CANADIAN JOURNAL of UNDER GRADUATE RESEARCH

Neurobiology for community

"By uniting translational neuroscience with sociocultural frameworks and structural reform, clinicians and researchers can mitigate compounded vulnerabilities faced by immigrants and refugees, fostering resilience across generations." (p. 25)

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Barriers in mental healthcare

"…bringing communities into conversation on how to improve mental health care supports will create spaces for dialogue and innovation beneficial to youth, their families and healthcare providers." (p. 12)

Indigenous architecture

"By honouring cultural heritage and leveraging empirical insights, architects and urban planners have the opportunity to create spaces that promote cognitive health, emotional resilience, and inclusive well-being." (p. 17)

CANADIAN JOURNAL *of* UNDERGRADUATE RESEARCH

A student-led publication that aims to highlight research by Canadian undergraduate students of all disciplines

Second Issue OF THE Tenth Volume
May 2026

COURTESY OF THE Undergraduate Research Opportunities, University of British Columbia, Vancouver

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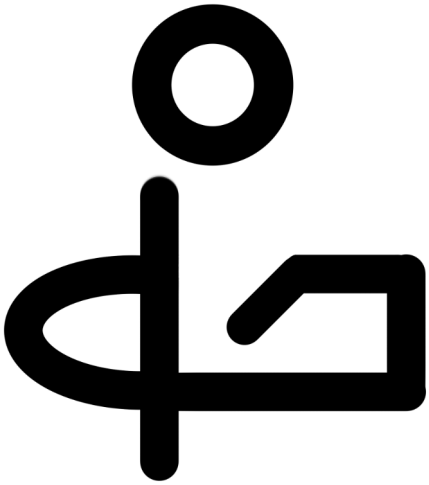
This issue is published on the traditional, ancestral, and unceded territory of the Coast Salish Nations, including xʷməθkʷəy̓əm (Musqueam), Sḵwx̱wú7mesh (Squamish), and səlilwətaɬ (Tsleil-Waututh).



This issue's cover was illustrated by Leslie Gao and Yasmine Spiro from the Figure Zero Project.

The Figure Zero Project is a non-profit organization committed to advancing scientific communication. By bridging the worlds of academia and arts, Figure Zero enhances public accessibility and comprehension of complex science topics. As a student-run organization, we empower students by providing them opportunities to collaborate with academic journals while also supporting these journals in their visual pursuits. Working with the Canadian Journal of Undergraduate Research has been a pleasure, and we hope you enjoyed the cover of this issue!

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Letter from the editors-in-chief

It is our honour to present Volume 10, Issue 2 of the Canadian Journal of Undergraduate Research. This issue showcases the efforts of Canadian undergraduates in the fields of neuroscience, psychology, and mental health. It is with great pleasure that, amid the numerous global issues, our journal is able to participate in the conversation around research in such important topics.

This publication comes at the end of the academic year, with many undergraduates, including those among our very own editorial team, moving into different phases of their lives. It is with great pride that we share this issue, as it is not only a fruit of the labour of the undergraduates featured within this issue and of the efforts of decades of research around the world, but also of the labour of the team that has worked tirelessly behind the scenes to deliver this publication to you. We would like to congratulate the graduates among our team, and we would like to cheer on those who are continuing their undergraduate studies and gaining knowledge with every step in their journey.

As the outgoing editors-in-chief, we are very thankful for the opportunity provided to us. We have seen the growth of this journal in the discussions we are having with different organizations, not only within British Columbia but also across Canada and even beyond. We are excited for what is next for CJUR, and we are thrilled to see what academic research is in store from such inspiring students. It has been a privilege to work with our seven editors, and we would also like to acknowledge the continued support of our senior advisors and numerous graduate student and faculty reviewers.

Volume 10, Issue 2 is now available, and we are grateful for your support of research.

Yours sincerely,

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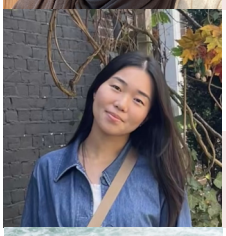

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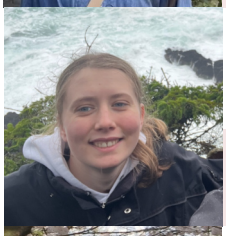

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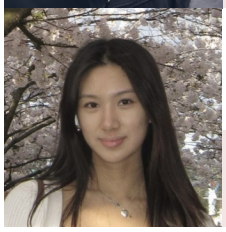

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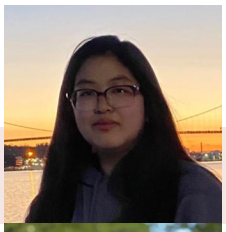

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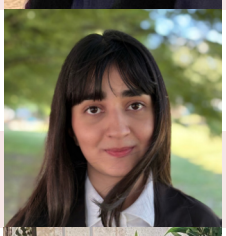

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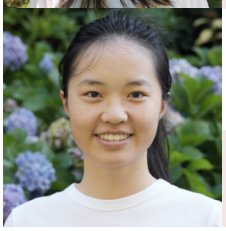

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CANADIAN JOURNAL of UNDERGRADUATE RESEARCH

RESEARCH
AUTISM
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Action prediction in autistic and non-autistic observers with perceptual and cognitive load

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ABSTRACT

According to the broken mirror neuron theory of autism, autistic individuals are less efficient at mapping the behaviors of others onto their own bodily representations, which leads to difficulties in imitating and understanding others' actions. However, limited research has explored the broken mirror neuron theory within the context of action prediction, the application of action understanding. In a pilot study, I employed a modified version of the pointing task where autistic and non-autistic participants predicted whether a target actor would point to the right or left without knowing that the actors were either instructed or allowed to choose freely where to point. I expanded on the original study by incorporating trials with perceptual or cognitive load. For the former, three actors were shown instead of just one, requiring the observer to respond to the actions of one target actor. For the latter, the observer was required to guess the target actor's actions by pressing a key that is in the opposite (anti) direction as the target actor's predicted pointing direction, as opposed to the same (pro) direction. All observers responded faster in the trials where the target actor chose freely where to point, called the choice advantage. However, an analysis of the autistic and non-autistic groups separately indicated that the choice advantage was observed in all experimental conditions in the non-autistic cohort but was reduced to the 1-actor, anti-pointing trials in the autistic group. These results indicate that autistic individuals may not be using body-language cues to predict the actions of others as effectively as non-autistic individuals, while offering a more nuanced perspective on autistic peoples' understanding of others' actions than the broken mirror neuron theory.

INTRODUCTION

In 1996, Gallese et al. discovered a novel class of neurons in the premotor cortex of macaque monkeys: Neurons that selectively fire both when a monkey performs a meaningful action, such as grasping an object, and when it observes an experimenter mirror the same action. Since then, a distributed collection of neurons in humans that display mirror neuron-like firing properties have been identified (Rizzolatti & Craighero, 2004). Subsequent experiments showing increased activity in brain regions that are thought to constitute the human mirror neuron system (MNS) during imitation (Iacoboni et al., 1999) and are responsive to the inferred intentions of an observed action (Iacoboni et al., 2005) suggest a functional role of mirror neurons in facilitating imitation and action understanding. Given the importance of imitation in facilitating social connectedness and in understanding others' intentions (Vivanti & Hamilton, 2014), differences in the MNS were thought to underly Autism Spectrum Disorder (ASD), a neurodevelopmental condition characterized by atypical social behavior (Smith & Bryson, 1994; Williams et al., 2001).

The potential role of mirror neurons in contributing to social cognition, as well as their functional differences in autism, is outlined in the direct matching hypothesis (Iacoboni et al., 1999). According to the hypothesis, our understanding of the intentions of others stems from an embodied simulation of their actions where observing an action recruits an internal representation of the same action in the form of a collection of mirror neurons such that it is as if the observer is performing the action themselves (Gallese, 2006; Iacoboni et al., 1999). Under the assumption that we understand the goals of our own actions, the observer may then use their internal representation, including its associated goals, to derive an experiential-based inference of others' actions.

While the broken mirror neuron theory of autism has been used to explain social differences of autistic people such as absent spontaneous imitation (McIntosh et al., 2006) and challenges in the use of motor information to understand the intentions of others (Boria et al., 2009), these findings are inconsistent (Sowden et al., 2016) and require further characterization (Chetcuti et al., 2019). Additionally, few experiments have examined the behavioural prediction component of social interactions directly, that is, the application of action understanding, or the nuances of autistic individuals' abilities in contexts of cognitive or perceptual load. To further contribute to our understanding of action understanding in autism and address these limitations in the literature, I asked the following question: How do autistic individuals use body-language cues differently than non-autistic individuals to predict the actions of others?

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According to the broken mirror neuron theory of autism, functional differences in the MNS of autistic individuals result in their ineffective use of internal representations to understand and predict the intentions of observed actions (Gallese, 2006). Given that predictive processing is practically useful in that it allows the observer to orient their actions at a future state of the target, it is possible to infer the efficiency of predictive processing and by extension, the functioning of participants' MNS by examining the speed at which observers make predictions. One experimental paradigm that assesses predictive processing in response to socially relevant body cues in others is the pointing task, where participants view actors pointing to a button on either the right or left side of the screen and are asked to predict in which direction they will point as fast as possible (Pesquita et al., 2016). Unknown to the participant, in half of the trials, the actors are instructed where to point while in the other half of the trials, the actors choose themselves where to point (Pesquita et al., 2016). The original paper reported that the observers' reaction times were significantly faster on the choice-trials compared to the directed-trials, showing a 19-ms choice advantage on average, independent of accuracy (Pesquita et al., 2016). Thus, the presence of the choice advantage indicates the capacity for observers to use internal representations of the actors' movements that are specific to the actors' choice of where to point to enhance the speed of their predictions, a process that is mediated by the MNS. To further explore subliminal body-language processing in autistic participants compared to non-autistic controls, I conducted a modified version of the pointing task by incorporating cognitive and perceptual types of load.

METHODS

I used a variation of the pointing task developed by Pesquita et al. (2016). The task was administered on MATLAB on a computer and the participants sat approximately 60 cm from the screen. Each participant completed four blocks with each block consisting of 100 trials. On each trial, a video was played that showed one of four possible actors pointing to one of two targets (black buttons) located on the right and left sides of the screen. In each trial, the participant was instructed to guess as quickly as possible where the actor would point—either to the left or to the right—by pressing one of two spatially-mapped keys on a keyboard. The video stimuli were identical to those used by Pesquita et al. (2016).

Each trial began with a black screen followed by a fixation cross shown for 100–150 ms (varied randomly). Then the video played until a response was made by the participant, or for 1000 ms (1 s) and was followed by a blank screen if no response was recorded. The inter-trial interval, or the time between the participant's response input and the reappearance of the fixation cross, was 1 s. While the participant was instructed to "try to beat the person" to their point and to "guess as quickly as possible", there was no time limit set for each trial. If the participant failed to respond prior to the end of each video, a black screen would appear, and they would be required to input a response to begin the next trial. The blocks were separated by self-paced breaks. The videos were centered in the middle of the screen but did not take up the full screen.

Each of the four blocks differed in two ways: the number of actors that were shown, and the participant's response type. Either one or three actors could be shown in each trial. Additionally, the participant could be asked to respond by pressing a key that is in the same (pro) or opposite (anti) direction as the target. Thus, each of the four blocks represented a unique combination of these two factors (Figure 1). The participant was given 6–12 practice trials prior to the start of each block. Practice trials differed from test trials in that when participants answered incorrectly, a feedback message was shown saying, "Oops!" and reinstated the task. The order of the four blocks were counterbalanced across the participants such that each participant could start with any of the four blocks. The three actors remained the same within each three-person block but differed both across participants and between the "triple-pro" and "triple-anti" blocks. Additionally, a different target actor was chosen for each of the four blocks such that all four actors were the target actor in one of the blocks. The target actor for each block was randomly selected for each participant.

