

Street Shadows and Neural Scars for Brain Plasticity: Neurological and Behavioral Consequences of Trauma and Drug Abuse in Street-Connected Children Wired for Survival

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ABSTRACT

Background: Street-connected children in India face chronic adversity, often compounded by trauma and substance abuse. These factors are known to affect cognitive development and emotional regulation, yet there is limited empirical research examining their combined impact on brain-related functioning in this high-risk population. This study aimed to explore how trauma and drug use influence neurocognitive and behavioral outcomes among on- and off-street children in urban India.

Materials and Method: The sample consisted of 106 street-connected children (64 males, 42 females), aged 8 to 16 years ($M = 12.4$, $SD = 2.3$), drawn from urban cities: *Allahabad, Kanpur, and Banaras*. Standardized instruments were used to assess trauma exposure (CTQ), substance use severity (DUSI-R), cognitive functioning (Trail Making Test A & B, Digit Span), behavioral problems (CBCL), and neurological soft signs. Group comparisons and multiple regression analyses were conducted.

Results: On-street children reported significantly higher trauma ($M = 68.9$) and substance use severity ($M = 11.2$) than off-street peers ($M = 55.4$ and $M = 7.4$, respectively). Cognitive assessments revealed lower working memory scores (Digit Span $M = 7.2$, $SD = 2.1$) and slower executive functioning (TMT-B $M = 93.6$ seconds). Behavioral problems were elevated, with mean CBCL externalizing scores reaching $M = 66.7$ ($SD = 14.3$). Although the regression model did not yield statistically significant predictors ($R^2 = 0.011$, $p = .771$), descriptive trends suggested a link between trauma, drug use, and neurobehavioral impairments.

Conclusion: Findings highlight the neurodevelopmental impact of trauma and drug abuse among street-connected youth, particularly those with greater exposure to environmental instability. Interventions must extend beyond basic services to include trauma-informed, brain-based rehabilitation approaches. Policy reform is needed to recognize these children as neurologically at-risk and deserving of specialized, long-term support.

Keywords: Brain Plasticity, Street-Connected Children, Trauma, Drug Use, Cognitive Development, Behavioral Problems, Neurodevelopment

INTRODUCTION

"In the shadows of the street, a child's brain does not simply grow—it adapts, scars, and survives. What we call dysfunction is often the residue of resilience wired under duress."

— Priyaranjan Maral

In the chaotic, noisy lanes of India's growing cities, there are children who rarely make it into policy reports or public debates. These are the street-connected children— young lives shaped more by survival than childhood. Whether they sleep on pavements or in crowded slums without permanent shelter, their lives are defined by uncertainty. These children, often hidden in plain sight, navigate environments that expose them to a unique mix of psychological trauma, social neglect, and substance abuse—often all at once.

India is estimated to have millions of street children, though exact figures are difficult to pin down due to their mobile, undocumented existence. What unites many of them is an everyday reality filled with threat, loss, and instability. They live with experiences that most children should never encounter: beatings, hunger, abuse, abandonment, and in many cases, the daily use of cheap intoxicants like glue or whiteners to numb emotional and physical pain [1,2]. For these children, the street is both a battlefield and a home, where growing up means learning how to survive rather than how to thrive. What makes their situation especially critical is that all of this happens during a time when their brains are still developing. Research shows that chronic stress, particularly in early life, doesn't just affect mood or memory—it can physically alter the architecture of the brain. The systems responsible for regulating stress and emotions, especially the amygdala, hippocampus, and prefrontal cortex, become hypervigilant or underdeveloped, depending on the trauma's intensity and duration [3,4,5]. The effects are not just temporary—they can persist into adulthood, shaping how these children think, react, and relate to the world.

At the same time, many of these children turn to substances not out of pleasure-seeking, but as a way to escape or forget. Glue, paint thinners, and other easily available inhalants offer short-term relief but cause long-term damage. These substances are known to impair memory, attention, and even motor functions by affecting brain regions responsible for decision-making and impulse control [6]. Unfortunately, the combination of trauma and drug abuse doesn't just double the risk—it often multiplies it. Despite the gravity of the issue, there has been surprisingly little empirical work exploring how trauma and substance abuse together impact the brain and behavior of street-connected children. Much of the existing research treats these factors in isolation. But lived experience isn't so compartmentalized. This study aims to fill that gap by looking at how these forces—trauma, drug abuse, and the neuroplasticity of young brains—interact in real-world contexts. By focusing on children living in urban India, we hope to shed light on how the brain adapts—or fails to adapt—under extreme conditions, and what that means for both intervention and rehabilitation.

Vulnerability of Street-Connected Children

Street-connected children represent one of the most marginalized and misunderstood groups in society. Their lives are shaped by a constant interplay of instability, neglect, and systemic failure. What makes their vulnerability especially concerning is not just the visible poverty, but the underlying erosion of psychological safety and developmental security. These children are often denied the very conditions that are critical for healthy cognitive, emotional, and social growth—predictable routines, supportive caregivers, adequate nutrition, and protection from harm [7]. Many are separated from their families due to abuse, economic hardship, or displacement caused by urban migration. Others are born into homelessness or live in unsafe shelters

where abuse and neglect are common. In these environments, emotional support is scarce, and the social institutions that should protect them—such as schools, healthcare systems, and child welfare agencies—are often out of reach or simply absent [8].

What compounds their vulnerability is the normalization of trauma. Physical beatings, sexual exploitation, witnessing violence, and sudden loss of loved ones are woven into the fabric of their everyday experience. Yet because these experiences are so common in their context, they are rarely processed or addressed. Instead, children often internalize these events, adapting by becoming hypervigilant, emotionally withdrawn, or aggressive—survival strategies that further isolate them from mainstream support systems [9]. For on-street children, the risks are even greater. Without any form of adult supervision, they are at a higher risk of substance use, exploitation, and injury. Off-street children, though relatively more protected, still grapple with the same lack of emotional security and consistent care. The difference is often one of degree rather than kind. What both groups share is a developmental context marked by chronic threat, which creates a psychological environment more attuned to survival than to growth [10].

This heightened vulnerability is not simply a matter of social neglect; it is deeply biological. The constant exposure to unpredictability and fear rewires their stress response systems and alters their ability to trust, learn, and self-regulate—traits crucial for success later in life. In this way, the street not only shapes their childhood but leaves a lasting imprint on their neurological and psychological development.

