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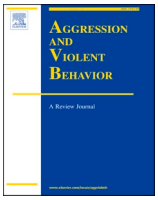

Reducing antisocial behavior through cognitive training: A systematic review and meta-analysis

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ABSTRACT

Cognitive deficits are a key risk factor for severe and persistent antisocial behavior (ASB); however, whether improving cognitive functioning reduces ASB remains unclear. To address this question, we conducted a systematic review and meta-analysis of cognitive training interventions among individuals displaying ASB.

We searched PubMed, PsycINFO, and Web of Science for studies published between 1990 and 2023. Of 529 records screened and 54 full-texts assessed, we identified 14 studies including a total of 601 participants (age $M = 39.12$, $SD = 9.33$, 84 % male). Most studies aimed at improving multiple cognitive domains. Cognitive training yielded moderate reductions in ASB ($g = 0.59$, $p < .001$ in pre-post studies; $g = 0.36$, $p = .003$ in controlled trials). Effect sizes were larger for interventions targeting social cognition. Cognitive improvements were moderate in pre-post studies ($g = 0.51$, $p < .001$) but non-significant in controlled trials ($g = 0.11$, $p = .27$).

Cognitive training holds promise as a complementary approach for reducing ASB, but greater theoretical and measurement precision is needed to elucidate the mechanisms driving behavioral change. Future research directions include anchoring interventions on cognitive models of ASB, aligning treatment and assessment targets, and evaluating treatment moderators, scalability, and transfer effects.

1. Introduction

1.1. The association between cognitive functioning and antisocial behavior

Antisocial behavior (ASB) is commonly defined as a conduct that harms or disregards the well-being of others, and generally encompasses aggression, deceit, and transgressions of the law. ASB has broad societal ramifications, including health, emotional, and economic costs to those affected, as well as costs relating to prosecution, incarceration, and rehabilitation efforts (Heeks et al., 2018; Krug et al., 2002). ASB is the hallmark feature of antisocial personality disorder (American Psychiatric Association, 2013) but it can also co-occur with psychiatric and neurological conditions. For example, schizophrenia (Ahmed et al., 2018) and traumatic brain injury (Buckley et al., 2017) are associated with behavioral difficulties including aggression. Furthermore, ASB can manifest in the absence of any diagnosed conditions (Baskin-Sommers, 2016; Krueger et al., 2021; Yu et al., 2012).

Given its broad impact, researchers have long sought to understand the etiological factors contributing to ASB. Some of this work has focused on examining the cognitive correlates of ASB. Across correlational and experimental studies, this body of research has consistently documented a moderate-to-strong association between ASB and cognitive difficulties, especially in the domains of executive functioning and social cognition (Blair, 2019; Morgan & Lilienfeld, 2000; Viding et al., 2023). For example, individuals exhibiting aggressive ASB, such as

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violent offending, appear to perform worse than healthy controls in experimental tasks measuring working memory and decision-making (Byrd et al., 2014; De Brito et al., 2013; Wallinius et al., 2019) as well as emotion recognition and empathy (Sedgwick et al., 2017; Winter et al., 2017). Similarly, individuals exhibiting non-aggressive ASB, such as rule-breaking and property crime, appear to perform worse than healthy controls in tasks measuring cognitive flexibility and planning (Ogilvie et al., 2011; Türel et al., 2024; Vaskinn et al., 2024) as well as facial affect recognition (Schönenberg et al., 2016; Zeng et al., 2022).

Behavioral research has been complemented by neuroimaging research aimed at identifying neural differences between individuals with and without ASB (Salehinejad et al., 2021; Yuan & Raz, 2014). Overall, neuroimaging research has supplied evidence of functional differences in brain regions underlying threat processing, reinforcement learning, social cognition, and executive functions (Dugré et al., 2020; Nikolic et al., 2022). For example, individuals with ASB tend to exhibit enhanced amygdala reactivity to emotional stimuli, which could indicate disrupted threat processing (Baskin-Sommers, 2016; Blair, 2010; Nikolic et al., 2022). They also tend to exhibit reduced activity in regions of the prefrontal cortex implicated in cognitive control during emotion processing (Dugré et al., 2020; Wong et al., 2019).

1.2. Cognitive training interventions for individuals displaying antisocial behavior

The association between cognitive functioning and ASB holds implications for the rehabilitation of individuals within correctional, psychiatric, and forensic settings. Within correctional settings, individuals experiencing cognitive difficulties are often involved in behavioral incidents, including verbal and physical aggression directed towards other inmates and staff (Wallinius et al., 2019; Young et al., 2009). Moreover, their overall outcomes, including recidivism, tend to be suboptimal relative to their counterparts without cognitive difficulties (Hancock et al., 2010; Meijers et al., 2015; Shumlich et al., 2019). Within psychiatric and forensic settings, cognitive difficulties can interfere with management and rehabilitation (Broderick et al., 2015; Lussier et al., 2010). For example, individuals experiencing cognitive deficits often manifest oppositional and aggressive behaviors, which can compromise rehabilitation efforts (Brown et al., 2018; Nazmie et al., 2013; Puzzo, 2019). Consequently, there has been interest in examining whether interventions aimed at enhancing cognitive functioning (i.e., cognitive training) can help prevent ASB in these settings (Quinn & Kolla, 2017; Ross & Hoaken, 2010).

Cognitive training interventions encompass a range of behavioral stimulation techniques explicitly aimed at restoring cognitive functioning (Kim et al., 2018; Medalia & Choi, 2009). Despite varying techniques, cognitive training interventions share the approach of using structured exercises to train cognitive skills. Structured exercises are often complemented by elements reminiscent of other psychotherapeutic interventions, such as strategy coaching and bridging discussions aimed at generalizing training to real-life situations (Kambeitz-Ilankovic et al., 2019; Medalia & Freilich, 2008). Meta-analyses have shown that cognitive training interventions are associated with cognitive and behavioral improvements in populations with various psychiatric and neurological conditions (Therond et al., 2021; Wykes et al., 2011). Narrative and systematic reviews have further suggested that cognitive training targeting executive functions and social cognition can reduce violent and aggressive behaviors in individuals with severe mental illness, particularly schizophrenia (Darmedru et al., 2017; Dumont et al., 2018). Yet cognitive training interventions are seldom incorporated into correctional, psychiatric, and forensic rehabilitation programs (Andiné & Bergman, 2019; Ross & Hoaken, 2010; Schwalbe & Medalia, 2014). Such programs typically include psychotherapy or psychosocial interventions addressing patterns of thought and behavior more broadly, but no formal cognitive training component (Hollin & Palmer, 2009; Jotangia et al., 2015; Landenberger & Lipsey, 2005). Given the potential of cognitive training to enhance rehabilitation outcomes in individuals displaying ASB, research exploring the effects of cognitive training in this population is warranted.

1.3. The present study

To evaluate the robustness of the association between cognitive training and ASB for potential clinical applications, we conducted a systematic review and meta-analysis of cognitive training interventions among individuals exhibiting ASB. This synthesis is timely as it may help identify areas requiring further investigation to achieve a more granular understanding of the cognitive mechanisms driving variation in ASB. It may also aid in setting priorities for implementation research and inform clinical decision-making, ensuring that interventions offered to individuals with ASB are supported by empirical evidence.

Based on existing reviews and preliminary literature searches, we predicted that cognitive training would be associated with significant reductions in ASB, with a moderate effect size (Darmedru et al., 2017; Dumont et al., 2018). Furthermore, based on prior meta-analyses of cognitive training interventions in individuals with psychiatric and neurological conditions, we predicted that cognitive training would be associated with significant improvements in cognitive functioning in individuals displaying ASB, with a moderate effect size (Anaya et al., 2012; McGurk et al., 2007; Rohling et al., 2009; Therond et al., 2021). We had also planned subgroup analyses assessing the effects of specific cognitive training on distinct cognitive domains, as well as moderator analyses aimed at elucidating participant and intervention characteristics that could influence the results. However, these analyses were precluded due to limited statistical power. Different cognitive training approaches, targeting different cognitive domains, were analyzed jointly.

2. Methods

We pre-registered this study on the international prospective register of systematic reviews of the National Institute for Health Research (PROSPERO), with protocol no. CRD42021215470.

2.1. Participants

We selected studies involving adult participants (18+) exhibiting ASB. ASB was defined by either an offense history, scoring above a normative threshold on assessments of ASB, aggression, or anger regulation problems, or as part of a psychiatric diagnosis characterized by disruptive and aggressive behaviors.

