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ORIGINAL ARTICLE

The consequences of traumatic brain injury from the classroom to the courtroom: understanding pathways through structural equation modelling

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ABSTRACT

Purpose: Paediatric traumatic brain injury (TBI) can have resultant ongoing significant impairments which can impact life outcomes. The primary aim of this research was to explore whether TBI contributes to the relationship between poor educational outcomes and offending trajectories.
Materials and methods: Through analysis of a dataset consisting of self-reported health, educational, and offending histories of 70 incarcerated young males, structural equation modelling was used to explore the mediation of educational outcomes and patterns in offending behaviour by chronic symptoms following TBI.
Results: Symptoms related to TBI significantly mediated the relationship between decreased educational attainment and more frequent convictions. It did not mediate any relationships involving age at first conviction.
Conclusions: Traumatic brain injury appears to have more influence over frequency of offending patterns than age at first conviction. However, TBI remains a pervasive factor in both higher rates of offending and poorer educational attainment. In order to tackle this effect on adverse social outcomes, greater attention to the impact of TBI is required in education and criminal justice systems.

➤ IMPLICATIONS FOR REHABILITATION

- Highlights traumatic brain injury as a contributory factor in some education to offending pathways, suggesting that greater focus on rehabilitation within the education and criminal justice systems is required.
- Reinforces that greater understanding of educational pathways post-injury is needed to better facilitate rehabilitation within the school system.

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Brain injuries; post-concussion syndrome; educational status; schools; crime; criminals

Introduction

Traumatic brain injury and adverse social outcomes

Traumatic brain injury (TBI) is one of the leading causes of paediatric death and disability worldwide and comes with enormous economic, social, and personal costs [1–3]. Any damage or injury to the brain caused by a bump, blow, or jolt to the head or a penetrating head injury (HI) is considered a TBI [4], and severity is usually defined as mild, mild-complicated, moderate, or severe. Severity may be determined by multiple routes in the acute stages of injury: including loss of consciousness (often measured by the Glasgow Coma Scale) [5], structural brain imaging techniques, or measures of post-traumatic amnesia. In community settings, these determinants may be problematic, and studies typically rely on self-reported measures of time spent unconscious post-injury. However, this measure can be problematic as it often relies on participants' to accurately self-report length of time spent unconscious.

Research has demonstrated that, following TBI, children may go on to develop post-concussion syndrome (PCS) symptoms across a range of cognitive, physical, and emotional domains [6]. Evidence suggests that PCS symptoms can be present following repeated concussions [7], complicated-mild TBI [8], and more severe injuries [9]. Such symptoms are therefore indicative of disruptive injuries, regardless of whether symptoms are caused by more severe injuries or mild higher frequency injuries. These symptoms can manifest over several years [10,11], and persist for months or years post-injury for some individuals [12,13], with young peoples' emerging skills more vulnerable to impact than those already established [14].

Such significant and ongoing impairments can be particularly detrimental to life outcomes [15–17]. In particular, symptoms may cause disruption to learners' educational progress and engagement [18,19]. However, it is becoming increasingly clear that there is a large gap between the incidence of paediatric TBI and provision of support [20], and it frequently remains either misdiagnosed or unidentified in education systems [21].

The prevalence rates of TBI have been identified as being consistently and significantly higher among young people exposed to a criminal justice system than in non-offender groups [22].

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Furthermore, a 35-year population-based study in Sweden determined that those who had been diagnosed with a TBI were three times more likely to commit a violent crime in comparison to age- and gender-matched controls, and two times more likely than their siblings [23]. TBI has also been found to be significantly associated with an earlier age at first conviction [24], and with higher rates of recidivism [25]. A pathway from educational disengagement to entrance into the criminal justice system has been repeatedly identified among young people experiencing TBI [26–28]. This suggests a need to identify ways to prevent adverse trajectories into criminality post-injury, so as to counteract this increased risk. Nonetheless, despite an extensive evidence base of risk factors and potentially life-changing impact of paediatric TBI, there has been limited exploration of how TBI may feed into the "school-to-prison pipeline".

Educational pathways into crime

Developmental trajectories relating to adverse outcomes are complex; however, advances in statistical methods provide an opportunity to examine long-term patterns and sequences of behaviour more flexibly [29]. One often discussed pathway is the "school-to-prison pipeline", which refers to processes whereby a disproportionate number of students with particular characteristics (e.g., special educational needs, disability, poverty, ethnic origin) are systemically disadvantaged and disengaged from the education system and subsequently engaged in the criminal justice system [30].