I recruited 40 participants via the Human Subject Pool (HSP) that constitutes the UBC Psychology Research Participation Program. The HSP consists of undergraduate students enrolled in at least one psychology course at the time of their participation, and was chosen as a convenient, efficient, and cost-effective method to recruit participants. Consent to participate in the study was obtained prior to their participation, and they received 1.0 course credit for 30 minutes of their participation. The only exclusion criterion was failing to consent to participate in the study. The participants completed the pointing task followed by a Qualtrics

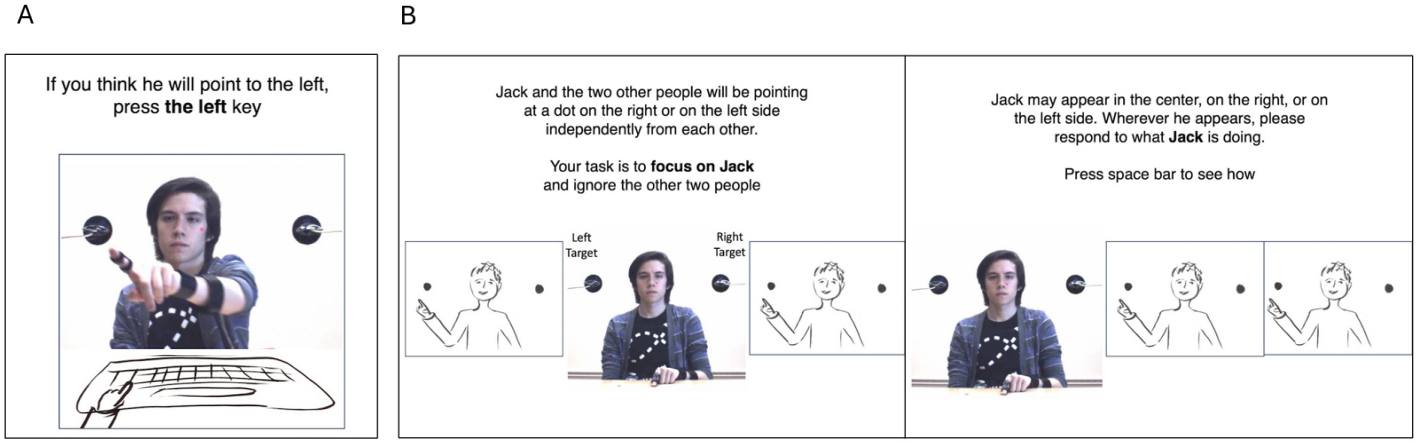

Figure 1. The pointing task instructions. **(A)** A screenshot of the instructions presented to participants at the start of a single-actor, pro-pointing block. The participant is instructed to press the key that is in the same direction as the target actor's predicted pointing direction. **(B)** Two screenshots of the successive instructions presented to participants at the start of a three-actor block. The participant is instructed to focus on the target actor who may appear on the left, middle, or right of the screen along with two distractor actors.

survey. The survey included questions about the participant's gender and age, as well as the 65-item Social Responsiveness Scale (SRS 2) (Constantino & Gruber, 2012). Additionally, since the study was not advertised to autistic individuals due to limited time and resources, 10 autistic participants were recruited from a separate lab at the university that actively seeks participants with a clinical diagnosis of ASD. There was no requirement that these participants were students enrolled at the university. Consent was obtained prior to their participation, and they received $5 CAD for their participation. The participants completed the pointing task, and their demographic information was obtained, with the participant's consent, from the first lab.

The study contained limited psychological or physical risks; no adverse events or side effects resulted from participation in the study. The study took place in-person at a lab located on the university campus by three undergraduate students who were trained in administering the experiment by a postdoctoral researcher at the lab. Data was also collected by the postdoctoral researcher themself. An a priori power analysis to determine the number of participants needed was not performed given that time was the limiting factor of the sample size. Instead, as many autistic and non-autistic participants were recruited as was possible within the available time to complete the study, which resulted in 50 participants (40 non-autistic, 10 autistic) who were initially recruited.

There were no statistically significant differences in the gender compositions of "female", "male", or "other" ($\chi^2(2, N = 50) = 4.33$, $p = .115$) between the non-autistic (30; 10; 0) and autistic (6; 3; 1) groups. An independent samples *t*-test revealed a statistically significant difference in age ($t(13) = -3.06$, $p = .009$, 95% CI [–6.23, –1.07]) between the two groups, with the non-autistic group ($M = 22.05$, $SD = 3.40$, range: 19–36 years) being younger than the autistic group ($M = 25.70$, $SD = 3.37$, range: 21–29 years). Additionally, there was a statistically significant difference in the SRS scores ($t(17) = -8.48$, $p < .001$, 95% CI [–64.05, –42.25]) between the two groups, with the non-autistic group ($M = 57.15$, $SD = 21.22$) scoring lower than the autistic group ($M = 110.30$, $SD = 16.73$).

RESULTS

Excel version 2502 was used for data preprocessing and Jamovi version 2.4.11 for statistical analysis. Outliers in the data based on reaction time and accuracy were removed to account for potential lapses in attention or effort by participants, which helped to ensure that the data used for the final analyses represented typical task performance. The data was preprocessed by first removing the reaction times for any trials where the participant's response was incorrect since these reaction times may not accurately represent participants' typical processing speed. Reaction times that were less than 200 ms, which would be too fast to be based on information from the video, or greater than 3 s, which would be significantly after the video had ended and the actor's movement had been completed, were also removed. Among those that remained, reaction times that were 3 SD above the average reaction time across all conditions and within each participant's data were removed to exclude data that may indicate lapses in effort or attention relative to each participant's typical reaction time. One individual in the non-autistic and another in the autistic group had incomplete and therefore unusable data, so their data were removed. Similarly, participants were excluded from the analysis if their average reaction time or accuracy across all conditions was less than or greater than 3 SD from the mean. Using this method, one outlier was identified in the non-autistic group, resulting in a final sample of 38 non-autistic participants and 9 autistic participants.

In addition to reducing the final sample size of the study, which decreased participant representation and slightly lowered the power to detect effects, removing these results improved the validity of the analyses with respect to two primary assumptions of ANOVA: normally distributed data and homogeneity of variance. Removing extreme reaction times between and within participants reduced skewness in the data and produced more comparable variances. To verify that the assumptions were met, a Q-Q plot was produced and indicated that standardized residuals across all conditions were approximately normally distributed. Additionally, a Levene's test for homogeneity of variance between autistic and non-autistic participants for all conditions were all non-significant ($p > 0.05$), suggesting that the variances were comparable. Thus, the assumptions of normality and homogeneity of variance were satisfied in our sample.

Statistical analyses used a four-way mixed ANOVA with point type (choice vs. directed), number of actors (1 vs. 3), and response type (pro vs. anti) as within-participant variables and group (non-autistic vs. autistic) as the between-participant variable, yielding three significant effects. There was a main effect of point type [$F(1, 45) = 48.989$, $p < 0.001$, $\eta^2 = 0.521$] where participants responded faster in the choice trials ($M = 0.747$ s, 95% CI [0.731, 0.763]) than in the directed trials ($M = 0.760$ s, 95% CI [0.744, 0.776]). Additionally, there was a main effect of the number of actors [$F(1, 45) = 124.960$, $p < .001$, $\eta^2 = 0.735$] where participants responded faster in the 1-actor trials ($M = 0.707$ s, 95% CI [0.691, 0.724]) than in the 3-actor trials ($M = 0.800$ s, 95% CI [0.780, 0.819]). Finally, there was a main of response type [$F(1, 45) = 33.399$, $p < .001$, $\eta^2 = 0.426$] where participants responded faster in the pro trials ($M = 0.726$ s, 95% CI [0.709, 0.742]) than in the anti trials ($M = 0.781$ s, 95% CI [0.761, 0.802]). Notably, the between-participant factor of group was not statistically significant [$F(1, 45) = 1.790$, $p = .187$, $\eta^2 = 0.038$]; the non-autistic participants did not respond faster ($M = 0.743$ s, 95% CI [0.729, 0.757]) compared to the autistic participants ($M = 0.764$ s, 95% CI [0.735, 0.793]). There were also no statistically significant interactions between any of the factors.

To further clarify any potential trends in the effects of point type, number of actors, and response type on reaction time between the autistic and non-autistic groups, I conducted paired samples t-tests to examine the presence of the choice advantage across the experimental conditions separately in autistic and control participants. The non-autistic group responded faster in the choice trials compared to the directed trials for all conditions, including in the 1-actor pro-pointing trials ($t(37) = 5.59$, $p < .001$, $MD = 0.020$ s, 95% CI [0.013, 0.027], $d = 0.907$, 95% CI [0.524, 1.281]), 1-actor anti-pointing trials ($t(37) = 2.71$, $p = .010$, $MD = 0.010$ s, 95% CI [0.003, 0.018], $d = 0.439$, 95% CI [0.103, 0.769]), 3-actor pro-pointing trials ($t(37) = 5.61$, $p < .001$, $MD = 0.019$ s, 95% CI [0.012, 0.026], $d = 0.910$, 95% CI [0.527, 1.285]), and 3-actor anti-pointing trials ($t(37) = 3.75$, $p < .001$, $MD = 0.015$ s, 95% CI [0.007, 0.023], $d = 0.608$, 95% CI [0.258, 0.951]). In contrast, the autistic participants only responded faster in the choice trials compared to the directed trials in the 1-actor anti-pointing trials ($t(8) = 2.73$, $p = .026$, $MD = 0.022$ s, 95% CI [0.003, 0.041], $d = 0.911$, 95% CI [0.105, 1.680]).

DISCUSSION

The present study sought to investigate how autistic people may differ from non-autistic people in interpreting the body-language cues of others and responding appropriately to motor predictions derived from them. I employed a pointing task that assesses participants' sensitivity to actors' movements to facilitate their prediction speed, an assessment of participants' action understanding mediated by the MNS. For all participants, the 3-actor and anti-pointing trials were overall slower to respond to compared to the 1-actor and pro-pointing trials respectively, indicating that the perceptual and cognitive load manipulations were effective. However, they did not impair the magnitude of the choice advantage due to the presence of a main effect of point type across all conditions. While there were no overall differences between the autistic and non-autistic groups in the presence of the choice advantage, contrasts comparing choice and directed trials in each condition separately between autistic and non-autistic participants revealed some interesting trends. For the non-autistic group, the choice advantage, although present in all conditions, was less robust for the 1-actor anti-pointing condition, which suggests that cognitive load was more effective at influencing the magnitude of the choice advantage compared to the 3-actor cognitive load. In the autistic group, the choice advantage was only present in the 1-actor, anti-pointing condition, suggesting that the autistic participants were not using the body cues of the actors as efficiently or consistently as the non-autistic participants to enhance their predictions.

Despite the small sample size of the study, the findings fail to provide support for the broken mirror neuron theory of autism, indicated by the presence of the choice advantage in the 1-actor anti-pointing trials in the autistic group, and across all conditions and independent of group membership more generally based on the ANOVA results. The presence of the choice advantage in the autistic group suggests that body cues that were present in the actors and that were specific to the actor's own choice of where to point were accurately detected by the autistic observers and used to enhance the speed of their predictions on at least some trials. Interpreted through the direct-matching hypothesis, the autistic participants displayed a similar capacity to map the bodily representations of the freely-choosing actors onto their own motor systems to obtain an understanding of the actors' intentions as the non-autistic participants, which were then used to more efficiently predict the actors' future decisions.

Instead, the results are more in line with the social top-down response modulation (STORM) framework, which posits that autism is characterized not by impairments in imitation or action understanding, but by differences in regulating when and how imitation and action understanding takes place (Southgate & Hamilton, 2008). In our study, the autistic participants were able to interpret the body cues of the actors that were specific to chosen (as opposed to directed) points and use the information to predict their actions in a task where they were explicitly told to do so, as predicted by the STORM model. However, further research is needed to directly address the STORM model. For example, it would be interesting to investigate whether autistic people would still predict the actions of the actors as effectively without top-down control signals, explicit instruction, or social motivational signals. Moreover, exploring whether the absence of the choice advantage in certain trials in the present study was due to challenges in regulating top-down control of action representation in autistic participants could more directly address the STORM model and provide new interpretations to the present study. For example, previous research has shown reduced automatic facial imitation in autistic adults but accurate facial imitation when they were explicitly instructed to imitate (McIntosh et al., 2006), demonstrating the role of social motivation in mediating imitation and potentially action prediction as well.