2.2. Interventions and control conditions

We included cognitive training interventions aimed at improving multiple or specific cognitive domains. We excluded other psychotherapies, such as cognitive-behavioral therapy, which integrate cognitive restructuring techniques and behavioral strategies to address broader maladaptive patterns of thought and behavior, and have been extensively studied in relation to ASB (Papalia et al., 2019). While cognitive training interventions may share some elements with other psychotherapies, such as shared goal-setting and teaching meta-cognitive strategies, they have a distinct focus and methodology – targeting specific cognitive functions (e.g., attention, memory, and problem-solving) using structured exercises (Medalia et al., 2017).

We analyzed results from controlled trials (with and without randomization) and pre-post studies separately. For controlled trials, we examined changes from pre- to post-intervention in participants receiving cognitive training relative to a control group in an active control condition, a waitlist, or receiving treatment as usual. For pre-post studies, we examined within-group changes from pre- to post-intervention.

2.3. Outcomes

We examined the effects of cognitive training on two outcomes: 1) ASB, assessed using clinician-rated, psychometric, or performance-based measures of aggression, other oppositional behaviors, or relevant emotional states (e.g., anger regulation problems), and 2) cognitive functioning, including standardized assessments of specific or multiple cognitive domains.

2.4. Literature search, study selection, and data extraction

Fig. 1 illustrates our literature search and study selection procedure, in compliance with the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) guidelines (Moher et al., 2009).

The systematic literature search was conducted in PubMed (Medline), PsycINFO (Ovid), and Web of Science, using the following keywords: "*cognitive training*" or "*cognitive remediation*" or "*cognitive rehabilitation*" or "*cognitive enhancement*" or "*brain training*" or "*neurocognitive training*" or "*neuropsychological training*" or "*neuropsychological rehabilitation*" AND "*antisocial*" or "*crim**" or "*forensic*" or "*offend**" or "*aggress**" or "*jail*" or "*prison*". Since we aimed to capture a broad range of cognitive training interventions, our keywords included different terms that are used in the literature, often interchangeably, while acknowledging potential differences in the specific exercises or techniques used under these terms. We searched for articles and dissertations published in English between January 1990 and January 2023. Electronic database searches were complemented by hand-searching reference lists of relevant articles and reviews. Four authors (PP, AT, SW, MN) were responsible for screening, data extraction, and data checks. At any given time, two authors worked independently and concurrently on these tasks to enhance coding reliability through periodic checking. Disagreements were resolved through discussion, and when necessary, with input from another co-author (SG). We used Covidence (covidence.org) to organize and screen records, and an Excel-based form created by the authors to extract the data.

The search yielded 999 results (PubMed = 530, PsycINFO = 220, Web of Science = 208, citation searching = 41). After removing 470 duplicates, we screened the titles and abstracts of 529 documents and selected 54 for full-text screening. From full-text screening, we excluded documents reporting interventions or experimental manipulations other than cognitive training. We excluded studies involving participants younger than 18 years, participants with no history of ASB, and in one occasion, too few participants within a larger sample meeting our inclusion criteria (Byrne et al., 2015). We ensured that samples involved participants with ASB through careful examination of the abstract and full text of each study. This determination was straightforward in most cases. In a few instances, it required checking pre-treatment scores on measures of ASB against normative thresholds (Elbogen et al., 2019; Gunnarsson, 2021). We excluded studies not in English, studies measuring neither of the two outcomes of interest, conference proceedings, and reviews.

We retained thirteen eligible documents reporting fourteen unique studies. These included five randomized controlled trials (Ahmed et al., 2015; Elbogen et al., 2019; O'Reilly et al., 2019; Romero-Martínez et al.,

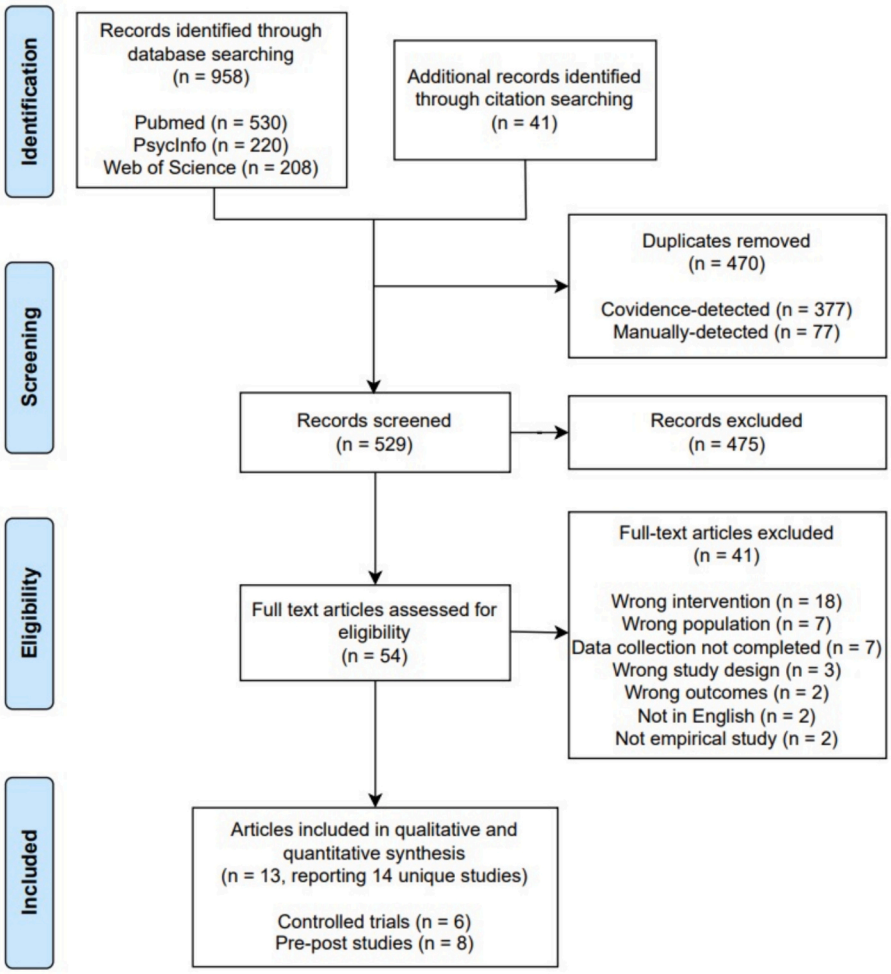

Fig. 1. PRISMA flow chart illustrating the literature search and study selection procedure.

2022; Wilson, 2015), one non-randomized controlled trial (Trujillo et al., 2017), three randomized pre-post studies (Baskin-Sommers et al., 2015; Khan et al., 2023), one non-randomized pre-post study with comparator condition (Hodel & West, 2003), and four non-randomized pre-post studies with no control or comparator conditions (Dodds, 2009; Gunnarsson, 2021; Marcer et al., 2016; Rocha et al., 2014). Eleven studies were published in peer-reviewed journals (Ahmed et al., 2015; Baskin-Sommers et al., 2015; Elbogen et al., 2019; Hodel & West, 2003; Khan et al., 2023; Marcer et al., 2016; O'Reilly et al., 2019; Rocha et al., 2014; Romero-Martínez et al., 2022; Trujillo et al., 2017); three were reported in doctoral dissertations (Dodds, 2009; Gunnarsson, 2021; Wilson, 2015).

2.5. Procedure

2.5.1. Power analysis

Albeit small, the number of eligible studies was greater than the minimum recommended to perform a meta-analysis (two) by the Cochrane Consumers and Communication Group (Higgins & Green, 2008; Ryan & Hill, 2018). Based on the available sample size and expected effect size, we formally estimated our likelihood to detect significant treatment effects in the controlled trials. We did not perform a power analysis for the pre-post studies due to lack of a suitable statistical tool. The power analysis, performed using the R package dmetar (Harrer et al., 2021), indicated adequate statistical power under the random-effects model (80.96 % for ASB, 79.95 % for cognitive functioning). Although the fixed-effects model showed greater power (90.34 % for ASB, 89.59 % for cognitive functioning), it is considered suboptimal as it does not account for between-study variability (Schwarzer et al., 2015). Nonetheless, for transparency, we reported results under both random-effects and fixed-effect models.