Statistical associations between education and juvenile offending have been long established [31]. Thirty years ago, Farrington [32] identified that working-class males from South London who had dropped out of school had accumulated more criminal convictions, and self-reported higher levels of violent crime than their school-finishing peers. Subsequent studies of young people in criminal justice systems have found relatively poor literacy and numeracy skills, and frequent early disengagement with education [33–35].

Whilst education appears to be a protective factor against offending, clearly not all of those with poor educational outcomes will offend [36]. There is a need to understand how other factors contribute to or offer protection from this pathway; this understanding is critical in order to determine how to focus often limited resources. Special educational needs and disability (SEN/D) are one such set of factors that warrant attention, given that, in England, almost half of all fixed-period and permanent exclusions are for young people categorised in such a way [37]. This pattern has been observed across a variety of international contexts; for instance, students with SEN/D from the USA, Australia, and Europe have also been identified as at substantially higher risk of suspension and exclusion [2,3,38]. This finding is particularly pertinent for brain injured students as further analyses in the USA identified that students with emotional/behavioural disorders are amongst the most likely to be excluded [39].

Confounding factors

Many individuals who either drop out of school, or later go on to offend have very complex needs; multiple risk factors (such as poor student-teacher relationships, motivation, or reduced participation in school activities) can compound each other and further increase the likelihood of adverse educational outcomes like school dropout [40,41]. In particular, there are many shared risk factors for TBI, criminality, and poor educational outcomes (e.g., low socioeconomic status, reduced family functioning, and substance misuse) which may confound any mediative effect of TBI on the link between education and crime. In order to ascertain whether TBI has a role in pathways to crime it is important to consider how these other factors may contribute. For example, lower socioeconomic status is associated with increased risk of involvement in the criminal justice system [42], but also with increased rates of TBI [43] and more problematic subsequent symptoms (for instance, reduced verbal comprehension, problematic behaviours, and distractibility) [44]. Similarly, family functioning (e.g., parental motivational strategies, consistency of parenting, support, and guidance) affects both the likelihood of criminality [45] and the progression of symptoms following TBI [46,47], but is also affected by family stressors, including those related to poverty [48].

Another confounding factor in the relationship between offending and TBI is substance abuse [49]. Within criminal justice populations, young people with TBI have been found to have higher problematic substance use than those without [50], as well as earlier onset of substance misuse [51]. Previous research has discovered that students who reported substance abuse problems or conduct disorder were almost 2.5 times more likely to drop out of school, suggesting that this may also be a factor in adverse educational trajectories [52]. Early substance misuse has also been found to mediate the relationship between TBI and offending, particularly for those injured in early childhood [53]. This supports the notion that TBI can increase the likelihood of substance misuse problems, which can contribute to pathways to crime post-injury. Furthermore, research has also indicated that the link between previous TBI and higher likelihood of committing a serious violent crime is increased when a history of problematic alcohol consumption is reported [54]. This suggests that it is not only drug misuse which contributes to this pathway, but also that alcohol misuse itself may be a contributory factor.

Whilst some studies have sought to control for many of these factors and continued to find an association between TBI and conviction [55], further exploration of TBI as a factor in educational pathways to crime is needed, so as to highlight any systemic disadvantage students may face post-injury and encourage development of appropriate supports and interventions. The overall aim of this research was to explore this theoretical pathway into offending post-injury by using structural equation modelling (SEM) of a dataset of educational and offending histories of young men in a youth justice custodial institution. The principal research hypothesis was that TBI would mediate the relationship between lower educational attainment and increased/earlier offending behaviours.

Methodology

Development of conceptual model

SEM is a group of multivariate statistical techniques which allow the researcher to simultaneously calculate the significance of various theoretical pathways; running multiple regression equations concurrently. It is able to determine whether hypothesised theoretical models are consistent with the data sourced to present the theory [56]. One of the particular strengths of SEM is its' flexibility; it can be used to examine complex associations in a variety of types of data [57].

Figure 1 displays a conceptual model of the relationships between TBI, education, and offending behaviours. Given the evidence highlighted previously it was hypothesised that lower educational outcomes would be associated with more frequent

