Cureus
Part of SPRINGER NATURE

Open Access Review Article

Published via Krishna Vishwa Vidyapeeth (Deemed to be University), Karad.

Toxoplasma gondii, Executive Dysfunction, Impulsivity, and Suicidal Behavior: A Narrative Review

Received 10/17/2026
Review began 10/25/2026
Review ended 11/04/2026
Published 11/11/2026

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DOI: 10.7759/cureus.119460

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Abstract

Suicidal behavior is multifactorial, and its prediction remains challenging. *Toxoplasma gondii* (*T. gondii*), an intracellular parasite capable of persistent central nervous system (CNS) infection, has been investigated as a potential contributor to neuropsychiatric and behavioral alterations. Executive dysfunction and impulsivity are independently associated with suicidal behavior and may represent intermediate phenotypes through which biological vulnerabilities influence behavioral outcomes. This narrative review synthesizes relevant experimental investigations, observational studies, systematic reviews, and meta-analyses concerning *T. gondii* biology, neuroinflammatory and neurotransmitter mechanisms, cognitive and behavioral outcomes, psychiatric disorders, executive functioning, impulsivity, and suicidal behavior. The evidence was synthesized thematically, with attention to study design, heterogeneity, potential confounding, and the distinction between experimental findings and human observational evidence; Indian epidemiological and psychiatric research was also considered. Experimental studies suggest that persistent *T. gondii* infection may influence neuroinflammatory processes, neurotransmitter signaling, synaptic function, and neural circuits. Human studies have reported associations between seropositivity and selected cognitive and behavioral characteristics, although findings are heterogeneous and cognitive differences appear small. Observational studies and meta-analyses suggest a modest association between *T. gondii* seropositivity and suicide attempts, whereas evidence concerning suicidal ideation is less consistent. Executive dysfunction, including impairments in working memory, inhibitory control, cognitive flexibility, and decision-making, and impulsivity are both associated with suicidal behavior. However, evidence directly linking *T. gondii* seropositivity with these domains among individuals with suicidal behavior remains limited. Indian research has documented seroprevalence and investigated selected psychiatric populations, but the integrated relationship between *T. gondii*, executive functioning, impulsivity, and suicidal behavior remains insufficiently explored. It is biologically plausible that *T. gondii* is a candidate factor in neuropsychiatric research, but current evidence does not establish a causal role in suicidal behavior or support seropositivity as a clinical screening or risk-stratification biomarker. Integrated, prospective studies using standardized serological, neurocognitive, behavioral, and clinical assessments are needed to investigate whether executive dysfunction and impulsivity contribute to the proposed association, particularly in Indian populations.

Categories: Psychiatry, Infectious Disease
Keywords: executive function, impulsivity, patho-physiology, suicidality, toxoplasma gondii infection

Introduction And Background

Introduction

Suicide remains a major preventable public health problem. Global Burden of Disease estimates indicate approximately 746,000 suicide deaths in 2021, with substantial variation by age, sex, and region [1]. India contributes substantially to this burden, with a disproportionate impact on younger populations. An analysis of National Crime Records Bureau data covering 2012-2021 reported an increase in recorded suicide deaths in India from 135,445 in 2012 to 164,033 in 2021. Maharashtra recorded 22,207 suicide deaths in 2021, placing it among the states with the highest reported numbers [2]. Despite advances in prevention, prediction of suicidal behavior remains difficult, and no single biological marker currently has sufficient predictive accuracy or clinical utility.

This has increased interest in biological mechanisms within a biopsychosocial framework, with infectious and immune-mediated mechanisms receiving increasing attention. Among infectious agents investigated in relation to psychiatric disorders, *Toxoplasma gondii* (*T. gondii*) is of particular interest because of its ability to persist within neural tissue and its potential effects on neuroinflammatory, neurotransmitter, and synaptic processes [3]. *T. gondii*, an intracellular protozoan capable of persistent central nervous system (CNS) infection, has been investigated in relation to psychiatric disorders, behavior, cognition, and suicidal behavior [4]. Associations vary across populations and outcomes, and most evidence is observational.

The relevance of *T. gondii* to suicidal behavior may extend beyond psychiatric diagnosis. Executive functioning, decision-making, inhibitory control, and impulsivity are independently associated with suicidal behavior and may represent intermediate phenotypes linking biological vulnerability to suicidal acts [5]. Executive functioning encompasses higher-order cognitive processes involved in goal-directed behavior, including working memory, cognitive flexibility, and decision-making; inhibitory control refers to the ability to suppress inappropriate or prepotent responses, while impulsivity involves a tendency to act rapidly with limited consideration of consequences. This review therefore examines evidence linking *T. gondii* with neurobiology, behavioral and cognitive changes, psychiatric disorders, executive dysfunction, impulsivity, and suicidal behavior, with particular emphasis on their potential interrelationships.

Methodology

This article was developed as a narrative review to synthesize current evidence concerning the potential relationships between *T. gondii* infection, neurobiological alterations, executive dysfunction, impulsivity, and suicidal behavior. Particular attention was given to the possible interrelationships among these domains and to the contribution of Indian epidemiological and psychiatric research. The objective was to critically examine the available evidence, identify areas of convergence and inconsistency, and develop a conceptual framework to guide future research.