2.5.2. Meta-analysis

We conducted the meta-analysis using the R package metaphor (Viechtbauer, 2010). First, we estimated the standardized mean difference between the pre- and post-intervention measurements for the treatment group (Hedges' g_T) as:

$$g_T = c(n_T - 1)\,\frac{\underline{x}_{post,T} - \underline{x}_{pre,T}}{SD_{pre,T}} \quad (1)$$

where n_T indicates the number of participants in the treatment group, $\underline{x}_{pre,T}$ and $\underline{x}_{post,T}$ indicate the pre- and post- intervention means for the treatment group, $SD_{pre,T}$ indicates the standard deviation of the pre-intervention measurement, and c indicates a bias correction factor (Becker, 1988). We set the bias correction factor conservatively at 0.50, as our stability analysis suggested that the random-effects estimates were sensitive to varying degrees of similarity between studies (r = 0.10–0.90). For the meta-analysis of pre-post studies, we then conducted a meta-analysis on the Hedges' g_T for each study and outcome.

For the meta-analysis of controlled trials, we also estimated the standardized mean difference between the pre- and post-intervention measurements for the control group (Hedges' g_C) as:

$$g_C = c(n_C - 1)\,\frac{\underline{x}_{post,C} - \underline{x}_{pre,C}}{SD_{pre,C}} \quad (2)$$

where all terms are defined as in Eq. (1) and the C subscripts refer to the control group. For each outcome, we then computed an aggregated measure of effect size, Hedges' g, as the difference between Hedges' g_T and Hedges' g_C. Hedges' g reflected the standardized difference between pre- and post- intervention measurements in the treatment vs. control group (Hedges et al., 1985). We reverse-coded the calculation of Hedges' g as needed, so that positive effect sizes always reflected improvements from pre- to post- intervention. Since some studies included multiple different outcomes, we aggregated the Hedge's g by study to address the dependency between observations (Borenstein et al., 2009). We then conducted a meta-analysis on the pooled Hedges' g estimates.

2.5.2.1. Study heterogeneity. We estimated study heterogeneity (namely, variability among the effect sizes estimated across the included studies) with the Cochran's Q test and the I^2 index. If statistically significant, the Cochran's Q test indicates substantial variation between studies. I^2 index values indicate whether heterogeneity is low (0 %–25 %), moderate (25 %–50 %), or high (> 50 %) (Borenstein, 2019).

2.5.3. Risk of bias

We assessed the presence of publication bias by visual inspection of funnel plots (see Supplementary Material SM1) and by adjusting meta-analyses using the trim-and-fill method (Duval & Tweedie, 2000). We assessed other sources of bias following the guidelines outlined in the Cochrane Handbook for Systematic Reviews of Interventions for randomized and non-randomized studies, as appropriate (Higgins and Altman, 2008) (Supplementary Material SM2). Two authors (MN, PP) independently assessed risk of bias for each study, achieving consensus through discussion as needed.

3. Results

3.1. Descriptive results

3.1.1. Participant characteristics

Participant demographic characteristics, history of ASB, and psychiatric or neurological diagnoses are reported in Tables 1, 2 and 3, respectively. The 14 eligible studies involved a total of 601 participants (434 in treatment groups, 167 in control groups). Across studies, participants were middle-aged (30.64 to 50 years, M = 39.12, SD = 9.33) and predominantly men (84 %). In controlled trials, treatment and control groups were matched for demographic characteristics. Most studies (9/14) involved participants with both criminal offenses and psychiatric diagnoses. Three studies involved participants with criminal offenses alone, and two involved participants with TBI and high levels of anger or aggression. The most prevalent psychiatric diagnosis was schizophrenia or schizoaffective disorder (7/14 studies). Participants in most studies involving psychiatric samples were under a stable medication regime (8/10; information on the pharmacological regime was not reported in the remaining two studies).

3.1.2. Cognitive training protocols (Table 4)

Five studies utilized commercially available computerized programs consisting of gamified cognitive exercises training a wide spectrum of cognitive skills. Of these five studies, one (Dodds, 2009) utilized COGPACK by Marker Software, which trains visuomotor skills, comprehension, attention, memory, and problem-solving. The remaining four studies utilized BrainHQ, developed by Posit Science, which progressively trains auditory and visual processing skills, verbal memory, and divided attention. One of these (Khan et al., 2023) further combined BrainHQ with a computerized emotion recognition training program (Golan & Baron-Cohen, 2006).

Three studies followed a manualized protocol. Of these studies, two (Marcer et al., 2016; Rocha et al., 2014) utilized a protocol involving pen-and-paper exercises training cognitive shift, memory, and planning through a combination of education on cognitive strategies and repeated practice of specific tasks (Delahunty et al., 2002). The third study (Wilson, 2015) utilized the protocol described in (Medalia et al., 2017). Participants received education about cognitive skills and completed problem-solving and memory exercises using real-life scenarios (e.g., practicing compensatory memory strategies by categorizing items in a grocery shopping list).

Six studies developed custom protocols. In Elbogen et al. (2019), participants completed a working memory task (the n-back; Kirchner, 1958), and behavioral goal-setting exercises (e.g., reviewing their

Table 1
Demographic characteristics.

Study	Country	*N*		Age *M* (*SD*) in years		Sex/gender (% female)		Education *M* (*SD*) in years		Race/ethnicity (%)	
		TG	CG	TG	CG	TG	CG	TG	CG	TG	CG
Controlled trials											
Ahmed et al., 2015	USA	42	36	40.38 (11.0)	40.64 (10.4)	10.0	15.80	10.11 (2.49)	9.53 (2.04)	African American (47.6), White (38.1), Latino/Hispanic (9.52), Other (4.76)	African American (52.78), White (38.89), Latino/ Hispanic (2.78), Other (5.56)
Elbogen et al., 2019	USA	57	55	36.77 (8.6)	36.25 (8.3)	7.00	9.10	N/R	N/R	N/R	N/R
O'Reilly et al., 2019	Ireland	32	33	42.68 (9.7)	39.3 (9.5)	12.50	18.20	N/R	N/R	N/R	N/R
Romero-Martínez et al., 2022	Spain	14	14	46.57 (5.92)	42.29 (7.24)	0	0	36 % Primary Level, 64 % Secondary Level	36 % Primary Level, 64 % Secondary Level	White (86), Other (14)	White (71), Other (29)
Trujillo et al., 2017	Columbia	14	13	39.5 (8.2)	35.2 (7.9)	12.50	0	10.4 (2.91)	10.1 (3.25)	N/R	N/R
Wilson, 2015	USA	17	16	39.5 (13.3)	39.2 (13.9)	0	0	11.6 (2.2)	11.6 (2.2)	White (12.5), Black (87.5)	White (29.4), Black (70.6)
Pre-post studies											
Baskin-Sommers et al., 2015	USA	103		30.64 (6.65)		0		10.55 (1.57)		White (68.9), Black (31.1)	
Dodds, 2009	UK	19		41.50 (N/R)		5.2		N/R		N/R	
Gunnarsson, 2021	USA	3		50 (7.55)		66.66		15.33 (3.06)		White (100)	
Hodel & West, 2003	USA	13		40.50 (10.50)		0		10 (N/R)		N/R	
Khan et al., 2023 [1]	USA	34		34.21 (10.48)		14.7		11.32 (2.40)		African American (44.1), Hispanic (29.4), White (17.6), Asian (8.8)	
Khan et al., 2023 [2]	USA	45		35.49 (9.5)		15.6		11.69 (1.70)		African American (51.1), Hispanic (24.4), White (20), Asian (4.4)	
Marcer et al., 2016	UK	13		33.9 (9.34)		23.08		N/R		N/R	
Rocha et al., 2014	Portugal	28		35.82 (8.86)		100		8.21 (2.81)		N/R	

Note: TG = Treatment group; CG = Control group; N/R = Not reported; Khan et al., 2023 [1] = Cognitive remediation plus control; Khan et al., 2023 [2] = Cognitive remediation plus social cognitive training.

actions and concentration). In Romero-Martínez et al. (2022), participants completed custom pen-and-paper exercises training attention, memory, language and executive functioning and emotion decoding skills. In O'Reilly et al. (2019), the content and sequence of the training sessions were developed based on collaborative goal setting and considering participants' goals, strengths, and areas of improvement. Patients were taught meta-cognitive strategies (e.g., goal setting, reflecting on their performance) and encouraged to utilize the cognitive skills trained in day-to-day life. In Trujillo et al. (2017), participants completed emotion recognition tasks (Peyroux & Franck, 2014) and role-playing exercises training social skills. In Hodel and West (2003), participants completed a cognitive flexibility and problem-solving task comparable to the Wisconsin Card Sorting Test (WCST), alongside thought organization and planning exercises (Brenner et al., 1992; Heaton, 1981). Baskin-Sommers et al. (2015) delivered two types of training: One encompassed the Reversal Learning Task (Budhani et al., 2006), the Divided Visual Field Paradigm (Llanes & Kosson, 2006), and the Affective Gaze Task (Baskin-Sommers & Newman, 2014); the second one encompassed a breath holding task, the Stop Signal Task (Logan & Cowan, 1984), and the Simon Task (Simon & Rudell, 1967).