Beyond the small sample size, there were several limitations of the study that impact the generalizability of the results. I did not verify that the students that constituted the control group were not autistic or were diagnosed with any other neurological condition. While they scored lower on the SRS 2 compared to the autistic group, a measure of social difficulties that might indicate the presence of autism, it cannot be used in isolation to draw conclusions about a diagnosis of ASD. Additionally, there was a statistically significant difference in the mean ages of the autistic and non-autistic participants with the autistic participants approximately three years older on average. Age may have acted as a confounding factor, which was not accounted for in the statistical analyses. Moreover, there was a lack of representation of both the autistic and non-autistic participants in the study. All non-autistic individuals were undergraduate students enrolled in a psychology course at the University of British Columbia, and thus do not represent a random sample of the general population. Similarly, the autistic participants were all verbal and capable of reading and speaking, a sample that excludes a great portion of non-verbal, minimally-verbal, or intellectually impaired autistic individuals (Russell et al., 2019).

CONCLUSION

In the present study, I confirmed the presence of the choice advantage in non-autistic and autistic observers when completing a modified version of the pointing task. All participants responded faster in the 1-actor tasks compared to the 3-actor tasks, and to the pro-pointing tasks compared to the anti-pointing tasks. The choice advantage was present for all conditions in the non-autistic participants but was reduced to the 1-actor, anti-pointing condition in the autistic participants. While our results do not provide support for the broken mirror neuron theory of autism, further work is needed to verify our results given the small sample size of the present study. Additionally, it would be interesting to examine the potential role of motivation in mediating social differences in autistic people, which may provide support for the social top-down response modulation (STORM) framework of autism (Southgate & Hamilton, 2008).

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CONFLICTS OF INTEREST

The author declares no conflicts of interest.

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REVIEW
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A literature review: Exploring barriers to Canadian youth mental health supports and services

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ABSTRACT

Mental health for Canadian youth is an increasingly worsening issue. For many young people who are struggling with their mental health, securing meaningful and appropriate mental health support is challenging. There are significant barriers to accessing mental health services. Barriers can include, but are not limited to, supports available, wait-times, cost, social stigma, and systemic discrimination. For youth belonging to vulnerable communities, these barriers can be exacerbated by social demographic factors (e.g., gender, race). Supports which do not address the unique needs of diverse youth can contribute to poor mental health. Individuals and families often incur large expenses when attempting to access services. The persistence of stigma associated with mental illness can make young people feel increasingly isolated and alienated from peers, family and community members. More research is needed on how to improve service design as well as inputting holistic measures to break down barriers for youth seeking mental health support. In this literature review, we explore key research on the demographics of Canadian youth seeking mental health help, focusing on barriers such as long wait times, service design and community-based options that affect access and outcomes.

INTRODUCTION

Youth mental health is an important issue within Canada. Mental health wait times in Canada have been increasing at an alarming rate, causing significant harm to youth and families waiting for mental health support. Youth who are already experiencing poor mental health are exposed to various barriers in accessing suitable mental health services. For example, youth who are racialized and/or gender diverse face unique challenges in obtaining suitable care (Scheim et al. 2021). Yang et al. (2024) highlighted:

> In Canada, models estimate prevalence rates of 19.8% (or 6.8 million) of all Canadians living with a mental disorder as of 2011, with a projected increase to 20.5% (or 8.9 million) in 2041. The prevalence of mental disorders is notably higher amongst youth, with an estimated 23.4% (or 1 million) of Canadian children and youth aged 9–19 living with a mental disorder. (p. 3)

In an increasingly online world, many Canadian youth find themselves targets of cyber-victimization (Kingsbury et al., 2023) which negatively impacts their mental health. Mental health conditions such as body dysmorphia are associated with depression and anxiety (Hammami et al., 2022). Youth whose communities regularly experience racially motivated violence and/or gender-based violence are subject to impoverished mental health (Menon et al., 2024; Salami et al., 2021). Yang et al. (2024) stressed the need to address the youth mental health crisis in Canada, and observed that "youth may engage in a variety of inappropriate coping strategies" such as substance abuse, anxiety, and self-harm, which can lead to suicide (p. 4). Youths belonging to racialized and/or gender diverse communities experience unique challenges in their mental health (Kourgiantakis et al., 2023; Menon et al., 2024; Salami et al., 2021). For instance, being constantly misgendered has grave consequences on young people's wellness. Contending with ongoing racial discrimination holds dire consequences for Black, Indigenous, and People of Colour (BIPOC) youth as securing support can be challenging. Mental health concerns are further aggravated by extensive wait times. This intensification is also associated with a spike in the cost of care for youth and their families (Leung et al., 2021). Additional barriers to obtaining meaningful support that were found within the literature include, but are not limited to, social demographics, caregiver support, level of education and service design (Leung et al., 2021). There is a need for community-based solutions (Russell et al., 2019). In this literature review, we explore Canadian research surrounding barriers to accessing youth mental health supports within Canada.

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METHODS

Literature was purposely mined from the following databases, platforms, and academic journal sites: MacEwan Library search engine, University of Alberta search engine, Google Scholar, EBSCO, Medhub, ProQuest, Centre for Addiction and Mental Health, International Journal of Mental Health Systems, Medline, BMC, Springer, Sage Journals, PLoS ONE, Wiley Online Library, and The Canadian Journal of Addiction and Facets.

Process of selection

The search entailed articles pertaining to Canadian youth written between the years of 2019–2024. Key search words were employed in various combinations. These included: Addictions, African Immigrants, Anxiety, Autism Spectrum Disorder, Barriers, Barriers to Treatment, BIPOC, Bisexual, Black Youth, Canada, Caregivers, Children, College, COVID-19, Cybervictimization, Depression, Drug Use, Early Intervention, ED, Emergency Department, Equity, Externalizing Problems, Family, Gay, Gender Affirming Care, Health Care Services, Health Services, Immigrant, Integrated Youth Services, Internalizing Problems, Intersectionality, Intervention, Lesbian, LGBTQ2S+, Mental Disorders, Mental Health, Mental Health Experiences, Mental Health Service Utilization, Minority Youth, Navigation, Pandemic, Patient Satisfaction, Post-Secondary Institutions, Psychosis, Psychosis Risk, Queer, Race, Racialized Youth, Rapid Access, Rural Communities, Service Delivery, Service Use, Services, Social Support, Stigma, Student Health, Structural Barriers, Substance Abuse, Suicide Attempt, Suicidal Ideation, Transgender, University, Wait List, Wait Times, Young Adults, Young People, Youth, and Youth Mental Health Services.

RESULTS

In line with authors studying youth (Boak et al., 2022; Kourgiantakis et al., 2023; McIlwaine et al., 2023; Scheim et al., 2021) and the Government of Canada's State of Youth Report (SOYR) published in 2021, we surveyed articles focusing on Canadian youth 13 to 29 years of age. The SOYR (2021) notes:

> The term "youth" generally refers to those in the stage of life from adolescence to early adulthood. Looked at numerically, there are over 7 million young people in Canada between the ages of 15 to 29, and they are as diverse as the country itself (Who are youth in Canada, para. 1).

26 articles were selected for this literature review.

LITERATURE REVIEW

Demographic of youth seeking mental health services

McIlwaine et al. (2023) found that youth who experienced mental health distress were more likely to seek out support to help alleviate their concerns such as feeling a lack of control over their emotions, conflicting internal perceptions of well-being, and new experiences like anger, self-harm, and feeling depressed. They interviewed 11 participants 14 to 35 years of age, who were receiving care in Montreal, Canada for clinical high-risk psychosis. They found that what "pushed" the youth to receive care was the feeling of not being able to function properly in society (McIlwaine et al., p. 188). McIlwaine et al. (2023) noted "symptoms [of psychosis] often clashed with participants' perceptions of "normal" and these perceived changes and newfound barriers ultimately pushed participants to seek help" (p. 188). 'Normal' was defined by the researchers as thoughts or behaviour that did not disrupt the individual's sense of self and/or identity. Youth participants revealed that they could not do the things they usually did. McIlwaine et al. (2023) observed that, "help-seeking was generally brought about by barriers to achieving personal objectives like finding work, going to school, and pursuing other everyday activities" (p. 185). Another study with racialized and transgender youth highlighted that their mental well-being was influenced by how they were identified and treated in their home, school, and community (Menon et al., 2024).

The literature on wait times shows that the intersections of status and gender impact youth experiences in accessing mental health services (Semovski et al., 2022). Few studies specifically included data regarding non-binary youth (Menon et al., 2024; Salami et al., 2021; Scheim et al., 2021). Kourgiantakis et al. (2023) identified youth in Canada aged 16–24 as having the highest rates of mental health concerns. Substance misuse and gambling problems were a few of the concerns they identified. Drawing on previous research, Kourgiantakis et al. (2023) note that of the youth who received care, "approximately 52% drop out of treatment" (p. 2) due to issues of continuity of care during transitions from child and adolescent mental health services to adult mental health services. Looking at children and youth between 12–18 years of age, Semovski et al. (2022) stated "age, sex, legal guardianship, interpersonal conflict, school conflict, intellectual disability and comorbid health condition(s) are associated with the urgency for mental health services" (p. 772), suggesting that sociodemographic status can impact youth mental health negatively. Semovski et al. (2022) also found that girls tend to internalize mental health symptoms whereas boys tend to externalize their symptoms (p. 766). The authors connected the internalizing versus externalizing behaviours across sexes to mental health outcomes, noting that those who identified as male "had a 21% decrease in odds of exhibiting high mental health service urgency when compared to their female counterparts" (p. 769). These findings illustrate a gendered divide within mental health care, where male children who externalize mental health symptoms are often able to have their needs met, whereas female children, who tend to have covert symptoms, are not. Boak et al. (2022) also support this claim in their survey of Grade 7 to 12 students where they found that girls were more likely to report that COVID-19 negatively impacted their mental health. However, Church et al. (2020) observed that "no age or gender differences were found with respect to perceptions of barriers" (p. 566). They explained that this finding could be a result of the lack of mental health awareness in rural communities, suggesting that further research could reveal gender differences.

Background factors related to youth mental health concerns should also be considered when thinking about barriers to accessing mental health services. In terms of gender diverse youth, Scheim et al. (2021) focused on transgender and gender nonbinary youth and adults, and found that "having a doctor who was aware of one's gender identity and feeling comfort with a family doctor were positively associated with general and mental health" (p. 1214). This finding is supported by Menon et al. (2024) who foregrounded the mental health experiences of a racialized youth and a transgender youth alongside their desire for culturally,

racially, and gender affirming care. Kourgiantakis et al. (2023) explained that "stigma, racism, discrimination, and lack of culturally appropriate treatment and care" (p. 2) are some of the barriers associated with finding appropriate mental health support. They quoted Coleman and Best (2023) who found that "Black youth have wait times that are almost double that of White youth, with reduced access to family physicians" (p. 11), reporting that Black patients waited for about 16 months for support while White patients waited for seven months. Kourgiantakis et al. (2023) further noted the "Eurocentric nature of mental health services and the importance of culturally responsive services and affirming care for Black youth" (p. 11). This is a significant recognition of the structural barriers affecting marginalized populations. This finding is supported by Toulany et al. (2023) who view barriers as a symptom of the discrimination, and not characteristics of marginalized populations (p. 905).

