Yes, reframing neurodevelopmental and psychiatric disorders as **multi-system neuro-immune conditions** strengthens the case for precision vaccines and personalized immunization strategies.

1. Introduction

The recognition that neurodevelopmental and psychiatric disorders involve bidirectional communication between the immune and nervous systems has reshaped how researchers conceptualize disease etiology, prevention, and treatment. Maternal immune activation during pregnancy—triggered by infection, obesity, autoimmune disease, or psychosocial stress—is now a well-established risk factor for autism spectrum disorder (ASD), schizophrenia, ADHD, and Tourette syndrome in offspring (Han et al., 2021; Kwon et al., 2022; Zengeler & Lukens, 2021). This evidence has converged with genetic findings showing significant polygenic overlap between neurodevelopmental and immune disorders, with 50–90% of immune-disorder risk variants shared with neurodevelopmental disorders (Xiu et al., 2024). The emerging field of "immunoneuropsychiatry" argues that these shared pathways demand mechanism-based immune treatments and subgroup identification rather than one-size-fits-all therapeutics (Pape et al., 2019; Nusslock et al., 2024; Dardani et al., 2024). Precision medicine frameworks are being proposed to stratify patients by inflammatory biomarkers and tailor interventions accordingly (Guo et al., 2026; Xiu et al., 2024; Yong et al., 2025). Against this backdrop, the question arises whether the multi-system neuro-immune understanding of these disorders specifically increases the need for precision vaccines—vaccines designed or timed with individual neuroimmune profiles in mind. One review directly advocates for a cautious, individualized neonatal vaccination approach guided by neuroimmune developmental considerations (Paymani et al., 2026), while another documents that adults with mental disorders can display attenuated vaccine responses (Xiao et al., 2022), underscoring the clinical relevance of personalized immunization in these populations.

Does understanding neurodevelopmental and psychiatric disorders as multi-system neuro-immune disorders increase the need for precision vaccines?
Requires at least 5 papers that directly answer your question. Try adjusting your query to find more papers.

FIGURE 1 Research consensus on neuro-immune framing supporting precision vaccines

2. Methods

The search ran over 170 million research papers indexed in Consensus, drawing from Semantic Scholar, PubMed, and other biomedical databases. An initial broad search using terms combining neurodevelopmental and psychiatric disorders with neuro-immune mechanisms and precision vaccine concepts returned over 80,000 papers. A structured six-group deep search strategy was then executed, covering foundational neuroimmune concepts, precision medicine context, the vaccine–neuroimmune intersection, terminology diversity (e.g., "immunopsychiatry," "personalized immunization"), critiques and counterarguments, and adjacent fields in immunology and systems vaccinology. Citation crawling from 50 seed papers identified 3,564 related works. Machine-learned relevance filtering screened 250 papers, of which 146 passed the relevance threshold; after deduplication, the top 50 were selected by relevance ranking for inclusion in this review.