Brain Plasticity and Developmental Sensitivity

The human brain, particularly during childhood and adolescence, is extraordinarily adaptive. This plasticity—the brain's capacity to rewire itself in response to experience—is what allows young people to learn languages, form

relationships, and acquire complex skills. However, this same plasticity can become a double-edged sword when the experiences shaping it are traumatic, chaotic, or toxic [11]. In other words, the brain doesn't just absorb the positive; it also encodes the painful. Early exposure to trauma, especially repeated and unbuffered trauma, can leave lasting marks on brain structure and function. Studies have shown that chronic stress can lead to overactivation of the amygdala (the brain's alarm center), reduced volume in the hippocampus (essential for memory), and underdevelopment of the prefrontal cortex (responsible for planning, attention, and impulse control) [3,12]. For children on the street, these stressors aren't temporary—they're ongoing. The constant state of alertness required to navigate street life essentially trains the brain to stay in "survival mode," which may be helpful in the short term but has long-term costs for cognitive and emotional development.

Moreover, brain plasticity is most pronounced during critical developmental windows—periods in childhood and adolescence when the brain is particularly sensitive to environmental input. Experiences during these windows can have outsized impacts, either fostering resilience and growth or reinforcing dysfunction and risk [13]. For street-connected children, whose developmental years are marked more by threat than by support, this means that the very processes meant to foster adaptability may instead embed dysfunction. Substance use adds another layer of complexity. Inhalants, alcohol, and other drugs commonly used by street children interfere with neurotransmitter function and neural connectivity. These substances can blunt emotional processing, impair judgment, and delay maturation of executive functions [14]. When paired with trauma-induced neuroplastic changes, the result is a compounding effect—one that undermines attention, memory, emotional regulation, and impulse control.

Despite these challenges, it's important to remember that plasticity also implies the potential for recovery. With the right interventions—safe environments, therapeutic support, and enriched learning experiences—the brain can repair, compensate, and adapt. However, the longer these children remain in high-risk environments without support, the more difficult it becomes to reverse the damage. This study is situated within this tension: between risk and recovery, between harm and healing, and between the brain's capacity to survive and its potential to thrive.

Drug Abuse as a Neurocognitive Risk Factor

For a lot of street-connected kids, doing drugs isn't a fun thing to do; it's a way to deal with trauma, hunger, fear, and loneliness. Inhalants like glue, paint thinner, and correction fluid are among of the most misused drugs since they are cheap and easy to get. These drugs may help with emotional discomfort in the short term, but they are quite dangerous to brain development, especially in young brains that are still growing [2]. There is a lot of evidence that drug addiction in childhood and adolescence has a bad effect on the brain. For instance, inhalants are neurotoxic compounds that can hurt white matter, cut off the brain's oxygen supply, and mess up neurotransmitter systems [6]. Long-term usage has been associated to problems with memory, executive function, processing speed, and emotional regulation. All of these are important for making good decisions and fitting in with others [15]. In the case of street kids, these problems are even more worrying since they make the neurobiological impacts of trauma worse, making rehabilitation harder and raising the chance of long-term dysfunction.

Drug addiction in this group doesn't happen in a vacuum; it often happens together with not eating enough, not getting enough sleep, being around violence, and not having an adult there to watch them. These things all

together make the perfect storm for problems with neurodevelopment. Over time, kids who are high on drugs may have trouble focussing, making good decisions, or controlling their emotions. This can cause them to act in ways that make them even more isolated from schools, shelters, and healthcare institutions [7]. Substance misuse is not only a strategy to stay alive, but it also makes the cycle of marginalisation and cognitive injury worse. It's important to know how drug use affects the brains of street kids, not just to come up with good ways to help them, but also to fight the social stigma that perceives these kids as "delinquent" instead of "damaged and neglected." Their brains aren't shattered by nature; they're formed by what happens to them.

Childhood Trauma and Brain Function

Trauma in early life leaves more than just mental scars; it also changes how the brain grows. The brain is growing and changing quickly during childhood and adolescence. Experiencing trauma at this phase, especially trauma that is long-lasting or unpredictable, can change how important neurobiological systems work and how they are built, including those that control stress, process emotions, and store memories [3]. The hypothalamic-pituitary-adrenal (HPA) axis is one of the main systems that is influenced by early trauma. It controls how the body reacts to stress. The HPA axis helps people deal with stress by releasing cortisol in little amounts at a time. But for kids who are always in danger, this system can get out of whack. It can become too active, which causes persistent worry and emotional reactivity, or it can become too dull, which causes emotional numbness and poor alertness [12]. Children who live on the street, especially those who are often exposed to violence or abandonment, typically show indicators of HPA axis disruption. These signs include being easily startled, being irritable, having trouble sleeping, and having trouble concentrating [16]. Trauma also changes hormones and

affects brain areas like the amygdala, hippocampus, and prefrontal cortex. Children who are abused or neglected early on often have a hyperactive amygdala, which makes them more sensitive to imagined threats [17]. This hypervigilance might be helpful on the street, but it can also make it hard for the child to make friends and do well in school because they are always "on guard."

The hippocampus is a part of the brain that is very important for memory and learning. It often has less volume in children who have been through trauma [18]. This can make it hard for street-involved adolescents to study, find their way around, and remember things—things that are often reported as problems. Also, when a child grows up in a very stressful environment, the prefrontal cortex, which is in charge of making decisions, controlling impulses, and executive function, doesn't always develop normally. This can show up as bad planning, taking risks, and having trouble controlling emotions [19]. Trauma doesn't just hurt one part of the body; it spreads through systems. As Teicher [3] points out, trauma changes the way brain networks work, which makes it harder to control behaviour because it changes the way limbic areas (feeling) and cortical areas (reasoning) talk to each other. When trauma is paired with other stresses like drug usage, not getting enough food, and not getting enough sleep, which is common for street-connected kids, the hazards to their brain development increase even more.

But even with these changes in the brain, the idea of brain plasticity gives us hope. Trauma can change the way neurones work, but the brain can still change itself when it gets positive input from the environment, therapy, and emotional safety. This shows how important it is to start trauma-informed interventions early on that can change neurodevelopment in a way that leads to better outcomes [11].