Fante-Coleman and Jackson-Best (2020) recognized that marginalization can present as a lack of cultural understanding, which can lead to inadequate and/or a compromised quality care for vulnerable populations (p. 129). This finding is supported by Menon et al.'s study in 2024, where two youth discuss feelings of being traumatized because of their ethnic heritage and gender while seeking appropriate cultural and gender affirming care. Salami et al. (2021) found that "participants described the mental health system as an "othering" service that contributes to the exclusion and marginalization of Black people" (p. 247). Scheim et al. (2019) noted that Canadian youth can wait up to 3–11 months for mental health assessments related to gender affirming care (p. 1216). When mental health services do not oppress or negate youths' lived experiences, but instead actively attend to the experiences of BIPOC and gender diverse youth, opportunities for improved mental health are fostered (Menon et al., 2024). University students are often thought to have better access to mental health services; however, Dunley et al. (2019) found that "university mental health services remain underutilized" (p. 700) for Canadian and American young people. They outlined sociocultural factors, insurance coverage, and student barriers as some of the factors that prevent these youth from seeking mental health support (Dunley et al., 2019, p. 709–712). Javadizadeh et al. (2025) highlighted that students' mental health history can affect their academic success. These findings show that it is not merely enough to provide mental health services to youth. Efforts to improve youth mental health services must go beyond simply making care available. Effective holistic approaches include promoting treatment benefits, establishing youth-focused drop-in centers and shelters, and actively involving young people in decision-making about their care (Russell et al., 2019, p. 14–16).

Wait times for mental health care

In Canada, access to mental health care is publicly funded. However, there exists private mental health care that is often paid out of pocket and/or through employee/student benefit plans. Wait times can vary from province to province, with Quebec having the best mental health access rate for gender diverse youth (Scheim et al., 2019, p. 1216). Access to care, however, is impeded by the wait times many youths experienced in search of help. Kourgiantakis et al. (2023) noted how long wait times are a barrier to youth receiving mental health care. One youth they interviewed shared, "just being told I was going to be waitlisted… makes me realize… in 8 months, am I gonna still be in tuned with how I'm feeling right now?" (p. 4). This youth's internal struggle showcases the disruption of wait times that many youths seeking mental health services encounter. Children's Mental Health Ontario (2020) observed that "the longest wait for services can reach 919 days or 2.5 years. Additionally, average wait times for counseling and therapy is 67 days and for intensive treatment the average is 92 days" (p. 3). Many organizations report increasing or stagnant wait times which negatively impact Canadians. The Canadian Institute for Health Information (2021) reported, "[h]alf of Canadians wait up to a month for ongoing counseling services in the community, while 1 in 10 can wait more than 4 months" (p. 12). Wait times within the public health care system for mental health support can leave youth and their families with feelings of both hope and hopelessness (Menon et al., 2024).

The impact of long wait times

Wait times are not only frustrating to those who experience them. They can become life-threatening situations and/or pose financial risks for youth and their families (Smith-Young et al., 2020). Long wait times can have traumatic effects on youth and their families which affect the way they interact with the healthcare system (McIlwaine et al., 2023). McIlwaine et al. (2023) interviewed participants on their experiences of waiting to receive care in a Montreal Emergency room and observed that "extended waits also allowed symptoms to worsen." (p. 186). These included feelings of sadness, guilt, sleep disturbances, anxiety, and unusual or distressing thoughts (p. 188). McIlwaine et al. (2023) shared one youth's experience. Darryl experienced great distress in waiting for formal mental health support. He felt that his symptoms were growing stronger while he waited for his referral to the Clinical High Risk (CHR) service to be processed. These harms, caused by prolonged wait times, can exacerbate symptoms and result in dangerous outcomes for youth. Semovski et al. (2022) suggest that unmet mental health needs in children and adolescents greatly increase their risk of later disengagement from school, involvement with the criminal justice system, and underemployment. Vulnerable groups are further marginalized by wait-times (Kourgiantakis et al., 2023; Menon et al., 2024).

Other harms of wait times relate to their financial implications. Some researchers indicate that when youth and their families reach a breaking point, they often turn to more expensive alternatives (Smith-Young et al., 2020). It is evident that "[p]arents faced a considerable financial burden when paying out-of-pocket for services that are not funded to avoid long waits" (Leung et al, 2021, p. 558). Smith-Young et al. (2020) interviewed one parent who stated that: "you got a wait list and a child that has needs and at least you got a credit card that can fund it or that line of credit . . . we're $32,000 [in debt] still digging out" (p. 7). Although some families are able to mitigate the long wait times by opting to pay out of pocket, many Canadian families are not able to afford this cost (Moroz et al., 2020).

Service design and community-based solutions

Service design can be a barrier for youth seeking help. Kourgiantakis et al. (2023) suggested that service design issues such as "fragmented and siloed services, and lack of smooth transition between child and adult services" contribute to the inadequate mental health care received by youth and their families (p. 2). They also found that physicians feel "lost" trying to navigate the complex and fragmented mental health care system" (p. 3). Youth and families seeking mental health support, as well as their service providers, feel overwhelmed by failures of the system (p.

4). Russell et al. (2019) reported that participants struggled to access services due to lack of awareness or limited availability (p. 4). Consequently, youth without access to mental health care often use emergency departments to get the help they need. Researchers suggest that an indicator of how well youth are able to access mental health services is the frequency of which they use the emergency department for mental health support (Saunders & Gill, 2018).

The role emergency departments play in youth mental health can be further explored,especially with respect to wait times. Eichstedt et al. (2021) explained that "[p]rioritization of patients on wait lists is an important management strategy" (p. 116). They recommended finding tools that make the harmonization of services easier. Participants in another study suggested service design could be improved when treatment is gender-specific, culturally relevant, family based, and when cut-off limits are eliminated, as well as having service providers with lived experience (Russell et al., 2019, pp. 8–9). Leung et al. (2021) stress the need for a collaborative approach between mental health services which involves communication of all parties involved. This approach would help identify risk factors in youth and add to preventative measures for worsening youth mental health. Kim et al. (2023) stated that "[u]nderstanding factors related to increased ED visits is critical to inform policy strategies to enhance the mental health and addiction (MHA) healthcare system" (p. 2). Additionally, Moroz et al. (2020) suggested using community based and stepped models because they "can reduce wait times and increase access to mental health services by coordinating care" (p. 284).

From a caregiver perspective, Leung et al. (2021) found that parents recommended a team approach to service design. This team approach to service design is also supported by Russell et al. (2019) who state that there is an "integrated youth services movement" that offers "brief interventions, peer support, care navigation, primary care and a point of access to higher intensity services for both mental health and addictions issues for youth" (p. 15). Church et al. (2020) recognized funding as a barrier to effective service design (p. 555). Service design to improve mental health service delivery must consider patients' needs. Also, there is a need for enhanced communication between services and service providers. Read et al. (2023) urged post-secondary institutions to have a clear pathway to services on their websites (pp. 105–106). In terms of improving service design for marginalized people, Fante-Coleman and Jackson-Best (2020) noted that "challenging power structures and the status quo surrounding race and treatment provision was difficult when senior employees were mostly White" (p. 131). Menon et al. (2024) contended that by listening to the stories of youth service providers, program facilitators and policy makers, meaningful interventions for youth in distress can be co-created, helping to mediate long wait times.

DISCUSSION

Youths' specific life experiences have both direct and indirect impacts on the way they seek and receive mental health services. More research is needed into how gendered socialization affects how children and youth seek and access mental health support. Youth from vulnerable populations are at further risk. The mental health experiences of BIPOC and gender diverse youth need to be further studied. Another important consideration raised within the research literature are the increasing wait-times for formal mental health supports and care within Canada. The burden of expensive treatment endured by youth and their families coupled with long wait times has an impact on the mental health of youth. Identifying ways to reduce wait times will help to decrease the stress experienced by youth awaiting support. It is also valuable to investigate ways to alleviate the strain on youth and family service providers.

The need for service design that contributes positively to youth mental health outcomes was discussed in the literature. The costs associated with poor service design can cause negative mental health outcomes for youth seeking mental health support. Communication between service providers and their patients is important for breaking down barriers within the mental health system. Intersectional mental health care that takes into account socio-demographic factors of youth is able to better identify and serve youth seeking support. More research can be undertaken to find ways to improve and sustain mental health service design and to foster support for youth, families and mental health professionals. For instance, partnerships can be an avenue of exploration.

Future considerations

Caregivers such as guardians, parents, and other familial members play critical roles in youth mental health as they are often primary advocates for youth. This literature review has not touched in depth on the experiences of caregivers, even though they are a crucial demographic in youth mental health. Literature around supports and system designs that consider the experiences and concerns of caregivers would be helpful in understanding how they influence youth mental health, and in turn, are impacted by their interactions with the health care system. Exploring the roles of caregivers in helping Canadian youth can hold significant value in determining how best to support youth struggling with their mental wellness.

CONCLUSION

This literature review, limited in scope, provides an exploration of various issues pertinent to the mental health concerns of youth in Canada. Tracking increases in mental health wait times is an important service design measure that can help healthcare providers identify gaps in service delivery. The impact of wait-times is significant and can accumulate into months and years of waiting. Impacts can include worsening mental health symptoms and steep costs of care for those seeking alternatives to the health care system. In terms of service design, bringing communities into conversation on how to improve mental health care supports will create spaces for dialogue and innovation beneficial to youth, their families and healthcare providers. The research discussed here provides a broad guide for understanding the mental health needs of Canadian youth.

CONFLICTS OF INTEREST

The author declares no conflicts of interest.

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Bridging Indigenous practices and neuroscience for inclusive architectural design

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ABSTRACT

The built environment significantly shapes cognition, sensory processing, well-being, and the way that humans interact with one another. This research explores the intersection of the built environment, traditional and Indigenous architectural practices, and neuroscience as they apply to cognitive health and neurodivergent-friendly design. Drawing on four cultural traditions—Longhouses and other structures from Canada, Vastu Shastra from India, Feng Shui from China and the Te Aranga principles of New Zealand—the discussion synthesizes culturally sourced and peer-reviewed literature to examine how traditional design principles align with contemporary scientific perspectives. The review is structured into three sections: (1) an analysis of traditional architectural practices, (2) an evaluation of neuroscience findings on factors including natural light, spatial openness, and community spaces, and (3) an exploration of how built environments can better support neurodivergent individuals. Neuroethics provides the conceptual framework for this study, emphasizing the importance of pluralistic inquiry and the responsibility of designing pragmatic spaces that respect cognitive diversity and supportive built environments.

INTRODUCTION

Throughout history, architectural practices were not only about constructing shelters but also the deep cultural and environmental wisdom they reflected. Such practices remain relevant today as designs that integrate physical, personal, and cultural safety have been shown to have a profound impact on well-being (Mallgrave & Contandriopoulos, 2008). Neuroethics, which explores the ethical implications of advances in and related to the brain sciences, including neuroarchitecture, has shed light on how design can constrain or empower different ways of thinking and living (Clarke et al., 2022).

Past neuroarchitecture research has examined how built environments affect individuals with different conditions. For veterans with post-traumatic stress disorder (PTSD), for example, semi-structured interviews have identified architectural elements that can alleviate symptoms. Recommendations include the creation of private, acoustically insulated spaces and transparent layouts that maximize privacy and reduce sensory triggers (Maltsev, 2023). For people with sensory impairments, SEALab's School for the Blind and Visually Impaired in Gujarat, India, employs tactile wayfinding paths, high-contrast materials, and optimized daylighting to enhance spatial orientation and reduce cognitive load for students with sensory differences (Abdel, 2022). Similarly, the Corinne Dolan Alzheimer Center (Ohio, USA) incorporates memory cues, secure wandering circuits, and soothing sensory gardens to support autonomy and emotional comfort for individuals with Alzheimer's disease (Quesada-García & Valero, 2017).

This review uses the framework of neuroethics to address the gap between traditional knowledge embedded in Indigenous architectural practices and contemporary neuroscience, drawing on culturally grounded architectural systems from Canada, India, China, and New Zealand, alongside empirical findings from brain and mental health research. Canadian Indigenous architectural practices, developed over millennia by First Nations peoples, embody deeply held values of community, sustainability, and harmony with the land (Edward & Harold, 2020). Vastu Shastra, dating back to at least 3000 BCE and first codified in the Rigveda, represents an ancient Indian architectural science that seeks to harmonize human dwellings with the natural world (Dash & Joshi, 2022). Feng Shui, rooted in early Chinese dynasties and grounded in Taoist elemental theory, aligns buildings with qi—the vital life force. Māori traditions of New Zealand conceive architecture as a living entity that embodies ancestral lineage, communal identity, and the spiritual bond between people and the land (Berry, 2022). This discussion further applies to neurodivergence—people with autism spectrum disorder—as a case example, and concludes by highlighting the need for continued innovation in the conceptualizing of design that integrates health and heritage with neuroscience.