Literature Search Strategy

A focused English-language literature search was conducted using PubMed/MEDLINE and Google Scholar. The search covered the period from database inception to September 2026. Search terms were selected to represent the major concepts addressed in the review and included combinations of the following: “Toxoplasma gondii,” “toxoplasmosis,” “seropositivity,” “neuroinflammation,” “neurotransmission,” “cognition,” “cognitive impairment,” “executive function,” “working memory,” “cognitive flexibility,” “inhibitory control,” “decision-making,” “impulsivity,” “suicidal ideation,” “suicide attempt,” “suicidal behavior,” “psychiatric disorders,” and “India.” Boolean operators, truncation, and alternative search terms were used as appropriate to the search platform. The search strategy was adapted to the requirements of individual databases, and reference lists of relevant articles and reviews were examined to identify additional potentially relevant publications. The final literature searches were completed in September 2026. Although the principal search concepts and overall search period were documented, the exact calendar dates of individual database searches and the verbatim database-specific search strings were not prospectively retained. The search terms reported above therefore represent the principal concepts used to identify relevant literature.

Eligibility and Selection of Literature

Literature was selected for its relevance to one or more of the principal themes of the review: (i) the epidemiology, transmission, life cycle, and persistence of *T. gondii*; (ii) mechanisms of CNS invasion, neuroinflammation, neurotransmitter alterations, and synaptic or circuit-level effects; (iii) behavioral and cognitive findings from experimental models and human populations; (iv) associations between *T. gondii* seropositivity and psychiatric disorders; (v) executive functioning, impulsivity, and their associations with suicidal behavior; and (vi) evidence concerning toxoplasmosis and psychiatric outcomes in India.

Publications were considered eligible when they addressed at least one of the above thematic domains and provided relevant empirical findings, mechanistic insights, or a synthesis of existing evidence. Eligible publication types included original observational studies, experimental and mechanistic investigations, systematic reviews, meta-analyses, and relevant narrative reviews and book chapters. Publications in languages other than English and those lacking substantive relevance to the objectives of the review were excluded. Epidemiological and clinical studies from India were included to contextualize regional seroprevalence, psychiatric findings, and existing research gaps. Reviews and book chapters were used where they contributed relevant background or synthesized evidence. Greater interpretive weight was given to systematic reviews and meta-analyses when available, while recognizing that their conclusions depended on the quality, comparability, and heterogeneity of the underlying studies. Experimental findings were considered primarily for their contribution to biological plausibility and were not treated as direct evidence of corresponding mechanisms in humans. No formal methodological quality assessment or risk-of-bias evaluation using standardized assessment tools was undertaken. However, the methodological strengths and limitations of individual studies were considered qualitatively during interpretation, with attention to study design, sample characteristics, measurement approaches, control-group selection, outcome definitions, and potential confounding. No numerical quality scores or formal grading of the overall certainty of evidence were assigned.

Narrative Synthesis and Interpretation

The literature was synthesized narratively rather than through quantitative pooling. The findings were organized thematically, progressing from parasite biology and proposed neurobiological mechanisms to behavioral and cognitive outcomes, psychiatric associations, executive dysfunction, impulsivity, and suicidal

behavior. The evidence was then integrated into a conceptual model examining whether neurocognitive and behavioral vulnerabilities could represent potential links between *T. gondii* exposure and suicidal behavior, particularly in the presence of established clinical and psychosocial risk factors.

Experimental animal studies were considered primarily for their contribution to understanding potential biological mechanisms and establishing biological plausibility, whereas human observational studies were examined for evidence of associations between *T. gondii* exposure and clinical, cognitive, behavioral, or suicidal outcomes. Systematic reviews and meta-analyses were used to assess the broader consistency and magnitude of reported associations, taking into account the heterogeneity of their constituent studies. Findings across different study designs were compared with reference to population characteristics, exposure assessment, outcome definitions, control-group selection, and potential confounding. Greater consideration was given to findings supported by multiple lines of evidence, while contradictory or inconsistent results were retained and discussed rather than excluded.

As a narrative review, the article aimed to provide a critical and clinically relevant synthesis of the available literature rather than an exhaustive systematic evaluation of all eligible studies. The literature selection was guided by thematic relevance and the objectives of the review rather than a predefined systematic screening protocol. A contemporaneous record of the number of publications identified, screened, excluded, and included was not maintained; therefore, a formal study-selection flow diagram and numerical screening summary could not be provided.

Review

T. gondii: a brief overview

Epidemiology

T. gondii is a ubiquitous intracellular protozoan infecting humans and many warm-blooded animals. Approximately one-quarter to one-third of the global population has been exposed, although prevalence varies substantially with geography, age, environmental conditions, and dietary practices. A large systematic review and meta-analysis involving 320 studies, 658,172 individuals, and 113 countries estimated global *T. gondii* seroprevalence at approximately 31% (95% CI: 28-34%), with substantial between-study heterogeneity (I^2 = 99.6%) [6]. Higher prevalence is generally reported in Australian (54%), African (42%), and South American (45%) populations than in parts of Asia (25%), and prevalence tends to increase with age [6]. These differences reflect the complex interaction between environmental contamination, food practices, socioeconomic conditions, and host factors.