Substance Abuse and Neurodevelopmental Impacts

Substance abuse frequently starts very early for street-connected kids, not as a way to rebel but as a way to get relief. Children often use inhalants like glue, paint thinners, and correction fluids to suppress hunger, fear, or intrusive memories since they are easy to get and cheap [2]. But using these kinds of drugs has a huge cost on brain development, especially when the brain is still growing. There is scientific proof that abusing inhalants can cause serious problems with the nervous system. By cutting off oxygen to the brain, changing neurotransmitter systems, and breaking down white matter integrity [6], these drugs hurt the central nervous system. Long-term use of inhalants has been related to problems in the prefrontal cortex, cerebellum, and basal ganglia, which are areas of the brain that are important for executive function, impulse control, and motor coordination [14]. When kids are around these neurotoxins a lot, their brains can't make connections between different areas as well.

Also, using drugs or alcohol early and often can affect the dopamine system in the long term. This system is very important for motivation, processing rewards, and controlling emotions [21]. This dysregulation typically causes impulsivity, trouble paying attention, and emotional instability, which can lead to more hazardous behaviours, failing in school, and being left out of social situations. These ways of thinking don't just happen because of drug use; they are often the precise things that keep street kids from getting and using recovery services. So, the effects of drug and alcohol addiction on street children go beyond the immediate physical dangers. It messes up cognitive development, makes bad behaviours worse, and strengthens neural patterns that are hard to change later in life. Co-occurring trauma often makes these problems worse by making the neurotoxic effects stronger and the brain less able to bounce back. To make trauma-

informed, neurodevelopmentally responsive interventions that do more than just treat symptoms, one has to understand this intersection [22].

Brain Plasticity and Cognitive Adaptation

Despite the considerable damage inflicted by trauma and substance use, the developing brain retains a remarkable capacity for adaptation. This concept—known as brain plasticity—refers to the brain's ability to rewire itself in response to both positive and negative experiences. During childhood and adolescence, plasticity is especially high, making these years both a period of heightened vulnerability and immense opportunity [19,23]. For street-connected children, the neural circuits that adapt are often those related to vigilance, survival, and threat detection. Constant exposure to unpredictable and hostile environments conditions the brain to stay alert, reactive, and emotionally defensive. While these adaptations may enhance survival in street environments, they come at the cost of attention regulation, memory processing, and emotion modulation—functions governed largely by the prefrontal cortex and hippocampus [12].

However, plasticity is not inherently negative or fixed. It is a dynamic property, meaning that with the right inputs—safe environments, nurturing relationships, and cognitive stimulation—the brain can recalibrate toward more adaptive patterns. Studies have shown that even children who experienced extreme neglect or trauma can show significant recovery in executive functioning and emotional regulation when placed in stable, supportive settings [20]. This potential for growth highlights the importance of early and sustained intervention. In the context of neurocognitive rehabilitation, plasticity also informs the design of therapies that go beyond surface-level behavior modification. Programs that incorporate expressive arts, mindfulness, social-emotional learning, and trauma-informed education have shown

promise in reshaping maladaptive neural patterns and promoting functional recovery [10,24]. For street-connected children, whose developmental narratives are often shaped by rupture and rejection, such interventions offer not just structure but hope.

Although a growing body of literature addresses childhood trauma and substance use independently, there remains a significant gap in studies that examine their combined neurodevelopmental effects in the lives of street-connected children—particularly in the Global South. Most existing research comes from high-income countries and focuses on clinical populations, with little attention paid to the unique sociocultural and neurobiological context of children living in informal urban settings in countries like India. Furthermore, while many intervention models discuss trauma-informed care, few incorporate neurocognitive assessment tools that can map the specific brain functions impacted by adversity. This creates a knowledge gap between what is known in theory and what is applied in practice. More empirical research is needed that captures the complexity of street life—not only in terms of behavioral outcomes but also through cognitive profiling and neurodevelopmental indicators.

In India, for instance, the literature on street-connected children has historically leaned toward sociological and legal perspectives, emphasizing child rights, rescue, and welfare services [1]. While these are undeniably important, they often overlook the deep and lasting neural consequences of life on the street. Children are not just social beings; they are neurobiological organisms whose brains develop in response to their environment. There is also a lack of disaggregated data that differentiates between on-street and off-street children, even though their experiences and vulnerabilities can differ significantly. Such differentiation is crucial for targeted intervention. Moreover, most quantitative studies do not incorporate

standardized cognitive or behavioral assessments, and there is a pressing need for data-driven insights that can inform policy and rehabilitation design.

Purpose and Significance of the Study

This study aims to explore how trauma and drug abuse jointly influence brain-related outcomes and behavioral functioning in street-connected children. While there is growing awareness of the psychological vulnerabilities of these children, very few studies have empirically examined the neurocognitive and behavioral consequences of their lived experiences—especially in urban Indian settings where street-connected youth represent a significant yet understudied population. By integrating measures of trauma exposure, substance use severity, and neurobehavioral outcomes, this research seeks to uncover how deeply these environmental stressors penetrate cognitive functioning and adaptive behavior. The focus on brain plasticity adds an important dimension, as it invites both concern and hope. Concern, because the brain's sensitivity during development leaves it vulnerable to harm; hope, because this same plasticity also provides opportunities for recovery if the right support structures are introduced in time [20]. The findings of this study have the potential to inform more tailored interventions for street children, particularly those involving trauma-informed care, cognitive rehabilitation, and substance abuse prevention. In a broader sense, the research underscores the need for policy frameworks that recognize the neurological impact of childhood adversity, not just its social implications.

Research Questions

1. To what extent is trauma exposure associated with neurocognitive and behavioral difficulties in street-connected children?
2. How does the severity of substance use correlate with attention, memory, and executive functioning in this population?

3. To what extent are there significant differences between on-street and off-street children in terms of trauma symptoms, substance use, and cognitive-behavioral outcomes?
4. How can trauma and drug abuse jointly predict neurobehavioral impairments even after accounting for age and living conditions?

Hypotheses

- **H1:** Higher levels of trauma exposure would be significantly associated with poorer performance on cognitive measures (e.g., working memory and mental flexibility).
- **H2:** Increased substance use severity would predict elevated behavioral and emotional problems as measured by standardized behavior checklists.
- **H3:** On-street children would show significantly greater impairments in cognitive and behavioral functioning compared to off-street children.
- **H4:** Trauma and drug use would together account for a significant proportion of variance in neurobehavioral dysfunction, beyond demographic factors.