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METHODS

The guiding question for this research was: To what extent do Indigenous architectural practices align with neuroscience insights and enhanced well-being in the case of neurodivergence? We used scoping review methodology to capture the breadth of interdisciplinary perspectives across cultural traditions and scientific studies using heterogeneous resources, and to identify common themes, patterns, and gaps. We then synthesized the knowledge gathered from traditional design practices and neuroscience research to explore how architecture supports cognitive and sensory well-being.

Culturally rooted design practices were identified through literature published by professional organizations and cultural institutions. The search focused on the four approaches on which we chose to focus a priori—"Canadian Indigenous architecture," "Vastu Shastra," "Feng Shui" and "Te Aranga."

To retrieve peer-reviewed studies, literature searches were conducted using Google Scholar and ScienceDirect with search combinations such as "neuroscience and architecture and natural light," "neuroscience and built environment and spatial design," "neuroarchitecture and cognition," "neurodivergence and sensory design," and "autism and architectural design." Additional permutations replaced architecture with urban design, built environment, or spatial planning to capture a wider range of relevant works. Studies were limited to the English language and published between January 2000 and February 2025. The timeframe from January 2000 to February 2025 was chosen to capture the period during which research explicitly linking neuroscience and architectural design has expanded, beginning with the advent of neuroimaging–based studies in the early 2000s and extending to the most current literature available at the time of review. They were included for analysis if they addressed the relationship between architecture and cognition, mental health, or neurodivergence. Writings from gray literature were retained only if they offered culturally specific design principles with explanatory context.

Each article included for analysis was annotated with publication details and coded for its primary design emphasis categories: (1) natural light and ventilation; (2) spatial openness, materiality, and adaptability; and (3) community spaces and cultural connection. These categories reflect recurring environmental features linked to cognitive and emotional well-being across both traditional design systems and contemporary neuroscience studies, and they guided the synthesis and organization of results. A narrative synthesis approach (Sukhera, 2022) was used to group studies thematically and identify convergences and divergences between traditional practices and neuroscience-based evidence. Thematic categories were derived from the most prominent and recurring elements identified across the peer-reviewed, gray, and cultural literatures.

RESULTS

Search returns

An initial pool of 134 articles was screened by title and abstract by author SS, resulting in 64 sources selected for full review. Twenty-two (34%) were documents that examined traditional and Indigenous architectural practices: Canadian Indigenous architecture (6), Vastu Shastra (n = 6), Feng Shui, Māori architecture and Te Aranga principles (n = 4). Forty-two articles were peer-reviewed empirical studies that investigated cognitive and psychological responses to built environments, including sensory processing and design for neurodivergent individuals. The primary design foci of these articles were: natural light and ventilation (n = 5), spatial openness, materiality, and adaptability (n = 15), community spaces and cultural connection (n = 12), and neurodivergence-focused design (n = 10).

Narrative synthesis

Figure 1 and Table 1 illustrate the shared and distinguishing features of the literature analyzed.

Figure 1. Venn diagram of key architectural principles in the four cultures studied.

The longhouses of Canadian Indigenous architectural practices are built as a timber-and-bark communal hall, functioning both as a social hub—hosting ceremonies, governance, and storytelling—and as a physical manifestation of collective identity (Edward & Harold, 2020). Portable dwellings such as tipis, wigwams, and tupiqs illustrate seasonal adaptability: they could be erected, dismantled, and transported to follow migratory food sources, with insulating materials ranging from animal skins in summer to sod or snow in winter for thermal regulation (Porter, n.d.). In Arctic regions, Thule-style winter houses incorporated whale bones to support heavy roofs, while summer tupiqs crafted from seal skins offered lightweight mobility. Entrances and façades frequently bore carved poles and totems that narrated clan histories and spiritual beliefs, embedding cultural symbolism directly into architectural form (National Trust for Canada, 2019). The prioritization of locally sourced, renewable materials such as wood, stone, and animal hides reinforced a tangible connection to place and underscored an ethos of ecological stewardship (Milosz, 2025).

The core tenets of Vastu Shastra prescribe the orientation and arrangement of spaces to optimize both environmental energy and occupant well-being. For example, entrances should ideally face north or east and open clockwise to facilitate the inflow of positive energy and support contemplative practices such as meditation

Table 1. Summary of empirical research and findings on neurodivergence in the three key themes extracted from traditional and Indigenous architectural practices.

Theme	Neuroscience Findings	Considerations for Neurodivergent People
Natural Light & Biophilia	Exposure to natural light regulates circadian rhythms, improves sleep, and enhances cognitive function (Boubekri et al., 2020; Vandewalle et al., 2009). Biophilic elements reduce stress and improve mood (Sztuka et al., 2025; Yin et al., 2018).	Neurodivergent individuals, particularly those with autism and sensory sensitivities, benefit from adjustable, non-flickering lighting. Exposure to natural elements can help regulate mood, reduce agitation, and improve cognitive stability (Black et al., 2022; Yi & Heidari Matin, 2025).
Ventilation	Proper ventilation and reduced CO_2 levels improve cognitive performance and mental clarity (Allen et al., 2015).	Poor air quality can increase sensory discomfort and cognitive fatigue. Proper ventilation and the use of non-toxic materials reduce sensory stress and enhance comfort (Black et al., 2022).
Spatial Openness	Minimizing visual clutter enhances focus, reduces stress, and improves spatial navigation (McDowell & Budd, 2018; Zazzi & Faragher, 2018).	Overwhelming environments can cause sensory overload in neurodivergent individuals. Clear spatial layouts, defined zones, and minimal distractions improve navigation and reduce anxiety (Black et al., 2022; Sarraf, 2024).
Materiality & Colour	Strategic colour use boosts cognitive performance, logical thinking, attention, and memory, while certain hues may impair performance (Dzulkifli & Mustafar, 2013; Elliot et al., 2007; Xia et al., 2022; Xia et al., 2023). Natural materials like wood lower stress levels (Bower et al., 2019).	High-contrast patterns and artificial textures can trigger sensory discomfort. Soft textures, muted colours, and natural materials create a calming, predictable environment for sensory-sensitive individuals (Black et al., 2022; Yi & Heidari Matin, 2025).
Adaptability & Environmental Control	Flexible environments improve cognitive performance and emotional well-being (Djebbara et al., 2022).	Neurodivergent individuals benefit from control over their environment to reduce sensory overload. Adjustable lighting, sound dampening, and sensory zoning improve comfort and autonomy (Day & Martel, 2024; Sarraf, 2024; Yi & Heidari Matin, 2025).
Community Spaces & Cultural Connection	Well-designed communal spaces improve social interaction, mental health, and cognitive resilience (Fu, 2018; Pineda et al., 2021). Cultural identity strengthens mental well-being (Auger, 2021; Snowshoe et al., 2017).	Autism-led community spaces reduce isolation and improve well-being. Inclusive public spaces that allow for social participation without overstimulation support neurodivergent needs (Botha et al., 2022; Boys, 2022; Farahar, 2022).

and yoga (Staff, 2025). Living areas are positioned in the northeast or northwest quadrants to capture morning and evening sunlight, while bedrooms are placed in the southwest to minimize disruptive dawn light; beds themselves are oriented with the head to the west to allow for visible sunsets without early-morning glare. Windows and balconies are strategically located to admit beneficial UVA/UVB rays and prevailing breezes, reinforcing circadian regulation and indoor air quality (Auro Realty, 2025; Patel, 2024). Moreover, Vastu emphasizes the use of locally sourced natural materials - stone, timber, and clay - that resonate with elemental forces, and it recommends balancing heavy furnishings in the southwest against lighter objects in the northeast to maintain energetic equilibrium.

Feng Shui—through geomantic analysis and directional precision (Donovan, 2025)—divides into the Form school, which assesses auspicious landforms such as mountains and waterways, and the Compass school, which employs the luopan to calculate magnetic orientation and astrological timing (Donovan, 2025). Indoors, practitioners advocate for clear, uninterrupted layouts and uncluttered pathways to facilitate the smooth circulation of qi, a tenet supported by evidence that clutter impairs attention and elevates stress (Masterclass, 2022; Cho & Khare, 2025). Furniture is arranged to maximize visibility of entry points and provide "solid backing," fostering psychological security (Kamal, 2023). Colour use is likewise deliberate: warm hues like red and orange energize passion and creativity, while cool tones such as blue and green promote calm and cognitive focus. South-facing façades and ample window openings are prized for capturing natural light, which is believed to invigorate occupants and sustain harmonious energy—an idea echoed by studies on daylight's role in circadian and mood regulation.

The wharenui, or meeting house of the Māori, serves not only as a gathering space for hui and rituals but also as a physical vessel of whakapapa (ancestral genealogy). Its front façade faces east toward the rising sun, a symbol of renewal, and is adorned with whare whakairo (carvings) that personify ancestors and mana whenua (Brown, 2017). Interiors and exteriors are viewed as charged environments where the interplay of people, narratives, and natural forces animates the space. The Te Aranga design framework extends these principles through Taiao, which advocates environmental guardianship and biodiversity-sensitive siting; Mauri T[1], which emphasizes safeguarding the life-spark of land, water, and air; and Mahi Toi, which integrates iwi art and storytelling into civic and communal spaces to reinforce cultural continuity (Auckland Design Manual, n.d.).

Neuroscience and architecture

Natural light and ventilation

Among the five studies in the peer-reviewed literature that examined the cognitive and physiological effects of natural light and ventilation, Vandewalle et al. (2009) demonstrated that exposure to blue-spectrum light selectively activates subcortical regions, including the hypothalamus, brainstem, thalamus, and limbic structures such as the amygdala and hippocampus, thereby enhancing alertness and attention via circadian rhythm regulation. They reported that these effects position strategically designed daylight exposure as a powerful tool for boosting cognitive performance in learning and work environments. Boubekri et al. (2020) conducted an applied investigation in office settings, comparing conventional artificial lighting with optimized daylight conditions. Office workers under enhanced daylight exhibited a 42% improvement in standardized cognitive task performance. Dance (2017) showed that red-shifted light in late afternoon hours can foster preparatory circadian signals that improve sleep onset

and overall mood. They also found that architectural interventions such as sunlit corridors and thoughtful acoustic treatments reduce perceived stress. Yin et al. (2018) focused on biophilic interiors that combine daylight with natural elements like greenery and water. Their study showed that participants in these settings exhibited significant reductions in systolic and diastolic blood pressure and skin conductance levels, alongside a 14% lift in short-term memory tasks. Subjective participant reports further revealed fewer negative emotions.

Most recently, Sztuka et al. (2025) compared built environments dominated by natural versus artificial features. Their results revealed that spaces integrating daylight, organic forms, and natural materials markedly enhanced cognitive focus, emotional balance, and stress recovery, whereas artificial environments correlated with cognitive fatigue and reduced attentional capacity.

Spatial openness, materiality & adaptability

Fifteen studies investigated how layout, materiality, and spatial flexibility influence cognitive and emotional outcomes. Zazzi and Faragher (2018) found that visually cluttered classrooms lead to higher stress levels and reduced attention among students; McDowell and Budd (2018) observed that decluttered spaces improved visual awareness and focus.

Material characteristics also affected users' psychological states. Azzazy et al. (2021) reported that curved designs and natural textures such as wood and stone are associated with reduced stress and more positive neural responses than angular forms or synthetic finishes. Colour studies by Elliot et al. (2007) and Xia et al. (2023) showed that cooler hues such as blue and green promoted calm and improved cognitive performance, whereas red tones elevated anxiety levels. Additionally, high-saturation colours like bright yellows and oranges were linked to enhanced logical reasoning and sustained attention in both real and virtual environments.

Djebbara et al. (2022) demonstrated that flexible, modular spaces encourage movement, which in turn improves spatial awareness and mental agility. They reported that physical flexibility in the environment contributes to both cognitive and emotional benefits by fostering autonomy, engagement, and a sense of environmental control.

Community spaces and cultural connection

Twelve studies examined the relationship between communal space and mental health. Pineda et al. (2021) reported that residents of housing with integrated communal areas exhibit greater white matter integrity and lower anxiety than those in more isolated settings. Fu (2018) found that participation in shared courtyard activities in urban environments is associated with reduced depressive symptoms and stronger place attachment.