Life Cycle and Persistence

Felids are the definitive hosts, while humans and other animals act as intermediate hosts. Following infection, tachyzoites disseminate before differentiating into bradyzoites within tissue cysts that may persist for prolonged periods, including in neural tissue. Infection is usually asymptomatic or self-limited in immunocompetent individuals [7]. IgG seropositivity indicates previous exposure but does not by itself demonstrate active CNS infection, parasite burden, or neural dysfunction. Nevertheless, persistence of tissue cysts within the CNS has generated interest in the possibility of subtle long-term effects on neural function (Figure *1*).

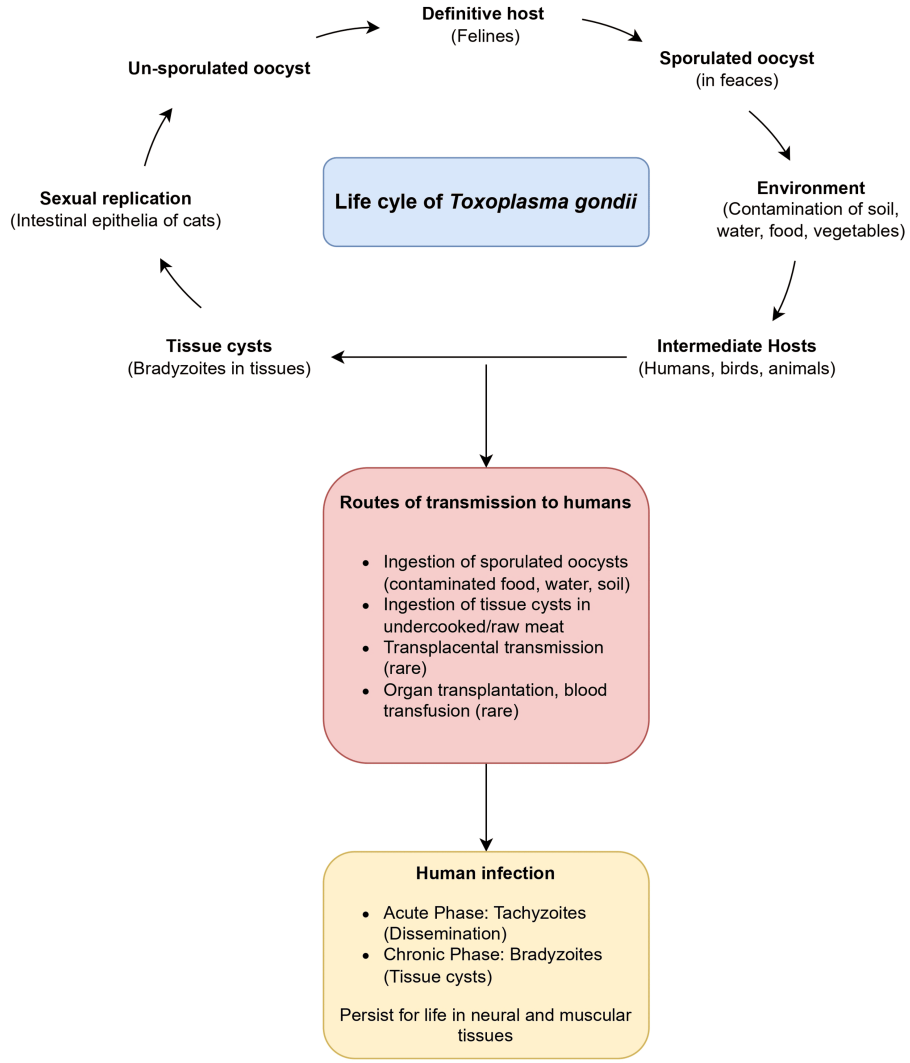

FIGURE 1: Life cycle of Toxoplasma gondii

The schematic diagram illustrates the sexual cycle in felids, environmental oocyst maturation, infection of intermediate hosts including humans, dissemination of tachyzoites, and formation of persistent tissue cysts containing bradyzoites (flowchart created using draw.io software, version 31.4.5, for the Microsoft Windows operating system).

Transmission and Latent Infection

Humans acquire infection through ingestion of tissue cysts in inadequately cooked meat, food or water contaminated with oocysts, and contaminated soil or environmental material; congenital transmission may follow primary maternal infection [3]. Thus, seropositivity represents cumulative exposure to heterogeneous environmental and dietary risks. Latent infection is common and generally clinically silent. Experimental and epidemiological observations nevertheless raise the possibility of subtle behavioral or cognitive effects, although such associations remain vulnerable to host, environmental, and socioeconomic confounding (Figure *1*) [8].