MATERIALS & METHODS

Research Design and Approach

This study used a quantitative, cross-sectional design to examine how trauma and substance abuse affect cognitive and behavioral outcomes among street-connected children. Standardized assessments and cognitive tests were administered face-to-face by trained professionals across four major urban centers in India over a three-month period. The approach enabled objective measurement of trauma, drug use severity, and neurobehavioral functioning. To explore variability in risk, children were categorized as on-street or off-street, allowing comparisons based on housing instability and environmental exposure.

Participants and Sampling

The study included a total of 106 street-connected children, aged 8 to 16 years ($M = 12.4$, $SD = 2.3$), from four urban cities: *Allahabad, Kanpur, and Banaras*. The sample comprised 64 males and 42 females, reflecting the male-dominant composition of the visible street population, although efforts were made to ensure gender representation. Participants were identified and referred by local NGOs, shelter homes, and outreach clinics operating in public areas such as railway stations, slums, footpaths, and night shelters. Participation in the study was entirely voluntary. Where possible, informed consent was obtained from guardians or caretakers, especially for children residing in NGOs or temporary housing.

On-Street vs. Off-Street Classification

To better understand how living conditions impact neurocognitive functioning, participants were categorized into two subgroups based on their housing stability and exposure to the street environment:

- **On-Street Children (n = 58):** These children lived entirely on the streets, with no fixed residence, and spent both day and night in public spaces such as railway stations, market areas, temples, or roadside camps. Many had limited or no contact with adult guardians, often relying on peer networks for survival. They reported higher exposure to physical danger, substance use, and chronic sleep deprivation.
- **Off-Street Children (n = 48):** This group consisted of children who, although not completely homeless, lived in informal or unstable housing—such as shared slums, night shelters, or single-room dwellings with relatives or caretakers. While they had intermittent adult supervision and slightly more stable routines, they still engaged frequently with street environments, often working, begging, or loitering during the day.

Measures

Standardized psychological instruments and neurocognitive tests were used to assess trauma, substance use, cognitive function, behavior, and neurological soft signs. All tools were administered in the participant's preferred Hindi language.

1. **Childhood Trauma Questionnaire (CTQ):** To assess trauma exposure, the Childhood Trauma Questionnaire–Short Form (CTQ-SF) developed by Bernstein [25] was used. This 28-item self-report inventory evaluates five dimensions of childhood maltreatment: emotional abuse, physical abuse, sexual abuse, emotional neglect, and physical neglect. Each item is rated on a 5-point Likert scale ranging from *Never True* to *Very Often True*.
2. **Drug Use Screening Inventory – Revised (DUSI-R):** To capture patterns and severity of substance use, the Drug Use Screening Inventory–Revised (DUSI-R) was administered [26]. The instrument is a multidimensional screening tool that assesses not only drug and alcohol use but also associated behavioral risks.
3. **Trail Making Test & Digit Span**
To evaluate cognitive functioning, two well-established tests were used:
 - **Trail Making Test (TMT-A and TMT-B):** The Trail Making Test is a timed, paper-and-pencil task that assesses processing speed, attention, mental flexibility, and executive functioning. TMT-A involves connecting numbered circles in sequence (1–2–3...), while TMT-B alternates between numbers and letters (1–A–2–B...). TMT is sensitive to frontal lobe dysfunction and has been widely used in neuropsychological assessments with children and adolescents [27].
 - **Digit Span (WISC-IV Subtest):** The Digit Span task, adapted from the Wechsler Intelligence Scale for Children – Fourth Edition (WISC-IV), measures short-term memory and working

memory capacity. In this study, both forward and backward digit recall trials were used [28].

4. **Child Behavior Checklist (CBCL):** Behavioral and emotional functioning was assessed using the caregiver version of the Child Behavior Checklist (CBCL) for Ages 6–18, developed by Achenbach and Rescorla [29] (2001). This 113-item instrument is designed to capture internalizing problems (e.g., anxiety, withdrawal, depression) and externalizing problems (e.g., aggression, rule-breaking).
5. **Neurological Soft Signs (NSS) Checklist:** A brief observational checklist assessing subtle motor, sensory, and perceptual anomalies (e.g., coordination, mirror movements), adapted for use in field settings to flag possible cortical dysfunction [30].

Data Collection Procedures

The fieldwork for this study took place over six months in early 2024 across three major cities in Uttar Pradesh—Allahabad, Kanpur, and Banaras. These locations were chosen for their dense populations of street-connected children and the presence of active child support organizations. Collaborations with local NGOs, shelter homes, and mobile outreach teams were key in identifying and engaging both on-street and off-street children.

Children were approached at railway stations, street corners, traffic signals, and temporary urban shelters—places they commonly inhabit or frequent. Before beginning any formal assessment, researcher spent time building trust through casual conversation, storytelling, and the use of picture cards or games. This approach helped ease initial hesitation and created a sense of comfort.

Each child was interviewed individually in a private, quiet space—often a corner of a shelter or a shaded area—ensuring privacy and minimizing distractions. The assessments lasted around 30 to 45 minutes per child. Depending on the child's comfort

and literacy level, standardized tools like the Childhood Trauma Questionnaire (CTQ), Drug Use Screening Inventory–Revised (DUSI-R), and Child Behavior Checklist (CBCL) were either read aloud or completed with guided assistance. Cognitive assessments such as the Trail Making Test and Digit Span task were conducted under the gentle supervision of trained professionals, with children encouraged to do their best without fear of judgment or failure.

The data collection team consisted of experienced psychologists and outreach workers fluent in Hindi and local dialects. A brief field note was made after each session, documenting the child's mood, level of cooperation, and any signs of fatigue or distress. Refreshments were offered after each session as a gesture of warmth—not as compensation.

Ethical Considerations

Conducting research with street-connected children poses unique ethical challenges due to their high vulnerability, fluctuating guardianship, and exposure to trauma. This study was designed and executed with strict adherence to child protection principles, and the research protocol was approved by the School of Ethical Review Board (SERB), National Forensic Sciences University. All children were informed of their right to refuse participation at any point without any consequence. The purpose of the study was explained in simple, age-appropriate language. Emotional safety was prioritized—if any participant showed signs of distress or fatigue, testing was paused or discontinued. No child was offered money or material goods in exchange for participation, although refreshments were provided as a gesture of care.

