBTp; Beck, Rector, Stolar, & Grant, 2011), address specific cognitive distortions as part of a case formulation that is idiosyncratic to the patient, we decided not to include such studies. These types of interventions also often include other therapeutic targets (e.g., negative symptoms) and strategies (e.g., behavioral activation) which could risk confounding the therapeutic source of the effects analyzed in the present study. Similarly, studies reporting on the effects of the "Social Cognition and Interaction Training" (SCIT; Roberts, Penn, & Combs, 2015) were not included even though they address attributional biases because they focus on broader therapeutic targets (e.g., improving social functioning) and incorporate different techniques (e.g., exposure exercises). Following screening of abstracts, 88 full-text articles were assessed for eligibility with careful consideration of inclusion and exclusion criteria. A total of 32 studies were included in the review; 29 studies (including 2,738 participants) were quantitatively synthesized in the meta-analysis portion. Three studies (Andreou et al., 2015; Favrod et al., 2015; Moritz, Veckenstedt, et al., 2014) were not included in the meta-analysis portion as they represented reanalyses of already published data. Study information (e.g., sample characteristics, data outcomes) is listed in Table 1.

Three meta-analyses assessing cognitive biases, positive symptoms, and insight were separately performed using the Comprehensive Meta-analysis software (version 2.2.021, Biostat, Englewood, NJ). We combined measures of clinical and cognitive insight in a single meta-analysis because the number of included studies would have been too low otherwise and due to the high correlation between the two (Beck et al., 2004). Subsequent use of

the term *insight* therefore refers to both clinical and cognitive insight, unless specified. Sample sizes, means and standard deviations for pre- and post-treatment measures were extracted from the published articles or obtained from the corresponding authors. Hedges' g effect size was chosen, in contrast to Cohen's d , in an attempt to correct for small sample sizes (Hedges, 1985). Hedges' g effect sizes were standardized using the change score standard deviation and were calculated for each study from the reported means and standard deviations of both intervention and control groups. For studies that reported multiple follow-up time points (e.g., 3-months, 6-months follow-up) and outcome measures (e.g., PANSS and PSYRATS as measures of positive symptoms), effect sizes were pooled to obtain a composite score. When a study failed to report the correlation between their pre-treatment and post-treatment scores, a conservative value of 0.7 was adopted, as suggested by Rosenthal (Rosenthal, 1993). When studies reported outcomes using percentages (e.g., percentage of participants showing the JTC bias), the percentage was converted into the number of participants and used the number of events to compute Hedge's g effect sizes. Hedges's g was interpreted in the following fashion: 0.2 a small effect, 0.5 a medium effect, and 0.7 or greater a large effect. A positive g value indicates an improvement in cognitive biases, a decrease in positive symptoms and increase in insight.

The presence of a publication bias was assessed for each outcome using the following methods: visual examination of the funnel plot (Egger, Smith, Schneider, & Minder, 1997), Egger's asymmetry test, and the fail-safe N of Rosenthal (Rosenthal, 1979). If publication bias is present, it will be detected by visual inspection of the funnel plot and Egger's test for bias (Egger et al., 1997). In the absence of publication bias, the studies are expected to fall symmetrically above and below the mean effect size, suggesting that any sampling error would be random (Borenstein, Hedges, Higgins, & Rothstein, 2009). The fail-safe N of Rosenthal indicates the number of studies required to refute significant meta-analytic means (Rosenthal, 1979). The unlikelihood of publication bias is suggested if Rosenthal's N exceeds the cutoff estimate, which represents five times the number of studies, plus 10 (Fragkos, Tsagris, & Frangos, 2014; Rosenthal, 1991).

Considerable heterogeneity between included studies was expected because of methodological differences between them (i.e., the studies administered different tests to measure symptoms, insight and cognitive biases). Therefore, we planned to use a random effects model to estimate the mean distribution of intervention effects, as it accommodates the variation in effect sizes between studies (Lipsey & Wilson, 2001). Heterogeneity of effect sizes'

was estimated using Cochran's Q -statistic (Cochran, 1954) and the I^2 index (Higgins, Thompson, Deeks, & Altman, 2003). By convention, a Q -statistic p -value below 0.1 indicates heterogeneity (Potvin, 2014), while I^2 values of 25, 50 and 75 are associated with low, moderate and strong heterogeneity, respectively (Higgins et al., 2003).

Subgroup analyses were performed to determine if any heterogeneity of effect sizes was influenced by the overall risk of bias and the use of an active versus passive control condition, as these variables are established moderators of meta-analytic findings in schizophrenia (Eichner & Berna, 2016; Jauhar et al., 2014). Two authors, GS and GP, independently evaluated the 32 studies included in this review for study quality and risk of bias using the criteria described by Eichner and Berna (2016), which classifies studies as being at high or low risk based on three factors: randomization to group allocation, masking of outcome assessments, and incompleteness of outcome data. Studies stating that participants were randomly allocated to different groups were considered to be at a low risk for bias with regard to randomized group allocation. Studies that used interviewers for assessing outcomes, who were blind to group allocation of the questioned participants, were considered as being at a low risk for bias. Studies with dropout rates of more than 20% that used no intent-to-treat approach were considered to be at a high risk for bias. Studies being at low risk of bias regarding randomization, masking and incomplete outcome data were considered to be at low risk of bias, and studies being at high risk of bias regarding at least one of these factors were considered to be at high risk. Ninety-six risk of bias ratings were assigned as binary outcomes: high and low. Q -statistics with significance tests were used to test for subgroup differences between high and low-risk studies.

Additional subgroup analyses were conducted to determine whether the use of an active control intervention influenced the effect sizes. Interventions including contact with treatment providers, typically delivered in treatment-as-usual settings, were defined as an active control condition (e.g., CogPack, attentional control). Q -statistics with significance tests were used to test for subgroup differences.

Results

Systematic review

The 32 reviewed studies covered 15 different interventions directly targeting cognitive biases. Table 1 presents details of each study as well as their main outcome. Twenty reported on cognitive biases, 19 on positive symptoms and 11 on insight (clinical insight = 4; cognitive insight = 5; both = 2). Eight studies reported 2 out of the 3

outcomes measures (i.e., cognitive biases, positive symptoms, and insight) and 6 studies reported on all of them. For each study, a list of the cognitive bias, symptoms, and/or insight outcome measures and participant inclusion/exclusion criteria regarding psychotic symptoms is provided in Supplementary Material Table S1. As well, the quality/risk of bias assessments for each study are presented in Supplementary Material Table S2.