Neurobiology of *T. gondii* infection

CNS Invasion

The ability of *T. gondii* to establish persistent CNS infection provides a biological basis for investigating potential neuropsychiatric effects. Experimental studies indicate that CNS entry can occur through infected immune cells, endothelial or transcellular pathways without necessarily causing widespread blood-brain barrier disruption [9]. The parasite subsequently persists predominantly within neurons as tissue cysts. Regional differences in parasite distribution have been described experimentally, but their relevance to

human neuro-behavioral phenotypes remains uncertain (Figure 2).

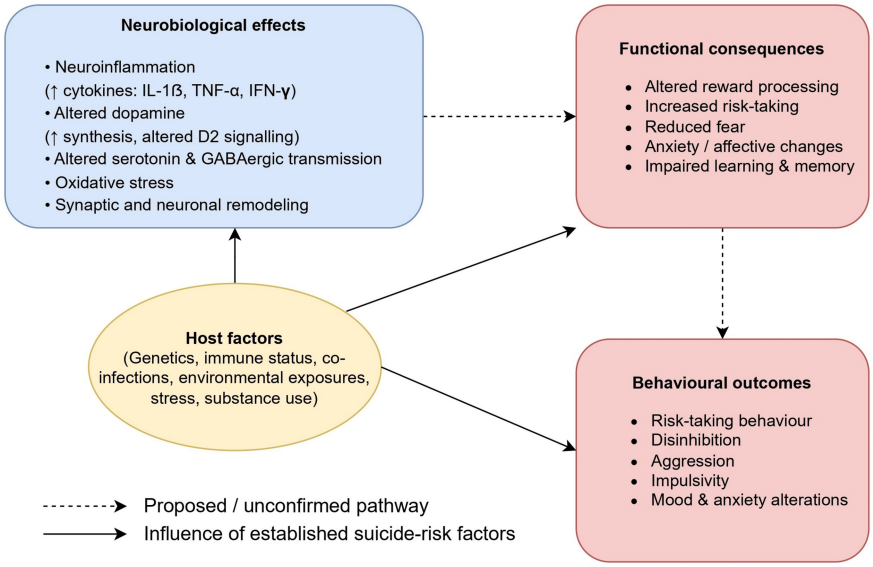

FIGURE 2: Potential mechanisms linking Toxoplasma gondii infection to neurocognitive and behavioral changes

Persistent central nervous system (CNS) infection may interact with host immune responses, neuroinflammatory processes, neurotransmitter systems, and synaptic/neural function, potentially influencing cognitive and behavioral processes (flowchart created using draw.io software, version 31.4.5, for the Microsoft Windows operating system).

Neuroinflammation

Neuroinflammation represents one of the principal mechanisms proposed to explain potential effects of chronic *T. gondii* infection on neural function. Experimental infection activates microglia, astrocytes, and infiltrating immune cells, with inflammatory mediators including interferon-γ, tumor necrosis factor, interleukin-1β, and interleukin-6 [10,11]. These responses are essential for controlling parasite replication, but prolonged immune activation may influence neuronal and synaptic function. However, most mechanistic evidence derives from experimental models, and the extent to which comparable processes occur in asymptomatic seropositive humans remains uncertain.

Neurotransmitter, Synaptic, and Circuit Alterations

Experimental studies have reported changes in glutamatergic and catecholaminergic signaling, including altered glutamate transport, dopamine-related pathways, and norepinephrine synthesis [12,13]. These systems contribute to cognition, reward processing, impulse control, and affective regulation and therefore provide plausible mechanisms for behavioral effects [11]. Postmortem investigations have demonstrated regional variation in the detection and distribution of *T. gondii* within human brain tissue, with a relatively greater parasite burden reported in the hippocampus; however, the functional implications of this regional distribution remain uncertain [14]. Nevertheless, findings are not sufficiently consistent to establish a specific neurotransmitter- or circuit-mediated mechanism in humans. Overall, persistent infection provides biological plausibility for altered neural function through interacting immune, neurotransmitter, synaptic, and circuit-level mechanisms, but biological plausibility should not be equated with causality.

T. gondii and behavioral and cognitive alterations

Evidence From Animal Models

Rodent studies provide experimental evidence that chronic *T. gondii* infection can alter predator avoidance, social behavior, locomotor activity, and fear-related responses [15]. The frequently described reduction in aversion to cat odor has been interpreted within an evolutionary framework as potentially facilitating transmission to the definitive host. Importantly, behavioral alterations appear to be more consistently observed during chronic rather than acute infection, supporting the possibility that persistent tissue infection or the associated host response contributes to these effects [16]. Although *T. gondii* infects

numerous vertebrate species, detailed behavioral evidence remains concentrated in laboratory rodents.

Human Behavioral Studies

Human studies have reported associations between seropositivity and personality traits, impulsivity, aggression, and reward-related behavior [17]. However, representative population studies have sometimes found little evidence of clinically meaningful behavioral differences, while positive studies have often involved small or selected samples. Differences in populations, instruments, age, sex, psychiatric status, and confounding factors limit comparability. The human evidence therefore suggests possible behavioral effects but does not establish a consistent phenotype.