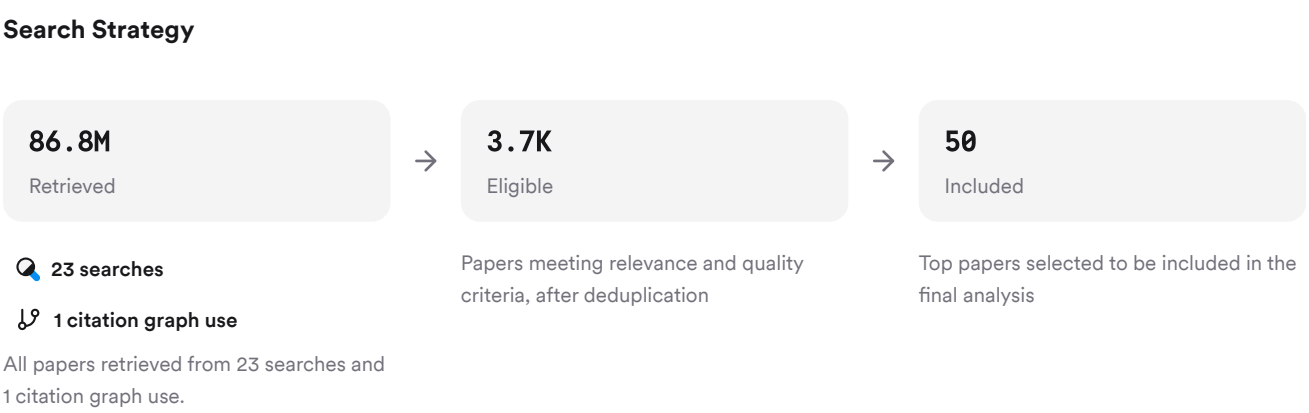

FIGURE 2 Search strategy from identification to included papers

The strategy combined neuroimmune mechanism searches with precision medicine and vaccinology queries to capture the interdisciplinary intersection this question demands.

3. Results

3.1 Key Papers

The corpus is anchored by several foundational reviews and empirical studies that establish the neuro-immune basis of neurodevelopmental and psychiatric disorders and draw explicit implications for precision interventions. Meyer's 2014 review (595 citations) established prenatal immune activation as a "neurodevelopmental disease primer" whose effects depend on genetic and environmental context (Meyer, 2014), providing the causal framework that underpins the precision argument. Han et al. (2021, 547 citations) synthesized human epidemiological evidence linking diverse maternal inflammatory states to NDDs and called for preventive strategies in pregnancy (Han et al., 2021). Pape et al. (2019, 392 citations) introduced "immunoneuropsychiatry" as a clinical framework, arguing for mechanism-based immune treatments and subgroup identification across psychiatric diseases (Pape et al., 2019). Dardani et al. (2024) applied Mendelian randomization to identify 29 potentially causal immune biomarkers for neuropsychiatric conditions, 20 of which are therapeutically tractable (Dardani et al., 2024).

Paper	Summary
(Pape et al., 2019)	Establishes prenatal immune activation as disease primer (Meyer, 2014)
(Chen et al., 2022)	Links diverse maternal inflammation to NDDs (Han et al., 2021)
(Gumusoglu & Stevens, 2019)	Proposes immunoneuropsychiatry clinical framework (Pape et al., 2019)

FIGURE 3 Foundational papers anchoring the neuro-immune precision literature

3.2 Shared Genetic and Immune Architecture

Genome-wide analyses reveal significant genetic correlations between neurodevelopmental and immune disorders, with 50–90% of immune-disorder risk variants shared with neurodevelopmental disorders and 154 genome-wide significant loci identified in cross-trait meta-analysis (Xiu et al., 2024). Shared biological pathways include neural signaling, inflammatory response, and PI3K-Akt signaling, with 26 of 30 lead SNPs also associated with blood cell traits (Xiu et al., 2024). A separate genome-wide analysis of ten neurological and ten psychiatric disorders demonstrated greater genetic pleiotropy than previously recognized, with implications for disease classification and precision medicine (Smeland et al., 2025). At the transcriptome level, more than 60% of immune-related genes show altered expression across six major brain disorders, with innate immune pathways carrying more alterations than adaptive immunity (Chen et al., 2022). Machine learning applied to immune profiling of children with NDDs identifies three immunologically distinct clusters—enhanced neurogenesis, Th-1 polarization, or IL-1 signaling—that may serve as novel drug targets (Sreenivas et al., 2023). These findings collectively support patient stratification by immune subtype, a prerequisite for any precision vaccine or immunomodulatory strategy.