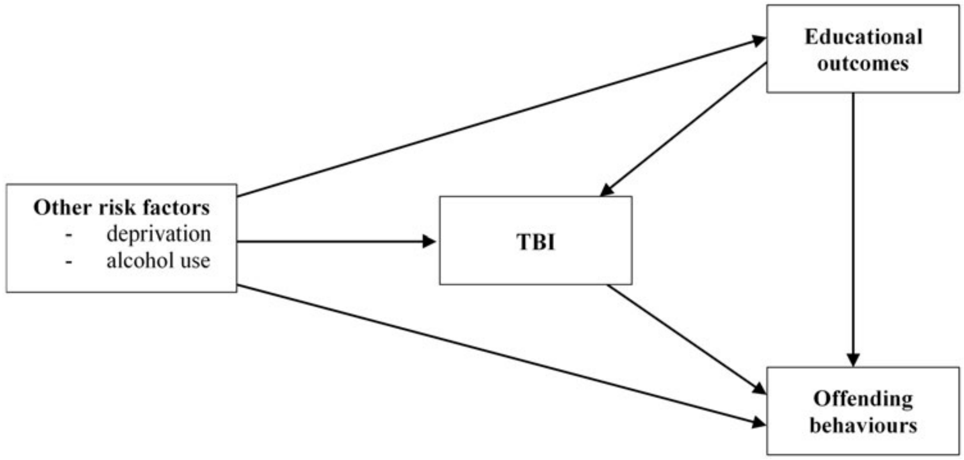

Figure 1. Conceptual model of the relationship between education and crime as mediated by TBI.

patterns of offending behaviour, and that this relationship would be partially mediated by TBI.

The exposure variable of interest in the study was TBI, and in the SEM model this was captured by the presence of chronic PCS symptoms. Dependent variables included those related to educational outcomes (total number of General Certificates of Secondary Education (GCSEs), as completed between the ages of 15 and 16 in the UK), and offending behaviours (including total number of convictions and age at first conviction). These variables formed the basis of the following study hypotheses:

> Hypothesis 1: Lower total number of GCSEs attained will be associated with greater number of total convictions, and this relationship will be partially mediated by PCS symptoms.

> Hypothesis 2: Lower total number of GCSEs attained will be associated with lower age at first conviction, and this relationship will be partially mediated by PCS symptoms.

The observed associations were adjusted for the effects of common confounding factors by including a series of control factors in the analysis, as previously highlighted as increasing the risk of TBI, poor educational outcomes, and offending behaviours; namely, alcohol use and deprivation. Indicators of family functioning (namely parenting) were not included as variables in the final model due to the poor quality of measures collected.

Study context

Data were collected from young men incarcerated in one Young Offenders Institute (YOI) in England. All eligible individuals from the institution were approached, and participants were recruited during free periods from their educational activities. One hundred and five potential participants were approached to participate in the study; six declined, and one did not meet inclusion criteria (see below), resulting in an initial sample of 98 (93.3% response rate). All participants were aged between 16 and 18 years (M 16.87, SD 0.64). The majority of participants described their ethnicity as White (56.8%, $N = 54$), with the second most common ethnicity being Black-Caribbean (22.1%, $N = 21$). Participants were excluded if there was active psychosis, suicidal ideation, severe visual or hearing impairments which would influence ability to complete the tasks, a diagnosis of congenital Learning Disability, Asperger's, Autism Spectrum Disorder, or any condition that may affect cognitive functioning. These individuals were excluded as a supplementary aim of data collection was to analyse cognitive functioning (using neuropsychological functioning tasks) specifically in relation to HI. Additionally, participants were excluded if English was not their first language.

Procedure

Interviews were conducted in a private room by either a researcher, or a trained member of staff in the Psychology team, together with a second member of staff. Interviews lasted approximately 30 min, and participants were encouraged to take breaks if needed. Following interview completion participants were debriefed and given two pounds of phone credit as payment.

Ethical approval for the study was given by the ethics committee of the University of Exeter, the University of Birmingham, and the Director of the YOI.

Measures

Traumatic brain injury

Participants were asked to complete a modified version of the Rivermead Post-Concussion Symptoms Questionnaire [58] as developed by Herrmann et al. [59], and later added to by Mounce [60]. This self-rated scale was used by participants who reported previous HI to measure the presence of symptoms over the 24-h period prior to assessment. A five-point Likert scale was used for each symptom (1 = "not experienced at all", 5 = "a severe problem"). Both the original scale [61] and the adapted scale ($\alpha = 0.69$) have been found to have acceptable internal reliability and validity. Alongside this, participants were asked to record how much they experienced each symptom in everyday life, and how problematic it was. This information was summed into a single measure of PCS; as the sample size was fairly restricted, including individual symptoms in the model would reduce power and overcomplicate the model, reducing the validity of the results. PCS symptoms were used as more comprehensive measure of chronic TBI; the measure considers the consequences of all injuries, regardless of age sustained, repetitive injuries, and original severity.

