Using the St Andrew’s – Swansea Neurobehavioural Outcome Scale (SASNOS) to determine prevalence and predictors of neurobehavioural disability amongst survivors with traumatic brain injury in the community

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ABSTRACT
Studies using the St Andrew’s – Swansea Neurobehavioural Outcome Scale (SASNOS) confirm neurobehavioural disability (NBD) is highly prevalent in inpatient Neurobehavioural Rehabilitation and Stroke samples. However, a recent study amongst a Danish community sample of acquired brain injury survivors found a relative paucity of NBD symptoms; and when symptoms were present, they tended to be of mild severity. The current observational study employed the SASNOS to explore prevalence of NBD in survivors with traumatic brain injury (TBI) living in the community, the extent of survivors’ self-awareness of NBD symptoms, and constructed prediction models of NBD. A de-identified data set was compiled, comprising data for 97 TBI survivors (74.2% men, mean time since injury 2.8 years). In addition to SASNOS self- and proxy-ratings, various demographic, clinical and injury-related characteristics were captured. NBD was found to be highly characteristic, although severity varied depending on subtype. Statistical comparison of self- and proxy-ratings did not support reduced self awareness regarding NBD, whereas treating the problem as one of inter-rater reliability suggested this was an issue. Executive impairment, depressed mood and sex were especially prognostic of NBD. Reasons accounting for differences in NBD between the community samples are discussed and recommendations for future research made.

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Introduction

Neurobehavioural disability (NBD) as a consequence of traumatic brain injury (TBI) is the product of complex interactions between damaged neural
systems, neurocognitive functions, and environmental factors, further modified by pre-morbid personality traits and post-injury learning (Wood, 2001). Symptoms of NBD can take many forms, often comprising elements of executive and attentional dysfunction, poor impulse control, altered emotional expression, labile mood, poor insight, problems of social judgment and awareness, and a plethora of personality changes that impede psychosocial recovery (Kreutzer et al., 1996; Williams et al., 2020). Challenging behaviour associated with NBD is enduring, often posing a greater impediment to community reintegration than physical limitations arising from injury (Alderman & Wood, 2013; Kelly et al., 2008).

Fortunately, there is now a substantial body of high-quality evidence demonstrating the clinical and cost effectiveness of post-acute neurobehavioural rehabilitation (NbR) for addressing poor social outcomes associated with NBD (e.g., Alderman & Wood, 2013; Alderman et al., 2013; Oddy & da Silva Ramos, 2013; Ylvisaker et al., 2007). However, whilst effective means of managing NBD have been demonstrated, methods for the accurate assessment and measurement of symptoms must also be available to help clinicians assess needs and measure effectiveness of rehabilitation, as well as to enable researchers to investigate the epidemiology of this important outcome of TBI.

However, there are challenges to assessment and measurement. NBD is a heterogeneous condition comprising multiple clusters of symptoms, whereas many studies of NBD have focused on a single, focal domain rather than the greater range of difficulties comprising NBD. For example, Sabaz and colleagues (2014) investigated the focal domain of challenging behaviour, reporting a prevalence rate of 54% amongst 507 participants with TBI in community-based rehabilitation services. Although, the investigation of focal domains is not straightforward either, as prevalence estimates can vary considerably, likely reflecting the use of different measures, instruments, and definitions. Challenging behaviour illustrates this point well; although aggression has been described as one of the most debilitating outcomes from TBI (Fleminger et al., 2006), reported prevalence estimates vary considerably (11%–96%; Tateno et al., 2003). Other examples of studies concerned with a focal domain of NBD include irritability (Yang et al., 2012), working memory (Manktelow et al., 2017) and impaired self-awareness (Prigatano & Sherer, 2020).

Further, even though focal domain studies provide useful insight, building an accurate representation of the prevalence of symptoms of NBD as a whole is also desirable. However, drawing information together from focal domain studies to achieve this goal is problematic, as sample composition and study context can vary considerably. Additionally, comparing results when different instruments and methodologies have been employed and/or when standardized scores are unavailable, is difficult. Thus, “global” measures containing items that are both representative of the multiple symptoms that characterize NBD and employ the same metric, are essential for building a comprehensive
picture of outcome. However, whilst there are several instruments available for this purpose, a review by Wood et al. (2008) concluded that many of these were unsatisfactory because they were not conceptualized to measure NBD and/or had weak or unknown psychometric properties; potentially explaining why researchers have tended to investigate focal rather than global aspects of NBD. A further point to consider is that some studies rely on self-report ratings (e.g., see Juengst et al., 2019), leading to potential threats of reliability. Namely, disorders of self-awareness and/or poor insight can be present after TBI, resulting in unrealistic self-appraisal and a tendency to understate difficulties (Spikman et al., 2013).

To overcome these challenges and provide an instrument to meaningfully measure NBD symptoms as a collective, Alderman et al. (2011) developed the St Andrew’s-Swansea Neurobehavioural Outcome Scale (SASNOS, https://projects.swan.ac.uk/sasnos). The SASNOS contains 49 items capturing five domains of NBD (Interpersonal Relationships; Cognition; Inhibition; Aggression, and Communication), each with 2–3 domains (see Table 1). Each item comprises a statement describing a symptom of NBD, which is rated using a seven-point scale (“1 – never” to “7 – always”), with both self- and proxy-ratings based on the proceeding 2-week period. Standardized T-scores (M = 50, SD = 10) are formed for total, domain and subdomains, enabling a balanced assessment of NBD. Higher scores reflect greater perception of ability and fewer symptoms of NBD, with total scores below 40 considered exceptional and indicative of NBD warranting focus in rehabilitation. SASNOS has robust psychometric properties (see Alderman et al., 2011) and can reliably assess change in NBD symptoms over time (Alderman et al., 2017).

Recently, the SASNOS has been used to assess the frequency and progression of NBD symptoms amongst people with both traumatic and other types of acquired brain injury across various contexts, allowing useful comparisons to be made. These include survivors with acquired brain injury (ABI) in the community (Soendergaard et al., 2019), stroke survivors in rehabilitation and community settings (O’Connell et al., 2020; Stolwyk et al., 2018, 2020), and participants in neurobehavioural rehabilitation programmes (Alderman et al., 2011, 2017, 2018).