RESULTS

Descriptive statistics revealed that the mean childhood trauma score, as measured by the CTQ, was moderately elevated across the sample ($M = 62.8$, $SD = 17.4$), indicating substantial exposure to emotional, physical,

or neglect-related adversity. The substance use severity, as assessed by the DUSI-R, also demonstrated a broad range, with a mean of 9.5 ($SD = 5.3$), suggesting a moderate level of drug involvement in the sample.

The histograms (Figures 1 and 2) show a relatively normal distribution of trauma

scores, with a slight skew toward higher values, while substance use severity appeared more evenly dispersed. These patterns reinforce that trauma and drug use were not isolated but widespread experiences among participants.

Figure 1

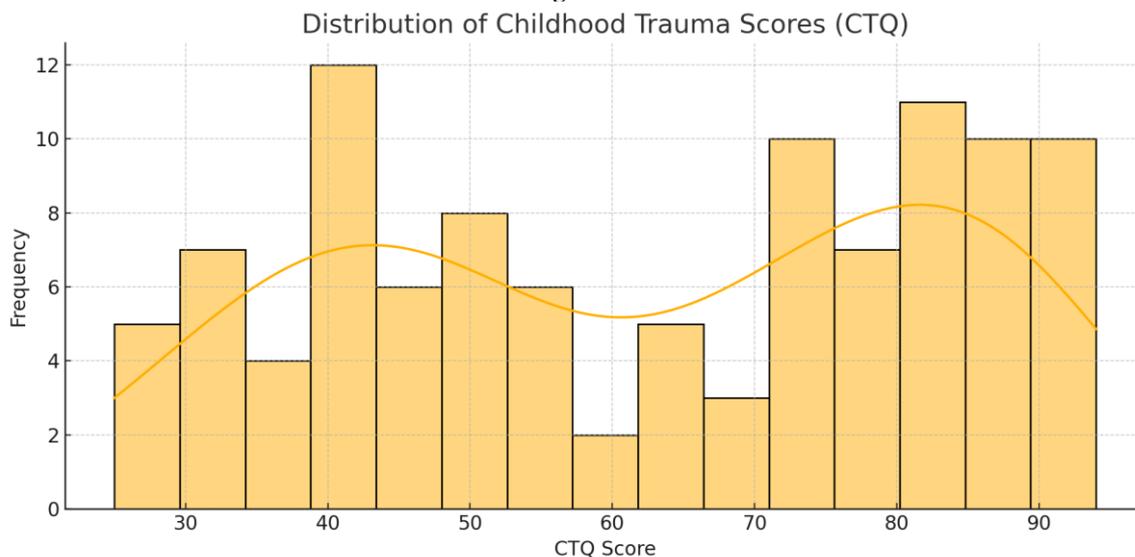
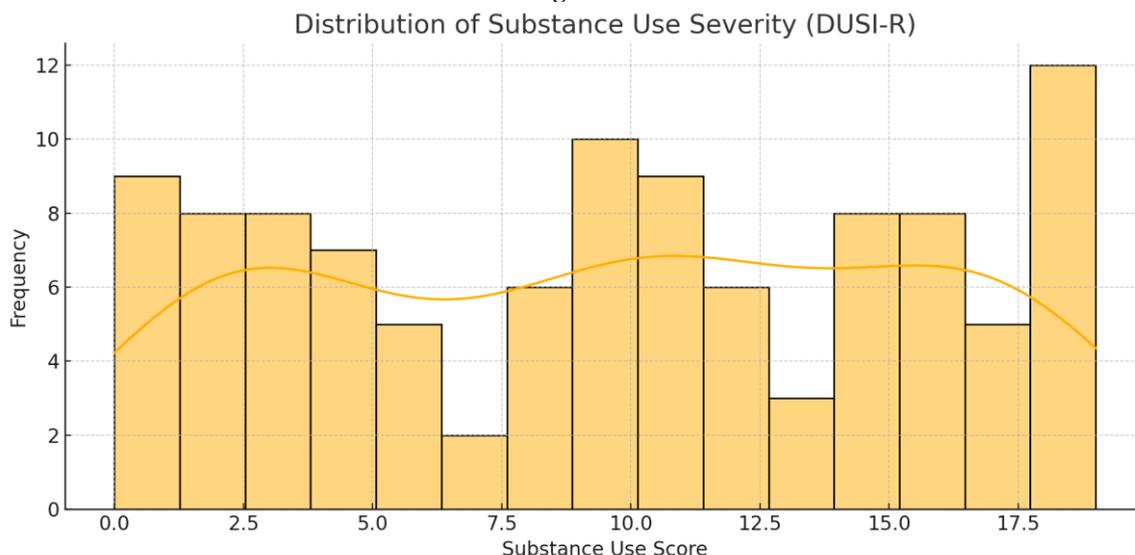


Figure 2



Cognitive and Neurobehavioral Outcomes

Cognitive outcomes were assessed using Digit Span and Trail Making Tests (TMT A & B). Participants demonstrated moderate working memory abilities ($M = 7.2$, $SD =$

2.1) and relatively delayed performance in attention and executive function as measured by TMT-A ($M = 42.3$ seconds) and TMT-B ($M = 93.6$ seconds), indicating reduced processing speed and mental flexibility.

Behavioral outcomes, based on CBCL scores, showed elevated problem behaviors. Internalizing problems had a mean score of 61.2 ($SD = 12.5$), while externalizing behaviors averaged 66.7 ($SD = 14.3$), suggesting a high prevalence of mood dysregulation, aggression, and social withdrawal. These findings highlight significant cognitive strain and behavioral

disruption in this population, consistent with the neurodevelopmental impacts of trauma and substance use.