Educational profile

Participants were asked to record the total number of GCSEs that they had achieved, which was then grouped (1 = none, 2 = one to three, 3 = four to six, 4 = seven to nine, 5 = 10 or more). Whilst the number of higher qualifications achieved – such as AS levels – were also collected, these were not included in the analysis;

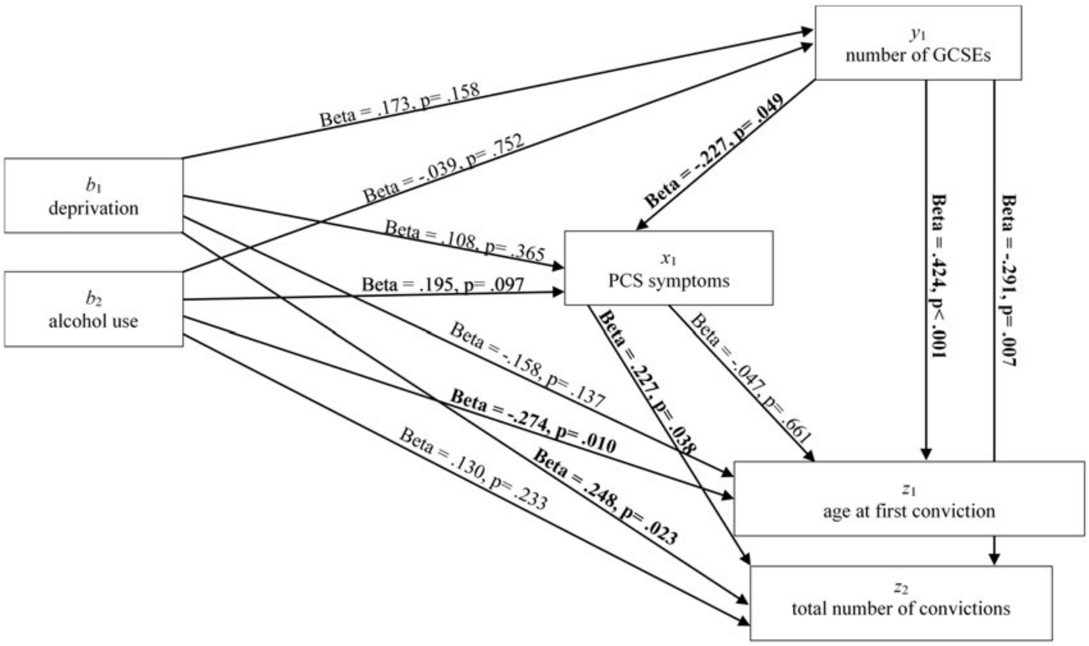

Figure 2. Final structural equation model of the relationship between education and crime as mediated by TBI.

only two participants achieved AS levels, and the wide range of vocational and supplementary qualifications achieved were not always reported fully, making categorisation difficult.

Criminal profile

Participants were asked to self-report the total number of previous convictions they had for a variety of different offences (including: burglary, shoplifting/theft, violent offences, joyriding, fraud/deception, drug offences, sexual offences, and other). This information was summed to create a count of the total number of convictions. Participants were also asked for their age at first conviction.

Control variables

Socio-economic status was measured by calculating the level of deprivation in the area participants' lived prior to incarceration. This Index of Multiple Deprivation score was computed using postcodes corresponding to the area participants' lived before custody, and based on the English Indices of Deprivation 2010, providing a relative local measure of deprivation. Alcohol use was measured by asking participants to record the frequency of alcohol use for various types of beverage, from none to everyday use (0 = never, 1 = once per year, 2 = once per month, 3 = weekends, 4 = most days, 5 = everyday). This information was summed to create a total alcohol use frequency score.

Data analysis

SEM was used as it combines multiple regression, factor analysis, and path analysis techniques, so as to estimate multiple and interrelated dependences between measured variables within a single analysis and model. Although SEM cannot explain any particular causal pathway [62], the analysis indicated how plausible the hypothesised model was. It was used to facilitate the examination of whether there is an indirect relationship between education and crime, through HI, whilst also simultaneously modelling a direct pathway between the two (see Figure 2).

The analyses were conducted using IBM SPSS version 20 and AMOS version 25 (Armonk, NY). Little's missing completely at random (MCAR) test was used to assess the overall mechanism of the missing data due to its flexibility in being applied under any missing data pattern [63,64]. Analysis of missing data found that Little's MCAR was non-significant, lending evidence to support an assumption of the data being missing at random ($\chi^2 = 18.489$, df $= 15$, $p = 0.238$). The data were largely normally distributed and were found to be MCAR; this means that using listwise deletion as a method of preparing the dataset was not likely to introduce bias, as opposed to other estimation methods (maximum likelihood, weighted least squares, two-stage least squares, asymptotically distribution) [65]. This resulted in a final sample size of 70.