None of the studies conducted an initial participant screening to identify specific cognitive deficits and subsequently tailor training and assessment procedures to their respective deficits. One pre-post study (Baskin-Sommers et al., 2015) took a step in addressing this shortcoming by using antisocial subtypes (psychopathic vs. externalizing traits) as a proxy for the cognitive deficits typically associated with these subtypes (attention to context vs. affective cognitive control deficits) and allocating participants to interventions that either matched or did not match their proposed deficits. This approach revealed cognitive improvements exclusively in participants receiving deficit-matched training.

Five studies were conducted in forensic mental health hospitals (Ahmed et al., 2015; Dodds, 2009; Marcer et al., 2016; O'Reilly et al., 2019; Wilson, 2015), three in prisons (Baskin-Sommers et al., 2015; Hodel & West, 2003; Rocha et al., 2014), three in university laboratories (Elbogen et al., 2019; Trujillo et al., 2017; Romero-Martínez et al., 2022), one in an inpatient psychiatric facility (Khan et al., 2023), and one remotely in participants' homes (Gunnarsson, 2021).

3.1.3. *Outcome measures (Table 5)*

All fourteen studies assessed cognitive functioning, eight also assessed ASB. Of these eight, four measured aggression (2/4 utilized 2 measures of aggression each), one measured anger, two measured both, and one measured risk of violent recidivism. Since no two studies used the same measures, a total of nine distinct measures of ASB were used across studies, all demonstrating good psychometric properties in previous studies: the Brief Aggression Questionnaire (Webster et al., 2015),

Table 2
History of antisocial behavior.

Study	Criminal offense history (Y/N)	ASB indicator
Controlled trials		
Ahmed et al., 2015	Y	Violent offense (unspecified)
Elbogen et al., 2019	N	Anger regulation problems
O'Reilly et al., 2019	Y	Violent offense (e.g., homicide)
Romero-Martínez et al., 2022	Y	Violent offense (intimate partner violence)
Trujillo et al., 2017	Y	Violent offense (illegal armed conflict/ terrorism)
Wilson, 2015	Y	Violent offense (e.g., murder/ manslaughter)
Pre-post studies		
Baskin-Sommers et al., 2015	Y	Criminal offense history (un specified)
Dodds, 2009	Y	Forensic history or violence history (minor to severe assault)
Gunnarsson, 2021	N	High levels of aggression
Hodel & West, 2003	Y	N/R
Khan et al., 2023 [1]	Y	Violent offense (unspecified)
Khan et al., 2023 [2]	Y	Violent offense (unspecified)
Marcer et al., 2016	Y	Forensic history (unspecified)
Rocha et al., 2014	Y	Violent (e.g., child sexual abuse, murder) and nonviolent offense history (e.g., swindling, drug trafficking)

Note. Khan et al., 2023 [1] = Cognitive remediation plus control; Khan et al., 2023 [2] = Cognitive remediation plus social cognition training.

the Overt Aggression Scale in its original and modified forms (Coccaro, 2020; Yudofsky et al., 1986), the Dimensions of Anger Reactions (Forbes et al., 2004), the Spousal Assault Risk Assessment (Kropp & Hart, 2000), the Situation and Aggressive Behavior Inventory and the Motives for Aggression Inventory (Juárez Aacosta & Montejo Hernández, 2008), the Prison Adjustment Questionnaire (Warren et al., 2004), and the Prison Behavior Rating Scale (Cooke, 1998).

The cognitive outcome most frequently assessed was executive functioning (12/14 studies), followed by working memory (8), attention and processing speed (7), and social cognition (5). A variety of measures were utilized across studies to assess cognition. Several studies utilized cognitive assessment batteries, including the MATRICS Consensus Cognitive battery (MCCB, 4 studies), which includes ten tests (Nuechterlein et al., 2008), and the Delis-Kaplan Executive Function System (DKEFS, 2 studies), including nine tests (Delis et al., 2004). Both assessment batteries have demonstrated good validity, reliability, and sensitivity to changes in cognitive function over time (Delis et al., 2004; Nuechterlein et al., 2008). Other studies utilized individual subscales of cognitive assessment batteries, such as the Digit Span subtest of the Wechsler Adult Intelligence Scale (WAIS, 4 studies) (Wechsler, 1997) or standalone tests/tasks, such as the WCST (two studies), also showing acceptable psychometric properties (Bowden et al., 1998; Kopp et al., 2019).

Across studies, outcome measures were collected at minimum one week pre- and post-intervention. Only one controlled trial (O'Reilly et al., 2019) and one pre-post study (Dodds, 2009) also included follow-up assessments, in both cases focusing on cognitive functioning only.

3.2. Meta-analysis results

Data, code, and output of the meta-analysis are publicly available on Open Science Framework (https://osf.io/eqp7r/).

3.2.1. Cognitive training effects on antisocial behavior

3.2.1.1. Controlled trials. We first analyzed data from the four controlled trials that assessed ASB. This meta-analysis included eight measures from five tests (one of which included four subtests; see Table 5) and involved 245 participants (127 in treatment groups, 118 in control groups). Results of the random-effects meta-analysis indicated a moderate statistically significant positive effect of cognitive training on ASB ($g = 0.36$, $p = .003$; Fig. 2A). The statistical significance of the results persisted after applying the trim-and-fill method to account for potential publication bias ($g = 0.27$, $p = .01$). Results were equivalent under the fixed-effects model ($g = 0.36$, $p = .003$). The 95 % confidence intervals of the estimates for most studies included zero. The one exception was the non-randomized controlled trial targeting social cognition in participants with a violent offense history and no psychiatric or neurological conditions (Trujillo et al., 2017).

3.2.1.2. Pre-post studies. Second, we analyzed data from the four pre-post studies that assessed ASB. This meta-analysis included nineteen measures from five tests (of which, one included five subtests, and one included three subtests) and involved 110 participants. Results of the random-effects meta-analysis indicated a moderate statistically significant positive effect of cognitive training on ASB ($g = 0.59$, $p < .001$; Fig. 2B); findings were consistent after applying the trim-and-fill method. Results were comparable under the fixed-effects model ($g = 0.62$, $p < .001$). Two of the studies, both training and assessing multiple cognitive domains among participants with a violent offense history and diagnosis of schizophrenia, showed large effect sizes and 95 % confidence intervals of the estimates not including zero, suggesting their strong contribution to the significant effect (Khan et al., 2023).

3.2.2. Cognitive training effects on cognitive functioning

3.2.2.1. Controlled trials. Next, we analyzed data from the six controlled trials assessing cognitive functioning. This analysis included fifty-seven measures from cognitive batteries and standalone tests or tasks (see Table 5) and involved 343 participants (175 in treatment groups, 168 in control groups). Results of the random-effects meta-analysis indicated a small, not statistically significant, positive effect on cognitive functioning ($g = 0.11$, $p = .27$; Fig. 3A), with the same results after applying the trim-and-fill method. Comparable results were obtained comparable results under the fixed-effects model ($g = 0.10$, $p = .24$). Studies that trained and assessed multiple cognitive domains among individuals with a history of violent offending and schizophrenia or without a diagnosis showed the largest effect sizes (Ahmed et al., 2015; O'Reilly et al., 2019; Romero-Martínez et al., 2022).

3.2.2.2. Pre-post studies. Lastly, we analyzed data from the seven pre-post studies that assessed cognitive functioning. This analysis included fifty-eight measures from cognitive batteries and standalone tests/tasks (see Table 5) and involved 201 participants. Results of the random-effects meta-analysis indicated a moderate statistically significant positive effect on cognitive functioning ($g = 0.51$, $p < .001$; Fig. 3B). Statistical significance persisted after applying the trim-and-fill method ($g = 0.38$, $p = .002$). Results were comparable under the fixed-effects model ($g = 0.47$, $p < .001$). Effect sizes were large and with positive 95 % confidence intervals for most (5/7) studies (Hodel & West, 2003; Khan et al., 2023; Marcer et al., 2016; Rocha et al., 2014).

3.2.3. Study heterogeneity

Heterogeneity was not statistically significant for the studies examining the effects of cognitive training on ASB (low for controlled trials, ($Q(3) = 2.62$, $p = .45$; I^2 0 %, high for pre-post studies: $Q(3) = 6.66$, $p = .084$, $I^2 = 59.71$ %). Regarding the studies examining the effects on cognitive functioning, heterogeneity was low and not statistically

Table 3
Psychiatric or neurological diagnosis.