Metacognitive training and adaptations

One of the most frequently used interventions was metacognitive training (**MCT**), which was developed by Moritz and Woodward (2007b). MCT combines techniques from psychoeducation, cognitive remediation and cognitive-behavioral therapies, and aims to help participants develop insight and awareness into the different cognitive biases known to be related to delusions (Kumar, Menon, Moritz, & Woodward, 2015). This intervention also includes a knowledge translation component, which further helps participants realize the negative consequences of their cognitive biases to daily life. MCT was initially developed for a group format (see below for individual format adaptations) and comprises 8 modules targeting the following cognitive biases: JTC, BADE, attributional biases, and overconfidence in memory errors. Two cycles with different examples are available. The training aims to enhance participants' metacognitive abilities (i.e., being more aware of their cognitive biases) by (a) engaging them in numerous cognitive tasks, (b) providing feedback and corrective exercises, and (c) explaining links between what has been learnt and daily life. In addition to the aforementioned biases, aspects related to *theory of mind*, mood and self-esteem are also covered (Moritz, Andreou, et al., 2014). The developers of the intervention provide all the materials (including presentation slides and therapist manual) necessary to conduct the intervention free of charge (<http://www.uke.de/mct>), which has fostered several adaptations and multiple language translations.

As mentioned earlier, the MCT developers have adapted their training to an individualized setting (referred to as **MCT+**). This flexible manualized individual version uses the same exercises as those presented in the group version but addresses them in relation to patients' specific symptoms and challenges (Moritz, Vitzthum, et al., 2010). The material is divided into 11 units in its most updated version (2.3) and each is covered over several sessions (Moritz, Bohn, et al., 2016). Several included studies also presented targeted adaptations of MCT+. For instance, some studies delivered combinations of units in a few sessions to specifically target JTC, delusions or belief flexibility (Balzan, Delfabbro, Galletly, & Woodward, 2014; Kowalski, Pankowski, Lew-Starowicz, & Lukasz, 2017; So et al., 2015).

Combination of metacognitive training and cognitive remediation therapy

Other interventions included in our review combined aspects of the MCT with cognitive remediation therapy (CRT) techniques. CRT is an evidence-based intervention aimed to enhance cognitive skills in order to compensate for the various neurocognitive deficits (e.g., memory, attention) frequently observed in SZ&RP (Medalia & Choi, 2009). One included intervention consists of combining MCT elements with the online cognitive remediation program, called ‘mybraintraining’, developed by Dr. Ryuta Kawashima (Moritz, Thoering, et al., 2015). The original online CRT program targets abilities in calculation, logic, memory and vision. In the intervention integrating MCT elements (**CRT+MCT**), participants are asked to rate their confidence in their answers to each exercise comprised in the training. When hasty incorrect decisions are made with high confidence, participants automatically receive feedback and are encouraged to take more time before making a decision for the next trials. The CRT+MCT intervention is conducted online without a therapist and participants can complete the training at the location of their choice.

Another reviewed intervention combines group sessions of computer-assisted CRT (**CA-CRT**) and MCT. The intervention (**CA-CRT+MCT**) differs from the CRT+MCT one in that it consists of three structured 1-hour sessions per week of CA-CRT using the CogPack program® (Marker, 2003) followed by a fourth session of MCT during the week (Buonocore et al., 2015). Also, the sessions are conducted in small groups of 4-5 participants and led by trained psychologists. The CogPack program includes four sets of exercises that are tailored to the participants’ needs according to their performances on a baseline neuropsychological assessment. The 8 modules of MCT are administered over the course of 16 weeks as modules are completed in two sessions.

Cognitive bias correction

Another reviewed intervention is called ‘cognitive bias correction’ (**CBC**) and was developed by Moritz, Mayer-Stassfurth, et al. (2015). CBC is an online psychoeducational program offering 6 modules that aim to teach participants about 20 general cognitive biases not necessarily implicated in psychosis (e.g., Cocktail party effect of selective attention, optical illusions, hindsight bias). Participants first complete tasks that are designed to elicit the cognitive biases so that they can be experienced firsthand. Afterwards, participants receive psychoeducation on these common thinking mistakes and how these cognitive biases emerge.

Cognitive bias modification

The ‘cognitive bias modification’ (**CBM**) method specifically targets negative interpretive biases. It trains participants to generate positive resolutions of ambiguous situations that can be interpreted in a negative way (Steel et al., 2010). Participants are presented with 100 audio-recordings of scenarios depicting ambiguous situations. Each scenario describes an initially ambiguous situation that is subsequently resolved in a positive way. The CBM intervention was originally developed for individuals with anxiety and depression disorders and used visual material instead of audio recordings (Grey & Mathews, 2000; Salemink, van den Hout, & Kindt, 2007). A variant of the CBM intervention targets threat-related interpretive bias (**CBM-I**) and uses visual training material (Hurley, Hodgekins, Coker, & Fowler, 2018; Turner et al., 2011). Three-sentence scenarios describing emotionally ambiguous social situations are presented to participants on a computer screen. The final word of the first sentence is presented in fragments (e.g., ‘ap---gis-’ for apologise). These fragments can lead to negative or positive words, but as the remaining sentences are revealed, the scenario is always disambiguated in a positive manner. The training involves asking participants to complete the fragmented words before they are revealed. A comprehension question follows each trial to ensure proper understanding of the described situation.

Maudsley Review Training Programme and adaptations

The ‘Maudsley Review Training Programme’ (**MRTP**) consists of a computerised program that introduces participants to the concept of JTC. Participants are also invited to complete 5 training tasks accompanied by a therapist who provides positive feedback, reinforces insight and normalizes JTC (Hurley et al., 2018; Waller, Freeman, Jolley, Dunn, & Garety, 2011). The first task, named ‘What’s the picture’ is adapted from Moritz and Woodward (2007a) and teaches participants to look for additional evidence before making a decision. Six pictures are revealed one piece at a time. After each revealed piece, participants are asked if they would prefer to see another piece or immediately decide on what the picture was, based on a choice of 6 options. At first, all options seem plausible, but as the picture is incrementally revealed, certain options can be ruled out. The second task teaches participants to slow their decision-making process by trying to see other interpretations of optical illusions. The third task, also addressing the JTC bias, shows participants series of 3 video clips. The clips are designed to make participants jump to conclusions at first, while the subsequent clips show alternative interpretations. The fourth task addresses thinking flexibility by showing participants three video clips that illustrate scenarios with a potential

paranoid interpretation. After each clip, participants are invited to think about alternative interpretations (neutral, positive and negative). Finally, in the fifth task, participants are shown 4 video clips depicting scenarios in which one character jumps to conclusions. Participants are then asked which character jumped to conclusions and how this character could have avoided such a bias. Handouts with key aspects of the training are provided to participants. The five tasks are completed in one session lasting about 1.5 hours. An MRTP adaptation, the **Thinking Well (TW)** intervention (Waller et al., 2015), combines MRTP with four sessions of individual therapy to further apply their learning to their own thinking errors. Through these sessions, participants apply the techniques learned during the MRTP to their own delusional beliefs and work toward a chosen goal with the therapist.