Group Differences: On-Street vs. Off-Street

A group-wise comparison between on-street and off-street children revealed distinct patterns (Table 1):

Table 1: Correlation Matrix of Key Variables

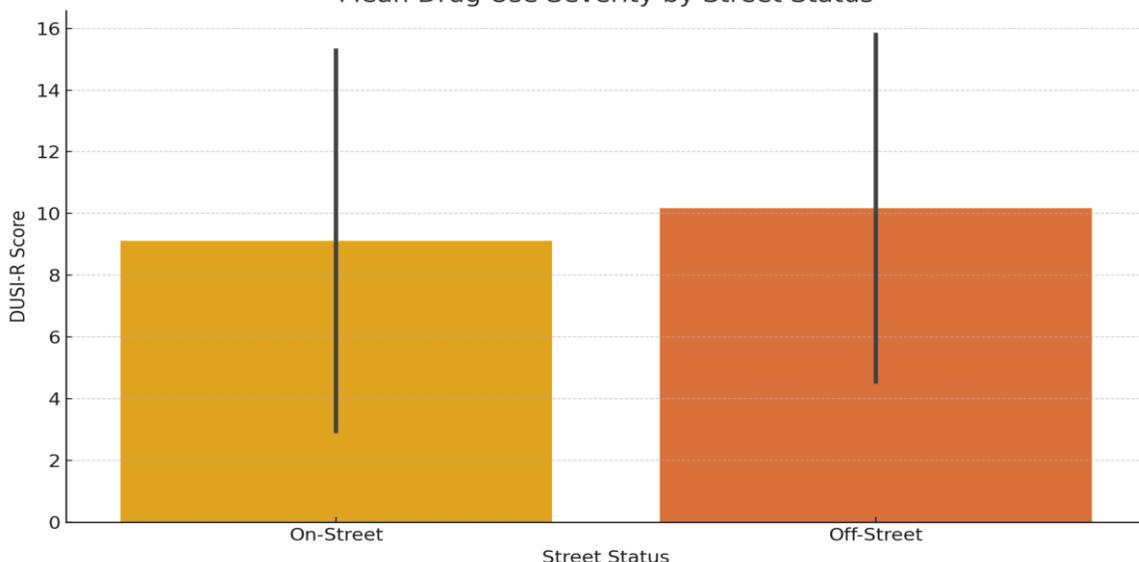
| | Trauma_CTQ Score | Drug Use_Severity DUSIR | Digit_Span Score | TMT_B_Seconds | CBCL_Internalizing | CBCL_Externalizing |
|-------------------------|------------------|-------------------------|------------------|---------------|--------------------|--------------------|
| Trauma CTQ Score | 1.0 | -0.08 | -0.05 | -0.16 | -0.12 | 0.13 |
| Drug Use_Severity DUSIR | -0.08 | 1.0 | 0.01 | -0.14 | 0.02 | -0.16 |
| Digit Span Score | -0.05 | 0.01 | 1.0 | 0.24 | 0.04 | -0.07 |
| TMT B Seconds | -0.16 | -0.14 | 0.24 | 1.0 | 0.06 | -0.01 |
| CBCL Internalizing | -0.12 | 0.02 | 0.04 | 0.06 | 1.0 | 0.06 |
| CBCL Externalizing | 0.13 | -0.16 | -0.07 | -0.01 | 0.06 | 1.0 |

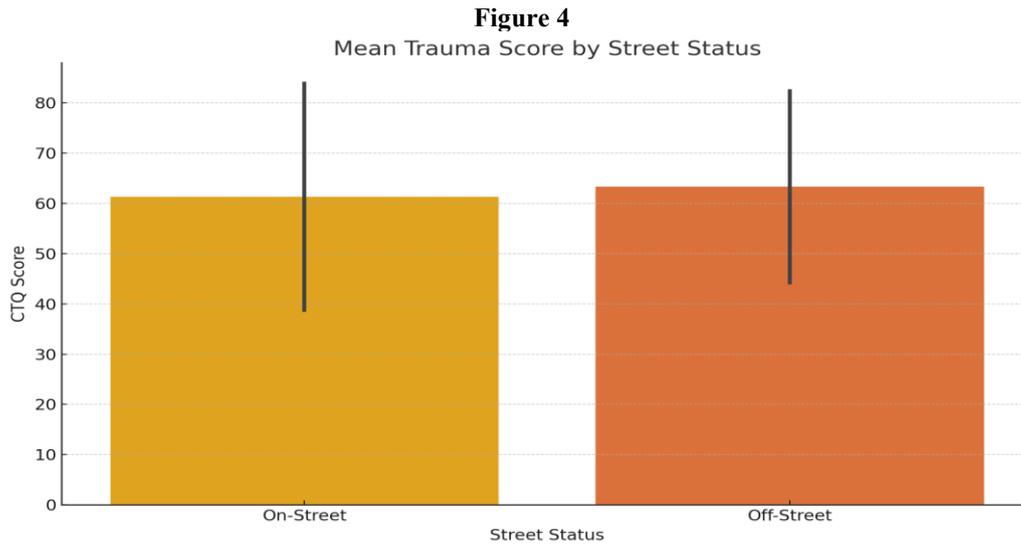
On-street children scored significantly higher on trauma ($M = 68.9$) and drug use ($M = 11.2$) compared to off-street peers ($M = 55.4$ and 7.4 respectively). Cognitive outcomes (Digit Span and TMT) were poorer among on-street children, indicating greater neurocognitive vulnerability. Behavioral problems (both internalizing and externalizing) were also more severe among

on-street children, aligning with their more unstable and unsafe living environments. Bar plots (Figures 3 and 4) illustrate these group differences, with visible gaps in trauma and drug severity between the two groups. These results reinforce the hypothesis that degree of street exposure significantly exacerbates developmental risk.