Cognition

A systematic review and meta-analysis involving 13 studies and 13,289 healthy participants found small differences between seropositive and seronegative individuals across several cognitive domains. Seronegative participants demonstrated better performance in processing speed (SMD = 0.12, 95% CI: 0.05-0.19), working memory (SMD = 0.16, 95% CI: 0.06-0.26), short-term verbal memory (SMD = 0.18, 95% CI: 0.09-0.27), and executive functioning (SMD = 0.15, 95% CI: 0.01-0.28). Significant heterogeneity was observed for executive functioning (I^2 = 63%, p = 0.008), suggesting variability in the magnitude of this association across studies [18]. Individual and older-adult studies have reported domain-specific differences, but psychiatric populations remain understudied. Overall, the evidence supports small and selective cognitive differences rather than generalized impairment.

T. gondii and psychiatric disorders

The strongest psychiatric evidence concerns schizophrenia. Several meta-analyses have reported up to 2.7-fold higher odds of seropositivity among people with schizophrenia or recent-onset psychosis, although null findings occur and associations may differ by illness stage [17]. Differences in populations, controls, serological methods, and timing of infection may contribute to heterogeneity. A meta-analysis of 23 studies involving 12,690 participants (4,021 with bipolar disorder and 8,669 controls) reported higher odds of *T. gondii* seropositivity among individuals with bipolar disorder. The pooled OR was 1.69 (95% CI: 1.21-2.36) using a random-effects model, although substantial heterogeneity was observed (I^2 = 84%; 95% CI: 77-89%) [19]. A recent systematic review identified 18 relevant studies, of which nine, involving 2,499 participants (1,018 individuals with substance use disorders and 1,481 controls), were included in the meta-analysis. The pooled odds of *T. gondii* IgG seropositivity were higher among individuals with substance use disorders (OR = 1.86, 95% CI: 1.25-2.76) [20]. Nevertheless, the relatively small number of studies contributing to the quantitative synthesis and the observational nature of the underlying evidence warrant cautious interpretation.

Overall, psychiatric findings provide contextual evidence that *T. gondii* may be relevant to neuropsychiatric functioning, particularly schizophrenia, but seropositivity should not be interpreted as a nonspecific risk factor for psychiatric illness. Psychiatric diagnosis is also a major determinant of suicidal behavior and may act as a confounder, mediator, or effect modifier in studies of *T. gondii* and suicide.

Executive functions and suicidal behavior

Executive functions include working memory, cognitive flexibility, inhibitory control, planning, and decision-making. Impairment may compromise emotional regulation, consideration of consequences, generation of alternatives, and inhibition of maladaptive responses. A systematic qualitative review of 43 studies found that the proportion reporting positive associations between executive dysfunction and suicidality varied across diagnostic groups, being highest in depressive-disorder samples (75%), followed by mixed diagnostic samples (54%), bipolar-disorder samples (29%), and psychotic-disorder samples (33%). These findings suggest that the relationship may be influenced by psychiatric diagnosis and should not be regarded as uniform across populations [21]. Cognitive flexibility refers to the ability to modify behavior or thought processes in response to changing circumstances. Several studies have associated reduced cognitive flexibility with suicidal behavior or ideation, including longitudinal evidence, but null findings occur, particularly in younger or acutely ill populations [22]. Working memory has a comparatively consistent relationship with suicidal behavior. A systematic review and meta-analysis involving 24 studies and 2,595 participants found that suicide attempters demonstrated reduced specificity (Hedges' g = 0.8) and greater over-generality (Hedges' g = 0.9) of autobiographical memory compared with individuals without a history of suicide attempts. Long-term and working memory were also more impaired among suicide attempters than among patient and healthy controls [23]. Because working memory supports maintenance and manipulation of information while regulating behavior, deficits may impair evaluation of alternatives during acute distress.

A systematic review and meta-analysis of 18 studies involving 902 young people with self-harm or suicidal behavior and 1,591 controls identified small but significant differences in inhibitory control (13 studies; SMD = 0.21, 95% CI: 0.08-0.34; p = 0.002) and impulsive decision-making (14 studies; SMD = 0.17, 95% CI: 0.045-0.30; p = 0.008). These findings suggest that specific neurocognitive dimensions of impulsivity may be

associated with suicidal behavior, although they do not establish a uniform impairment across all facets of impulsivity [24]. Inhibitory control represents an important component of executive functioning. While a meta-analysis of studies examining suicidal behavior identified significant deficits in inhibitory control, individual studies in depression have reported poorer response inhibition among suicide attempters [24,25]. Planning findings are less consistent. Overall, executive dysfunction appears domain-specific rather than global; working memory, inhibitory control, and decision-making may be particularly relevant. This distinction is important when examining possible biological contributors to suicidal behavior, because a putative biological factor may affect one or more specific executive domains without producing generalized cognitive impairment.