Study	Psychiatric or neurological diagnosis (Y/N)	Diagnosis	Diagnostic assessment	Medication	Other treatment
Controlled trials					
Ahmed et al., 2015	Y	SCZ, AUD, CUD, other SUD, polysubstance dependence, lifetime nicotine use, PTSD, OCD, PD	DSM IV	Antipsychotics, benzodiazepine, antidepressants, mood stabilizers	Individual psychotherapy, psychosocial interventions, psychoeducation
Elbogen et al., 2019	Y	TBI and PTSD	DSM IV	N/R	N/R
O'Reilly et al., 2019	Y	SCZ	DSM IV	Antipsychotics	Psychotherapy and psychosocial interventions
Romero-Martínez et al., 2022	N	N/A	N/A	N/A	N/A
Trujillo et al., 2017	N	N/A	N/A	N/A	N/A
Wilson, 2015	Y	SCZ, psychosis NOS, delusional disorder, bipolar, depression, PD	N/A	Psychotropic (unspecified)	Recreational and group therapy
Pre-post studies					
Baskin-Sommers et al., 2015	Y	Psychopathy or externalizing traits	Semi-structured interview and Psychopathy Checklist-Revised (PCL-R)	N/R	N/R
Dodds, 2009	Y	SCZ	N/R	Antipsychotic (100 %), antidepressants, anti-anxiolytics, stable for ≧3 months	N/R
Gunnarsson, 2021	Y	TBI	N/A	Antidepressants (33.33 %)	N/A
Hodel & West, 2003	Y	SCZ	DSM-IV	Antipsychotic (100 %), stable for ≧2 months	Symptom management, anger management
Khan et al., 2023 [1]	Y	SCZ	DSM-IV	Antipsychotics, stable	N/R
Khan et al., 2023 [2]	Y	SCZ	DSM-IV	Antipsychotics, stable	N/R
Marcer et al., 2016	Y	SCZ, bipolar affective disorder, borderline personality disorder	ICD-10	Typical (15 %) and atypical (85 %) antipsychotic, mood stabilizers, antidepressants, anti-anxiolytics	N/R
Rocha et al., 2014	N	N/A	N/A	N/A	N/R

Note. SCZ = Schizophrenia or schizoaffective disorder; PTSD = Post-traumatic stress disorder; PD = Personality disorder (not specified); AUD = Alcohol use disorder; CUD = Cocaine use disorder; SUD = Substance use disorder; OCD = Obsessive compulsive disorder; TBI = Traumatic brain injury. DSM IV = Diagnostic and Statistical Manual of Mental Disorders, IV edition. ICD-10 = International Classification of Diseases, 10th edition. Khan et al., 2023 [1] = Cognitive remediation plus control; Khan et al., 2023 [2] = Cognitive remediation plus social cognition training.

significant for controlled trials ($Q(5) = 5.99$, $p = .31$, $I^2 = 15.37$ %), but high and statistically significant for the pre-post studies ($Q(6) = 28.67$, $p < .001$, $I^2 = 79.08$ %).

3.3. Risk of bias

Most randomized controlled studies demonstrated appropriate methods for randomization and allocation concealment. Blinding of participants and/or personnel was generally well-implemented across controlled studies, with two studies employing double-blind designs (Ahmed et al., 2015; Romero-Martínez et al., 2022). Pre-post studies often had no or unclear blinding procedures. Most controlled trials handled attrition by employing an intention-to-treat approach or comparing completers and non-completers, whereas most pre-post studies showed lack of systematic handling of incomplete outcome data. Most studies had clear pre-specified eligibility criteria and enrolled all participants deemed eligible from the clinical populations of interest. Pre-post studies generally had small deviations from intended interventions, such as technical issues or lack of systematic feedback provision. No studies showed evidence of selective reporting of the results. Quality of evidence was particularly robust in two studies, which demonstrated low risk of bias across most domains (Ahmed et al., 2015; Khan et al., 2023). Two controlled trials (Elbogen et al., 2019; Wilson, 2015) and no pre-post studies reported a priori power analyses estimating the sample size required to detect statistically significant treatment effects. The risk of bias assessment for each study is reported in Supplementary Materials SM2.

4. Discussion

Individuals with ASB often exhibit cognitive difficulties, which contribute to more severe and persistent ASB trajectories (Brugman et al., 2018; Carlisi et al., 2020; Meijers et al., 2017). Here, we conducted the first systematic review and meta-analysis of cognitive training interventions in individuals with ASB, to ascertain their potential efficacy in reducing ASB. In line with our first prediction, the meta-analysis indicated moderate reductions in ASB post-intervention, evidenced by both controlled trials ($g = 0.36$) and pre-post studies ($g = 0.59$). This result was largely driven by interventions targeting social cognition (Khan et al., 2023; Trujillo et al., 2017). Our second prediction was that cognitive training would be associated with moderate improvements in cognitive functioning. While the meta-analysis of pre-post studies supported this prediction ($g = 0.51$, $p < .001$), the meta-analysis of controlled trials did not ($g = 0.11$, $p = .27$). Therefore, since controlled trials offer more robust evidence, our findings do not supply conclusive evidence that the reductions in ASB associated with cognitive training were driven by cognitive improvements. The main implications of our findings, and corresponding recommendations for future research, are

Table 4
Cognitive training protocols.

Study	Conditions		Program		Modality	Cognitive function targeted	Duration	
	TG	CG	TG	CG	TG	TG	TG	CG
Controlled trials								
Ahmed et al., 2015	Cognitive remediation	Active control	BrainHQ + coaching (bridging group discussion influenced by the Neuropsychological Educational Approach to Remediation NEAR; Medalia & Freilich, 2008)	Computer games and discussion about healthy behaviors	Group, computerized	Attention and processing speed, memory encoding and retrieval	50 h (2.5 h*20 weeks)	50 h (2.5 h*20 weeks)
Elbogen et al., 2019	Cognitive Applications for Life Management (CALM)	Active control	Goal management training with content-free cueing + n-back task + coaching (social support by family/friend)	Psychoeducation on TBI and visual memory training	Individual, pen-and-paper and mobile application	Executive functioning	3–4.5 h (60–90 min * 3 sessions, once every two months)	3–4.5 h (60–90 min * 3 sessions, once every two months)
O'Reilly et al., 2019	Cognitive remediation	Treatment as usual	Cognitive exercises (unspecified) + coaching (meta-cognitive strategies and generalization)	Antipsychotic medication, psychosocial treatment	Group, computerized and pen-and-paper	Speed of processing, executive functioning, visual learning, social cognition	N/R	N/R
Romero-Martínez et al., 2022	Standard batterer intervention program (SBIP) + cognitive training	Standard batterer intervention program (SBIP) + placebo training	Cognitive exercises (unspecified) + coaching	Debates on topics unrelated to intimate partner violence, training in relaxing exercises, listening to music	Group, pen-and-paper, and videos.	Verbal and non-verbal abilities, working memory, speed of processing, attention, executive functioning, emotion decoding	7.75 h (31 sessions, 15 min/ session, 2/ week)	7.75 h (31 sessions, 15 min/ session, 2/ week)
Trujillo et al., 2017	Social cognition training	Active control	Cognitive exercises (unspecified) + discussion + role playing	Psychosocial education	Individual, pen-and-paper	Social cognition	9 h (45 min * 12 sessions, 1/week)	9 h (45 min * 12 sessions, 1/week)
Wilson, 2015	Cognitive remediation	Treatment as usual	Cognitive exercises focused on memory and problem-solving (unspecified) + coaching (Medalia's NEAR model)	Treatment as usual	Group, computerized and pen-and-paper	Verbal memory, executive functioning	10 h	N/R
Pre-post studies								
Baskin-Sommers et al., 2015	Cognitive training		Attention to context (ATC) training or Affective cognitive control (ACC) training		Individual, computerized	ATC: Reversal learning, visual attention, distress tolerance; ACC: Motor response inhibition, interference/ conflict resolution	6 h (1/ week *6 weeks)	N/A
Dodds, 2009	Cognitive training		COGPACK		Individual, computerized	Visuomotor skills, comprehension, attention, memory, problem-solving	5.25 h (75 min *1/ week *7 weeks)	N/A
Gunnarsson, 2021	Cognitive remediation		BrainHQ		Individual, computerized	Attention and processing speed, memory encoding and retrieval	20 h (5/ week * 4 weeks)	N/A
Hodel & West, 2003	In vivo Training of goal-directed Actions (IVTA)		Therapist-led cognitive exercises (card sorting task, thought organizer, planning a multiple-step task)		Group, pen-and-paper	Attention; Reasoning; Planning	15 h (75 min *2 times/ week *10 weeks)	N/A
Khan et al., 2023 [1]	Cognitive remediation		BrainHQ + computer games		Computerized	Cognitive domains assessed by MCCB-MATRICS	36 h (1 h *3 times/ week *12 weeks)	N/A
Khan et al., 2023 [2]	Cognitive remediation and social cognition training		BrainHQ + social cognition training		Computerized	Cognitive domains assessed by MCCB-MATRICS + Social cognition	36 h (1 h *3 times/ week *12 weeks)	N/A
Marcer et al., 2016	Cognitive remediation		Cognitive Remediation Therapy manual (Delahunty et al., 2002)		Individual, pen-and-paper	Cognitive flexibility, memory, planning	39 h (1 h *3 times/	N/A