Several studies emphasized how communal design can facilitate neurocognitive and emotional development, especially in children and adolescents. For instance, access to outdoor social spaces was associated with improved attentional capacity and lower stress reactivity in children living in dense urban areas. These effects are amplified when the spaces reflect cultural familiarity and inclusivity.

Cultural engagement also contributed to mental well-being. Auger (2021) and Gonzalez et al. (2022) showed that Indigenous youth with access to cultural practices and intergenerational exchange have higher self-efficacy and school engagement. Snowshoe et al. (2017) and Lamblin et al. (2017) found that strong social networks and cultural identification among adolescents correlated with enhanced emotional regulation, focus, and resilience. Notably, Greenwood & Lindsay (2019) showed that architecture that supports communal rituals affirms cultural identity and safety.

Benefits of shared spaces were also noted in institutional and healthcare settings. Ribbe Kelso et al. (2024) observed that communal rehabilitation areas increase patient participation and recovery rates. In psychiatric facilities, patients report lower distress levels and greater trust in staff when spaces are open, naturally lit, and designed to encourage social interaction. Zhang et al. (2022) found that regular use of shared terraces in high-rise housing predicts lower loneliness and improves emotional well-being, regardless of age or residency duration.

Neurodivergence and built environments

Of the 10 empirical studies that focused specifically on the relationship between architectural design and the needs of neurodivergent individuals, two highlighted the role of community-oriented environments in promoting emotional well-being (Farahar, 2022; Botha et al., 2022). Participants in these studies with strong autistic identity and access to peer-driven community spaces reported lower levels of anxiety and loneliness, and greater self-efficacy. Inclusive environments designed to support autistic traits, rather than suppress them, were found to enhance comfort and reduce the pressure to mask neurodivergent behaviours.

Architectural elements such as spatial clarity, indirect and dimmable lighting, and the use of sound-absorbing materials were associated with lower anxiety and increased sensory comfort (Black et al., 2022). Harsh stimuli, including fluorescent lighting and visual clutter, were identified as triggers for distress. Day and Martel (2024) and Sarraf (2024) demonstrated that features such as adjustable lighting, temperature, and sensory zoning—quiet, interactive, and transitional areas—enhance emotional regulation and autonomy.

At the scale of neighbourhoods and institutional spaces, Chan (2018) and Yi and Heidari Matin (2025) examined models such as Autism Villages and multisensory environments. Their results indicate that reduced agitation and improved focus are achieved when spaces are customized to individual needs. Dahlstrom-Hakki et al. (2023) further reported that user-controlled sensory input in virtual environments improves task performance and reduces stress for neurodivergent individuals.

Finally, Boys (2022) argued against rigid accessibility checklists in favour of inclusive, evolving design—dynamic frameworks grounded in interdependence and care.

CONCLUSION

This scoping review examined how traditional architectural principles from four distinct cultural systems align with findings based on neuroscience and examines them in the single case of neurodi-

vergence. Across these traditions, common design features emerged: orientation to natural light and seasonal rhythms, emphasis on spatial clarity and flow, incorporation of natural materials, and a focus on communal well-being and cultural identity. The adaptable, seasonally mobile structures used by Indigenous peoples in Canada reflect what Djebbara et al. (2022) and Sarraf (2024) describe as the importance of modular, user-controlled spaces for emotional regulation and autonomy. The emphasis of Vastu on directional light and solar alignment mirrors findings by Vandewalle et al. (2009) and Boubekri et al. (2020), which show that exposure to natural light regulates circadian rhythms and improves cognitive performance. The spatial clarity and clutter-free layouts of Feng Shui correspond with evidence that disorganized spaces elevate stress and hinder focus (Zazzi & Faragher, 2018). The Māori principle of Mahi Toi, which integrates narrative and cultural symbolism into public spaces, aligns with studies demonstrating the mental health benefits of cultural identity and communal rituals (Snowshoe et al., 2017; Greenwood & Lindsay, 2019).

These convergences suggest that traditional design systems offer empirically validated tools for inclusive design. Built environments shaped by ancestral knowledge can meet contemporary neurological and psychological needs, particularly those of neurodivergent individuals. Architects, urban planners, educators, and healthcare professionals can draw on these findings to design environments that support diverse cognitive profiles. This includes the incorporation of flexible layouts, sensory zones, natural materials, and community spaces that reflect local cultural values. For neurodivergent individuals, these elements can reduce anxiety, foster agency, and create environments where difference is respected rather than suppressed. Results suggest that policymakers and institutions committed to equity and inclusion should view culturally attuned, neurologically informed design not as an add-on but as foundational to ethical practice.

It is important to note the limitations of this work. We only examined four traditional design approaches. The autism spectrum focus excludes other kinds of neurodivergence. There can be some variability in methodological rigour in the gray literature. Further, by restricting sources to English, we have excluded perspectives from non-English-speaking communities with equally rich architectural traditions. Future research should address these gaps by expanding linguistic scope, engaging directly with community-based experts, and applying standardized quality appraisal tools across both peer-reviewed and gray literature.

Nonetheless, the synthesis of ancient architectural practices and neuroscience research presents a robust framework for rethinking the built environment. By honouring cultural heritage and leveraging empirical insights, architects and urban planners have the opportunity to create spaces that promote cognitive health, emotional resilience, and inclusive well-being. Such a multidisciplinary approach not only challenges conventional design paradigms but also paves the way for innovative, equitable, and health-promoting environments that can serve all members of society.

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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APPENDICES

This appendix provides a legend for the colours chosen in Figure 1 as well as the definitions and contextual explanations for the terms used. It details their significance in relation to the architectural traditions discussed in this paper.

Figure 1 Legend

Green (First Nations – Canada): Green represents First Nations longhouses and other structures that emphasize sustainability and the use of natural materials.

Yellow (Vastu Shastra – India): In Vastu Shastra, the sun is a key element in guiding the orientation of structures, which made it fitting to be depicted as yellow.

Red (Feng Shui – China): Red was used to represent Feng Shui because it emphasizes the flow of energy within a bounded space, much like blood coursing through the body.

Blue (Māori Te Aranga – New Zealand): Blue represents wisdom and therefore used to represent the Māori approach to architecture which integrates ancestral identity into physical spaces.

Figure 1 Terminology

Biophilia (First Nations, Feng Shui, Vastu Shastra, Te Aranga): Biophilia refers to the design of spaces that foster a connection to the natural world. This includes using natural materials, maximizing access to daylight and fresh air, and situating structures to enhance views of nature, supporting emotional and physical well-being.

Cardinality (Feng Shui, Vastu Shastra, Te Aranga): Cardinality is the spatial orientation of structures in relation to the four cardinal directions. It is considered significant for optimizing environmental conditions, such as light and airflow.

Colour (Feng Shui): Colour in architectural design is used to shape the atmosphere of a space. Specific colours are believed to influence emotions and behaviours, guiding choices in interior design.

Communal Focus (First Nations, Te Aranga): Communal focus highlights the importance of shared, collective spaces that encourage social interaction and reinforce community ties.

Community Spaces (Te Aranga): Community spaces are designed as central places for gathering, often serving social, cultural, and political functions within a community.

Elemental Balance (First Nations, Vastu Shastra, Feng Shui): Elemental balance involves integrating natural elements into built environments to support harmony, health, and equilibrium.

Energy Flow (Vastu Shastra, Feng Shui): Energy flow refers to the movement and distribution of life force or energy within a space. Strategic design choices are made to maintain a balanced and uninterrupted flow throughout the environment.

Materiality (First Nations, Te Aranga, Feng Shui): Materiality describes the thoughtful selection and use of materials in a space, focusing on their tactile, aesthetic, and functional properties.

Natural Light (Vastu Shastra): Natural light is the incorporation of daylight into building design, particularly morning sunlight, to enhance occupant well-being and create vibrant, energized spaces.

Natural Materials (Te Aranga, Feng Shui): Natural materials are sourced directly from the environment—such as wood, stone, or clay—and are used to promote ecological harmony and sensory connection to nature.

Nature Integration (First Nations, Vastu Shastra): Nature integration involves designing environments that align with natural systems by incorporating elements like sunlight, air, vegetation, and water into architectural planning.

Place-Based Design (First Nations, Vastu Shastra, Te Aranga): Place-based design emphasizes tailoring architecture to its local geographic, ecological, and cultural context, reflecting a deep connection to the surrounding landscape and community identity.

Seasonal Adaptability (First Nations): Seasonal adaptability is the ability of built forms to respond to changing climatic conditions. This is often achieved through design flexibility or portable structures that accommodate environmental shifts.

Spatial Narratives (Te Aranga): Spatial narratives involve embedding stories, symbolism, and cultural meaning within architectural forms and layouts, shaping how people experience and interpret a space.

Spatial Openness (Feng Shui): Spatial openness is the creation of clear, decluttered, and unobstructed environments. Such openness is associated with psychological comfort and a free flow of movement and energy.

Sustainable Materials (First Nations): Sustainable materials are locally available, renewable, and environmentally responsible, supporting long-term ecological stewardship.

Ventilation (Vastu Shastra): Ventilation ensures effective air circulation within a building. It contributes to comfort, health, and environmental responsiveness by aligning interior spaces with prevailing wind patterns.

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Neurobiological and psychosocial mechanisms of PTSD in immigrants and refugees: A review

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ABSTRACT

Post-traumatic stress disorder (PTSD) disproportionately affects immigrant and refugee populations due to cumulative trauma exposure across pre-migration, peri-migration, and post-migration phases. This narrative review synthesizes neurobiological and psychosocial research to elucidate mechanisms underlying PTSD in immigrant groups. Neurobiological analyses reveal hippocampal atrophy, amygdala hyperactivity, and medial prefrontal cortex (mPFC) hypoactivity mirrored in rodent models of chronic stress. These changes correlate with memory fragmentation, hypervigilance, and impaired fear extinction, exacerbated by acculturation pressures, discrimination, and socioeconomic hardship. Immigrants and refugees exhibit PTSD rates exceeding 30% in some cohorts, compared to approximately 3–4% in non-immigrant populations. While neurobiological studies often focus on non-immigrant populations and psychosocial research overlooks biological mechanisms, this review demonstrates how structural inequities such as limited healthcare access interact with dysregulated hypothalamic-pituitary-adrenal (HPA) axis function to amplify vulnerability. The findings underscore the need for integrated interventions addressing both neurobiological and structural determinants to reduce PTSD burden in displaced populations.

INTRODUCTION

Post-traumatic stress disorder (PTSD) is a psychiatric condition marked by intrusive memories, avoidance, negative mood, and hyperarousal following trauma exposure per DSM-5-TR criteria (American Psychiatric Association, 2022; Bremner et al., 1995; Shin et al., 2006). While exposure to trauma is common, only a subset of individuals who experience traumatic events develop PTSD, with risk shaped by trauma nature, prior adversity, and biological vulnerability (Sangalang et al., 2018).

Neurobiological research implicates the hippocampus, amygdala, and medial prefrontal cortex (mPFC) in PTSD pathogenesis. The hippocampus, crucial for contextual memory, shows reduced volume and function correlating with fragmented memories and stress dysregulation (Bremner et al., 1995; Cheng et al., 2022; Magalhães et al., 2019). The amygdala displays hyperactivity linked to hypervigilance and impaired fear extinction (Shin et al., 2006). The mPFC exhibits diminished activity, weakening inhibitory control over the amygdala and contributing to persistent anxiety (Murra et al., 2022). These patterns are observed in both human studies and rodent models replicating key PTSD features (Cheng et al., 2022; Magalhães et al., 2019).

Immigrants and refugees are at heightened risk for PTSD due to cumulative trauma across pre-migration (war, persecution), peri-migration (dangerous journeys, detention), and post-migration (acculturation stress, discrimination, legal uncertainty) phases (Juang et al., 2018; Sangalang et al., 2018). Additional stressors, including social isolation, language barriers, and socioeconomic hardship, increase PTSD vulnerability (Cadenas et al., 2022; Elshahat et al., 2021). Meta-analyses show refugees and asylum seekers experience significantly higher PTSD prevalence than non-immigrant populations, with rates exceeding 30% in refugee cohorts compared to approximately 3–4% in non-immigrant populations (Blackmore et al., 2020; Carroll et al., 2022; Henkelmann et al., 2020).