Reasoning training

The **reasoning training (RT)** targeted JTC and BADE. RT was delivered in a single 45-minute session and comprised three training tasks of about 15 minutes each. RT introduces participants to cognitive biases and provides strategies to avoid them (Ross et al., 2011). The first two tasks are adapted from the MCT material (object identification and picture interpretation; Moritz & Woodward, 2007a) and the third task is the optical illusion task of MRTP (Waller et al., 2011). Each task is divided in 3 phases. In the object identification task, participants are first presented 5 pictures of incomplete objects that are incrementally revealed over a series of 8 slides. After each slide, participants are asked if they want to see another slide before identifying the object from a list of 6 options. Participants are free to select their answer after any number of revealed pieces although some options became less plausible as pieces are revealed. This represents the first phase (baseline). In the second phase (training), the same pictures are reviewed with the therapist and all pieces are shown to the participant to illustrate how hasty decision-making can lead to erroneous answers. In the third and final phase (bolster), a different set of 5 pictures are presented and participants are encouraged to request as many slides as they wish before making their decision. Similarly, in the picture interpretation task, participants are asked to identify among 4 options the correct title of 9 paintings. During the baseline phase, answers are collected for 4 paintings without indicating to the participants whether they are correct or not. The paintings with their correct answers are then reviewed with the therapist during the training phase and participants are encouraged to weigh the evidence supporting and refuting each possible option before making a decision. In the bolster phase, participants are shown an additional 5 paintings and encouraged to weigh the evidence before making a choice. Finally, the optical illusion task consists of 11 images

that can be interpreted in 2 ways, for example the depicted woman can be either perceived as old or young. The baseline phase comprises 5 pictures and participants freely describe what they see. In the training phase, each picture is reviewed and the different perspectives are revealed. An additional 6 pictures are presented after during the bolster phase.

Meta-analysis results

Cognitive biases

Twenty studies, comprised of 1,085 participants with a schizophrenia spectrum diagnosis, were included in our first meta-analysis investigating the effects of interventions on cognitive biases. About half of the studies ($N = 11$) investigated the effects MCT or one of its adaptations. Two studies verified the impact of combining MCT with cognitive remediation (Buonocore et al., 2015; Moritz, Thoering, et al., 2015). Three studies used the MRTP alone (Garety et al., 2015) or in combination with the CBM-I (Hurley et al., 2018) or its adaptation, the TW program (Waller et al., 2015). The remaining four studies verified the effects of RT (Ross et al., 2011), CBC (Moritz, Mayer-Stassfurth, et al., 2015), and CBM (Steel et al., 2010; Turner et al., 2011). Results of the meta-analysis suggest that interventions have a small, positive and statistically significant effect on the reduction of cognitive biases (Hedge's $g = 0.27$; 95% $CI = [.13-.41]$; $z = 3.77$; $p < .001$). The forest plot is presented in Figure 2.

Additional analyses were conducted to verify the robustness of this finding. Results suggest it is unlikely that the included studies' characteristics are heterogeneous ($Q_{19} = 24.649$; $df = 20$; $p = .21$; $I^2 = 23.66$). The funnel plot (Supplementary Material Figure S1) and the results of Egger's asymmetry test, $t(18) = 1.48$; $p = .16$, which suggest no evidence of funnel plot asymmetry, also indicate that the presence of a publication bias is unlikely. However, the Rosenthal's fail-safe N was 80, which is lower than the cut-off of 110, indicating a potential publication bias.

Subgroup analyses were also conducted to test whether overall risk bias (high vs. low) and inclusion of active control condition modified the effect of interventions on cognitive biases in comparison to control conditions. For studies at high risk of bias, the mean effect size was higher (Hedge's $g = 0.35$; 95% $CI = [.18-.53]$, $z = 3.990$; $p < .001$) than the main results where all levels of risk of bias were combined. However, statistical significance was not retained in studies at low of risk bias (Hedges' $g = .14$; 95% $CI = [-.07-.34]$; $z = 1.32$; $p = .19$). Although the effect

size of studies with a high risk of bias was larger than those with low risk of bias, there was no statistically significant difference between the effect sizes of studies at high and low risk of bias, $Q_{(1)brwn} = 2.43, p = .12$. This indicates that the main result may be driven by studies at high risk of bias.

When examining differences in control conditions, both the presence (Hedges' $g = .27$; $95\%CI = [.08-.47]$; $z = 2.73$; $p = .006$) and absence of an active control condition (Hedges' $g = .20$; $95\%CI = [-.04-.45]$; $z = 1.66$; $p = .10$) identified a small effect on the improvement of cognitive biases. Further, the difference between these effects was not statistically significant ($Q_{(1)brwn} = .91$; $p = .64$). Overall, both risk of bias and type of control condition therefore do not considerably affect the impact of interventions on the reduction of cognitive biases.

Positive symptoms

Our second meta-analysis investigating the effects of interventions on positive symptoms included 19 studies, totalling 1,005 participants. The vast majority of studies investigated the effects of diverse forms of MCT ($N = 16$). One study examined the outcomes of the CBC program (Moritz, Mayer-Stassfurth, et al., 2015). The other two studies verified the impacts of the following combinations: (1) MCT + CRT (Moritz, Thoering, et al., 2015), and (2) MRTP + CBM (Hurley et al., 2018). Results indicate that interventions have a moderate significant positive effect on the improvement of psychotic symptoms (Hedge's $g = 0.30$; $95\% CI = [.13-.48]$; $z = 3.44$, $p < .005$). The forest plot is presented in Figure 3.