(continued on next page)

Table 4 (*continued*)

Study	Conditions		Program		Modality	Cognitive function targeted	Duration	
	TG	CG	TG	CG	TG	TG	TG	CG
Rocha et al., 2014	Cognitive remediation		Cognitive Remediation Therapy manual (Delahunty et al., 2002)		Individual, pen-and-paper	Cognitive flexibility, memory, planning	week * 13 weeks 28.32 h (1 h, 2/3 times/ week)	N/A

Note. TG = Treatment group; CG = Control group; Khan et al., 2023 [1] = Cognitive remediation plus control; Khan et al., 2023 [2] = Cognitive remediation plus social cognition training; in both studies, participants completed three one-hour sessions per week for twelve weeks, plus two backup weeks for participants who had not completed all the sessions within the twelve weeks.

synthesized in Table 6.

4.1. Possible mechanisms driving change in antisocial behavior after cognitive training

The finding that cognitive training was associated with reductions in ASB across study designs, even in the absence of statistically significant cognitive improvements in controlled trials, warrants further inquiry. Alongside methodological concerns, the observed reductions in ASB in the absence of cognitive improvements could be attributed to alternative treatment components driving behavioral change. For instance, all controlled trials involved a coaching component aimed to support the transfer of treatment effects to real-life situations. Coaching can be personalized to encompass bridging discussions on how to effectively leverage the skills trained in the intervention setting in daily situations (Kambeitz-Ilankovic et al., 2019), including the ability to inhibit impulsive responses during interpersonal conflict. Coaching may be particularly important to support individuals with ASB. Indeed, this treatment component resembles elements of other psychotherapeutic interventions associated with reductions in externalizing behavior and violent recidivism (Baskin-Sommers et al., 2022; Papalia et al., 2019). Future studies could manipulate specific protocol characteristics to isolate active ingredients underlying the effects of cognitive training on ASB.

A related possibility is that the positive effects of cognitive training on ASB might be partly driven by treatment effects on other important domains, such as mental health (Cella et al., 2017; Trapp et al., 2022) and functional capacity (Bowie et al., 2012; Garrido et al., 2013). Here, only three controlled trials (Ahmed et al., 2015; Elbogen et al., 2019; O'Reilly et al., 2019) and four pre-post studies (Dodds, 2009; Khan et al., 2023; Rocha et al., 2014) included assessments of mental health, and only one controlled trial (Ahmed et al., 2015) and one pre-post study (Hodel & West, 2003) assessed functional capacity. Hence, we lacked sufficient power to analyze treatment effects on these outcomes. Nonetheless, all controlled trials and most pre-post studies assessing these outcomes reported improvements, prompting investigations on the association between changes in these outcomes and changes in ASB. Furthermore, the non-significant effects on cognitive functioning observed in our meta-analysis of controlled trials could be attributed to control conditions also enhancing cognitive functioning. While withholding treatment from control groups with ASB poses ethical challenges, future intervention studies could explore manipulating the components of control conditions to minimize their impact on cognitive functioning.

4.2. The challenge of linking specific cognitive functions with diverse antisocial manifestations

An important area of concern in the current literature is the limited available information on the rationale for targeting specific cognitive domains. This lack of specificity may stem from the mixed results observed in previous attempts to relate differences in cognitive performance with differences in ASB manifestation (Janes et al., 2023; Meijers et al., 2015). For example, previous meta-analyses have indicated that executive functioning deficits may be particularly pronounced in non-aggressive forms of ASB (Ogilvie et al., 2011; Türel et al., 2024). However, a recent meta-analysis comparing violent and non-violent offenders found poorer performances on measures of reasoning, impulsivity, and expressive speech in violent offenders, although the variability in effect sizes and overall quality of the evidence warranted caution (Janes et al., 2023). Considering the heterogeneity of ASB, as well as the current results, transdiagnostic interventions such as cognitive training hold promise. However, to advance the field and provide better guidance for intervention development, more "mechanistic" investigations are needed. Future studies could examine how specific cognitive parameters relate to individual differences, particularly across development, as well as to differences between ASB groups (Pezzoli et al., 2022; Viding & McCrory, 2020). For instance, investigating differences in cognitive profiles among developmental trajectories of ASB varying in other etiological factors (e.g., age of onset, exposure to environmental adversity) may illuminate targets for developmentally sensitive cognitive training interventions (Moffitt, 2017). Despite our aim to evaluate the effects of cognitive training on different manifestations of ASB, our findings highlight the prevailing focus on aggressive ASB within the current cognitive training literature, evidenced by the predominance of participants with a history of violent offending. The focus on this form of ASB may stem from several factors, including its perceived severity and apparent connection with cognitive functioning, alongside the empirical evidence linking brain areas responsible for higher-order cognition to aggression (Nikolic et al., 2022; Wallinius et al., 2019). Further research is needed to develop cognitive training interventions tailored to individuals displaying different manifestations of ASB. While interventions focusing on social cognition show promise for aggressive ASB, reducing non-aggressive ASB may require different cognitive training targets (Moffitt, 2017; Raine et al., 2005).

4.3. Implications for clinical research with individuals displaying antisocial behavior

Cognitive training interventions have been shown to be a cost-effective method to improve patient outcomes within psychiatric rehabilitation settings (Garrido et al., 2017). For example, computerized cognitive training can be delivered through commercially available, user-friendly software, comprising batteries of standardized cognitive exercises, usually inspired by traditional neuropsychological tests. Treatment plans can be tailored to individual needs, such as by selecting sets of exercises targeting the specific cognitive deficits of interest (Larøi & Van der Linden, 2013). Once an individualized treatment plan has been developed, cognitive exercises can be often self-administered. Training resources, including intervention and coaching manuals, have been sometimes published alongside intervention studies (Delahunty et al., 2002). No specific qualifications are required, at present, to deliver cognitive training, although personnel training

Table 5
Outcome measures.