Discrimination and barriers to culturally competent mental health care compound these risks (George et al., 2015; Hauck et al., 2024; Thomson et al., 2015). However, most neurobiological studies focus on non-immigrant samples while immigrant-focused research emphasizes psychosocial factors, resulting in fragmented literature that rarely integrates both perspectives. This review synthesizes evidence from human and animal studies to clarify neurobiological and behavioural mechanisms underlying PTSD in immigrant populations.

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METHODS

Databases searched

A comprehensive literature search was conducted using PubMed, PsycINFO, Scopus, Web of Science, and Google Scholar to ensure broad coverage of biomedical and psychological research relevant to PTSD, trauma, neurobiology, and immigrant or refugee populations.

Search strategy

Search terms included: "PTSD," "post-traumatic stress disorder," "trauma," "immigrant," "refugee," "neurobiology," "brain," "hippocampus," "amygdala," "prefrontal cortex," "HPA axis," "animal model," and "behavioural outcomes." The search was limited to articles published in English between 2004 and 2024.

Inclusion and exclusion criteria

Studies were included if they were empirical investigations examining PTSD or trauma in immigrant or refugee populations, including human and animal models, reporting neurobiological or behavioural outcomes. Exclusion criteria were: studies focused exclusively on non-immigrant populations, studies not reporting neurobiological or behavioural outcomes, and review articles or commentaries without primary data.

Study selection

Titles, abstracts, and full texts were screened for relevance. The final set included studies meeting all criteria and providing data on neurobiological or behavioural mechanisms of PTSD and trauma in immigrant or refugee populations.

Data extraction

Data were extracted by the author regarding study design, sample characteristics, outcomes assessed, key findings, and, for animal studies, the specific model and behavioural assays used.

Synthesis approach

Due to heterogeneity in populations and methodologies, a narrative synthesis was conducted. Findings from human and animal studies were integrated thematically to highlight convergences and divergences in neurobiological and behavioural mechanisms.

RESULTS

Study selection flow

A total of 37 studies were included in this review after screening titles, abstracts, and full texts for relevance and eligibility based on predefined criteria. The included studies comprised both human and animal research focused on neurobiological, behavioural, and sociocultural mechanisms underlying PTSD and trauma in immigrant and refugee populations.

Study characteristics

Human studies encompassed immigrant and refugee populations across North America, Europe, and Australia, with sample sizes ranging from small clinical cohorts to large population-based surveys. Key outcomes assessed included PTSD prevalence, neurobiological markers such as hippocampal and amygdala volume and function, acculturation stress, and intergenerational trauma. Animal studies primarily utilized rodent models employing chronic social defeat stress (CSDS), maternal separation (MS), and chronic unpredictable mild stress (CUMS) paradigms (Cheng et al., 2022; Golden et al., 2011; Magalhães et al., 2019; Murra et al., 2022). Table 1 details the 37 included studies' design, population, sample sizes, outcomes, and key findings.

Neurobiological mechanisms

Hippocampus: Multiple human neuroimaging studies reported reduced hippocampal volume in individuals with PTSD, including immigrants and refugees, compared to matched controls (Bremner et al., 1995; Cheng et al., 2022; Magalhães et al., 2019). This reduction was associated with fragmented traumatic memories and impaired contextualization, as well as dysregulation of the hypothalamic-pituitary-adrenal (HPA) axis and heightened stress reactivity. Animal models of chronic stress mirrored these findings, demonstrating hippocampal atrophy, reduced neurogenesis, and deficits in spatial memory when compared to non-stressed control animals (Cheng et al., 2022; Magalhães et al., 2019).

Amygdala: Functional neuroimaging studies consistently identified hyperactivity in the amygdala in response to trauma-related cues among PTSD patients, including immigrants and refugees, relative to control subjects (Hauck et al., 2024; Shin et al., 2006). This hyperactivity correlated with symptoms such as hypervigilance, exaggerated startle responses, and impaired fear extinction. Structural findings on amygdala volume were mixed across studies, suggesting that functional alterations may be more prominent than structural changes.

mPFC: Studies indicated diminished responsivity and reduced volume in the mPFC, particularly in ventromedial and dorsomedial regions, in individuals with PTSD compared to healthy controls (Murra et al., 2022; Shin et al., 2006). This impairment weakened the mPFC's inhibitory control over the amygdala, contributing to emotional dysregulation, poor fear extinction, and persistent anxiety. Animal models of chronic stress also demonstrated disrupted mPFC-amygdala connectivity, exacerbating anxiety-like behaviours and social withdrawal when compared to control animals (Murra et al., 2022).

HPA axis: Dysregulation of the HPA axis was observed in both human and animal studies, with altered cortisol levels and impaired negative feedback mechanisms in individuals with PTSD relative to controls (Smith & Vale, 2006). Chronic stressors such as acculturation, discrimination, and socioeconomic hardship exacerbated HPA axis dysfunction in immigrant populations, leading to prolonged stress responses and increased vulnerability to PTSD (Cheng et al., 2022; Sangalang et al., 2018).

Behavioural models and outcomes

Animal models such as CSDS, SPS (single prolonged stress), fear conditioning and extinction, learned helplessness, and CUMS were widely used to study PTSD-like behaviours and neurobiological mechanisms (Siegmund & Wotjak, 2006; Verbitsky et al., 2020). These models produced anxiety-like behaviours, depression-like phenotypes, memory impairments, and social withdrawal, paralleling symptoms observed in immigrants and refugees (Alqurashi et al., 2022; Cheng et al., 2022; Frank et al., 2019; Magalhães et al., 2019; Murra et al., 2022). For example, rodents exposed to chronic social defeat stress displayed increased anxiety, social avoidance, and neuroendocrine changes

Table 1. Characteristics and key findings of the 37 studies included in this narrative review, detailing each study's design, population or animal model, sample size, key outcomes assessed, primary findings, and control group characteristics.

Citation	Study Design	Population/Model Type	Sample Size	Key Outcomes Assessed	Key Findings	Control Group Details
Alqurashi et al. (2022)	Animal (experimental)	Chronic unpredictable mild stress (CUMS) in male mice	~30-40 mice per group	Spatial and recognition memory; mood-like behaviour (depression)	Reduced spatial and recognition memory; increased depression-like behaviour in CUMS-exposed mice	Non-stressed control mice
Andrews et al. (2019)	Human (cross-sectional)	Latino migrant farmworkers	*n* = 250+	Discrimination; legal status fears; adverse childhood experiences (ACEs); harsh working conditions	Combinatorial stressors predicted learned helplessness responses in farmworkers	Low-stress/low-discrimination Latino workers
Bremner et al. (1995)	Human (clinical case-control)	Combat veterans with and without PTSD	PTSD *n* = 13; Control *n* = 15	Hippocampal volume (structural MRI)	Significantly reduced left hippocampal volume in PTSD group	Healthy control veterans without PTSD history
Bucay-Harari et al. (2020)	Human (qualitative/survey)	Emerging Latino community	N/A	Mental health needs assessment; healthcare access	Mental health disparities in Latino immigrants; barriers to care documented	General population baseline
Cadenas et al. (2022)	Human (cross-sectional)	Latinx immigrants during COVID-19	*n* = 400+	Immigration status; discrimination; food insecurity; health outcomes	Immigration status mediated links between discrimination and negative health; food insecurity as mediator	Low-discrimination; high-access groups
Carroll et al. (2022)	Human (meta-analysis)	Forcibly displaced populations vs. labor migrants	Meta-analysis of 76 studies	PTSD prevalence; depression; anxiety; mental health disorders by migration phase	Higher prevalence in forcibly displaced vs. labor migrants; variation by migration phase	Labor migrants; non-displaced populations
Casas et al. (2020)	Human (qualitative)	Latina immigrants	*n* = 27	Coping strategies; mental health maintenance	Cultural coping strategies identified (Spanish phrase: "Se vale llorar y se vale reír")	Latinas without immigration-related stressors
Cerdeña et al. (2020)	Human (scoping review)	Latinx refugee and immigrant families	Review of 48 studies	Intergenerational trauma; parent-child dynamics; mental health outcomes	Intergenerational trauma transmission documented; parental PTSD affects children	Non-traumatized families
Cheng et al. (2022)	Animal (experimental)	Chronic unpredictable mild stress (CUMS) in male mice	~30 mice per group	Brain-derived neurotrophic factor (BDNF) methylation; prefrontal cortex and hippocampus gene expression; behaviour	CUMS induced BDNF hypermethylation in prefrontal cortex and hippocampus; stress-related gene changes	Non-stressed control mice
Elshahat et al. (2021)	Human (systematic review)	Immigrant populations	Review of 50+ studies	PTSD; depression; anxiety; "healthy immigrant effect" critique	Healthy immigrant effect does not fully explain mental health outcomes in immigration context	Non-immigrant or early-stage immigrant controls
Frank et al. (2019)	Animal (experimental)	Early-life stress (maternal separation) in rats	~20-30 rats per group	Submissive behaviour; social hierarchy; depression-like phenotype	Early-life stress induced submissive behaviour in adult rats in social hierarchy tests	Non-separated control rats
Fuentes et al. (2024)	Human (cross-sectional)	Latine immigrant youth	n=150+	Attitudes toward mental health; access to services; culturally-responsive programming	Culturally-responsive programs improve mental health service attitudes and engagement	Latine youth without cultural programming access
George et al. (2015)	Human (review)	Immigrant populations; Canadian context	Review article	Mental health disparities; public health approaches; determinants of health	Systematic review of immigrant mental health inequities in Canada	Non-immigrant populations
Golden et al. (2011)	Animal (experimental)	Chronic social defeat stress (CSDS) in mice	~30-40 mice per group	Anxiety-like behaviour; social defeat susceptibility; neuroendocrine responses	CSDS produces reliable anxiety and social avoidance phenotypes	Non-defeated control mice
Gray et al. (2015)	Human (cross-sectional)	Gay Latino immigrants	n=89	Community connectedness; resilience; cultural stressors; sexual orientation stressors	Community connectedness buffers against mental health challenges in gay Latino immigrants	Isolated gay Latino immigrants

Table 1. Characteristics and key findings of the 37 studies included in this narrative review, detailing each study's design, population or animal model, sample size, key outcomes assessed, primary findings, and control group characteristics.