3.3 Vaccine Response and Timing in Vulnerable Populations

Dimension	General Population	Mental Disorder Patients	Citations
Antibody response	Expected levels	Attenuated in MDD, schizophrenia	(Xiao et al., 2022)
PTSD response	Expected levels	No attenuation observed	(Xiao et al., 2022)
Insomnia response	Expected levels	Lower antibody levels	(Xiao et al., 2022)
Immunotherapy interaction	Standard timing	DMT-dependent vaccine efficacy	(Winkelmann et al., 2022)
Neonatal timing concern	Standard schedule	ALLARA principle proposed	(Paymani et al., 2026)

Adults with major depressive disorder or schizophrenia show attenuated immune responses to vaccination, while those with anorexia nervosa or PTSD display no significant difference from controls (Xiao et al., 2022). In neuroimmunological diseases such as multiple sclerosis, immunotherapies can impair vaccine responses, making timing and vaccine selection critical (Winkelmann et al., 2022). A neonatal vaccination review advocates for individualized scheduling guided by the "As Low and Late As Reasonably Achievable" (ALLARA) principle, citing concerns that vaccine-induced immune activation during critical neurodevelopmental windows could alter neuroimmune developmental programs through epigenetic mechanisms (Paymani et al., 2026). Current evidence-based recommendations for pediatric NDDs, however, state that all vaccines are recommended and none are contraindicated in ASD, ADHD, or Down syndrome (Richard et al., 2025), creating a tension between caution-based individualization and universal immunization guidelines.

3.4 Precision Medicine and Immune-Targeted Therapeutics

Neuroimmune network models of depression explicitly argue for moving beyond one-size-fits-all therapeutics toward personalized interventions targeting specific pathophysiological pathways and symptom clusters (Nusslock et al., 2024). Inflammatory biomarkers such as CRP and IL-6 may facilitate patient stratification, with anti-inflammatory treatments prioritized for individuals with elevated markers (Guo et al., 2026). Mendelian randomization has identified 20 therapeutically tractable immune biomarkers—including ACE, TNFRSF17, and CD40—with drugs already approved or in advanced trials (Dardani et al., 2024). Emerging immune-targeted therapies for neurodevelopmental conditions include IVIG, plasmapheresis, targeted B-cell therapies, and cytokine pathway blockade (Sun & Bai, 2026; Yong et al., 2025). iPSC-based models hold potential for identifying disease-relevant therapeutics targeting the neuro-immune axis through high-throughput screening (Michalski & Wen, 2023). The evolving landscape of NDD interventions—spanning immunomodulation, targeted blockade, and cellular replacement—has been explicitly framed as heralding a new era in precision medicine for neurodevelopmental disorders (Yong et al., 2025).

Results Timeline

The research arc has progressed through three phases.