Additional analyses conducted to verify the robustness of this finding suggest that characteristics of included studies are heterogeneous ($Q_{18} = 37.1$; $df = 19$; $p = .008$; $I^2 = 51.5$). Such heterogeneity can stem from the differences between the interventions, outcomes measures, samples' characteristics, etc. While both the funnel plot (Supplementary Material Figure S2) and results of Egger's asymmetry test, $t(17) = 1.01$, $p = .33$ indicate that the presence of a publication bias is unlikely, such a bias could not be entirely ruled out because Rosenthal's fail-safe $N = 99$ was slightly below the cut-off of 105.

Subgroup analyses were conducted to test whether overall risk bias (high vs. low) and inclusion of active control condition modified the effect of interventions on positive symptoms in comparison to control conditions. The mean effect size of studies at high risk of bias was higher (Hedge's $g = 0.40$; $95\%CI = [.17-.63]$; $z = 3.45$; $p = .001$) compared to the main result including all levels of risk. In contrast, the mean effect size of studies at low

risk of bias was lower (Hedges' $g = .19$; $95\%CI = [-.06-.44]$; $z=1.52$; $p=.13$) than the main result. However, there was no statistically significant difference between the improvement of positive symptoms among studies presenting a high versus low risk of bias ($Q_{(1)btwn} = 1.45$; $p=.23$).

When examining differences in control conditions, both the presence (Hedges' $g = .23$; $95\%CI = [-.01-.47]$; $z = 1.92$; $p=.06$) and absence of an active control condition (Hedges' $g = .22$; $95\%CI = [-.01-.45]$; $z = 1.86$; $p=.06$) identified a small effect on the improvement of positive symptoms. The difference between these effects was not statistically significant ($Q_{(1)btwn} = .01$; $p=.92$). Thus, both risk of bias and type of control condition do not considerably affect the impact of interventions on the improvement of positive symptoms.

Insight

For this third meta-analysis verifying the effects of interventions on insight levels, 11 studies were included. This represents 648 participants. All studies investigated the effects of MCT or its variants, and one its combination with CRT (Moritz, Thoering, et al., 2015). Results of this meta-analysis indicate that interventions have a moderate significant positive effect on the improvement of patients' insight levels (Hedge's $g = 0.35$; $95\% CI = [.15-.56]$; $z = 3.37$, $p < .005$). The forest plot is presented in Figure 4. As with the meta-analysis on symptoms, characteristics of included studies assessing insight were found to be heterogeneous ($Q_{10} = 18.57$; $df = 11$; $p = .069$; $I^2 = 46.1$). While visual inspection of the funnel plot (Supplementary Material Figure S3) and results of Egger's asymmetry test ($t(9) = .16$, $p = .88$) did not hint towards a publication bias, Rosenthal's fail-safe N of 50 was lower than the cut-off of 65, suggesting the likelihood of publication bias. Further, subgroup analyses indicate that effects sizes do not significantly differ between studies of high versus low risk of bias ($Q_{(1)btwn} = .53$; $p=.47$), nor between studies with or without an active control group ($Q_{(1)btwn} = 2.58$; $p=.11$). Therefore, both risk of bias and type of control condition do not considerably affect the impact of interventions on the improvement of insight.

Discussion

The present study reviewed the literature on psychological interventions systematically targeting cognitive biases in SZ&RP and evaluated their efficacy at improving cognitive biases, positive symptoms, and insight (clinical and cognitive) via meta-analysis. We identified 32 relevant studies, which included 15 different psychological interventions directly targeting cognitive biases in patients with SZ&RP, and wherein the following cognitive biases

were measured: JTC, BADE, belief inflexibility, intentionalising, catastrophizing, dichotomous thinking, emotional reasoning, representativeness bias, illusion of control bias, and interpretive bias. Surprisingly, no study reported results on the overconfidence in errors bias, which calls for more comprehensive investigations of cognitive biases in intervention studies. As expected, the most common intervention used to target cognitive biases was MCT. Several studies used MCT variants, developed for individual treatment (MCT+, MCT-T, MCT-JTC), delusion-specific biases (MCTd), or combined with other cognitive interventions (CA-/CRT+MCT). Several of the additional reviewed interventions borrow modules or modify tasks from MCT, but all shared the aims of improving cognitive biases and/or symptoms by teaching patients about cognitive biases that have been associated with symptoms in psychosis. Due to this overlap, and our interest in investigating psychological interventions targeting cognitive biases overall, we included all relevant studies in our review and meta-analysis.

A total of 29 studies were included in our quantitative meta-analyses. We found that psychological interventions targeting cognitive biases have small to moderate significant effects on the improvement of cognitive biases, psychotic symptoms and insight. Overall, these results appear to be relatively robust. While studies' characteristics do not appear to be heterogeneous for cognitive biases, heterogeneity was found for positive symptoms and insight. The presence of a publication bias seems unlikely for insight, but is possible for cognitive biases and positive symptoms. Nonetheless, the risk of bias and the inclusion of an active control group does not seem to artificially increase effect sizes.

Interestingly, the global effect size for cognitive biases was smaller than for either positive symptoms or insight although all included interventions were developed to specifically target cognitive biases. This could be explained by several factors. First, it could represent a non-significant numerical difference given that the confidence intervals are fairly large and overlap (Bakker et al., 2019). It could also partly stem from the psychometric properties of the instruments used to measure change in cognitive biases. Several issues have been raised for the beads/fish task (e.g., difficulty understanding the task, lack of parallel test-retest versions; Moritz et al., 2017), which was the most frequently used in our included studies. On the other hand, positive symptoms and insight were most often evaluated with robust instruments that contained multiple items and were clinician-rated (e.g., SAPS, PSYRATS, SUMD). The fact that multiple cognitive biases were regularly measured using a single tool (e.g., beads/fish task), as opposed to the variety of scales used to evaluate positive symptoms and insight, could also

partly explain why larger effect sizes were found. Further, interventions could have more generalized effects on positive symptoms and insight, due to their integrative and normalizing nature, also explaining in part the larger effects sizes compared to cognitive biases. These findings have important theoretical and clinical implications, which will be discussed below.