Prior to SEM, the data were checked for violations of the assumptions of linearity and multicollinearity [65]. The Durbin Watson test was used in several regressions to assess for autocorrelation in the residuals. Kurtosis and skewness were assessed statistically and visually using histograms for all residuals of endogenous variables. As SEM can be sensitive to anomalies [66], data were screened for outliers using Cook's distance. As per the guidelines developed by Hoyle and Panter [67] and Shah and Goldstein [68], a variety of model fit indices from several different index families were calculated. These included Chi-Square (χ^2), the root mean square error of approximation (RMSEA[1]), the Tucker–Lewis index (TLI[2]), and the comparative fit indices (CFI[3]) [69]. Parameter estimates were then collected for each model tested. The model was modified in an iterative process, according to modification indices, significance of regression paths, and overall model fit if modifications were reasonable according to theoretical considerations. Post hoc alterations to the model were limited as the structural model was based on substantive theory, and by permitting model fit to drive the research process it counters the original aim of testing the theoretical model [70].

Results

Participants' demographic and clinical characteristics

Table 1 displays detailed demographic characteristics for all of the participants in the study, and Table 2 presents descriptive statistics for all variables included in the model. The reported

Table 1. Demographic characteristics.

		Frequency	Percent
Previous head injury	Yes	72	73.5
	No	26	26.5
Current age	16	27	27.6
	17	57	58.2
	18	14	14.3
Ethnic group	White English	54	55.1
	Black-Caribbean	21	21.4
	Black-African	5	5.1
	Black-Other	5	5.1
	Asian-Pakistani	3	3.1
	Asian-Bangladeshi	2	2.0
	Asian-Other	2	2.0
	White Other	2	2.0
	Mixed	1	1.0
	Missing	3	3.1
Still in education	Yes	32	32.7
	No	66	67.3
Age left education	9	1	1.0
	10	2	2.0
	12	4	4.1
	13	10	10.2
	14	14	14.3
	15	17	17.3
	16	15	15.3
	17	2	2.0
Highest qualification achieved	None	17	17.3
	GCSE	31	31.6
	AS level	2	2.0
	Other	34	34.7
	Total	84	85.7
How many GCSEs achieved	None	52	53.1
	One to three	11	11.2
	Four to six	9	9.2
	Seven to nine	3	3.1
	Ten or more	5	5.1

N = 98.
GCSE (General Certificate of Secondary Education) – a qualification for a specific subject taken in the UK between 14 and 16 years of age; AS-Level (Advanced Subsidiary Level) – the next qualification in the UK after GCSEs, which represents the first component of A-Levels, and is usually taken between the ages of 16 and 17.

Table 2. Descriptive statistics for variables in the model.

	N	Mean	SD
Total number of GCSEs achieved	89	1.66	1.15
Number of PCS symptoms	98	14.08	4.26
Total number of convictions	98	9.45	9.05
Years since first conviction	93	3.87	2.18
Alcohol use	98	6.50	4.45
Deprivation indices	84	4.90	2.53

Valid *N* = 70.

prevalence of TBI was found to be consistent with the literature [22], with 73.5% of participants self-reported a previous HI ($N = 72$). As no formal diagnostic information was available via medical records, it was only possible for participants to indicate themselves if they had previously encountered a blow to the head (termed "head injury"), which may then indicate a TBI. It should be noted that self-reporting head injuries have been found to result in the under-reporting of TBI incidents, even those which required hospitalisation [71]. Recall is particularly challenging if the hospitalisation for TBI occurred during infancy and early childhood, or if a long period of time has passed post-injury [71].