However, although symptoms of NBD are strongly associated with outcomes after TBI, it should not be expected that the prevalence and impact of symptoms will be consistent across different contexts and types of ABI. For example, severe symptoms may reasonably be expected to occur amongst survivors admitted into NbR programmes (at least in the early stage of admission), as admission is usually driven by the presence of challenging behaviour. Indeed, Alderman et al. (2011) found that difficulties with Interpersonal Relationships (95.6%) and Cognition (97.1%) were especially prolific in their sample of NbR participants, whilst symptoms of Aggression (63.2%), Communication (50%), and Inhibition (79.4%) were more variable. Further, Alderman et al. (2018) demonstrated how individual symptom clusters on the SASNOS combined to form distinct
NBD profiles; 66% of their sample of NbR participants co-presented with difficulties relating to Interpersonal Relationships and Cognition, whereas evidence of co-existing clinical problems with Aggression, Inhibition and Communication were not as endemic.

Investigation of NBD amongst stroke survivors across rehabilitation and community contexts via SASNOS has also been extensively undertaken (e.g., O’Connell et al., 2020; Stolwyk et al., 2018, 2020). Whilst it is not surprising that NBD symptoms were not as frequent or severe compared to NbR contexts, their presence nonetheless had a negative impact on outcome overall. For example, in a subacute inpatient sample of 82 stroke survivors (57.3% men; M = 47.2 days post-stroke), Stolwyk et al. (2018) found that nearly 60% exhibited “mild” or worse NBD in at least one SASNOS domain. Difficulties with Interpersonal Relationships (44.4%) and Cognition (52.4%) were most frequent (mild-moderate severity), while NBD associated with Inhibition (1.2%), Aggression (3.6%) and Communication (2.5%) were uncommon and tended to be of mild severity. Individuals rated as presenting with more severe NBD were also assessed as having decreased functional independence, greater cognitive impairment, and higher levels of self-reported anxiety and depression. NBD was also more prolific amongst stroke survivors who had sustained anterior lesions, with symptoms exerting a negative impact on those around them. However, even though results met expectations regarding the relatively high incidence of NBD amongst stroke survivors, Stolwyk and colleagues were surprised that difficulties with Inhibition and Aggression were less common. They attributed this finding to patients with more challenging behaviour having been excluded by, for example, refusing to take part or being admitted to specialized behavioural units.

Subsequently, Stolwyk et al. (2020) followed up a subsample of 27 stroke survivors in the community post-discharge from an inpatient rehabilitation unit. SASNOS self-ratings were used. Results suggested perception of NBD whilst in hospital was infrequent, with a third of the sample reporting occasional or rare problems with Interpersonal Relationships and Cognition, with smaller numbers reporting difficulties with Inhibition, Aggression and Communication. There was little change in perceived prevalence of NBD symptoms pre- to post-discharge. Consequently, the authors suggested that NBD may have been under-reported owing to reduced self-awareness post-stroke (see O’Connell et al., 2020). However, even mild self-reported NBD was significantly correlated with greater functional dependence, anxiety, and depression during inpatient rehabilitation and with depressive symptoms at follow-up.

Another context in which the SASNOS has been used to quantify the extent of NBD is amongst ABI survivors (68.8% men, 68.8% TBI) at least one year post-injury living in the community (Soendergaard et al., 2019). Only one person had a proxy-rated SASNOS total score below cut-off (1 SD below the mean; T-score <40), and few were assessed as having difficulties on individual SASNOS domains. For example, only ten (32.3%) were rated below cut-off for Cognition, where
proxies rated cognition as significantly poorer the longer the time since injury and when Glasgow Outcome Scale Extended Scores (Wilson et al., 1998) were lower. Further, although all mean scores fell in the normal range for neurologically healthy controls, a lack of concordance between SASNOS self- and proxy-ratings was noted for ten of 18 comparisons; although secondary analysis of data by the current authors found a small effect size (ES: Cohen, 1988) (≥.20 to <.50) for all but two of these comparisons. Overall, Soendergaard and colleagues concluded that the prevalence of NBD in their sample was much lower than expected, potentially attributable to time since injury, proxy-ratings being provided by relatives than rehabilitation professionals, and the possible exclusion of survivors with the most severe NBD. Indeed, single domain studies have typically reported much higher rates of NBD in community ABI samples at one, two, and five or more years post-injury (e.g., Stéfan et al., 2016).

In summary, studies of global symptoms of NBD using the SASNOS suggest these are highly characteristic amongst participants receiving NbR compared to stroke survivors in both rehabilitation and community contexts, whereas Soendergaard et al. (2019) reported surprisingly low levels of NBD in their community sample of ABI survivors (68.8% TBI). Therefore, we believe that clarifying the extent of NBD amongst survivors with TBI in the community, as well as exploring how different clusters of NBD symptoms co-exist and what factors are associated with them, is highly desirable.

Consequently, the aim of this study is to employ the SASNOS to investigate NBD symptoms in a representative sample of survivors with TBI living in the community, and to test the following hypotheses. First, in contrast to the findings of Soendergaard et al. (2019), we predict that our sample will present with significant NBD symptoms, consistent with the general findings from investigations of single, focal domain studies; we also anticipate that most survivors will present with multiple clusters of symptoms, which we will compare with the studies summarized earlier. Second, consistent with previous findings regarding disorders of self-awareness and poor insight after TBI, we assert that our sample will underestimate the prevalence and severity of NBD symptoms compared to informants who know them well (self- versus proxy-ratings). Finally, previous studies using SASNOS have demonstrated associations between NBD and other factors. Therefore, we will expand on this line of investigation by building statistical models to determine if demographic, injury and other related variables influence symptoms of NBD.

**Method**

**Participants**

An observational cohort study design was employed utilizing an opportunistic sample through compilation of a de-identified data set (CW), drawing on
information extracted from the case records of survivors with TBI living in the community who had been assessed (conducted by RLW) at the University Brain Injury Clinic. Here, survivors are typically referred for neuropsychological assessment for medicolegal purposes and/or for advice on the management of long-term neuropsychological sequelae. Participant data was included providing that: the individual had consented for their data to be de-identified for research purposes, a diagnosis of TBI applied with no additional diagnosis of a progressive neurological condition, and a SASNOS rating (proxy, self or both) was available.