Theoretical implications

Several theoretical models of SZ&RP include cognitive biases as an important mechanism of the formation and maintenance of positive symptoms (Bell, Halligan, & Ellis, 2006; Broyd et al., 2017; Moritz, Pfuhl, et al., 2016; Sarin & Wallin, 2014). In a seminal paper, Kapur (2003) proposed the “aberrant salience” account of positive symptoms in psychosis, which posits that cognitive biases modify perceptual processing of certain irrelevant stimuli to render them hypersalient; hallucinations are a direct manifestation of this hypersalience, while delusions arise from a natural desire to explain these experiences. Garety and colleagues’ (2001) cognitive model of positive symptoms places greater emphasis on affective disturbances and emotional distress interacting with cognitive biases to produce hallucinations and delusions. In a similar vein, Salvatore et al. (2012) indicated that cognitive biases could contribute to paranoid delusions because they arise when patients feel threatened. Bentall & Kaney (2005) proposed that cognitive biases arise from attempts to reduce discrepancies between actual and ideal self-representations, which in turn may lead to persecutory delusions. More recent cognitive models of positive symptoms in psychosis (Broyd et al., 2017; Moritz, Pfuhl, et al., 2016) build on previous accounts and distinguish between biases affecting the formation and maintenance of delusional beliefs. In our view, these aforementioned theoretical models are further supported by our findings. Indeed, the currently reviewed interventions specifically targeting cognitive biases appear to efficaciously improve positive symptoms without addressing them directly. This further raises important clinical implications for the development and treatment of SZ&RP.

Clinical implications

Cognitive biases have not only been observed in multi-episode or enduring SZ&RP patients. Individuals at clinical high-risk (CHR) of developing SZ&RP and those experiencing a first episode of psychosis (FEP) also seem to present with cognitive biases (Eisenacher & Zink, 2017; Ross et al., 2015). This suggests that cognitive biases could begin to increase in the early stages of the illness. Given evidence that cognitive biases could be markers of

psychosis (Eisenacher & Zink, 2017), they may represent an interesting therapeutic target. Further, psychological interventions targeting cognitive biases may also have preventative or beneficial effects in these at-risk and early illness groups. Therefore, it would be worth investigating whether the interventions currently reviewed could be beneficial for these populations and perhaps even prevent conversion to psychosis. Promising results have been published so far. Studies offering MCT to FEP participants have shown improvements in positive symptoms and cognitive insight (Orcel et al., 2013; Ussorio et al., 2016). Future research would benefit from assessing the effects of psychological interventions targeting cognitive biases to determine whether they may be utilized as preventative or mitigating treatments for these groups.

Relatedly, our results suggest that cognitive biases are malleable in SZ&RP via psychological interventions. Such finding adds important information to the current debate of whether cognitive-behavioral therapy for psychosis (CBTp) represents an efficient treatment for positive symptoms (McKenna, Leucht, Jauhar, Laws, & Bighelli, 2019). Change in cognitive biases following intervention could arguably represent one of the mechanisms at work in CBTp. Future trials examining the efficacy of CBTp could likely benefit from including outcome measures of cognitive biases in addition to the typical evaluation of positive and negative symptoms. Although it was not included in the current analyses, one study by Lincoln et al. (2014) have reported that cognitive biases were significantly related to positive symptoms at 1-year follow-up of CBTp in 80 SZ&RP patients. The authors concluded that their finding supports the notion that the success of CBTp can partly be explained by correcting cognitive biases. The fact that psychological interventions systematically targeting cognitive biases also improve insight could represent a further evidence of this notion.

Limitations

We observed heterogeneity of effect sizes for studies assessing symptoms and insight, but not for cognitive biases as well as some evidence of publication bias for and positive symptoms cognitive biases due to the low fail-safe N (though analysis of the funnel plots suggests no publication bias). This heterogeneity may be due to the differences in intervention types, outcome measures, and sample characteristics included in the meta-analysis. This limitation was, however, circumvented by using a random-effects model, which assumes that the real effect size varies from one study to another (Borenstein et al., 2009). Our risk of bias analysis indicated that low versus high quality studies in terms of randomization, masking, and incomplete data did not result in significantly different effect sizes;

however, the subgroup analysis suggested a trend towards stronger effect sizes for interventions on symptoms when using an active control. Further, it would have been interesting to conduct additional subgroup analyses (e.g., different targeted cognitive biases, different types of interventions). This was unfortunately not possible because the number of studies in each subgroup would have been too small. These findings highlight the importance of conducting additional high quality, randomized-controlled trials in larger samples and taking into consideration the type of control condition (active versus passive) used. Finally, assessment of the tolerance/feasibility of these interventions was beyond the scope of this report, but has been addressed in a previous meta-analysis on MCT (Eichner & Berna, 2016).

Conclusions and future directions

The current study reviewed the literature on psychological interventions targeting cognitive biases in patients with enduring SZ&RP. Our review highlights several available interventions addressing a range of cognitive biases affected in SZ&RP that show good feasibility and acceptance in this population. The meta-analytic results support the use of these interventions in enduring SZ&RP and indicate that they have small to moderate effects on cognitive biases, symptoms, and insight (clinical and cognitive insight combined). However, future research should systematically include change in cognitive biases as a primary outcome to better understand how improvement in cognitive biases lead or be associated with better insight and reduced positive symptoms. Future studies should also use an active control condition, and reduce the risk of bias by using randomisation, blinding/masking, and avoiding incomplete outcome data. A promising avenue will be to assess the efficacy of interventions targeting cognitive biases in CHR and FEP groups to determine whether they may help mitigate prodromal or early symptoms, improve insight, or even help prevent conversion to psychosis.

Table 1. Description of studies included in the systematic review.

Study	Intervention	Design*	Control condition	Assessments	Outcome of experimental intervention	Included in meta-analysis
Aghotor, Pfueller et al. (2010)	MCT	RCT (n=16: 12m+4f, 28.9yo)	Active control (newspaper discussion group)	Baseline, Post	No improvement related to uniquely to experimental intervention (MCT).	Yes (cognitive biases, symptoms)
Andreou, Schneider et al. (2015)	MCT	FUP analysis of data presented in (Moritz et al., 2013)	Active control (CogPack)	Baseline, 6-mth FUP	Improvements in data-gathering is associated with delusion decline.	No (duplicate publication)
Andreou, Wittekind et al. (2017)	MCT+	RCT (n=46: 21m + 25f, 36.9yo)	Active control (CogPack)	Baseline, Post, 6mth-FUP	Improvement of delusions and self-reflectiveness score at post-MCT+.	Yes (cognitive biases, symptoms, insight)
Balzan, Delfabbro et al. (2014)	MCT-T	Intervention study (n=14: 11m+3f, 38yo)	TAU	Baseline, Post	Improvement on global delusion score, positive symptoms, delusional conviction and clinical insight.	Yes (symptoms, insight)
Balzan, Mattiske et al. (2018)	MCT+	RCT (n=27: 15m + 12f, 35.4yo)	Active control (cognitive remediation)	Baseline, Post, 6mth-FUP	Improvement in delusional and overall positive symptom severity, and clinical insight. No improvement in JTC bias at post-intervention.	Yes (cognitive biases, symptoms, insight)
Briki, Monnin et al. (2014)	MCT	RCT (n=25: 16m+9f, 41.1yo)	Active control (Supportive therapy)	Baseline, Post	Improvement on positive symptoms.	Yes (symptoms, insight)
Buonocore, Bosia et al. (2015)	CACR+MCT	RCT (n=30: 17m+13f, 34.4yo)	Active control (CACR + newspaper group discussion)	Baseline, Post	Improvement on the BADE measure.	Yes (cognitive biases)
Erawati, Keliat et al. (2014)	MCT	Intervention study (n=26:	TAU	Baseline, Post	Improvement on delusional severity and metacognition.	Yes (symptoms)