Of the participants who did report an HI, most injuries were sustained either during a fight (50%, $N = 36$), falling over when sober (15.3%, $N = 11$), or in road traffic accidents (12.5%, $N = 9$). In the UK, it is compulsory for children and adolescents to attend school or other training between five and 18 years of age for those born on or after the 1st of September 1997. If born before this date the end of compulsory school was at 16 years of age. The mean age at first injury was 11.17 years (SD 3.68), and 43.4% of participants encountered their first HI at primary school age (5–11 years of age, $N = 26$). The majority of participants sustained their HI between the ages of 12 and 16 years (51.6%, $N = 31$). With respect to patterns of injury, multiple injury was common; 33 participants had sustained three or more injuries (33.7%), with a further 15 participants reporting two previous injuries (15.3%), and 24 participants reporting only one incident of HI (24.5%). The mean number of PCS symptoms experienced by participants who had history of HI was 14.76 (SD 4.26), and 12.19 (SD 3.05) for those without. Studies have shown that typically people who have had an HI stop experiencing PCS symptoms after 3–12 months post-injury [72]; however, approximately a subgroup of 15–25% of people experience persistent PCS symptoms [73]. Table 3 shows the frequency of each PCS symptom by whether or not previous HI was reported. All respondents reported PCS symptoms; however, the median total score of the sample was 13 (the first quartile was 11, and the third was 17). This compares to a median score of eight (the first quartile was 0, and the third was 22) in the general population of the UK using the same measure (not taking brain injury into account) [74]. The majority of participants had already left education at the time of interview (67.3%, $N = 66$), and of these most left in secondary school at the mean age of 14.34 years (SD 1.63). The mean age at first conviction was just before at 12.98 years (SD 2.2), and the most common offences were violent offences (50%, $N = 49$), burglary (21.4%, $N = 21$), and robbery (12.2%, $N = 12$), and drug offences (7.1%, $N = 7$).

Bivariate correlations

Several significant correlations between variables were observed. PCS symptoms were strongly associated with offending, as shown in correlations with age at first conviction ($r = 0.24$, $p = 0.018$), and total number of convictions ($r = 0.31$, $p = 0.002$). PCS symptoms were also significantly negatively correlated with educational achievement, as measured by total number of GCSEs ($r = -0.23$, $p = 0.027$).

Estimation and fit

The model provided acceptable fit as shown: χ^2 (1, $N = 70$)=3.478, $p = 0.062$, TLI = 0.210, CFI = 0.947, RMSEA = 0.190, suggesting that the model generally represents the sample data well. Whilst the RMSEA did not reach the <0.08 cut off for good fit, this fit statistic is known to favour more parsimonious models, which may have contributed to worse fit on this measure [70].

Direct effects

Table 4 displays all direct effect parameter estimates. Total number of GCSEs achieved was related negatively to PCS symptoms (standardized coefficient $\beta = -0.227$, $p = 0.049$), in support of hypothesised relationships between TBI and educational outcomes. Total number of GCSEs also related negatively to total number of convictions (standardized coefficient $\beta = -0.291$, $p = 0.007$), and positively to age at first conviction (standardized coefficient $\beta = 0.424$, $p < 0.001$), supporting a link between education as a protective factor in criminal outcomes. PCS symptoms were predictive of an increase in total number of convictions

Table 3. PCS symptoms and head injury.

	Head injury yes/no	I do not experience it	Not much of a problem	A mild problem	A moderate problem	A severe problem
Headaches	HI (*N* = 72)	17 (23.6%)	27 (37.5%)	16 (22.2%)	12 (16.7%)	0
	No HI (*N* = 26)	11 (42.3%)	8 (30.7%)	5 (19.2%)	2 (7.7%)	0
Feelings of dizziness	HI	35 (48.6%)	26 (36.1%)	8 (11.1%)	2 (2.8%)	1 (1.4%)
	No HI	22 (84.6%)	3 (11.5%)	0	1 (3.8%)	0
Nausea and/or vomiting	HI	64 (88.9%)	7 (9.7%)	1 (1.4%)	0	0
	No HI	26 (36.1%)	0	0	0	0
Forgetfulness	HI	24 (33.3%)	21 (29.2%)	16 (22.2%)	8 (11.1%)	3 (4.2%)
	No HI	14 (53.9%)	5 (19.2%)	6 (23.1%)	1 (3.8%)	0
Poor concentration	HI	13 (18.1%)	20 (27.8%)	20 (27.8%)	17 (23.6%)	2 (2.8%)
	No HI	8 (30.8%)	6 (23.1%)	8 (30.8%)	3 (11.5%)	1 (3.8%)
Confusion	HI	46 (63.9%)	15 (20.8%)	11 (15.3%)	0	0
	No HI	16 (61.5%)	8 (30.8%)	2 (7.7%)	0	0
Fogginess	HI	56 (77.8%)	6 (8.3%)	6 (8.3%)	4 (5.6%)	0
	No HI	23 (88.5%)	2 (7.7%)	1 (3.8%)	0	0
Difficulty recalling everyday events	HI	42 (58.3%)	12 (16.7%)	11 (15.3%)	6 (8.3%)	1 (1.4%)
	No HI	21 (80.8%)	3 (11.5%)	1 (3.8%)	1 (3.8%)	0
Other similar difficulties	HI	62 (86.1%)	0	4 (5.6%)	3 (4.2%)	3 (4.2%)
	No HI	25 (96.2%)	0	1 (3.8%)	0	0

Table 4. Tabulated parameter estimates: direct effects.