Ninety seven participants met these criteria, of whom 74.2% were men. Mean age at injury was 34.6 years (SD = 14.5, range = 12.9–66.5) and 37.3 years (SD = 14.0, range 18.4–72.0) at assessment. Mean time since injury was 2.9 years (SD = 3.1, Range = .01–25.1). There were multiple causes of TBI: road traffic accident (63.9%), fall (18.6%), assault (9.3%), “other” blow to the head (7.2%), and as a consequence of an explosion (1.0%). Severity of injury was determined by the length of post-traumatic amnesia (Teasdale & Jennett, 1974), with participants classified as mild (14.6%) or moderate/severe (85.4%–18.3% and 67.1% respectively). Pre-morbid intelligence was estimated using the Wechsler Test of Adult Reading UK (Full-scale IQ M = 88.7, SD = 10.8, range 70–114; Wechsler, 2001), with scores positively correlated (r = .41, p < .001) with number of years spent in formal education (M = 13.5 years, SD = 2.53, range 11–23). Prior to injury, 78.0% were in either full or part-time employment, compared to only 31.4% post-injury. Additionally, 67.0% reported being in a committed relationship pre-injury compared to 59.8% post-injury. Finally, sizeable minorities reported a pre-injury psychiatric history (26.8%), relevant medical history (17.5%, such as previous alcohol dependency, investigations for epileptic seizures, chronic headaches), or history of learning difficulty, including dyslexia, or requiring additional support in school (17.5%). A few reported a previous non-progressive neurological history prior to TBI (7.2%, such as fractured skull, birth trauma, or history of a possible concussion/mild head trauma). Just over half (51.5%) of participants had one of these recorded in their clinical notes, with a small number reporting two or more (11.2%).

From the total sample, 87 proxies who knew the survivor well completed the proxy version of the SASNOS. Each proxy was categorized into one of seven groups: spouse/partner (47.1%), parent (39.9%), son/daughter (4.6%), sibling (3.4%), other relative (1.1%), close friend (1.1%), care/support worker (3.4%). Most proxies were women (75.9%) and the majority of raters in six of the seven groups were women (e.g., 80.5% and 70.6% of spouses/partners and parents were women, respectively). Overall, 92% of survivors were rated by proxies as exhibiting at least “mild” symptoms of NBD. Of these cases, 18.8% were rated below cut-off on a single SASNOS domain, 38.8% in two, 30% in three, 10% in four, and 2.5% in all five.

Ethical approval for the study was granted by the Department of Psychology Ethics Committee, Swansea University.
Measures

In addition to the SASNOS (outlined previously), the following measures were utilized:

Wechsler Test of Adult Reading UK (WTAR-UK; Wechsler, 2001): A word recognition test consisting of 50 irregular words with atypical grapheme to phoneme translations. As reading recognition is relatively stable in the presence of cognitive impairments associated with neurological injury or normal ageing, performance provides an estimation of pre-morbid intellectual ability. The WTAR is scored in terms of the number of correct pronunciations, with total raw scores transformed to age-adjusted standard scores to predict IQ. The WTAR has been shown to be a valid measure of pre-morbid IQ after TBI which remains robust even in the face of suboptimal effort (Green et al., 2008). Estimated full-scale IQ was used in the current study.

Dysexecutive Questionnaire (DEX; Burgess et al., 1996): Part of the Behavioural Assessment of the Dysexecutive Syndrome battery (Wilson et al., 1996), the DEX consists of 20 items designed to assess commonly reported cognitive, emotional, personality and behavioural symptoms of the Dysexecutive Syndrome. Items are rated on a five-point Likert scale (0 – “never” to 4 – “very often”), with higher scores reflecting more severe difficulties. Self and proxy (DEX-O) versions are available, although because of disorders of self-awareness and/or poor insight after TBI, DEX-O ratings are considered a more reliable post-morbid index of executive dysfunction. Further, although various DEX subscales have been proposed, there remains a lack of consensus regarding a robust and parsimonious factor structure (e.g., Burgess et al., 1998; Mooney et al., 2006; Shaw et al., 2015; Wilson et al., 1996). Consequently, only total DEX-O scores were considered here.

Beck Depression Inventory-II (BDI-II; Beck et al., 1996): 21 items assessing the severity of depressive symptoms (e.g., sadness, pessimism) experienced during the preceding two-week period. Each item comprises a list of four statements (scored 0–3) arranged in increasing severity. Total scores between 0–13 indicate the presence of “minimal” depression, 14–19 “mild”, 20–28 “moderate”, and 29–63 “severe”. The BDI has high levels of reliability and validity and is routinely used in research and clinical practice (e.g., Wang & Gorenstein, 2013).

Beck Anxiety Inventory (BAI; Beck et al., 1988): 21 items asking participants to rate how much they have been bothered by emotional, cognitive, and physiological symptoms of anxiety in the last week, using a four-point Likert type scale (0 = “not at all” to 3 = “severely”). Total scores between 0–7 indicate “minimal” levels of anxiety, 8–15 “mild”, 16–35 “moderate”, and 26–63 “severe”. The BAI has excellent psychometric properties and is used widely in research and clinical practice (e.g., Beck et al., 1988).

Other Variables: To provide a range of potential current and historical predictors of NBD, a range of demographic, clinical and injury related characteristics
were extracted from case files and medical records (CW). These included both continuous (e.g., age at assessment, age at time of injury, time since injury, years in formal education) and binary (coded 0, 1) variables, including sex (male/female) severity of TBI as indexed by duration of post-traumatic amnesia (mild or moderate/severe), pre- and post-injury relationship status (in a relationship yes/no), employment status pre- and post-injury (in paid employment yes/no), and yes/no for each of the following - pre-injury psychiatric history/medical history/history of learning difficulty/neurological history.

**Statistical analysis**

Consistent with criteria used by Stolwyk et al. (2018), SASNOS scores were recoded to create an ordinal variable reflecting the presence and severity of NBD: normal >39.9, coded 0; mild 30–39.9, coded 1; moderate 20–29.9, coded 2, and severe ≤ 19.9, coded 3. To counter issues arising from deviation from normal distributions in some predictors, binary variables were created using recommended cut-offs to discriminate normal vs. abnormal scores on the DEX-O (scores exceeding the 95th percentile – yes/no), BDI-II (≥ 14 yes/no) and BAI (≥ 7 yes/no).