	ASB		Cognitive functioning	
Study	Outcome	Measure	Outcome	Measure
Controlled trials				
Ahmed et al., 2015	Aggression	Overt Aggression Scale (OAS)	1) Attention and processing speed, working memory, verbal learning, social cognition, executive functioning	1) MATRICS Consensus Cognitive battery (MCCB)
Elbogen et al., 2019	Anger	Dimensions of Anger Reactions (DAR)	1) Executive functioning; 2) Impulsivity	1) Delis-Kaplan Executive Function System (DKEFS); 2) Barratt Impulsiveness Scale (BIS)
O'Reilly et al., 2019	None	N/A	1) Attention and processing speed, working memory, verbal learning, visual learning, social cognition, executive functioning	1) MCCB
Romero-Martínez et al., 2022	Risk of violent recidivism	Spousal Assault Risk Assessment (SARA)	1) Working memory; 2) Sustained visual and auditory attention, sequencing, and processing speed; 3) Executive functioning (verbal phonemic and semantic fluency); 4) Executive functioning (cognitive flexibility); 5) Theory of mind	1) Wechsler Adult Intelligence Scale-III (WAIS-III), Digit Span subtests (direct and inverse); 2) Conners' Continuous Performance Test (CPT-II); 3) F-A-S test; 4) Winconsin Card Sorting Test (WCST); 5) Reading the Mind in the Eyes test
Trujillo et al., 2017	1) Aggression; 2) Intensity of motives for aggression	1) Situation and Aggressive Behavior Inventory (ISCA); 2) Motives for Aggression Inventory	1) Emotion recognition based on faces and words	1) Emotion Recognition Task (ERT)
Wilson, 2015	None	N/A	1) Verbal learning; 2) Executive functioning	1) California Verbal Learning Test-II (CVLT-II); 2) DKEFS
Pre-post studies				
Baskin-Sommers et al., 2015	None	N/A	1) Working memory; 2) Response inhibition and conflict resolution; 3) Distress tolerance; 4) Lexical processing and word recognition	1) n-back task; 2) Modified Stroop task; 3) Paced Auditory Serial Addition Task-Computerized (PASAT-C); 4) Lexical Decision task
Dodds, 2009	None	N/A	1) Verbal memory; 2) Visuospatial memory; 3) Working memory; 4) Visual memory and perceptual organization; 5) Attention and processing speed; 6) Executive functioning	1) Rey Auditory Verbal Learning Test (AVLT); 2) Wechsler Abbreviated Intelligence Scale (WASI/WAIS-III), Block Design subtest; 3) Wechsler Adult Intelligence Scale (WAIS-IV), Digit Span Forward and Backward subtests; 4) Rey Complex Figure Test (CFT); 5) Trail Making Test (A and B); 6) Modified Wisconsin Card Sorting Test (mWCST)
Gunnarsson, 2021	Aggression and anger	Brief Aggression Questionnaire (BAQ)	1) Planning; 2) Working memory; 3) Response inhibition	1) Tower of London (TOL); 2) WAIS-IV, Digit Span Forward and Backward subtests; 3) Go/no-go
Hodel & West, 2003	None	N/A	1) Attention and short-term verbal memory	1) Syllable-memorizing test
Khan et al., 2023 [1,2]	1) Aggression, self-reported, 2) Aggression, performance-based	Modified Overt Aggression Scale (OAS-M); Taylor Aggression Paradigm (TAP)	1) Attention and processing speed, working memory, verbal learning, social cognition, executive functioning; 2) Social cognition; 3) Theory of Mind	1) MCCB; 2) Penn Emotion Recognition Task (ER-40); 3) Reading the Mind in the Eyes Test
Marcer et al., 2016	None	N/A	1) Cognitive flexibility and response inhibition; 2) Response inhibition; 3) Working memory; 4) Planning and problem-solving	1) Brixton Anticipation Test; 2) Hayling Sentence Completion Test; 3) WAIS-IV, Digit Span Forward and Backward subtests; 4) Behavioral Assessment of the Dysexecutive Syndrome (BADS), Zoo map subtest
Rocha et al., 2014	Aggression and anger	Prison Adjustment Questionnaire (PAQ), Prison Behavior Rating Scale (PBRS)	1, 2) Attention and processing speed; 3) Verbal memory; 4) Planning and problem-solving; 5) Cognitive flexibility; 6) Spatial planning	1) d2 Cancelation Test; 2) Trail Making Test (A and B); 3) Hopkins Verbal Learning Test - Revised (HVLT-R); 4) BADS, Modified Six Elements subtest; 5) BADS, Rule Shift Cards subtest (RSC); 6) MCCB Neuropsychological Assessment Battery - Mazes Test (NASB - Mazes)

Note. N/A = Not applicable. For the OAS-M, the subscales "verbal", "objects", "physical", "subjective", and "overt" were included in the meta-analysis, as the remaining subscales ("self", "suicidal", and "total"). For the same reason, we included the "conflict" subscale of the PAQ (not the "anxious-depressed" and "dull-confused" subscales) and the "anti-authority" subscale of the PBRS (not the "distress" subscale). The conduct dimension scale of the ISCA (Trujillo et al., 2017) was included in the meta-analysis. The Lexical Decision task included in Baskin-Sommers et al. (2015) was not included in the meta-analysis as only standardized scores were available. Results for Khan et al., 2023 [1] and Khan et al., 2023 [2] are reported together as they measured the same outcomes.

predicts greater treatment outcomes (Medalia & Richardson, 2005). Moreover, progress tracking and feedback mechanisms are typically embedded in cognitive training software, although additional coaching or clinical support is preferable (Kim et al., 2018). Despite these advantages, which make cognitive training interventions particularly versatile, further rigorous randomized controlled trials are needed before clinical recommendations for individuals with ASB can be made. Studies should also assess the scalability of cognitive training interventions in this population, and examine whether behavioral improvements in ASB generalize to real-life situations. It would seem critical to examine whether cognitive training can help mitigate recidivism risk in those with an offense history, as shown in one of the included studies (Romero-Martínez et al., 2022).

The present study also highlights that, despite promising results, the body of research in this area is limited and varied in methodological quality. Risk of bias was higher in pre-post studies compared to controlled trials. For instance, while most controlled trials addressed attrition and exclusions statistically, many pre-post studies lacked systematic approaches to handle incomplete outcome data. Pre-post studies also generally lacked clear allocation and blinding procedures. However, although double-blind designs are recommended, performance improvements solely attributable to participant expectations are

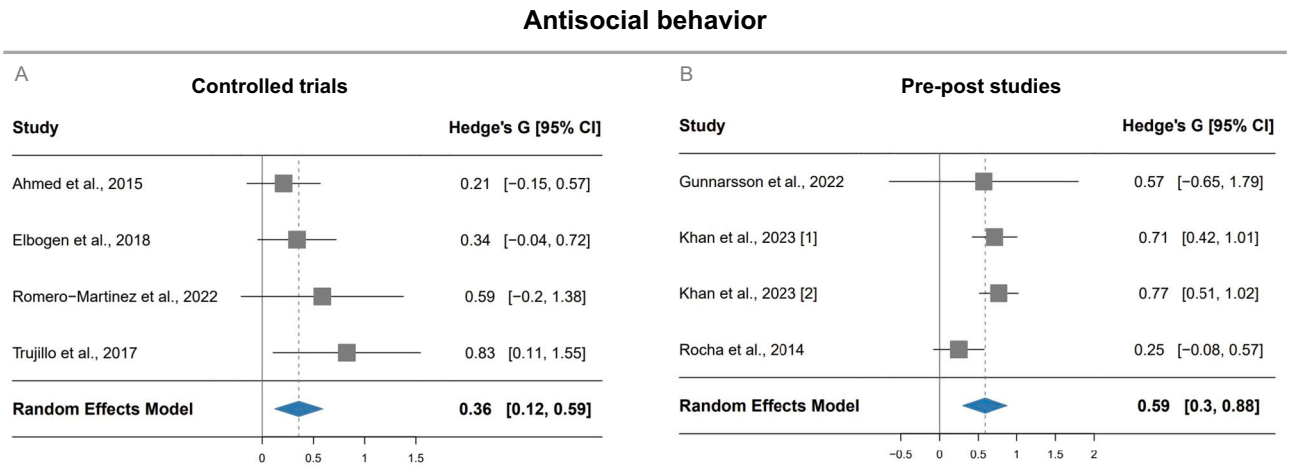

Fig. 2. Forest plots illustrating the estimated effect size of cognitive training on antisocial behavior in controlled trials (2A) and pre-post studies (2B).

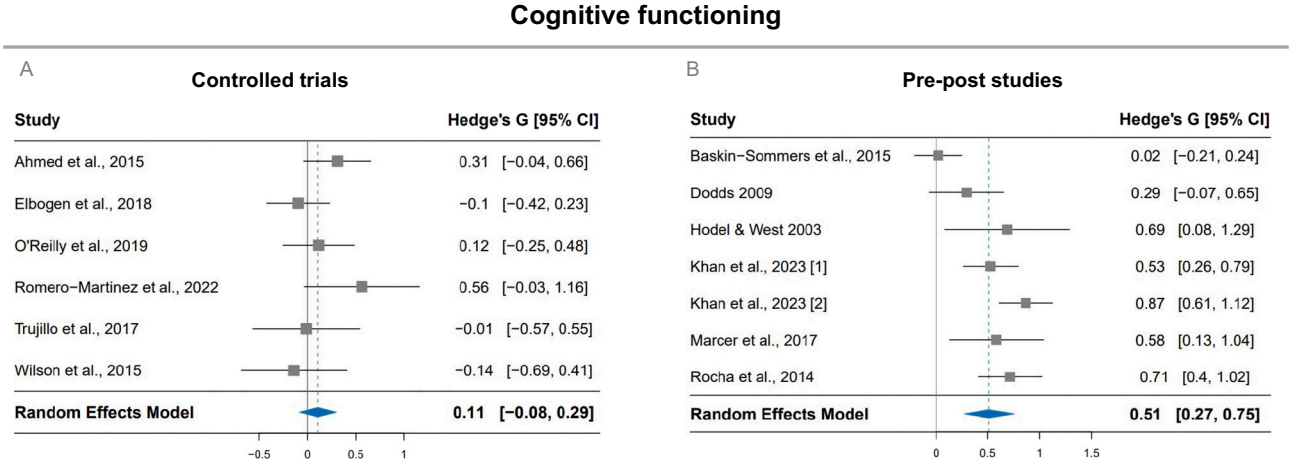

Fig. 3. Forest plots illustrating the estimated effect size of cognitive training on cognitive functioning in controlled trials (3A) and pre-post studies (3B).