		16m+10f, 37.1yo)				
Favrod, Brana et al. (2015)	MCT	RCT (n=26: 17m+9f, 36.9yo)	TAU	Baseline, Post, 6-mth FUP	Improvement of awareness of delusional ideation at FUP.	No (duplicate publication)
Favrod, Maire et al. (2011)	MCT	Pilot study (n=18: 11m+7f, 41.8yo)	None	Baseline, Post	Improvement in symptoms (delusions and hallucinations), insight, and depression.	Yes (symptoms, insight)
Favrod, Rexhaj et al. (2014)	MCT	RCT (n=26: 17m+9f, 36.9yo)	TAU	Baseline, Post, 6mth-FUP	Improvement on delusions and auditory hallucinations.	Yes, symptoms, insight)
Garety, Waller et al. (2015)	M RTP	Intervention study (n=51, info on age and sex n/a)	Active control (cognitive tasks)	Baseline, Pre, Post, 1wk-FUP	Improvement of JTC and belief flexibility and reduction in state paranoia at FUP.	Yes (cognitive biases)
Gaweda, Krezolek et al. (2015)	MCT	Intervention study (n=23: 11m+12f, 50.4yo)	TAU	Baseline, Post	Improvement on catastrophization, emotional reasoning, JTC, clinical insight, and paranoia.	Yes (cognitive biases, symptoms, insight)
Hurley, Hodgekins et al. (2018)	M RTP and CBM-I	Intervention Study (n=12: 8m + 4f, 39.4yo)	None	Baseline, Pre, Post, 1mth-FUP	Improvement on delusional severity and positive symptoms.	Yes (symptoms)
Ishakawa et al. (2019)	MCT	RCT (n=50: 25m + 25f, 47.5yo)	TAU	Baseline, Mid-intervention, Post, 4wk-FUP	Improvement on JTC, hallucinations, positive symptoms, and cognitive insight at post-intervention. Improvement maintained at FUP for JTC, hallucination and positive symptoms. Improvement on	Yes (cognitive biases, symptoms, insight)

					cognitive biases (CBQp) at FUP only.	
Kowalski, Pankowski et al. (2017)	MCT-JTC	Pilot study (n=12: 9m + 3f, 28yo)	1) MCT-ToM 2) Control	Baseline, Post	Improvement on JTC. No improvement in paranoia.	Yes (cognitive biases, symptoms)
Lam, Ho et al. (2015)	MCT	RCT (n=38: 21m+17f, 41.3yo)	TAU	Baseline, Post	Improvement of self-reflectiveness (cognitive insight).	Yes (insight)
Moritz, Kerstan et al. (2011)	MCT	Intervention study (n=18, 15m+3f, 33.6yo)	Wait-list	Baseline, Post	Improvement on JTC, memory and social relationships.	Yes (cognitive biases)
Moritz, Mayer-Stassfurth et al. (2015)	CBC	Intervention study (n=33: 14m + 19f, 41.8yo)	Wait-list	Baseline, Post	Fewer participants showed JTC at post-intervention.	Yes (cognitive biases, symptoms)
Moritz, Thoering et al. (2015)	CRT+MCT	Intervention study (n=30: 12m + 18f, 40.8yo)	1) Active control (mybraintraining) 2) Wait-list	Baseline, Post, 3mth-FUP	Delayed decision-making (baseline-post) and fewer participants showed a JTC bias at FUP.	Yes (cognitive biases, symptoms, insight)
Moritz, Veckenstedt et al. (2011)	MCT (group + ind)	Clinical trial (n=24: 17m+7f, 32.6yo)	Active control (CogPack)	Baseline, Post	Improvement on delusion (severity and conviction) and JTC.	Yes (symptoms)
Moritz, Veckenstedt et al. (2013)	MCT	RCT (n=76: 45m+31f, 36.8yo)	Active control (CogPack)	Baseline, Post, 6mth-FUP	Improvement on delusions which was partially sustained at FUP. Reduction of preoccupation, and distress (amount and intensity).	Yes (cognitive biases, symptoms)
Moritz, Veckenstedt et al. (2014)	MCT	FUP analysis of Moritz et al. (2013)	Active control (CogPack)	Baseline, Post, 6mth-FUP, 3y-FUP	Improvement on delusions at both FUPs. No advantage of MCT on JTC compared to active control.	No (duplicate publication)

Naughton, Nulty et al. (2012)	MCT	Intervention study (n=11: 11m+0f, 37.5yo)	Wait-list	Baseline, Post	Improvement in mental capacity (understanding and reasoning) and functioning.	Yes (symptoms)
Ross, Freeman et al. (2011)	RT	Intervention study (n=34 : 25m+9f, 39yo)	Active control (cognitive tasks)	Baseline, Post	Improvement in JTC and belief flexibility.	Yes (cognitive biases)
So, Chan et al. (2015)	MCTd	RCT (n=23: 12m+11f, 32.4yo)	TAU	Baseline (Ctrl), Pre-int (exp.), Post, 4wk-FUP	Improvement of positive symptoms, which is mediated by improvement in belief flexibility.	Yes (cognitive biases, symptoms)
Steel, Wykes et al. (2010)	CBM	Intervention study (n=21: 15m + 6f, 43yo)	Active control (cognitive tasks)	Baseline, Post	No improvement related to uniquely to experimental intervention (CBM).	Yes (cognitive biases)
Turner, Hoppitt et al. (2011)	CBM-I	Pilot study (n=8 : 7m+1f, 24.8yo)	None	Baseline, Post	Improvement on interpretive bias (change from a negative to positive interpretive bias).	Yes (cognitive biases)
Turner, Macbeth et al. (2018)	MCT-JTC (single session)	RCT (n=19: 14m + 5f, 45.3yo)	Active control (attention control)	Baseline, Post	Improvement in JTC (draws to decision).	Yes (cognitive biases)
van Oosterhout, Krabbendam et al. (2014)	MCT	RCT (n=75: 54m+21f, 38.3yo)	TAU	Baseline, Post, 6mth-FUP	No improvement related to uniquely to experimental intervention (MCT).	Yes (cognitive biases, symptoms, insight)
Waller, Emsley et al. (2015)	TW	RC feasibility study (n=20: 15m+5f, 39.1yo)	TAU	Baseline, Post-MRTP, Post-TW, 2wk-FUP	Improvement of belief flexibility at post-MRTP and post-TW.	Yes (cognitive biases)
Waller, Freeman et al. (2011)	MRTP	Pilot study (n=13: 7m+6f, 44.6yo)	None.	Baseline, Pre, Post, 2wk-FUP	Improvement on JTC, belief flexibility, and delusional conviction.	Yes (cognitive biases)