Using SPSS v24.0 (IBM Corp., 2016), analyses were undertaken in three stages. First, prevalence of NBD was determined by constructing means and standard deviations for the various SASNOS scores (proxy- and self-ratings); these were also compared to results derived from the studies described earlier. Second, the extent of any reduction in self-awareness was investigated by comparing mean differences (paired t-tests) between SASNOS proxy- and self-ratings. However, as there can be difficulties interpreting differences between means using statistical significance alone (Alderman et al., 2017), findings were also considered in terms of effect size (ES) and interpreted using the cut-off thresholds proposed by Cohen (1988): <.20 “trivial”; ≥ .20 to <.50 “small”; ≥.50 to <.80 “medium”; ≥ .80 “large”. As a “medium” difference has been cited as corresponding to a meaningful difference, this threshold was employed here (Alderman et al., 2017, 2020). Potential differences between SASNOS proxy- and self-ratings were further examined by considering data as agreement between raters (equivalent to inter-rater reliability). Extraneous variability from pooling data was reduced by using ordered SASNOS categorical variables based on severity; the extent of absolute agreement between pairs of raters (proxy vs. self) were determined using weighted kappa as a means of inferring the degree of self-awareness. Kappa coefficients were interpreted in line with Altman (1991): <.20 “poor”; .21 to .40 “fair”; .41 to .60 “moderate”; .61 to .80 “good”; .81–1.00 “very good”. As variance in scores was reduced by assigning means to one of four ordered categories, a conservative threshold of .75 was adopted to reflect an acceptable level of agreement.

Finally, a range of methods appropriate for the type of data and comparisons being made were utilized to identify potential univariate predictors of NBD, including Pearson correlation, point biserial correlation, t-test, Man-Whitney U
test, Chi-square “Goodness-of-Fit” test and ES. Variables identified as potential predictors were entered into a series of ordinal logistic regression analyses to determine prediction models of NBD. This method was used as it builds models using both continuous and ordinal variables, and because we used an ordered categorical dependent variable.

Results

Descriptives

Dysexecutive Syndrome ratings (DEX-O total: M = 40.9, SD = 15.5) exceeded the 95th percentile for neurologically healthy controls in 57.3% of our sample. Mood disorders were also prolific, with 86.8% and 79.5% reporting mild or worse depression or anxiety respectively (BDI-II: M = 26.5, SD = 11.0, range 5–50; BAI: M = 18.3, SD = 18.3, range 0–51).

Prevalence of Neurobehavioural symptoms

Prevalence of NBD amongst survivors of TBI as measured by SASNOS proxy-ratings are shown in Table 1.

Overall, there were 13 different combinations of SASNOS domains. Half of our sample were categorized on just two of these 13 categories; “Interpersonal Relationships + Cognition” (27.5%), and “Interpersonal Relationships + Cognition + Aggression” (22.5%).

Table 1. Prevalence of neurobehavioural symptoms amongst TBI survivors as measured by SASNOS proxy-ratings (N = 87).

| SASNOS domains & subdomains | T-score mean (SD) | Normal % | Mildly impaired % | Moderately impaired % | Severely impaired % |
|-----------------------------|-------------------|----------|-------------------|-----------------------|---------------------|
| Interpersonal Relationships |                   |          |                   |                       |                     |
| – Social Interaction        | 32.5 (13.2)       | 29.9     | 28.7              | 23.0                  | 18.4                |
| – Relationships             | 31.2 (17.4)       | 35.6     | 12.6              | 24.1                  | 27.6                |
| – Engagement                | 33.3 (14.7)       | 32.2     | 28.7              | 19.5                  | 19.5                |
| Cognition                   | 26.1 (12.6)       | 16.1     | 20.7              | 24.1                  | 39.1                |
| – Executive Function        | 33.4 (10.8)       | 27.6     | 35.6              | 26.4                  | 10.3                |
| – Attention & Memory        | 21.0 (15.1)       | 16.1     | 11.5              | 17.2                  | 55.2                |
| Inhibition                  | 53.3 (10.2)       | 92.0     | 3.4               | 4.6                   | 0.0                 |
| – Sexual                    | 62.0 (8.6)        | 96.6     | 2.3               | 1.1                   | 0.0                 |
| – Social                    | 43.2 (12.7)       | 54.0     | 34.5              | 9.2                   | 2.3                 |
| Aggression                  | 44.2 (13.4)       | 59.8     | 25.3              | 12.6                  | 2.3                 |
| – Provocative Behaviour     | 48.0 (12.0)       | 71.3     | 23.0              | 5.7                   | 0.0                 |
| – Irritability              | 34.7 (15.4)       | 33.3     | 21.8              | 28.7                  | 16.1                |
| – Overt Aggression          | 53.3 (16.2)       | 82.8     | 2.3               | 10.3                  | 4.6                 |
| Communication               | 50.1 (11.7)       | 81.6     | 12.6              | 5.7                   | 0.0                 |
| – Speech & Language         | 44.5 (15.3)       | 59.8     | 20.7              | 12.6                  | 6.9                 |
| – Mental State              | 54.5 (11.0)       | 95.4     | 0.0               | 4.6                   | 0.0                 |
| SASNOS total score          | 36.1 (12.0)       | 35.6     | 35.6              | 19.5                  | 9.2                 |
At the domain level, the most frequent NBD difficulties reported were in Interpersonal Relationships (69%) and Cognition (83.9%), with most survivors rated as having moderate-to-severe impairments (73.3% and 85.5%, respectively). At subdomain level, the percentage of survivors being rated as at least mildly impaired was broadly similar across the three Interpersonal Relationship subdomains (64.3%–70.1%). However, ratings for Social Interaction and Engagement tended to be “mild”, whereas ratings were skewed towards the “severe” category for Relationships. A similar dissociation was found for the two Cognition subdomains; difficulties with Executive Function were mainly categorized as “mild-to-moderate”, whereas difficulties with Attention and Memory were mainly rated as “severe”.

Less than half of survivors (40.2%) were rated as exhibiting problems with Aggression; however 66.7% were rated as having at least “mild” problems with Irritability, with most rated as being “mild-to-moderate” in severity. In contrast, problems with Inhibition (8%) were less evident, although there was large disparity between its two subdomains: only 8% of survivors were rated as having Sexual Inhibition problems compared to 46% for Social Inhibition, albeit predominantly to a “mild” extent. Similarly, problems with Communication (18.4%) were also less evident, but there was again disparity at subdomain level; 40.2% of survivors were rated as having at least “mild” problems with Speech & Language (predominantly mild in severity) compared to only 4.6% for Mental State.