improbable, and strategies to mitigate the influence of lack of blinding on the results were evident across most studies. Overall, the higher risk of bias in pre-post studies is likely attributable to their nature as small-scale feasibility studies with potentially constrained resources. We also did not observe an obvious correspondence between study quality and effect sizes (e.g., studies with higher risk of bias showing larger effect sizes or wider confidence intervals), potentially implying that study quality did not affect treatment outcomes systematically. The scarcity of randomized controlled trials could be due to several factors. For example, skepticism regarding the "treatability" of individuals with ASB compared to other clinical groups might deter research efforts in this area (Johnston & Burke, 2020; Wilson, 2014). Historically, ASB has been perceived as untreatable, partly due to features of this condition posing challenges to treatment compliance (Glenn et al., 2013; Wilson, 2014). Nevertheless, our findings align with a growing literature of interventions for ASB showing favourable outcomes (Papalia et al., 2019) and offer a compelling rationale for further clinical research with this population. Investigating barriers and facilitators to cognitive training interventions for ASB, also through qualitative and co-production methods, might help shed light on this research gap and indicate ways forward.

Lastly, while most statistical tests for heterogeneity did not reach significance, it is important to acknowledge the variability among the included studies. Variability was evident in the cognitive training protocols, spanning computerized and pen-and-paper interventions across individual and group settings. We also observed variability in the outcome measures; although most studies assessed the cognitive functions targeted by the interventions and measured ASB using self-reports. There was some variation in the clinical characteristics of participants, albeit with a predominance of schizophrenia diagnoses. Notably, one study involved military veterans with TBI and PTSD experiencing anger regulation problems, a group that would not typically be classified as "antisocial" and may differ from other participants on relevant characteristics (Elbogen et al., 2019). Most studies were conducted in the context of broader rehabilitative programs in forensic hospitals or prisons. Greater consistency, particularly in cognitive training protocols and outcome measures, is essential in future research to strengthen the reliability and generalizability of results.

4.4. Limitations

The present meta-analysis was subject to limitations, stemming from the current state of the field alongside inherent shortcomings. First, the pool of eligible studies was relatively modest, encompassing fourteen studies. Studies often involved small samples, justified by power analyses in only two instances. Undersized pilot and feasibility studies, while instrumental for cumulative knowledge, are subject to the risk of producing spurious results, potentially misleading research efforts and

Table 6
Implications and recommendations for future research.

Findings	Implications	Recommendations for future research
Participant characteristics: Mostly middle-aged men with offense histories and diverse psychiatric diagnoses.	Heterogeneity in participant characteristics could moderate treatment effects.	1) Involve homogeneous samples while recognizing the transdiagnostic nature of ASB, 2) Investigate demographic and clinical moderators of treatments effects.
Cognitive training protocols: Commercial and custom programs with different combinations of cognitive exercises and coaching.	Various protocols exist, also with the possibility of tailoring training to participant needs.	1)) Choose protocols based on theoretical models of cognitive functioning in ASB and participant deficits, 2) Develop standardized procedures across studies.
Outcome measures: Various measures of aggression and anger, cognitive batteries, and standalone cognitive tests. Attention, working memory, and executive functioning were commonly assessed.	Conclusions are limited by heterogeneity in the outcomes examined.	1) Achieve consensus on relevant outcomes, 2) Examine treatment effects on specific cognitive domains and other relevant domains (e.g., mental health and functional capacity) potentially driving behavioral change.
Cognitive training effects on ASB: Moderate significant reductions in aggression and anger regulation problems ($g = 0.36$ for controlled trials, $g = 0.59$ for pre-post studies), larger for social cognition training.	Cognitive training, especially targeting social cognition, represents a promising intervention to help mitigate ASB.	1) Investigate acceptability, scalability, generalization to real-life situations, and long-term impact on relevant outcomes (e.g., recidivism risk).
Cognitive training effects on cognitive functioning: Mixed results, including moderate significant post-intervention improvements in pre-post studies ($g = 0.51$), and no significant effects in controlled trials($g = 0.11$).	Limited cognitive improvements despite ASB reduction could be due to methodological limitations and unmeasured mechanisms.	1) Improve theoretical and methodological precision, 2) Explore potential alternative mechanisms underlying treatment effects on ASB.
Study heterogeneity: Low and non-significant for studies examining ASB and for controlled trials examining cognitive functioning. High and significant for pre-post studies examining cognitive functioning.	Heterogeneity might play a role in the mixed results concerning cognitive functioning.	1) Minimize heterogeneity in pre-post studies of cognitive functioning to enhance comparability.
Risk of bias: Sources of selection, attrition, and detection bias were identified, particularly in pre-post studies.	While overall methodologically rigorous, this literature largely comprises small-scale studies.	1) Conduct larger randomized controlled trials supported by power calculations to provide more robust evidence concerning treatment effects.
Lack of extensive follow-up assessments.	Long-term effects remain unclear, particularly in terms of real-world translation.	1) Examine long-term trajectories of treatment effects in daily life, 2) Explore possible "booster" treatments.

diverting resources from more promising avenues. Therefore, through its systematic and quantitative synthesis, our review was a necessary step to evaluate this evolving field. While somewhat constrained in its scope, our meta-analysis achieved acceptable power and produced substantial effect sizes. It can be deemed exploratory, paving the way for future investigations.

Second, this meta-analysis did not include a direct examination of the mechanisms underlying the observed effects of cognitive training on ASB. The included studies did not explicitly assess the strength of the association between changes in cognitive parameters and changes in ASB. Future intervention studies should include statistical analyses of this association to provide further insights into causal mechanisms. In addition, due to lack of statistical power to conduct moderator analyses, we could not examine whether treatment effects were moderated by participant characteristics, such as their specific cognitive deficits. For the same reason, we were unable to examine whether protocol characteristics moderated treatment effects. For example, it remains to be clarified whether, akin to what has been found in general psychiatric samples, tailored (vs. "one-size-fit-all") cognitive remediation approaches incorporating a coaching component are associated with enhanced treatment efficacy and generalization (Medalia & Richardson, 2005).

Moreover, our study focused exclusively on adults. Cognitive training in the context of early interventions for children with behavioral problems has been associated with cognitive and behavioral improvements (Oldrati et al., 2020; Wells et al., 2021). Its gamified nature makes it particularly acceptable for young populations (Vermeir et al., 2020). However, most of these early cognitive training interventions have been designed for attention deficit/hyperactivity disorder, whereas cognitive training interventions tailored for youth with ASB require further exploration (Van Goozen et al., 2022).

Lastly, this meta-analysis did not examine other pertinent domains, particularly mental health and functional capacity, and long-term outcomes. This precludes drawing conclusions about the translation of treatment effects into real-world functioning. It is possible that sustained treatment effects would require an initial intervention, to be discontinued once performance ceiling is achieved, followed by subsequent maintenance interventions.

4.5. Concluding remarks

This systematic review and meta-analysis provided evidence supporting the potential of cognitive training interventions to reduce ASB. Treatment effects on cognitive functioning were significant in pre-post studies but not in controlled trials. While revealing a promising avenue for rehabilitation in correctional, psychiatric, and forensic settings, our results underscored the complexity of elucidating the mechanisms underlying behavioral changes.

We provided several recommendations for future studies that may build upon our findings and help illuminate such mechanisms, optimize treatment delivery, and enhance effectiveness. Notable examples include grounding interventions on evidence-based theoretical models of cognitive functioning in ASB, examining the influence of participant and protocol characteristics on treatment effects, and exploring the role of mental health and functional capacity as potential mechanisms underlying behavioral change, as well as evaluating scalability, real-world applicability, and long-term effects of cognitive training in individuals displaying ASB.

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Patrizia Pezzoli: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing, Software. **Alexandra Therond:** Data curation, Formal analysis, Methodology, Visualization, Writing – review &

editing, Investigation. **Maja Nikolic:** Data curation, Formal analysis, Investigation, Writing – review & editing. **Sarah K. Watts:** Data curation, Investigation, Writing – review & editing. **Synthia Guimond:** Conceptualization, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Writing – review & editing. **Michael C. Seto:** Conceptualization, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Writing – review & editing.

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During the preparation of this work, the authors used ChatGPT to improve readability and language. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Declaration of competing interest

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Data availability

Links to pre-registration, data, code, and analysis output are in the manuscript

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Appendix A. Supplementary materials

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