Note. * N refers to number of patients in experimental group. Abbreviations: BADE: Bias against disconfirmatory evidence; CACR+MCT: Computer-assisted cognitive remediation + metacognitive training; CBC: Cognitive bias correction; CBM-I: Cognitive bias modification – for interpretive biases; CBM: Cognitive bias modification; CRT+MCT: Cognitive remediation therapy + metacognitive training; Ctrl: control; f: Female; FUP: Follow-up; JTC: Jumping to conclusions; m: Male; MCT (group+ind): Group and individual metacognitive training; MCT-T: Metacognitive training targeted; MCT: Metacognitive training; MCTd: Metacognitive training for delusions; MRTP: Maudsley review training programme; mth: Month; n/a: non-available; RC: Randomized controlled; RCT: Randomized controlled trial; RT: Reasoning training; TAU: Treatment as usual; TW: Thinking Well; wk: week; y: Year; yo: years old. A more detailed description of the studies outcomes can be found in Supplementary Material.

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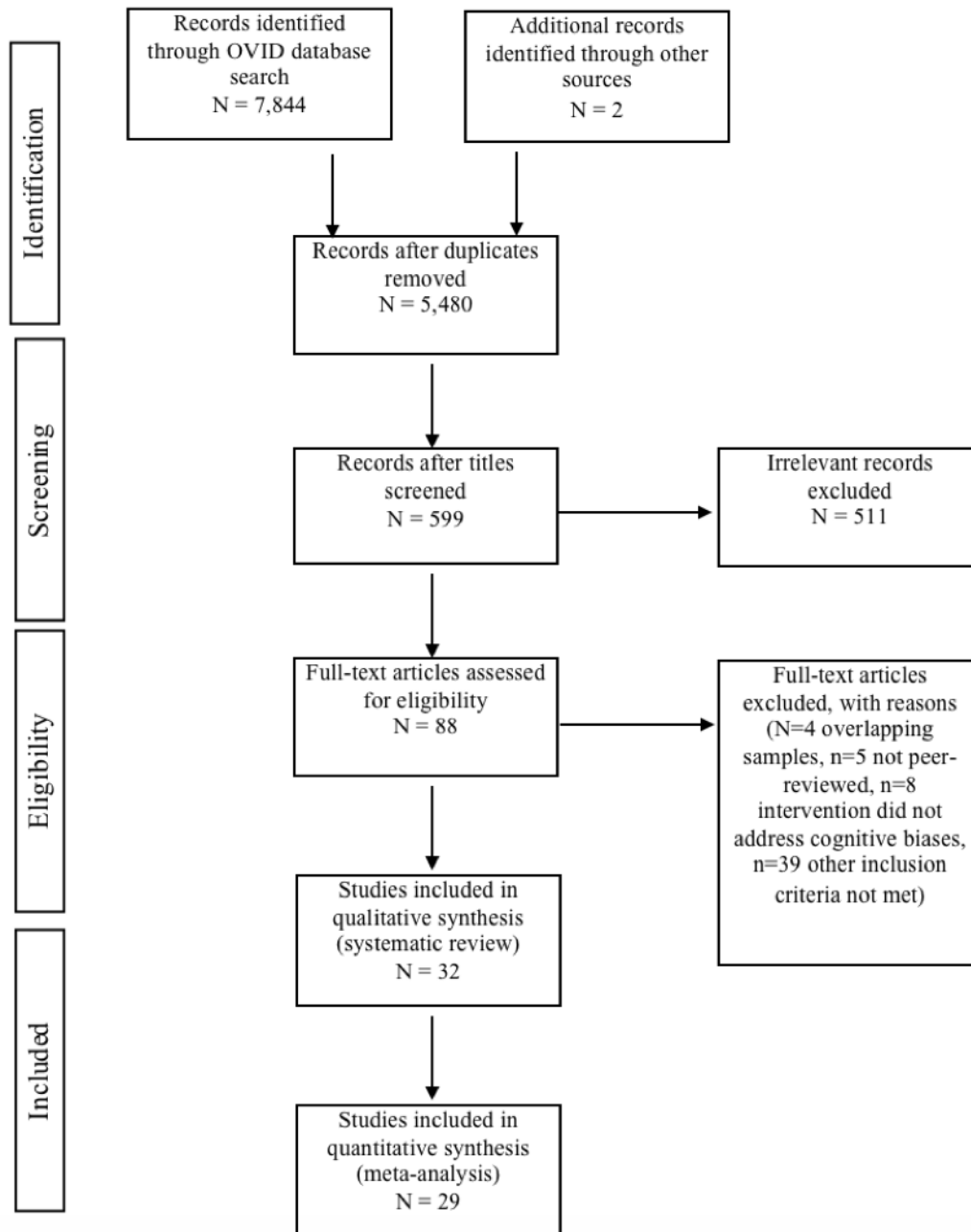


Figure 1. PRISMA flow diagram of study selection, inclusion, and exclusion. N = number of studies.