**Comparison of NBD characteristics across samples**

The prevalence of NBD in NbR, stroke rehabilitation and community samples were compared (Tables 2 and 3). All NbR participants were assessed as having “mild” or worse symptoms in at least one SASNOS domain, with 72.1% reporting global symptoms of NBD in 4–5 domains. Difficulties with Interpersonal Relationships and Cognition were most evident, with 92.6% presenting with “mild” or worse symptoms (predominantly “moderate” or “severe”) in both these domains. Problems with Inhibition and Aggression were also very characteristic, although severity was more evenly distributed from “mild” to “severe”.

In contrast, survivors in the stroke and community samples tended to present with focal rather than global NBD. However, whilst NBD was very characteristic of Welsh community dwellers (92%) and notable in the stroke sample (59.6%), only 32.3% of survivors in the Danish community sample reported “mild” or worse NBD in at least one domain. As with the NbR sample, difficulties with Interpersonal Relationships and Cognition were most prolific; amongst the Welsh sample, 63.2% were assessed as having “mild” or worse symptoms in both these domains. Unfortunately, equivalent data for the two other samples (Stroke, Danish Community) was not available. Further, the severity of problems in the Interpersonal Relationships and Cognition domains tended
Table 2. Comparison of NBD characteristics across NbR, subacute inpatient stroke and community samples.

| Predominant type: TBI | Predominant type: CVA | Predominant type: TBI | Predominant type: TBI |
|---------------------|---------------------|---------------------|---------------------|
| Predominant sex: Men | Predominant sex: Men | Predominant sex: Men | Predominant sex: Men |
| Age: m40.3 yrs (sd 11.3) | Age: m67.6 yrs (sd 15.6) | Age: m44.9 yrs (sd 16.8) | Age: m36.9 yrs (sd 14.1) |
| Time since injury: m10.5 yrs (sd 8.7) | Time since injury: m47.2 days (sd 24.7) | Time since injury: m19.4 mths (sd 10.0) | Time since injury: m33.5 mths (sd 37.2) |
| “Mild” or worse NBD in at least one domain: 100% | “Mild” or worse NBD in at least one domain: 59.6% | “Mild” or worse NBD in at least one domain: 32.3% | “Mild” or worse NBD in at least one domain: 92.0% |
| Focal vs. global NBD: Global rated “mild” or worse in 4–5 domains | Focal vs. global NBD: Focal rated “mild” or worse in 1–2 domains | Focal vs. global NBD: Focal rated “mild” or worse apparent | Focal vs. global NBD: Focal rated “mild” or worse in 1–3 domains |
| Most frequently observed NBD: Cognition (97.1%) | Most frequently observed NBD: Interpersonal Relationships (95.6%) | Most frequently observed NBD: Interpersonal Relationships (52.4%) | Most frequently observed NBD: Interpersonal Relationships (33.3%) |
| Most frequently observed NBD: Inhibition (79.4%) | Most frequently observed NBD: Aggression (72.1%) | Most frequently observed NBD: Tendency for severity categories to be more evenly distributed | Most frequently observed NBD: Predominantly “mild” severity |
| Tendency for “moderate to severe” severity for Interpersonal Relationships & Cognition; more evenly distributed for Inhibition & Aggression | | | |
| Least frequently observed NBD: Communication (50%) | Least frequently observed NBD: Aggression (3.6%) | Least frequently observed NBD: Aggression (3.2%) | Least frequently observed NBD: Communication (18.4%) |
| Least frequently observed NBD: Predominantly “mild” severity | Least frequently observed NBD: Communication (2.5%) | Least frequently observed NBD: Inhibition (0%) | Least frequently observed NBD: Inhibition (8%) |
| Least frequently observed NBD: Inhibition (1.2%) | Least frequently observed NBD: Predominantly “mild” severity | Least frequently observed NBD: Aggression predominantly “mild” severity | Least frequently observed NBD: Predominantly “mild” severity |

Note: *Alderman et al. (2011); †Stolwyk et al. (2018); ††Soendergaard et al. (2019); ‡Current study; † Number of domains by participants not given.

Table 3. Comparison of SASNOS subdomain scores between the Welsh Community and NbR, Subacute Inpatient Stroke and Danish Community samples.

| SASNOS Subdomain | NbR | Subacute inpatient stroke | Danish community |
|------------------|-----|--------------------------|------------------|
| Social Interaction | – | .74** | 1.28** |
| Relationships | 1.03†† | .53** | 1.14** |
| Engagement | – | – | 1.41** |
| Executive Function | – | – | 1.12*** |
| Attention & Memory | – | .95** | 1.27** |
| Sexual Inhibition | 2.74† | – | 1.88* |
| Social Inhibition | – | 1.06* | 1.13* |
| Provocative Behaviour | .73† | 1.63* | 1.50* |
| Irritability | .59†† | 2.12** | 1.91** |
| Overt Aggression | 1.35† | .99* | .87* |
| Speech & Language | 1.29† | .94* | 1.11* |
| Mental State | 1.15†† | .80* | .63* |

Note: ES of ≤ .50 (“medium” or higher shown); †Welsh mean score higher; ††Welsh mean score higher and below cut-off; †Welsh mean score lower; **Welsh mean score lower and below cut-off.
to be rated as mostly “mild-to-moderate” in the Welsh Community sample, whereas severity was more evenly distributed in the Stroke sample, and predominantly “mild” in the Danish Community sample.

Aggression was also far more prevalent in the Welsh (40.2%) compared to the Danish (3.2%) and Stroke (3.6%) samples, but was less severe than observed in the NbR sample, being assessed as mostly “mild” in severity. In contrast, few NBD symptoms in Inhibition (0-8%) and Communication (0%–18.4%) were observed across the Stroke and community samples, and when reported, tended to be “mild” in severity.

Mean differences across the four samples were also explored (Table 3), with a “medium” ES (≤.50) adopted as the minimum threshold for a meaningful difference (Norman et al., 2003). Means were lower in the NbR sample overall, reflecting more severe impairment than amongst the Welsh Community sample. However, difficulties with Social Interaction, Engagement, Executive Function, Social Inhibition and Attention and Memory were equivalent, with ES below .50 in each instance. In contrast, both samples exhibited mean scores below 40 for Relationships and Irritability, although the severity of symptoms was greater for NbR participants.