DV		IV	Beta	S.E.	Standardised beta	*p*
Number of GCSEs	<—	Alcohol use	−0.010	0.033	−0.039	0.752
Number of GCSEs	<—	Deprivation	0.083	0.059	0.173	0.158
PCS symptoms	**<—**	**Number ofGCSEs**	**−0.720**	**0.366**	**−0.227**	**0.049**
PCS symptoms	<—	Deprivation	0.165	0.182	0.108	0.365
PCS symptoms	<—	Alcohol use	0.167	0.101	0.195	0.097
Age at first conviction	**<—**	**Number ofGCSEs**	**0.755**	**0.188**	**0.424**	**0.001**
Age at first conviction	<—	Deprivation	−0.136	0.091	−0.158	0.137
Age at first conviction	<—	PCS symptoms	−0.026	0.060	−0.047	0.661
Age at first conviction	**<—**	**Alcohol use**	**−0.132**	**0.051**	**−0.274**	**0.010**
Number of convictions	**<—**	**PCS symptoms**	**0.573**	**0.276**	**0.227**	**0.038**
Number of convictions	**<—**	**Number ofGCSEs**	**−2.324**	**0.861**	**−0.291**	**0.007**
Number of convictions	<—	Alcohol use	0.281	0.236	0.130	0.233
Number of convictions	**<—**	**Deprivation**	**0.955**	**0.419**	**0.248**	**0.023**

Significant relationships are highlighted in bold text.

(standardized coefficient $\beta = 0.227$, $p = 0.038$). Increased alcohol use was positively related to age at first conviction (standardized coefficient $\beta = -0.274$, $p = 0.010$). Finally, deprivation was also predictive of total number of convictions (standardized coefficient $\beta = 0.248$, $p = 0.023$).

Indirect effects

Table 5 displays all indirect effect parameter estimates. It was hypothesized that the relationships between educational outcomes (total number of GCSEs) and offending (total number of convictions and age at first conviction) were mediated by PCS symptoms (chronic BI measure). Results indicate indirect effects of education through PCS symptoms on total number of convictions (standardized indirect coefficient $\beta = -0.412$).

Discussion

To our knowledge, this is the first study to develop an SEM of educational pathways to crime where TBI has been considered as a contributing factor. The proposed model was used to test the hypothesised mediation of educational outcomes and crime by indicators of TBI. The results partially supported the hypothesised model, with a significant association between the number of GCSEs attained and the total number of convictions, which was mediated by a higher number of reported PCS symptoms (Hypothesis 1). Whilst this result does not and cannot indicate causation, it strongly suggests that TBI is a factor in educational pathways to crime, despite rarely being accounted for in either the educational system [75] or the criminal justice system [76].

In this sample of incarcerated young people, PCS symptoms appeared to have a greater influence on frequency of offending behaviour than age at first conviction. PCS symptoms did not significantly mediate the relationship between educational attainment and age at first conviction (Hypothesis 2). This was also observed in the direct effects between TBI and more frequent offending behaviours, which highlighted a significant association between increased PCS symptoms and more frequent convictions, yet no significant relationship with age at first conviction.

Whilst this result indicates that an injury to the head is associated with higher conviction rates, this may reflect an increased likelihood to commit more frequent violent offences, given that the variable "total number of convictions" captures frequency of violent offences. Consideration to the frequency of violent offending may better reflect the impact of impairments related to TBI. This includes propensity to behavioural dysregulation and increased impulsivity [77], which can contribute to violent offending trajectories [55], deficits in inhibition and slower information processing may contribute to frustration and impulsive reactions when challenged [78] and deficits in executive functioning, which have been found to be associated with violent behaviour [79].

The key relationship between educational outcomes and criminality in the theoretical model was also supported by the results. Significant relationships were identified between increased educational attainment and both more frequent convictions, and younger age at first conviction. Both findings are consistent with

Table 5. Tabulated parameter estimates: indirect effects.

	Alcohol use	Deprivation	Number of GCSEs	PCS symptoms
Number of GCSEs	0.000	0.000	0.000	0.000
PCS symptoms	0.008	−0.060	0.000	0.000
Age at first conviction	−0.013	0.060	0.019	0.000
Total number of convictions	0.125	−0.134	−0.412	0.000

All results refer to standardized indirect coefficient betas. Other similar difficulties reported include: sleeplessness, mood swings, poor eyesight, pain in head, memories surfacing, feeling dazed, hypervigilance, and experiencing flashbacks.

the literature review, which suggests that educational attainment is an important factor in later offending behaviours [80,81]. Accounting for both frequency of convictions and age at first conviction allowed for greater examination of patterns in pathways to crime relating to different risk factors, including TBI.