T. gondii and executive dysfunction

The possibility that *T. gondii* affects executive functioning provides a potential link between persistent infection and suicidal behavior. The strongest quantitative evidence comes from a meta-analysis of 13 studies involving 13,289 healthy participants, in which seronegative participants showed modestly better processing speed, working memory, short-term verbal memory, and executive functioning; heterogeneity for executive function was significant [18]. The evidence therefore supports a cautious interpretation: seropositivity may be associated with small, domain-specific cognitive differences, particularly involving working memory and broader executive performance. Evidence for inhibitory control and cognitive flexibility is insufficient or inconsistent. Neuroinflammation, altered glutamatergic and catecholaminergic signaling, and synaptic changes are plausible mechanisms, but human observational evidence does not establish causation [11-13]. The small effect sizes argue against viewing *T. gondii* as a major determinant of cognitive dysfunction; potential relevance may instead lie in interaction with psychiatric illness, impulsivity, psychosocial stress, and other vulnerabilities.

T. gondii and impulsivity

Evidence linking *T. gondii* seropositivity with impulsivity and related traits is suggestive but inconsistent. Associations with aggression, impulsivity, or sensation seeking have been reported in some populations, sometimes varying by sex, age, or clinical status. A systematic review found behavioral associations in many studies, commonly involving aggression or impulsivity, but highlighted cross-sectional designs, small samples, and restricted populations [17]. Conversely, representative birth-cohort data have found little overall evidence of abnormal impulse control or personality [8]. Risk-taking and behavioral disinhibition are similarly inconclusive. Broad personality traits, aggression, and self-reported impulsivity should not be treated as interchangeable constructs. The available evidence therefore does not establish a specific impulsivity phenotype associated with *T. gondii*.

T. gondii and suicidal behavior

The association between *T. gondii* and suicidal behavior has been examined in several systematic reviews and meta-analyses, but causal inference remains impossible. Sutterland et al. reported an association between *T. gondii* antibodies and suicide attempts (pooled OR: 1.39, 95% CI: 1.10-1.76); importantly, the association was stronger with healthy controls and was not significant when psychiatric controls were used [26]. Evidence for suicidal ideation is weaker [27]. The distinction between ideation and behavior may be important because biological factors affecting cognitive control, impulsivity or behavioral disinhibition could theoretically contribute more to the transition from thought to action than to the generation of suicidal thoughts. The predominance of IgG associations is compatible with a relationship involving previous or persistent exposure rather than acute toxoplasmosis, but serology cannot establish CNS cyst burden or activity.

More recent studies have provided additional, although not entirely consistent, evidence concerning this association. A systematic review by Zerekidze et al. (2024) found that 12 of the 18 included studies reported a positive association between *T. gondii* and suicidal behavior, while highlighting considerable methodological heterogeneity [28]. In a registry-based case-control study, Fakhar et al. (2024) reported higher IgG seropositivity among 147 suicide attempters than among 135 controls (42.9% versus 16.3%); however, all participants were negative for IgM antibodies and parasite DNA, suggesting previous exposure rather than evidence of acute infection [29]. Similarly, Poursalar et al. (2025), in a study involving 250 suicide attempters and 250 controls, reported significantly higher IgG seropositivity among attempters (39.2% versus 22.0%; $p < 0.001$), along with findings suggestive of increased inflammatory activity [30]. In contrast, Postolache et al. (2025), studying 407 US veterans, found no significant overall association between seropositivity and suicidal self-directed violence [31]. However, higher antibody sero-intensity was associated with suicidal ideation and impulsivity in participants with a history of suicidal self-directed violence, although the authors acknowledged the limitations of the cross-sectional design and multiple comparisons [31]. Collectively, these findings provide further support for investigating the possible association but do not establish an independent causal role for *T. gondii* in suicidal behavior.

Heterogeneity in control selection, serological methods, outcome definitions, psychiatric comorbidity, geography, and study design may substantially influence estimates. Overall, the evidence supports a modest association, particularly with suicide attempts, but not an independent causal role for *T. gondii*. A key unresolved question is whether executive dysfunction and impulsivity represent intermediate pathways

linking biological exposure to suicidal behavior.

Integrating the evidence: a proposed mechanistic model

The reviewed evidence supports several overlapping pathways through which persistent *T. gondii* infection could potentially modify vulnerability to suicidal behavior, but not a simple linear causal sequence. A plausible model involves persistent CNS infection, immune and neuroinflammatory signaling, neurotransmitter and synaptic alterations, and downstream effects on cognitive and behavioral regulation (Figure *3*).