In contrast, NBD symptoms were generally more prevalent amongst the Welsh compared to stroke sample; the Welsh group had significantly lower mean ratings (i.e., more severe NBD) on nine of 12 subdomains (“medium” or higher ES). However, means for five of these were above cut-off, signifying that the clinically meaningful differences where the Welsh Community sample were more impaired were in the Social Interaction, Relationships, Attention and Memory, and Irritability subdomains. Engagement and Executive Function subdomain scores were comparable across the two samples, and both achieved mean ratings in the normal range for Sexual Inhibition.

Of greatest interest was the comparison between the two community samples. All 12 subdomain ratings were significantly lower (i.e., more severe NBD) in the Welsh than Danish sample. However, although mean ratings were lower for Sexual and Social Inhibition, Provocative Behaviour, Overt Aggression, Speech & Language, and Mental State in the Welsh sample, both samples were above cut-off. In contrast, the clinical meaningfulness of the remaining six subdomains was apparent; scores were above cut-off for the Danish sample, but below for the Welsh sample. Therefore, the two community samples were easily distinguishable by ratings in all subdomains pertaining to Interpersonal Relationships and Cognition, as well as aspects of Aggression (e.g., Irritability).

**Concordance between SASNOS self- and proxy-ratings**

Self- and proxy-ratings (N = 79) were compared to investigate potential issues regarding reduced self-awareness of NBD amongst TBI survivors (Table 4). Self-ratings for two domains (Interpersonal Relationships, Cognition) and six
subdomains (Social Interaction, Relationships, Engagement, Executive Function, Attention and Memory, and Irritability) fell below the cut-off of 40, suggesting many survivors perceived themselves as having clinically significant symptoms of NBD; although visual inspection of mean ratings suggests survivors tended to underestimate the extent of their NBD, with proxy-ratings lower for 12 of 18 scores. However, statistically significant differences were limited to one domain (Interpersonal Relationships) and two of its three subdomains (Social Interaction and Engagement). In each instance, mean proxy-ratings were significantly lower, suggesting potential lack of self-awareness amongst survivors. Re-examining differences between self- versus proxy-ratings by ES revealed 17 “trivial” differences, and one “small”. Therefore, whilst there appears to be a tendency for survivors to rate themselves as having less severe NBD difficulties than those observed by proxy-raters, the size of these differences was not enough to be meaningful, at least as far as can be measured though differences between mean ratings. Given this, the concordance between self- and proxy-ratings was further examined by determining levels of absolute agreement (weighted kappa) using the ordered categorical variable representations of domain and subdomain scores (Table 5).

Absolute concordance between self- and proxy-ratings can be interpreted as reflecting parity in acknowledgement of the presence of NBD symptoms, assuming the latter represents the “gold standard”. Whilst Table 4 displayed little evidence of meaningful differences between mean scores, Table 5 suggests there was lack of agreement between raters. No weighted kappa coefficient fell above the .75 threshold to indicate acceptable levels of agreement. The best level of agreement was for Provocative Behaviour (categorized as “good”), but most comparisons (12 of 18) were classified as “fair” or worse.

Table 4. Concordance between SASNOS self- and proxy-ratings in the Welsh Community sample.

| Domains & subdomains       | Self-ratings Mean (SD) | Proxy-ratings Mean (SD) | t* | P** | Effect size |
|----------------------------|------------------------|-------------------------|----|-----|-------------|
| Interpersonal Relationships| 32.1 (16.1)            | 29.3 (15.3)             | 1.776 | .040** | .18         |
| – Social Interaction       | 36.0 (14.2)            | 32.1 (13.1)             | 2.487 | .008** | .29         |
| – Relationships            | 30.9 (17.5)            | 30.2 (17.1)             | 0.371 | .356 | .04         |
| – Engagement               | 35.3 (15.1)            | 32.6 (14.6)             | 1.797 | .038** | .18         |
| Cognition                  | 26.7 (13.0)            | 25.5 (12.6)             | 0.904 | .185 | .09         |
| – Executive Function       | 34.5 (11.2)            | 32.7 (10.7)             | 1.615 | .055 | .16         |
| – Attention & Memory       | 20.6 (15.4)            | 20.8 (15.1)             | 0.104 | .459 | .01         |
| Inhibition                 | 53.2 (8.5)             | 53.3 (10.5)             | 0.042 | .483 | .01         |
| – Sexual                   | 61.3 (8.5)             | 61.7 (8.9)              | 0.330 | .371 | .05         |
| – Social                   | 43.8 (10.7)            | 43.4 (13.1)             | 0.203 | .420 | .03         |
| Aggression                 | 45.4 (14.5)            | 44.8 (13.8)             | 0.515 | .304 | .05         |
| – Provocative Behaviour    | 49.0 (12.4)            | 48.5 (12.0)             | 0.403 | .344 | .04         |
| – Irritability             | 38.3 (16.0)            | 35.5 (15.8)             | 1.604 | .057 | .18         |
| – Overt Aggression         | 50.9 (17.8)            | 53.5 (16.5)             | 1.411 | .081 | .15         |
| Communication              | 49.6 (12.4)            | 49.6 (11.7)             | 0.016 | .494 | .00         |
| – Speech & Language        | 44.6 (14.6)            | 43.9 (15.2)             | 0.372 | .356 | .05         |
| – Mental State             | 53.6 (11.5)            | 54.3 (11.1)             | 0.454 | .327 | .06         |
| SASNOS total score         | 37.2 (12.4)            | 35.8 (12.3)             | 1.084 | .141 | .11         |

Note: N = 79 in each group; *df = 78; **p < .50; 1-tailed probability.
Predictive models of NBD as captured by SASNOS

Relationships between SASNOS scores and a range of potential predictors were determined. Where univariate analyses suggested associations existed, variables were entered as potential predictors in ordinal logistic regression analyses. Those subsequently shown not to contribute were excluded and analyses repeated until final models emerged that only contained variables that made a significant contribution (see Tables 6–13 for final models).

Each set of analyses is captured across two tables. The first describes model fitting information for the “final model”, where potential predictor variables that made a significant contribution were retained. In the interests of clarity, model fitting information regarding the intercept and “first model”, consisting of all potential predictors identified from univariate analyses, is not captured across Tables 6–13 but is available as Supplementary Information (see Supplementary Material for further details). The likelihood ratio chi-square test confirms if there was a significant improvement in fit of the model tested relative to the intercept-only baseline model; a significant result confirms this was the case. The Pseudo $R^2$ (Nagelkerke) values correspond to approximate analogues of the $R^2$ values generated in ordinary least squares regression which are used to summarize the proportion of variance in the dependent variable associated with the predictor variables. Goodness-of-Fit includes the Deviance and Pearson chi-square tests that help ascertain if a model exhibits good fit to the data; non-significant results indicate this is the case. The Test of Parallel Lines provides a test of the assumption that the relationship between predictor variables is the same across all possible comparisons involving the predicted variable – non-significance is interpreted as evidence that this assumption is met.