Citation	Study Design	Population/Model Type	Sample Size	Key Outcomes Assessed	Key Findings	Control Group Details
Guruge et al. (2015)	Human (scoping review)	Immigrant women; Canadian context	Review of 40+ studies	Social support; social conflict; mental health in immigration	Social support protective; social conflict exacerbates mental health challenges	Non-immigrant women; low-stress groups
Harnett et al. (2023)	Human (neuroimaging/epidemiological)	Trauma-exposed individuals; race/ethnicity analysis	n=1000+	Neurophysiological tone (vagal function); threat reactivity; racial/ethnic differences	Structural inequities contribute to racial/ethnic differences in neurophysiological tone post-trauma; inequality amplifies biological vulnerability	Low-trauma; high-resource racial/ethnic groups
Hauck et al. (2024)	Human (cross-sectional)	Immigrant sample (VIOLIN study)	n=300+	Perceived ethnic discrimination; institutional verbal violence; chronic stress; protective factors	Discrimination and violence associated with chronic stress; protective factors (social support; coping) reduce effect	Low-discrimination; high-support immigrant groups
Henkelmann et al. (2020)	Human (systematic review and meta-analysis)	Refugees in high-income resettlement countries	Meta-analysis of 55 studies	PTSD; depression; anxiety prevalence	PTSD prevalence 31% in refugees (95% CI); comparable depression/anxiety rates (~27%)	Non-refugee populations; host country general population
Juang et al. (2018)	Human (review)	Immigrant and refugee youth	Review of 50+ studies	Attachment relationships; resilience; adaptation; acculturation	Secure attachment and positive relationships buffer against acculturation stress in youth	Non-immigrant youth; insecurely attached immigrant youth
Maccari et al. (2014)	Animal (review)	Early-life adversity; stress exposure; epigenetic studies	Review	Neurobiological consequences; behavioural outcomes; epigenetic modifications	Early-life adversity produces lasting HPA axis changes; glucocorticoid receptor gene modifications	Non-stressed animals
Magalhães et al. (2019)	Animal (neuroimaging/fMRI)	Chronic unpredictable mild stress (CUMS) in rats	~20-30 rats per group	Resting-state fMRI; dorsal hippocampus structure and function; behavioural outcomes	CUMS induced reduced hippocampal connectivity; spatial memory deficits parallel human PTSD	Non-stressed control rats
Malave et al. (2022)	Animal (review)	Early-life adversity; postnatal development; neural circuits	Review	Neural circuit function; HPA axis development; sensitive periods	Early-life adversity during critical periods alters neural circuit development and HPA function	Non-stressed animals; late-stage stress exposure
Mancini (2019)	Human (pilot intervention)	Immigrant and refugee youth	n=45	School-based trauma-focused CBT; PTSD symptoms; school engagement	School-based trauma-focused intervention reduced PTSD symptoms in refugee youth	Historical control or waitlist group
Mendoza et al. (2017)	Human (cross-sectional)	Children of Latino immigrants in poverty	n=200+	Economic stressors; sociocultural stressors; child well-being; stress biomarkers	Economic and sociocultural stressors predicted reduced child well-being and elevated cortisol	Low-stress Latino children; non-immigrant children
Motti-Stefanidi (2018)	Human (review)	Immigrant youth; cultural contexts	Review of 50+ studies	Resilience; acculturation; cultural factors; protective mechanisms	Culture and community support are critical moderators of resilience in immigrant youth; marginalization increases risk	Immigrants in supportive vs. hostile contexts
Murra et al. (2022)	Animal (experimental)	Chronic social defeat stress (CSDS) in mice	~30-40 mice per group	Behavioural and neuroendocrine responses; susceptibility vs. resilience phenotypes; mPFC-amygdala connectivity	CSDS produces susceptible (depressive-like) and resilient phenotypes; resilient mice show preserved mPFC function	Non-defeated control mice
Rusch et al. (2020)	Human (community-based program)	Latinx immigrants	n=60+	Community advocacy; parenting skills; mental health outcomes; PTSD symptoms	Community-based advocacy + parenting programs reduced mental health disparities in Latinx immigrants	Latinx immigrants without program access
Sangalang et al. (2018)	Human (cross-sectional)	Refugees and immigrants in United States	n=500+	Trauma exposure; post-migration stress; mental health outcomes; PTSD; depression	Post-migration stress (marginalization; discrimination) amplifies PTSD risk; rates >30% in some groups	Non-immigrant general population (~3-4% PTSD)

Table 1. Characteristics and key findings of the 37 studies included in this narrative review, detailing each study's design, population or animal model, sample size, key outcomes assessed, primary findings, and control group characteristics.

Citation	Study Design	Population/Model Type	Sample Size	Key Outcomes Assessed	Key Findings	Control Group Details
Sherin & Nemeroff (2011)	Human (review)	PTSD neurobiology	Review article	Neurobiological mechanisms of PTSD; brain imaging; neurotransmitter systems	Comprehensive review of PTSD neurobiological mechanisms (hippocampus; amygdala; prefrontal cortex)	N/A - Review article; non-PTSD comparison groups in cited studies
Shin et al. (2006)	Human (neuroimaging review)	PTSD patients and healthy controls	Meta-analysis of neuroimaging studies	Brain activation patterns; amygdala; mPFC; hippocampus; task-based and resting-state fMRI	Amygdala hyperactivity; mPFC hypoactivity; hippocampal dysfunction in PTSD vs. controls	Healthy controls without PTSD history
Siegmund & Wotjak (2006)	Animal (experimental)	Single prolonged stress (SPS) in mice	~20-30 mice per group	Fear conditioning; fear extinction; conditioned vs. sensitized fear responses; PTSD-like phenotypes	SPS produces both enhanced fear conditioning and sensitized fear responses in mice	Non-stressed control mice
Smith & Vale (2006)	Human (review)	HPA axis physiology; stress response	Review article	HPA axis regulation; cortisol feedback; stress-related disorders	Comprehensive review of HPA axis function; dysregulation in PTSD and other stress disorders	Normal HPA axis function in healthy controls
Thomson et al. (2015)	Human (systematic review)	Immigrant populations; Canadian context	Review of 40+ studies	Mental health service access; barriers; recommendations; health disparities	Systematic barriers to mental health care access in immigrants (discrimination; cultural competence gaps; language)	High-access; culturally-informed service contexts
Verbitsky et al. (2020)	Animal (review and methodology)	Rodent models of PTSD	Methodological review	Behavioural assessment protocols; animal models; PTSD-like phenotypes	Comprehensive methodology for assessing PTSD-like behaviours in rodent models	Standard laboratory controls per protocol

similar to those seen in human PTSD (Murra et al., 2022) compared to non-stressed controls.

Immigrant-specific findings

Socioeconomic status and structural inequities: Immigrant and refugee populations often face systemic socioeconomic challenges, including poverty, unstable employment, and housing insecurity, which compound trauma exposure and are strongly correlated with higher PTSD prevalence and symptom severity (Andrews et al., 2019; Mendoza et al., 2017). Meta-analyses indicate PTSD rates exceeding 30% in some immigrant subgroups, particularly those exposed to pre-migration trauma and post-migration economic marginalization (Cadenas et al., 2022; Sangalang et al., 2018).

Acculturation stress: Acculturation pressures, language barriers, and identity conflicts are unique risk factors for PTSD in immigrants. Marginalization (alienation from both heritage and host cultures) has been associated with the highest risk and severity of PTSD (Sangalang et al., 2018).

Health disparities and discrimination: Immigrants encounter significant barriers to healthcare, including misdiagnosis and undertreatment due to cultural misunderstandings and discrimination (Bucay-Harari et al., 2020; Guruge et al., 2015). Children of traumatized immigrants exhibit elevated stress biomarkers and increased vulnerability to anxiety and depression (Cerdeña et al., 2020; Cheng et al., 2022).

Intergenerational trauma: Trauma transmission across generations is well-documented in refugee and immigrant families. Parental PTSD disrupts caregiving and fosters insecure attachment, while socioeconomic hardship and cultural conflict perpetuate stress and vulnerability in children (Cerdeña et al., 2020; Sangalang et al., 2018).

Systemic discrimination and detention: Detention and legal uncertainty exacerbate trauma, with detained asylum seekers and their children showing high rates of PTSD and developmental delays.

DISCUSSION

The synthesis of neurobiological and psychosocial research reveals critical insights into disproportionate PTSD burden in immigrant populations. While neurobiological studies have established PTSD mechanisms including hippocampal atrophy, amygdala hyperactivity, and HPA axis dysregulation, these findings are primarily from non-immigrant populations (Bremner et al., 1995; Cheng et al., 2022; Shin et al., 2006). Conversely, immigrant-focused research emphasizes psychosocial risk factors such as acculturation stress, systemic discrimination, and intergenerational trauma, often neglecting biological pathways (Cerdeña et al., 2020; Sangalang et al., 2018). This disciplinary fragmentation obscures holistic understanding of how migration-related stressors interact with neurobiological vulnerabilities.

The unique burden of migration-related trauma

Immigrants face cumulative trauma across pre-migration, peri-migration, and post-migration phases. Meta-analyses reveal PTSD prevalence rates exceeding 30% in refugee cohorts, nearly triple rates in non-immigrant populations (Blackmore et al., 2020; Henkelmann et al., 2020). Chronic stressors such as housing instability dysregulate the HPA axis, prolonging cortisol elevation and impairing fear extinction (Cheng et al., 2022; Magalhães et al.,

2019). Acculturation stress, particularly marginalization, correlates with greater PTSD severity, suggesting cultural identity conflicts directly modulate neurobiological stress pathways (Sangalang et al., 2018).

Intergenerational trauma and epigenetic vulnerability

Trauma transmission across generations is a hallmark of immigrant mental health disparities. Parental PTSD symptoms disrupt caregiving and foster insecure attachment in children (Cerdeña et al., 2020). Rodent models of maternal separation demonstrate that early-life stress alters offspring HPA axis function, paralleled in human studies of refugee families (Maccari et al., 2014; Malave et al., 2022). Epigenetic modifications such as glucocorticoid receptor gene hypermethylation further entrench intergenerational risk (Cheng et al., 2022). These biological mechanisms intersect with structural inequities: children in undocumented immigrant families exhibit elevated cortisol levels and anxiety rates, compounded by systemic barriers to education and healthcare (Thomson et al., 2015).

Structural inequities and neurobiological interactions

A critical yet understudied domain concerns how structural inequities directly interact with and amplify neurobiological PTSD mechanisms. While PTSD neurobiology is well-documented in general populations, its expression and severity are markedly influenced by systemic factors unique to immigrant experiences. Limited access to mental healthcare prevents timely intervention that could interrupt persistent amygdala hyperactivity or impaired fear extinction. This structural barrier exacerbates HPA axis dysregulation, as chronic legal uncertainty and social marginalization maintain elevated cortisol levels even when trauma-focused treatments become available.

Detention represents an extreme case of structural inequity intersecting with neurobiology: detained asylum seekers experience ongoing confinement trauma concurrent with neurobiological stress responses, creating a vicious cycle where structural violence perpetuates biological vulnerability (Harnett et al., 2023). Discrimination itself activates neurobiological stress responses. Recent neuroimaging work shows ethnic discrimination correlates with altered amygdala-prefrontal connectivity and heightened threat reactivity, suggesting social marginalization is neurobiologically embodied (Hauck et al., 2024).

Thus, interventions must address not only brain-based mechanisms but also structural contexts that maintain dysregulation, including policies affecting housing stability, legal status, employment access, and healthcare availability. Integration of structural reform with neurobiological treatment represents the frontier for improving mental health outcomes in this population.

Bridging the neurobiological-psychosocial divide

A critical gap persists between neurobiological research overlooking sociocultural contexts and psychosocial studies neglecting biomarkers. While animal models link chronic stress to mPFC hypoactivity and social withdrawal, few human trials examine culturally specific coping strategies. Discrimination's neurobiological correlates remain underexplored in immigrant populations. This disconnect impedes culturally sensitive intervention development. Cognitive-behavioural therapies show efficacy, but effectiveness diminishes without cultural adaptations.

Toward integrated interventions

Addressing PTSD requires interventions targeting both neurobiological and contextual determinants. Community-based programs combining trauma-informed therapy with advocacy for housing and legal rights demonstrate promise (Fuentes et al., 2024; Mancini, 2019; Rusch et al., 2020). Animal studies suggest that enriching environments enhance resilience, underscoring social integration's therapeutic potential. Policymakers must prioritize reducing detention durations and improving culturally competent care access.

Future research directions

Future research must prioritize longitudinal neurobiological studies tracking brain changes across migration phases using multimodal neuroimaging and culturally sensitive protocols. Intervention research should test integrated approaches combining trauma-focused therapy with structural supports via randomized controlled trials examining cortisol patterns and amygdala reactivity. Additional priorities include expanding assessment to the insula and anterior cingulate cortex, implementing interventions in resource-limited settings via digital platforms, and employing community-based participatory research positioning refugee communities as research partners.

CONCLUSION

This review underscores the necessity of integrating neurobiological and psychosocial frameworks to elucidate PTSD mechanisms in immigrant populations. Evidence demonstrates that while conserved PTSD mechanisms exist, their manifestation in immigrant populations is shaped by unique migration-related stressors and structural inequities. Future research must prioritize longitudinal studies tracking neurobiological changes alongside post-migration stressors and employ community-partnered approaches. Interventions should adopt dual focuses on brain-based therapies and structural equity, recognizing that cortisol dysregulation cannot be resolved through therapy alone if individuals remain in precarious conditions. By uniting translational neuroscience with sociocultural frameworks and structural reform, clinicians and researchers can mitigate compounded vulnerabilities faced by immigrants and refugees, fostering resilience across generations.

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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