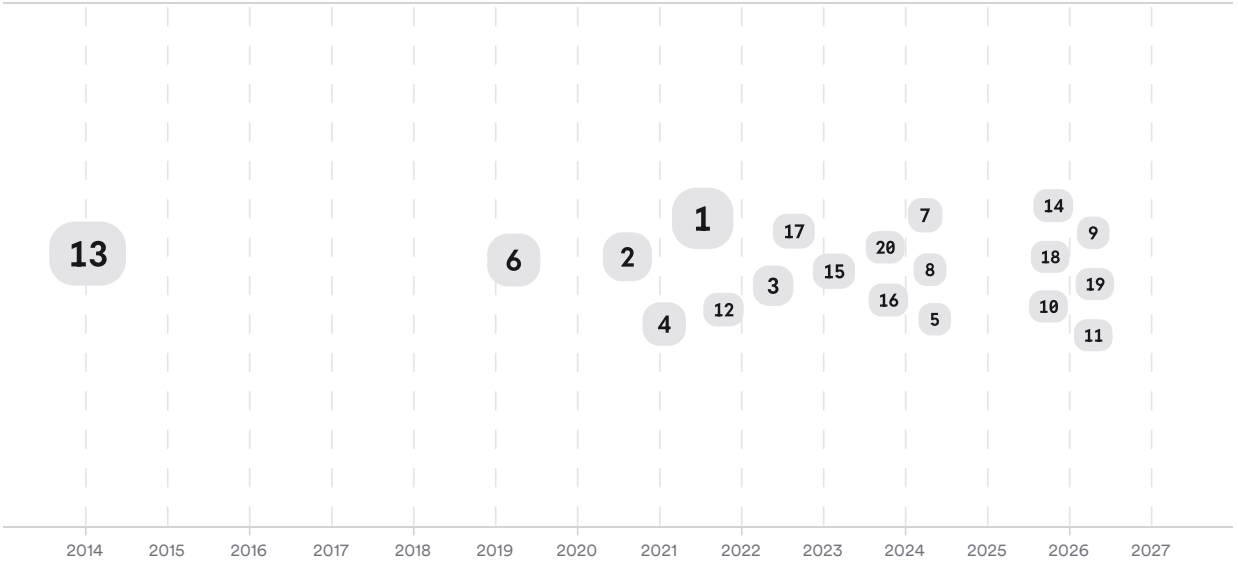

FIGURE 4 Timeline of influential neuro-immune and precision medicine papers; larger markers indicate more citations

Early epidemiological work established infection–neurodevelopment links, followed by a proliferation of mechanistic and genetic studies from 2014–2024, and a recent shift toward precision intervention frameworks and individualized immunization strategies.

Top Contributors

Based on the 50 papers in this corpus, **M. Maes**, **U. Meyer**, and **R. Dale** emerge as the most-cited authors on neuro-immune mechanisms in neurodevelopmental and psychiatric disorders, with **Nature Reviews Neurology** and **Biological Psychiatry** as leading journals.

Type	Name	Papers
Author	M. Maes	[b5132b2a944d59cdb572c81524df9e8b] [e44da7e374ea5f728b46342692151db8]

Type	Name	Papers
		[588d79847df259c8862ba078c17ed532]
Author	U. Meyer	[15ffaebd640e5ebab7c5c5434058ae0a]
Author	R. Dale	[84cbc061f8355462bb30e1ad97fe23cf][d2ed57b60d8e51f3bf291cf2868b37f4]
Journal	*Nature Reviews Neurology*	[84cbc061f8355462bb30e1ad97fe23cf][e44da7e374ea5f728b46342692151db8]
Journal	*Biological Psychiatry*	[b749a28259e75b3cb70b349bf0900c17] [15ffaebd640e5ebab7c5c5434058ae0a] [dc260797b9e65035b0438ee3156190ab]
Journal	*Molecular Psychiatry*	[2f6692bc29de55f7b0e5b6335d58b8d2] [9d90e71f8fed590096d1b847f4f066c8]

FIGURE 5 Authors and journals that appeared most frequently in the included papers

4. Discussion

The corpus demonstrates strong convergent evidence that immune dysregulation is a shared pathway across neurodevelopmental and psychiatric disorders, supported by epidemiological, genetic, transcriptomic, and mechanistic data. Multiple large-scale reviews and meta-analyses consistently link maternal immune activation to increased NDD risk (Han et al., 2021), and genetic analyses confirm substantial pleiotropy between immune and neurodevelopmental disorders (Xiu et al., 2024; Smeland et al., 2025). This convergence provides a robust rationale for precision approaches: if immune subtypes define distinct patient clusters with different treatment responses (Sreenivas et al., 2023), then vaccine design, timing, and adjuvant selection may need to account for neuroimmune heterogeneity.

However, the evidence for precision vaccines specifically—as opposed to precision immunotherapy or personalized medicine more broadly—remains preliminary. The vaccine-response literature in mental disorders is limited by small sample sizes (most studies under 30 subjects) and heterogeneity across disorders, yielding inconclusive overall results (Xiao et al., 2022). The ALLARA principle for neonatal vaccination is advocated as a cautionary framework but acknowledges significant evidence gaps (Paymani et al., 2026), while pediatric NDD guidelines maintain that all vaccines remain recommended and none are contraindicated (Richard et al., 2025). This tension between individualized caution and universal immunization represents a key unresolved debate. Additionally, most mechanistic evidence derives from animal models whose translational relevance to human vaccine timing remains uncertain (Harvey & Boksa, 2012). The gap between identifying therapeutically tractable immune targets (Dardani et al., 2024)and demonstrating that precision vaccine strategies improve outcomes in neurodevelopmental or psychiatric populations is substantial and largely unaddressed.