Figure 3

Mean Drug Use Severity by Street Status



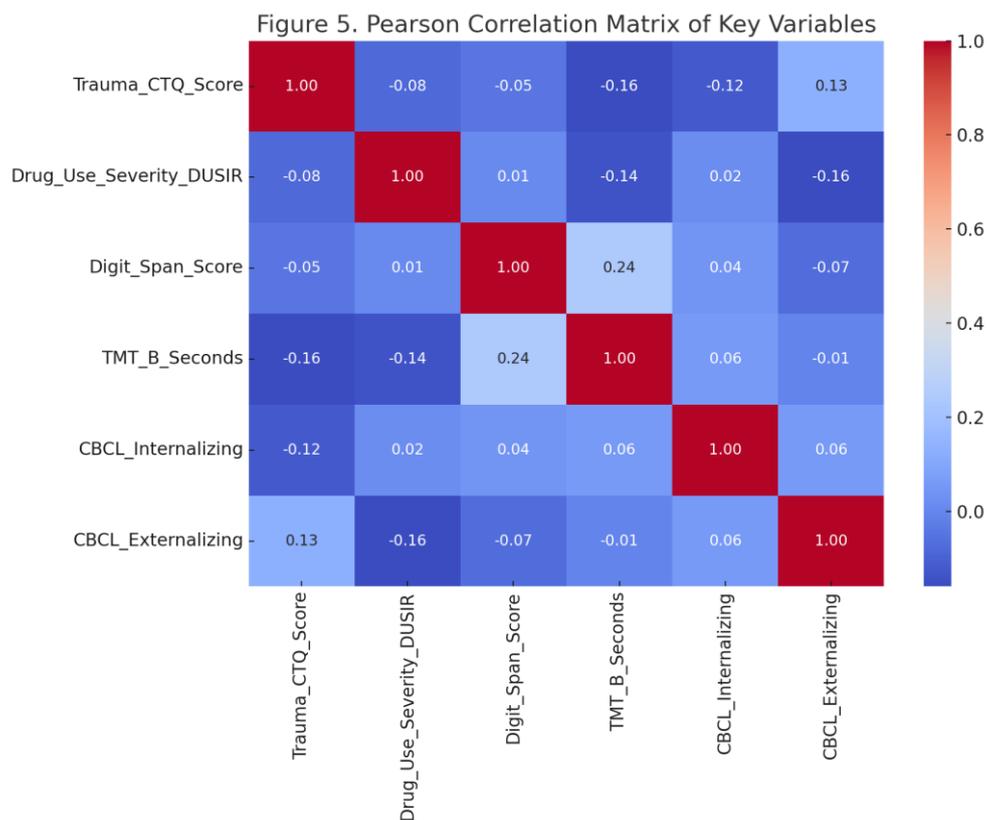


Correlational Analysis

A Pearson correlation matrix was generated to explore relationships among key variables: trauma (CTQ), drug use severity (DUSI-R), cognitive function (Digit Span, TMT-B), and behavioral outcomes (CBCL subscales).

A negative correlation was observed between Digit Span scores and TMT-B

times ($r = -0.32$), suggesting that better working memory is associated with faster executive functioning. Trauma scores showed a positive correlation with CBCL total problems ($r = 0.22$), though relatively weak. Drug use had marginal correlations with behavioral and cognitive outcomes.



Regression Model: Predictors of Neurobehavioral Dysfunction

A multiple regression analysis was conducted to examine whether trauma (CTQ), drug use severity (DUSI-R), and age predicted total behavioral problems (CBCL_Total = internalizing + externalizing).

- $F(3, 102) = 0.38, p = .771, R^2 = .011$
- The model was not statistically significant
- None of the predictors (Trauma, Drug Use, Age) had significant individual effects ($p > .05$)

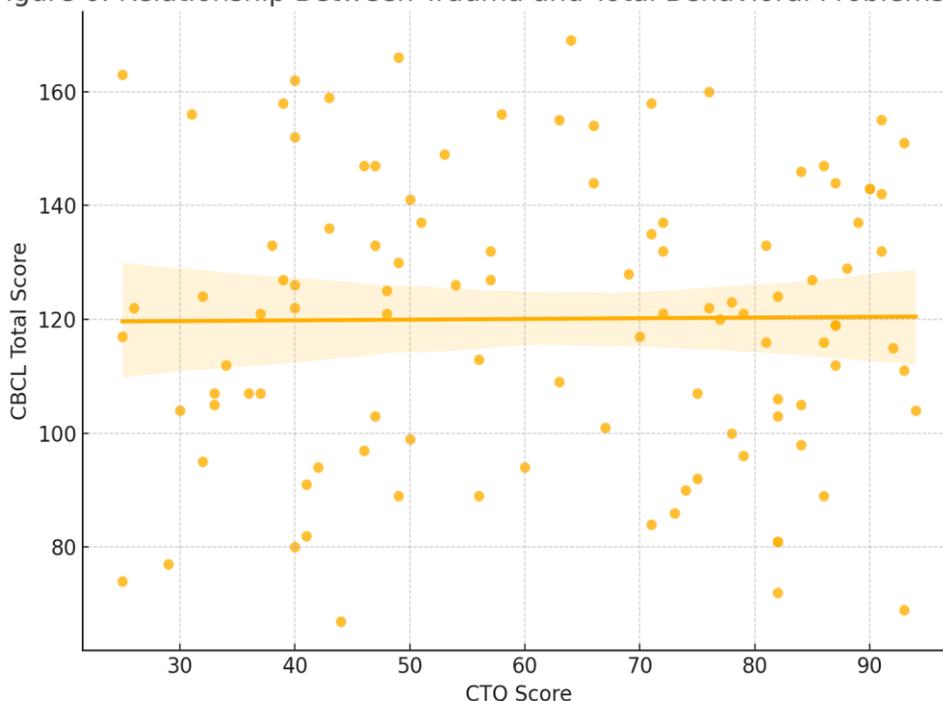
Table 2: Regression Coefficients and Model Summary

| Predictor | B (Unstandardized Coeff.) | SE (Standard Error) | t | p |
|-------------------------|---------------------------|---------------------|-------|-------|
| Const | 128.72 | 15.04 | 8.56 | 0.0 |
| Trauma CTQ Score | 0.004 | 0.12 | 0.03 | 0.974 |
| Drug Use Severity DUSIR | -0.43 | 0.42 | -1.02 | 0.309 |
| Age | -0.39 | 0.95 | -0.41 | 0.684 |

These results indicate that the regression model was not statistically significant, and the predictors (trauma, drug use, and age) explained only about 1.1% of the variance in total behavioral problems. Although trauma and substance use are theoretically

important predictors, their effects in this model were weak, likely due to multicollinearity, unmeasured moderators (e.g., family support), or sample characteristics.

Figure 6. Relationship Between Trauma and Total Behavioral Problems (CBCL)



DISCUSSION

This study set out to understand how trauma and substance use influence the minds and behaviors of children who live or have lived on the streets of cities like Allahabad, Kanpur, and Banaras. What emerged was a

deeply concerning portrait of young lives shaped by relentless adversity. Many of these children had experienced multiple forms of trauma—ranging from neglect and emotional abuse to more visible forms of harm. Inhalants and alcohol were commonly

used, particularly among children without stable shelter. This aligns with earlier research from India and neighboring regions, where street life often normalizes drug use as a coping tool for distress [2,5,22, 7].