### Table 5. Weighted Kappa coefficients reflecting the extent of absolute agreement between SASNOS self- and proxy-ratings.

| Domains & subdomains          | Weighted Kappa | Strength of Agreement* |
|-------------------------------|----------------|------------------------|
| Interpersonal Relationships   |                |                        |
| - Social Interaction          | .50            | moderate               |
| - Relationships               | .29            | fair                   |
| - Engagement                  | .44            | moderate               |
| Cognition                     |                |                        |
| - Executive Function          | .39            | fair                   |
| - Attention & Memory          |                |                        |
| Inhibition                    | -.06           | poor                   |
| - Sexual                      | .24            | fair                   |
| - Social                      | -.03           | poor                   |
| Aggression                    |                |                        |
| - Provocative Behaviour       | .46            | moderate               |
| - Irritability                | .65            | good                   |
| - Overt Aggression            | .45            | moderate               |
| Communication                 |                |                        |
| - Speech & Language           | .34            | fair                   |
| - Mental State                | .29            | fair                   |
| SASNOS total score            | .43            | moderate               |

Note: *Altman, 1991 – < .20 “poor”; .21 to .40 “fair”; .41 to .60 “moderate”; .61 to .80 “good”; .81–1.00 “very good”. A conservative threshold .75 was used to reflect an acceptable level of agreement.
The second table pertaining to each analysis presents the parameter estimates for the final models. Regression coefficients are presented (B column), whilst the Wald Chi-square test result confirms that predictor/s made a significant contribution to the final model. The Exp(B) column contains odd ratios, reflecting the changing probabilities of a case falling at a higher/lower level on the dependent variable. An odds ratio greater than one suggests an increasing probability of a higher categorical classification of NBD severity as values on the independent variable increase. Likewise, an odds ratio of less than one suggests a decreasing likelihood as the independent variable increases. 95% confidence intervals for Exp(B) are also captured.

### Table 6. Results of ordinal logistic regression analysis for SASNOS Total and Interpersonal Relationships (domain and subdomains), final model solution.

| Domains & subdomains | Model fitting information | Goodness-of-Fit* | Test of Parallel Lines* |
|----------------------|---------------------------|------------------|-------------------------|
|                      | Variables in final model  | —2 Log Likelihood | Chi-square (df) p       | Pseudo R²     | Chi-square (df) p | Chi-square (df) p |
| SASNOS total score   | DEX                       | 101.61           | 68.37 (1) <.001         | .624         | Pearson Deviance  | 98.43 (125) .962  |
|                      |                           |                  |                         |             |                | 78.56 (125) 1.00  |
| Interpersonal        | Sex BDI                  | 158.87           | 42.64 (3) <.001         | .465         | Pearson Deviance  | 200.17 (216) .773 |
| Relationships        | DEX                       | 146.50           | 29.14 (1) <.001         | .326         | Pearson Deviance  | 113.33 (125) .289 |
|                      |                           |                  |                         |             |                | 114.67 (125) .736 |
|                      |                           |                  |                         |             |                | 3.89 (6) .692     |
| – Social Interaction | DEX                       | 139.89           | 26.24 (1) <.001         | .301         | Pearson Deviance  | 113.30 (125) .765 |
|                      |                           |                  |                         |             |                | 104.36 (125) .960 |
|                      |                           |                  |                         |             |                | 2.01 (2) .366     |
|                      |                           |                  |                         |             |                | 7.45 (6) .281     |
| – Relationships      | DEX                       | 164.12           | 38.17 (3) <.001         | .427         | Pearson Deviance  | 191.13 (216) .888 |
|                      |                           |                  |                         |             |                | 162.73 (216) .997 |
| – Engagement         | Sex BDI                  | 146.50           | 29.14 (1) <.001         | .326         | Pearson Deviance  | 113.33 (125) .289 |
|                      | DEX                       | 139.89           | 26.24 (1) <.001         | .301         | Pearson Deviance  | 113.30 (125) .765 |
|                      |                           |                  |                         |             |                | 104.36 (125) .960 |
|                      |                           |                  |                         |             |                | 2.01 (2) .366     |
|                      |                           |                  |                         |             |                | 7.45 (6) .281     |

Note: *Final model only; BDI – Beck Depression Inventory; DEX – Dysexecutive Questionnaire Proxy Rating.

The second table pertaining to each analysis presents the parameter estimates for the final models. Regression coefficients are presented (B column), whilst the Wald Chi-square test result confirms that predictor/s made a significant contribution to the final model. The Exp(B) column contains odd ratios, reflecting the changing probabilities of a case falling at a higher/lower level on the dependent variable. An odds ratio greater than one suggests an increasing probability of a higher categorical classification of NBD severity as values on the independent variable increase. Likewise, an odds ratio of less than one suggests a decreasing likelihood as the independent variable increases. 95% confidence intervals for Exp(B) are also captured.

### Table 7. Parameter estimates for SASNOS Total and Interpersonal Relationships (domain and subdomains), final model solution.

| Domain & subdomains | Variables | B       | Std. error | Wald Chi-square df p | Exp (B) | 95% confidence interval for Exp(B) |
|---------------------|-----------|---------|------------|-----------------------|---------|-----------------------------------|
| SASNOS total score  | DEX       | .166    | .027       | 39.037                | 1 .001  | 1.181                             |
| Interpersonal       | Sex       | −1.420  | .577       | 6.074                 | 1 .014  | .242                             |
| Relationships       | BDI       | .064    | .024       | 6.703                 | 1 .010  | 1.066                             |
|                      | DEX       | .087    | .020       | 19.652                | 1 <.001 | 1.090                             |
|                      |           |         |            |                       |         | 1.050                             |
|                      |           |         |            |                       |         | 1.133                             |
|                      | DEX       | .080    | .017       | 23.613                | 1 <.001 | 1.084                             |
|                      |           |         |            |                       |         | 1.049                             |
|                      |           |         |            |                       |         | 1.119                             |
|                      | DEX       | .078    | .017       | 20.670                | 1 <.001 | 1.081                             |
|                      |           |         |            |                       |         | 1.045                             |
|                      |           |         |            |                       |         | 1.118                             |
| – Social Interaction | DEX       | −1.824  | .589       | 9.945                 | 1 .002  | .161                             |
|                      |           |         |            |                       |         | .052                             |
|                      |           |         |            |                       |         | .501                             |
| – Relationships      | BDI       | .063    | .023       | 6.983                 | 1 .009  | 1.065                             |
|                      | DEX       | .065    | .018       | 13.959                | 1 <.001 | 1.067                             |
|                      |           |         |            |                       |         | 1.031                             |
|                      |           |         |            |                       |         | 1.104                             |