Claim	Evidence Strength	Reasoning	Papers
Maternal immune activation increases NDD risk in offspring	Strong	Multiple meta-analyses, systematic reviews, and convergent animal-human evidence	(Han et al., 2021; Meyer, 2014; Zengeler & Lukens, 2021)
Neurodevelopmental and immune disorders share genetic architecture	Strong	Genome-wide analyses with large samples and Mendelian randomization	(Xiu et al., 2024; Smeland et al., 2025; Dardani et al., 2024)
Immune biomarkers enable patient stratification for targeted treatment	Moderate	Observational biomarker studies and machine-learning clustering with moderate samples	(Guo et al., 2026; Sreenivas et al., 2023; Guo et al., 2026)
Adults with mental disorders show attenuated vaccine responses	Moderate	Systematic review of 13 small studies with mixed and inconclusive results	(Xiao et al., 2022)
Neonatal vaccination timing should be individualized per neuroimmune risk	Weak	Single narrative review with no direct empirical data; contradicted by current guidelines	(Paymani et al., 2026; Richard et al., 2025)

FIGURE 6 Key claims and supporting evidence identified in these papers

5. Conclusion

The synthesis of 50 papers confirms that reframing neurodevelopmental and psychiatric disorders as multi-system neuro-immune conditions substantially strengthens the scientific rationale for precision approaches to immune intervention—including, by extension, precision vaccines. The shared genetic architecture, identifiable immune subtypes, and variable vaccine responses across psychiatric populations all point toward the need for individualized immunization strategies. However, the evidence specifically supporting precision vaccines (as distinct from precision immunotherapy or personalized medicine) remains early-stage, with significant gaps between mechanistic insight and clinical implementation.

Research Gaps

The literature converges on neuro-immune mechanisms but leaves critical intersections with vaccinology underexplored.

	Human longitudinal data	Animal model evidence	Mechanism elucidated	Clinical intervention tested
Maternal immune activation	GAP	GAP	GAP	GAP
Vaccine response in psychiatric patients	GAP	GAP	GAP	GAP
Neonatal vaccination timing	GAP	GAP	GAP	GAP
Immune biomarker stratification	GAP	GAP	GAP	GAP
Genetic pleiotropy	GAP	GAP	GAP	GAP

FIGURE 7 Research gap matrix across neuro-immune and vaccinology dimensions

The most striking gap is the near-absence of longitudinal human studies linking neuroimmune profiling to vaccine design or timing decisions. While immune biomarkers can stratify patients (Sreenivas et al., 2023; Guo et al., 2026)and vaccine responses vary by psychiatric diagnosis (Xiao et al., 2022), no study in this corpus tests a precision vaccine strategy in a neurodevelopmental or psychiatric population. The ALLARA proposal (Paymani et al., 2026)and pediatric NDD vaccination guidelines (Richard et al., 2025)represent opposing poles of a debate that currently lacks the empirical data to resolve it.

Open Research Questions

Future work must bridge mechanistic neuro-immune science with vaccinology to translate precision concepts into clinical reality.

Question	Why
Can immune biomarker profiles guide vaccine adjuvant selection or timing in children with neurodevelopmental disorders?	Would test whether stratification by inflammatory subtype improves vaccine safety and efficacy in vulnerable populations.
Does maternal immune profiling during pregnancy enable precision preventive vaccination to reduce NDD risk in offspring?	Could transform prenatal care by linking maternal immune status to targeted infection prevention strategies.

Question	Why
How do immunotherapies for neuroimmunological diseases interact with precision vaccine schedules across the lifespan?	Addresses the clinical gap between immunotherapy and vaccination timing in patients with comorbid neuroimmune conditions.