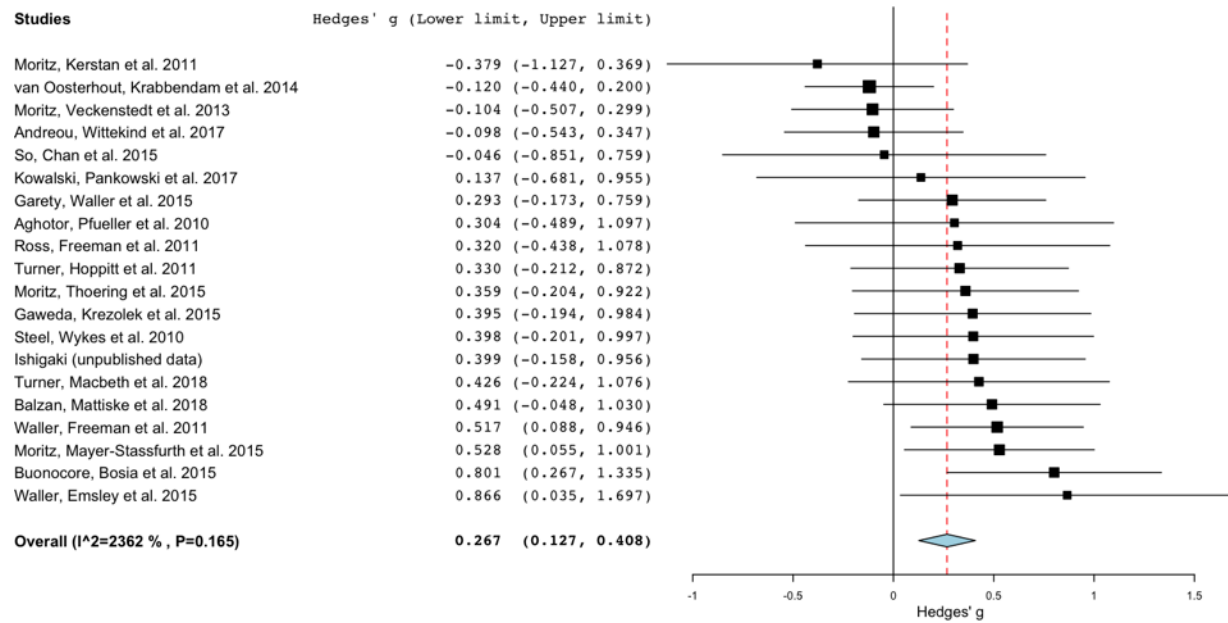


Figure 2. Forest plot of studies in the meta-analysis of cognitive biases. Effect sizes of interventions on cognitive biases. Positive effect sizes favour the effect of treatment on cognitive biases over the effect of control.

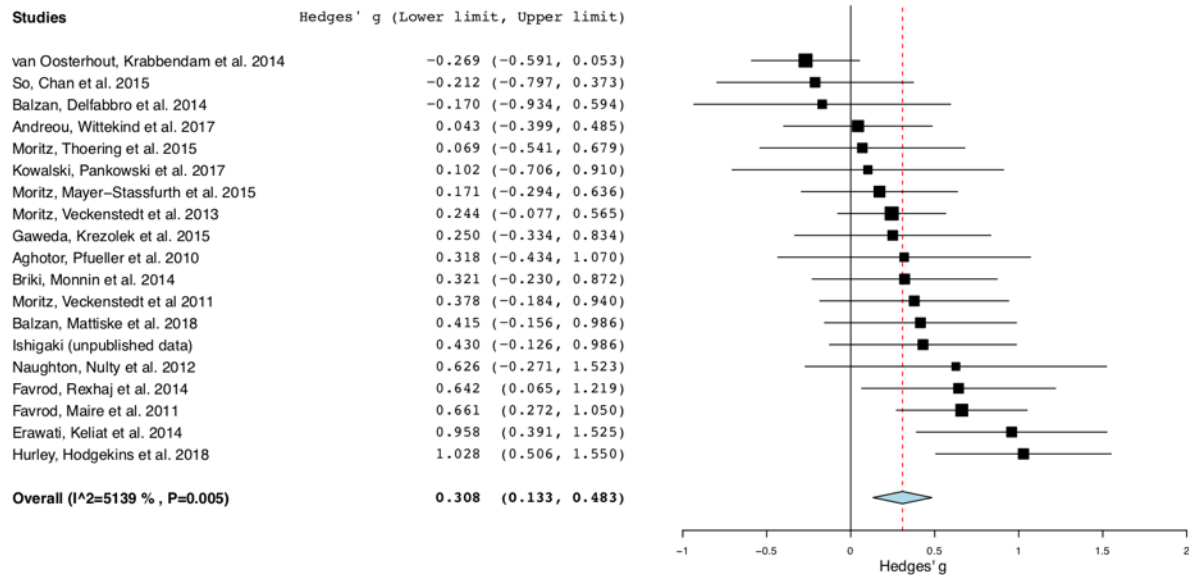


Figure 3. Forest plot of studies in the meta-analysis of positive symptoms. Effect sizes of interventions on positive symptoms. Positive effect sizes favour the effect of treatment on positive symptoms over the effect of control condition.

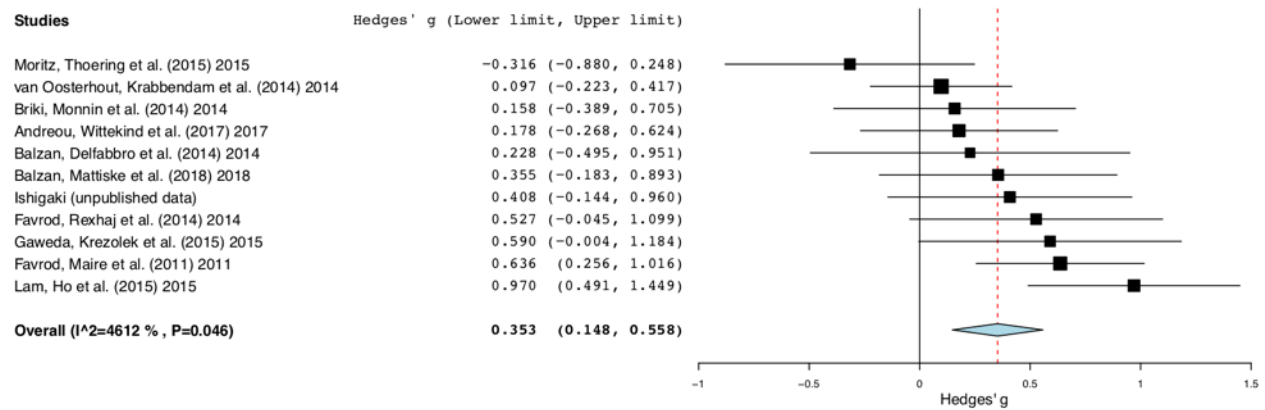


Figure 4. Forest plot of studies in the meta-analysis of insight. Effect sizes of interventions on insight. Positive effect sizes favour the effect of treatment on insight over the effect of control condition.