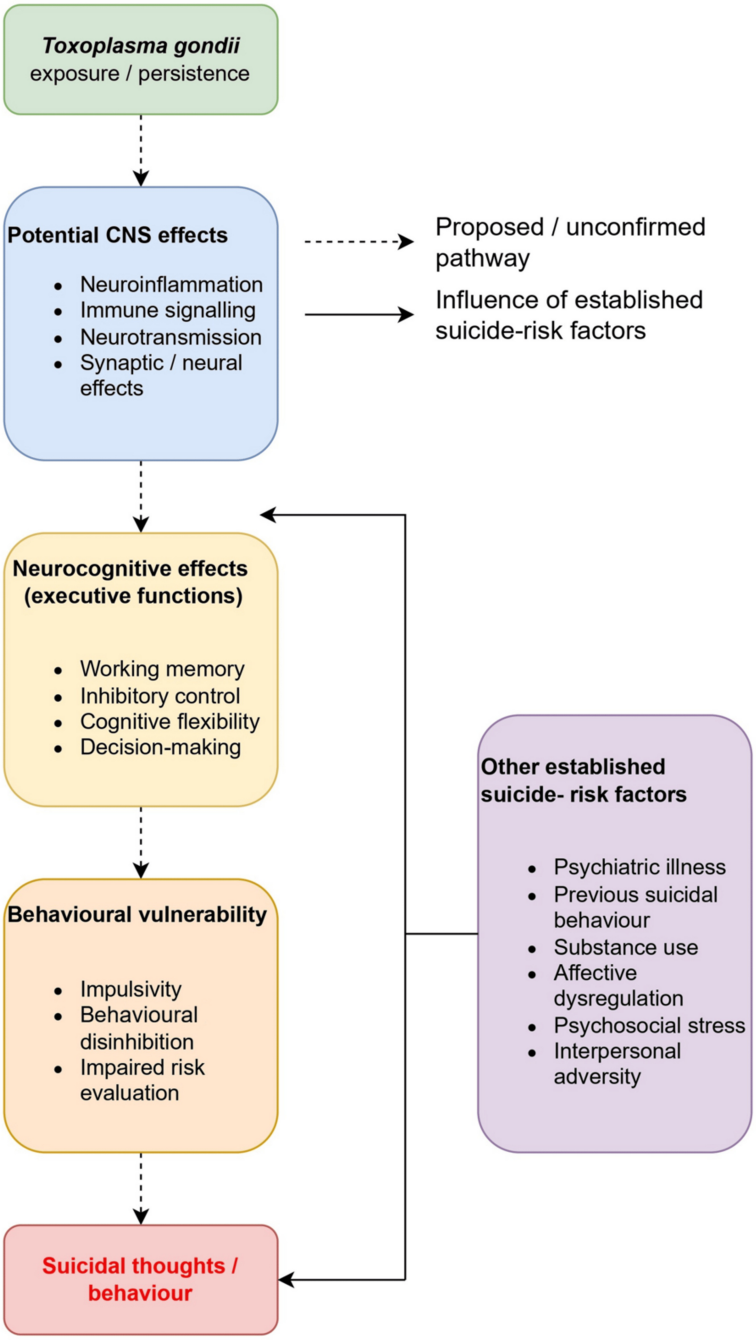

FIGURE 3: Proposed integrative model linking Toxoplasma gondii seropositivity with neurocognitive and behavioral vulnerability to suicidal behavior

Persistent *T. gondii* infection may influence central nervous system (CNS) function through neuroinflammatory, immune, neurotransmitter, and synaptic mechanisms, potentially affecting executive processes such as working memory, inhibitory control, cognitive flexibility, and decision-making. These neurocognitive alterations may contribute to impulsivity and behavioral dysregulation, which could facilitate the transition from suicidal ideation to suicidal behavior in the presence of established psychiatric and psychosocial risk factors (flowchart created using draw.io software, version 31.4.5, for the Microsoft Windows operating system).

Executive functions, including working memory, inhibitory control, cognitive flexibility, and decision-making, support evaluation of consequences, generation of alternatives, and behavioral inhibition; subtle changes in these processes could interact with impulsivity and behavioral dysregulation, particularly during acute psychological distress. Suicidal behavior remains multifactorial; psychiatric illness, previous suicidal

behavior, substance use, interpersonal adversity, psychosocial stress, and affective dysregulation may determine whether biological or cognitive vulnerabilities become clinically consequential. Thus, *T. gondii* is better conceptualized as a possible biological modifier than as a direct or sufficient cause of suicidal behavior.

The key unresolved question is whether seropositivity is associated with a specific pattern of executive dysfunction and impulsivity among individuals with suicidal behavior. Demonstrating such an association would not establish causality but could identify a potential intermediate link and generate hypotheses for longitudinal and mechanistic research.

Indian perspective: epidemiology, psychiatric evidence, and the remaining gap

India is an important but comparatively under-investigated setting. A national sero-epidemiological study involving 23,094 serum samples reported an overall *T. gondii* IgG seroprevalence of 24.3%, while IgM antibodies were detected in 2% of samples. Regional prevalence varied considerably, ranging from 9.4% in Rajasthan to 48.2% in Kerala, as reported in subsequent descriptions of the study [32]. Mangot et al. (2018) subsequently found that serum *T. gondii* IgG levels were significantly higher in patients with mania than in controls ($U = 766.5$, $z = 3.25$, $p = 0.001$), without correlation with age at onset or psychopathological severity [33]. The study was small, cross-sectional and single-center, and excluded patients at risk of suicidal or marked aggression; consequently, it provides no direct evidence concerning suicidal behavior. Maheshwari et al. (2026) examined 281 patients with psychiatric or neurological disorders and 281 matched controls in Delhi [34]. Overall seropositivity was 30.96% versus 24.91% (OR: 1.35, 95% CI: 0.93-1.95; $p = 0.11$). Seropositivity was 33.3% in schizophrenia, 32% in bipolar disorder, 30% in substance-use disorders, and 20% in depressive disorders, without statistically significant diagnostic associations. The study did not assess executive function, impulsivity, or suicidal outcomes and was cross-sectional.