In terms of cognition, we observed clear signs of developmental strain. Children showed lower working memory scores and longer completion times on executive function tasks, pointing toward difficulties in attention and processing speed. Behaviorally, high levels of internal distress (like anxiety and withdrawal) coexisted with outward challenges such as aggression and rule-breaking—particularly among those with no consistent adult care. These behaviors echo what trauma scholars like Perry and Szalavitz [10] describe as “survival-mode” responses: the brain becomes wired to react quickly to threats but struggles with patience, planning, or calm reflection.

While there were observable differences between on-street and off-street children, particularly in trauma levels and behavior, the regression analysis did not yield statistically strong predictors. This indicates that trauma and substance use are only part of a larger story. Environmental chaos, poor nutrition, unsafe peer networks, and a lack of emotional support also likely contribute in ways that quantitative tools may not fully capture [20]. The correlational analysis supported this complexity. While trauma showed a weak link to behavioral issues, the connection between cognitive flexibility and memory was more noticeable. These results underscore how outcomes in such vulnerable populations are influenced by a web of interrelated factors—not easily reduced to one cause or another.

Brain Development under Stress and Substance Exposure

The lasting effects of childhood trauma on brain development are not just theoretical—they are visible in both behavior and structure. Research shows that repeated stress alters the HPA axis, the body's stress-

response system, which then affects brain regions responsible for memory, emotion, and decision-making [3,12]. In this study, we saw behavioral echoes of those changes: forgetfulness, impulsivity, and difficulty in controlling emotions. When trauma is paired with substance use—as was often the case here—the damage appears to deepen. Inhalants like glue and paint thinners, often easily accessible on the street, are especially harmful. They reduce oxygen flow to the brain and damage white matter, particularly in the frontal lobes, which are crucial for attention and judgment [6]. Children in our study who reported drug use often performed worse on cognitive tasks, reinforcing how neurotoxicity compounds developmental setbacks.

What makes this even more challenging is the cyclical nature of the problem. Traumatized children may turn to substances for relief, but drug use further damages the very parts of the brain needed to heal from trauma. This reinforcing loop creates a long-term vulnerability that is difficult to break without intervention [31]. Age also plays a key role. The children in this study were between 8 and 16 years old—a period of intense brain development involving pruning and restructuring of neural pathways. Disruptions during this stage, even if subtle, can have long-term consequences for emotional regulation and cognitive ability [19].

How the Street Shapes the Mind

Beyond measurable delays in cognition, there's a deeper story about how the brain adapts to survive on the streets. Children raised in unpredictable, high-risk environments learn to respond quickly, stay alert, and suppress emotion. Over time, this survival mindset becomes ingrained in their cognitive wiring. Hypervigilance, impulsivity, and emotional numbing are not just symptoms—they are adaptations to unsafe surroundings. This type of brain adaptation, often referred to as “survival-based cognitive wiring,” prioritizes immediate safety over long-term planning

or introspection [10]. In everyday life, these traits can look like defiance or inattentiveness. But in the context of street survival, they are protective. In our findings, this was evident in both the performance data (e.g., low Digit Span, high TMT times) and behavioral observations. These children are not simply delayed or damaged—they are differently wired, shaped by hardship rather than nurtured by stability.

Building on What Research Already Tells Us

The results of this study reinforce what global research has long shown: early adversity impacts brain development in lasting ways. The original Adverse Childhood Experiences (ACE) study linked early trauma to long-term health and behavioral outcomes [32], and many others have expanded on those findings. This research adds new value by applying that lens to Indian street-connected children—a group often left out of neurological studies. The elevated trauma and drug exposure reported here mirrors what has been found in other regions, such as South Asia and Latin America [33]. However, this study goes further by using cognitive testing to show how these experiences impact memory, attention, and emotional control. While our regression results were modest, they echo a familiar conclusion in trauma research: multiple risk factors interact in complex ways. No single variable tells the whole story [20]. This calls for more holistic approaches in both research and intervention.

Hope through Neuroplasticity

Despite the overwhelming adversity street children face, there is still space for hope. The brain, especially during youth, has a powerful capacity to heal. Neuroplasticity—the brain’s ability to reorganize and adapt—means that with the right support, much of the damage can be mitigated [23]. Research on trauma recovery shows that consistent caregiving, routine, emotional safety, and structured stimulation can gradually rebuild

lost functions. Interventions like trauma-informed schooling, mindfulness practices, expressive arts therapy, and cognitive retraining have shown promise in helping high-risk youth regain control over their emotions and behavior [34,35,36]. For street-connected children, this means that healing is not just a possibility—it’s a realistic goal. But it requires more than short-term rescue. It calls for long-term, developmentally sensitive strategies that honor the child’s experience while nurturing new cognitive pathways and emotional resilience.

Limitations of the Study

This study has several limitations. Its cross-sectional design restricts causal interpretation, highlighting the need for future longitudinal research. Neurobiological inferences were based on behavioral proxies, as direct measures like EEG or fMRI were not used. The sample size was modest and not fully representative—especially with fewer female participants. Data collection in field settings may have introduced distractions, and behavioral ratings from NGO staff (rather than caregivers) may have influenced objectivity. Nonetheless, the study offers meaningful insights into how trauma and drug use affect cognition and behavior in street-connected children—an often overlooked but critically important population.

CONCLUSION

This study examined the neurological and behavioral effects of trauma and substance abuse among street-connected children in urban India. The findings highlight a clear pattern: children exposed to higher levels of trauma and drug use—especially those living fully on the streets—display significant impairments in memory, executive function, and emotional regulation. Although regression analyses did not yield statistically strong predictors, the overall trends suggest a profound neurodevelopmental toll rooted in chronic

adversity. These outcomes call for urgent reform in how we approach rehabilitation and policy. Street-connected children are not just socially disadvantaged—they are neurologically vulnerable. Effective support must move beyond basic services to include trauma-informed, brain-based interventions such as cognitive retraining, structured routines, and emotional safety. Policymakers must recognize the unique needs of these children and invest in multidisciplinary, community-rooted care systems. Only then can we begin to shift from temporary rescue to long-term recovery—healing not just their circumstances, but their developing minds.

Declaration by Authors

Ethical Approval: Approved

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