FIGURE 8 Open research questions for precision vaccines in neuro-immune disorders

The multi-system neuro-immune framework has undeniably increased the theoretical need for precision vaccines; the challenge now is generating the clinical evidence to meet that need.

References

Chen, Y., Dai, J., Tang, L., Mikhailova, T., Liang, Q., Li, M., Zhou, J., Kopp, R., Weickert, C., Chen, C., & Liu, C. (2022). Neuroimmune transcriptome changes in patient brains of psychiatric and neurological disorders. *Molecular psychiatry, 28*, 710 - 721. https://doi.org/10.1038/s41380-022-01854-7

Dardani, C., Robinson, J. W., Jones, H., Rai, D., Stergiakouli, E., Grove, J., Gardner, R., McIntosh, A. M., Havdahl, A., Hemani, G., Smith, D. G., Richardson, T., Gaunt, T., & Khandaker, G. (2024). Immunological drivers and potential novel drug targets for major psychiatric, neurodevelopmental, and neurodegenerative conditions. *Molecular Psychiatry, 30*, 4487 - 4496. https://doi.org/10.1038/s41380-025-03032-x

Gumusoglu, S., & Stevens, H. (2019). Maternal Inflammation and Neurodevelopmental Programming: A Review of Preclinical Outcomes and Implications for Translational Psychiatry.. *Biological psychiatry, 85 2*, 107-121. https://doi.org/10.1016/j.biopsych.2018.08.008

Guo, X., Liu, H., Song, Y., Wang, J., Liu, D., Zheng, Z., Li, J., Li, B., Song, A., He, W., Yang, L.-L., & Wang, S. (2026). Neuro-Immune Crosstalk: Molecular Mechanisms, Biological Functions, Diseases, and Therapeutic Targets. *MedComm, 7*. https://doi.org/10.1002/mco2.70497

Han, V., Patel, S., Jones, H., & Dale, R. (2021). Maternal immune activation and neuroinflammation in human neurodevelopmental disorders. *Nature Reviews Neurology, 17*, 564 - 579. https://doi.org/10.1038/s41582-021-00530-8

Han, V., Patel, S., Jones, H., Nielsen, T. C., Mohammad, S., Hofer, M., Gold, W., Brilot, F., Lain, S., Nassar, N., & Dale, R. (2021). Maternal acute and chronic inflammation in pregnancy is associated with common neurodevelopmental disorders: a systematic review. *Translational Psychiatry, 11*. https://doi.org/10.1038/s41398-021-01198-w

Harvey, L., & Boksa, P. (2012). Prenatal and postnatal animal models of immune activation: Relevance to a range of neurodevelopmental disorders. *Developmental Neurobiology, 72*. https://doi.org/10.1002/dneu.22043

Kwon, H.-K., Choi, G., & Huh, J. R. (2022). Maternal inflammation and its ramifications on fetal neurodevelopment. *Trends in immunology, 43*, 230 - 244. https://doi.org/10.1016/j.it.2022.01.007

Meyer, U. (2014). Prenatal poly(i:C) exposure and other developmental immune activation models in rodent systems.. *Biological psychiatry, 75 4*, 307-15. https://doi.org/10.1016/j.biopsych.2013.07.011

Michalski, C., & Wen, Z. (2023). Leveraging iPSC technology to assess neuro-immune interactions in neurological and psychiatric disorders. *Frontiers in Psychiatry, 14*. https://doi.org/10.3389/fpsyt.2023.1291115

Nusslock, R., Alloy, L. B., Brody, G., & Miller, G. E. (2024). Neuroimmune Network Model of Depression: A Developmental Perspective. *Journal of child psychology and psychiatry, and allied disciplines, 65*, 538 - 567. https://doi.org/10.1111/jcpp.13961

Pape, K., Tamouza, R., Leboyer, M., & Zipp, F. (2019). Immunoneuropsychiatry — novel perspectives on brain disorders. *Nature Reviews Neurology, 15*, 317-328. https://doi.org/10.1038/s41582-019-0174-4