Thus, Indian research has progressed from documenting exposure to examining selected psychiatric populations, but the specific relationship between *T. gondii*, suicidal behavior, executive functioning, and impulsivity remains unexplored. Future Indian studies should account for regional, dietary, environmental, clinical, and sociodemographic heterogeneity and use adequately powered, standardized, and preferably multicenter designs.

Clinical implications

T. gondii seropositivity is a potentially informative research marker but is not currently suitable as a clinical screening or risk-stratification biomarker for suicidal behavior. Most evidence is cross-sectional or case-control, IgG indicates previous exposure rather than active CNS infection, and associations may be influenced by psychiatric diagnosis, medication, substance use, and other confounders. Control selection also materially affects estimates. Accordingly, seropositivity should currently be regarded as a candidate research biomarker. Prospective studies incorporating standardized suicidal outcomes, measures of executive function and impulsivity, together with relevant clinical and biological confounders, are required before predictive utility can be assessed.

Current gaps in knowledge

Important gaps remain in determining how *T. gondii* might relate to suicidal behavior. Indian research remains limited and fragmented despite substantial and geographically variable exposure. International cognitive studies have generally involved psychiatrically healthy populations and heterogeneous neuropsychological measures, leaving uncertainty about whether seropositivity relates specifically to executive domains relevant to suicide.

Studies of *T. gondii* and impulsivity have likewise used heterogeneous constructs, often combining aggression, personality, and self-reported impulsivity. It remains unclear whether exposure is associated with specific forms of impulsivity, such as impaired inhibitory control, impulsive decision-making, or affective urgency, that may facilitate the transition from ideation to action.

Most importantly, these domains have rarely been examined together. To the best of our knowledge, no adequately characterized study has specifically examined *T. gondii* seropositivity, executive functioning, and impulsivity among individuals with a recent suicide attempt. Most available studies are cross-sectional or case-control, preventing assessment of temporality. Methodological heterogeneity in suicidal outcomes, serology, control selection, neuropsychological instruments, impulsivity measures, and confounder adjustment further limits synthesis.

Future directions

Future research should examine when, how, and in whom associations occur. Longitudinal studies with repeated assessment of serology, executive functioning, impulsivity, psychiatric symptoms, and suicidal outcomes are particularly important for addressing temporality and distinguishing stable traits from state-

dependent effects.

Multimodal studies combining serology with neuroimaging and inflammatory or immune markers could clarify whether neural or neuroinflammatory changes accompany cognitive differences. Serological characterization may incorporate IgG, IgM, antibody avidity and, where scientifically justified, molecular or inflammatory markers, while recognizing that serology cannot establish CNS parasite burden.

Executive functions and impulsivity should be assessed as specific, multidimensional constructs. Longitudinal designs could eventually permit mediation or moderation analyses testing whether these characteristics contribute to associations between biological exposure and suicidal outcomes. Because suicidal behavior is multifactorial, predictive models should integrate biological, clinical, neurocognitive, and psychosocial variables. Machine-learning approaches may assist such integration but require external validation, transparent reporting, and demonstration of incremental predictive value beyond established clinical factors.

If reproducible biological pathways are established, intervention studies could investigate whether modifying relevant mechanisms affects neurocognitive or clinical outcomes. Anti-parasitic or anti-inflammatory treatment should not presently be proposed specifically for suicide prevention. Multicenter Indian studies involving diverse populations are particularly needed to address regional variation and improve generalizability.

Conclusions

T. gondii is a biologically plausible candidate factor in neuropsychiatric research because it can establish persistent CNS infection and may influence immune, neurotransmitter, and neural processes. Observational evidence suggests modest associations with selected psychiatric disorders, cognitive and behavioral characteristics, and particularly associations with suicide attempts. However, the evidence remains heterogeneous; associations with executive functioning and impulsivity are generally small or inconsistent, and the relationship with suicidal behavior is influenced by control selection, psychiatric comorbidity, and methodological differences. Seropositivity indicates previous exposure rather than active CNS infection, and current evidence does not establish causality or clinical predictive utility.

The most important unresolved question is whether executive dysfunction and impulsivity represent intermediate pathways linking *T. gondii* exposure with suicidal behavior. Integrated, prospective, and multimodal studies, particularly in Indian populations, are needed to determine whether this proposed relationship is reproducible and biologically meaningful.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: Ajish Mangot, Satish Patil

Acquisition, analysis, or interpretation of data: Ajish Mangot

Drafting of the manuscript: Ajish Mangot

Critical review of the manuscript for important intellectual content: Ajish Mangot, Satish Patil

Supervision: Satish Patil

Disclosures

Conflicts of interest: In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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