Despite much of the literature discussing how these risk factors are linked with TBI, none of the risk factors included in the model had either direct or indirect relationships, including PCS symptoms. This does not mean that this is the only potential mediation model; in SEM many different equivalent models may work. For the purposes of this study, all other suitably measured risk factors were controlled for in the same way, so as to highlight the main relationship; other models would also likely have worked well due to the complex nature of the relationships between risk factors and outcomes.

It is important to consider the possibility that school exclusion may have influenced the trajectory of those following TBI; 25% of permanent school exclusions in England last year were for students aged 14, and this age group also had the highest rate of fixed period exclusions [37]. This is a critical age in educational trajectories as it is when students are preparing to take their GCSE exams later in the year.

Any relationship between exclusion and TBI may partially explain the relationship between TBI and total number of GCSEs achieved. It would be interesting to explore whether exclusion itself was a factor in possible pathways to crime post-injury, particularly how experience of education such as enrolment in Pupil Referral Units can affect the education to crime pathway. In the UK, Pupil Referral Units are institutions designed to provide alternative education for students who are either excluded, sick, or otherwise unable to receive education through typical schooling. This is particularly important considering nearly a third of the sample identified as currently still being in education; understanding more about the educational pathways of this select group may give more insight into how students perceive "education", and whether current provision is appropriate.

Although this research has achieved its initial aim to understand more about how TBI can be a factor in developmental pathways to crime, it is important to acknowledge its limitations. First, this research included some variables which violated the assumptions of linearity and normality. To work out whether this would be problematic, the dataset was explored for possible non-linear relationships (such as curvilinear or quadratic) and none were identified, suggesting no relationships that would undermine the results. Additionally, no amount of transformation could have changed the single variable with kurtosis identified; however, as this was not extended to the residuals it was not considered to destabilise the parameter estimates [66,82].

Second, as both education and criminality are complex concepts, there may be factors unaccounted for in this model (such as family functioning, ethnicity, and school-level factors for instance the quality of teaching). However, as there are so many factors interplaying it would be impossible to account for them all, particularly with a limited sample size. The model was already complex for the estimated parameters, and so a compromise had to be reached during the analysis. Additionally, this model does not take into consideration that multiple risk factors can compound one another, leading to an increased likelihood of adverse outcomes [83], and instead simplifies this by attempting to isolate the impact of TBI. In future studies, greater consideration of how these mechanisms interplay would be beneficial.

Finally, it was not possible to time order the events being studied. Whilst there was a general developmental pattern of age at TBI (mean = 11.17 years), occurring before age on leaving education (mean = 14.34 years), and age at first conviction (mean = 12.98 years), this was not consistent across subjects; thus temporal relationships between the variables cannot be measured. Indeed, as the measure of TBI was PCS symptoms at the time of interview, it would not be possible to measure this. As such, theoretical assumptions were made about how the variables related to one another. This still allowed the original hypotheses to be tested, but reinforces that it is not possible to determine causality from the findings. It is possible that TBI may have contributed to these outcomes, but it is also possible that TBI may be a marker for these risk factors. From these results, the most pertinent finding is that whichever way TBI is modelled, it continues to be a pervasive factor in both offending and reduced educational outcomes.

Conclusions

The SEM resulting from this study demonstrates that TBI is a significant factor in adverse pathways between poor educational outcomes and more frequent offending. This evidence therefore echoes similar studies in suggesting that greater consideration of TBI is required in policy and practice within the education and criminal justice sectors. In particular, greater understanding of the contribution of TBI to educational disengagement is needed. This implies routine screening for TBI and PCS symptoms where educational difficulties are apparent, as well as the inclusion of TBI within categorisations in receipt of funding for special educational support. Routine screening for TBI should also occur within criminal justice settings. The current costs of TBI without effective rehabilitation are high for learners, families, communities, and society. Studies like this which highlight the links between "hidden" injuries such as TBI, education, and crime accentuate the economic and social consequences of failing to act; greater focus on school-based rehabilitation will likely save money and improve lives in the long-term.

Notes

1. The RMSEA estimated the lack of fit compared to the saturated model, and a fit of <0.08 was considered adequate fit [71].
2. A cut-off of 0.90 and above on the TLI can be used to interpret adequate fit on this index [72].

3. The CFI compared the model to the independence model. Scores range from 0 to 1, and generally scores of 0.95 or higher are used to indicate good fit. This fit index is reported to perform well even with a smaller sample size [72].

Disclosure statement

The authors report no conflicts of interest.

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