Paymani, Z., Nazari, M., Mirnia, K., Sangsari, R., Ebrahimi, M., & Haghighi, F. (2026). Rethinking Neonatal Vaccination Policies: A Neuroimmune Perspective. *Iranian Journal of Medical Sciences, 51*, 84 - 103. https://doi.org/10.30476/ijms.2025.106591.4083

Richard, J. P., Kiruthika, S., Sharon, J. A., Prasad, L., & Kompithra, R. (2025). Immunization in Pediatric Neurodevelopmental disorders: Current Evidence-Based Recommendations. *RESEARCH REVIEW International Journal of Multidisciplinary*. https://doi.org/10.31305/rrijm.2025.v10.n10.002

Smeland, O., Kutrolli, G., Bahrami, S., Fominykh, V., Parker, N., Fuhrer, J., Hindley, G., Rødevand, L., Jahołkowski, P., Tesfaye, M., Parekh, P., Elvsåshagen, T., Grotzinger, A., Steen, N. E., Van Der Meer, D., O'Connell, K., Djurovic, S., Dale, A., Shadrin, A., . . . Andreassen, O. (2025). A genome-wide analysis of the shared genetic risk architecture of complex neurological and psychiatric disorders. *Nature Neuroscience, 28*, 2439 - 2450. https://doi.org/10.1038/s41593-025-02090-2

Sreenivas, N., Maes, M., Padmanabha, H., Dharmendra, A., Chakkera, P., Choudhury, S. P., Abdul, F., Mullapudi, T., Gowda, V., Berk, M., Kommu, J. V. S., & Debnath, M. (2023). Comprehensive immunoprofiling of neurodevelopmental disorders suggests three distinct classes based on increased neurogenesis, Th-1 polarization or IL-1 signaling.. *Brain, behavior, and immunity*. https://doi.org/10.1016/j.bbi.2023.11.013

Sun, X., & Bai, X. (2026). Immune dysregulation in pediatric tic disorders: mechanisms, biomarkers, and therapeutic frontiers. *Frontiers in Immunology, 17*. https://doi.org/10.3389/fimmu.2026.1708940

Winkelmann, A., Loebermann, M., Barnett, M., Hartung, H., & Zettl, U. (2022). Vaccination and immunotherapies in neuroimmunological diseases. *Nature Reviews. Neurology, 18*, 289 - 306. https://doi.org/10.1038/s41582-022-00646-5

Xiao, K., Gillissie, E. S., Lui, L., Ceban, F., Teopiz, K., Gill, H., Cao, B., Ho, R., Rosenblat, J., & McIntyre, R. (2022). Immune response to vaccination in adults with mental disorders: A systematic review. *Journal of Affective Disorders, 304*, 66 - 77. https://doi.org/10.1016/j.jad.2022.02.025

Xiu, Z., Sun, L., Cao, H., Qu, H.-Q., Glessner, J., Ding, Z., Zheng, G., Wang, N., Xia, Q., Li, J., Hakonarson, H., Liu, W., & Li, J. (2024). Shared molecular mechanisms and transdiagnostic potential of neurodevelopmental disorders and immune disorders.. *Brain, behavior, and immunity*. https://doi.org/10.1016/j.bbi.2024.04.026

Yong, Q., Zhao, C., Xia, L., Zhu, T., & Xia, K. (2025). Maternal Immune Activation and Neurodevelopmental Disorders: Integrating Molecular, Cellular and Systems Mechanisms. *Neuropsychiatric Disease and Treatment, 21*, 2575 - 2594. https://doi.org/10.2147/ndt.s533813

Zengeler, K. E., & Lukens, J. (2021). Innate immunity at the crossroads of healthy brain maturation and neurodevelopmental disorders. *Nature reviews. Immunology, 21*, 454 - 468. https://doi.org/10.1038/s41577-020-00487-7