Note: Final model results presented; BDI – Beck Depression Inventory; DEX – Dysexecutive Questionnaire Proxy Rating.
Table 8. Results of ordinal logistic regression analysis for Cognition and Inhibition (domain and subdomains), final model solution.

| Domain and subdomains | Model fitting information | Goodness-of-Fit* | Test of Parallel Lines* |
|-----------------------|---------------------------|------------------|-------------------------|
|                       | Variables in final model  | Goodness-of-Fit* |                         |
|                       |                           | Pseudo R²        |                         |
|                       | −2 Log Likelihood | Chi-square (df) | p | Chi-square (df) | p | Chi-square (df) | p |
| Cognition             | Sex DEX                   | 138.81           | 51.04 (2) | .507 | 192.80 (154) | .018 | 2.19 (4) | .700 |
|                       | DEX                       | 142.56           | 23.77 (1) | .277 | 106.74 (125) | .880 | 1.76 (2) | .415 |
|                       | Executive Function        |                  |            |     |                  |     |            |     |
|                       | DEX                       | 125.05           | 47.03 (2) | .493 | 187.61 (154) | .034 | 2.68 (4) | .614 |
|                       | Attention & Memory        |                  |            |     |                  |     |            |     |
|                       | Sex DEX                   | 21.53            | 26.96 (1) | .561 | 27.17 (83)    | 1.00 | 3.56 (1) | .059 |
|                       | DEX                       | 14.31            | 12.90 (1) | .484 | 15.99 (83)    | 1.00 | 0.01 (1) | .969 |
|                       | Social DEX                | 95.64            | 27.73 (1) | .340 | 67.60 (125) | 1.00 | .02 (2) | .992 |
| Inhibition            | DEX                       | 21.53            | 26.96 (1) | .561 | 27.17 (83)    | 1.00 | 3.56 (1) | .059 |
|                       | Sexual DEX                | 14.31            | 12.90 (1) | .484 | 15.99 (83)    | 1.00 | 0.01 (1) | .969 |
|                       | Social DEX                | 95.64            | 27.73 (1) | .340 | 67.60 (125) | 1.00 | .02 (2) | .992 |
| Note: *Final models only; DEX – Dysexecutive Questionnaire Proxy Rating.

Table 9. Parameter estimates for Cognition and Inhibition (domain and subdomains), final model solution.

| Domain/ subdomain | Variables | B   | Std. error | Wald Chi-square | df | p       | Exp(B) | 95% confidence interval for Exp(B) |
|-------------------|-----------|-----|------------|-----------------|----|---------|--------|-----------------------------------|
| Cognition         | Sex       | −1.467 | .526 | 8.204 | 1   | .004   | .231 | .085 to .629                      |
|                   | DEX       | .109  | .020 | 27.870 | 1   | <.001  | 1.115 | 1.071 to 1.162                    |
|                   | DEX       | .070  | .016 | 20.508 | 1   | <.001  | 1.073 | 1.041 to 1.106                    |
| Executive Function| Sex       | −1.801 | .560 | 11.028 | 1   | .001   | .165 | .057 to .478                      |
|                   | DEX       | .107  | .022 | 22.359 | 1   | <.001  | 1.113 | 1.065 to 1.164                    |
|                   | DEX       | .241  | .072 | 11.067 | 1   | .001   | 1.273 | 1.104 to 1.467                    |
| Inhibition         | DEX       | .195  | .075 | 6.659  | 1   | .010   | 1.216 | 1.048 to 1.410                    |
| Sexual             | DEX       | .089  | .020 | 20.851 | 1   | <.001  | 1.093 | 1.052 to 1.136                    |
| Social             | DEX       | .089  | .020 | 20.851 | 1   | <.001  | 1.093 | 1.052 to 1.136                    |
| Note: Final model results presented; DEX – Dysexecutive Questionnaire Proxy Rating.

Table 10. Results of ordinal logistic regression analysis for Aggression (domain and subdomains), final model solution.

| Domain & subdomains | Model fitting information | Goodness-of-Fit* | Test of Parallel Lines* |
|---------------------|---------------------------|------------------|-------------------------|
|                     | Variables in final model  | −2 Log Likelihood | Pseudo R² | Chi-square (df) | p | Chi-square (df) | p | Chi-square (df) | p |
| Aggression          | DEX                       | 91.19            | 33.25 (1) | .396 | 73.79 (125) | 1.00 | 91.19 (2) | .001 |
|                     | Provocative Behaviour     | 77.88            | 22.47 (1) | .313 | 69.65 (83) | .852 | 0.09 (1) | .762 |
|                     | Irritability              | 141.68           | 26.18 (1) | .299 | 138.94 (125) | .186 | 2.17 (2) | .339 |
| Overt Aggression    | MH DEX                    | 66.04            | 18.19 (2) | .304 | 126.80 (145) | .859 | 3.94 (4) | .479 |
| Note: *Final models only; MH – Relevant Medical History pre-TBI; DEX – Dysexecutive Questionnaire Proxy Rating.
Model Fitting Information: For 17 of 18 SASNOS outputs, the likelihood ratio chi-square tests confirmed a significant improvement in fit of the final models relative to the intercept-only baseline models (see Supplementary Materials). The only SASNOS output where this was not the case was Communication (chi-square = 3.83, \( P = .281 \)) (see Tables 6, 8, 10, and 12).

Goodness-of-fit/Test of Parallel Lines: Assumptions were generally met, with only a few exceptions. The Pearson test proved significant for Cognition and Attention and Memory (whilst the Deviance and Test of Parallel Lines tests did not); and the Test of Parallel Lines was significant for
Aggression and *Speech and Language* (whilst the Pearson and Deviance tests were not).

**Pseudo $R^2$:** Estimates of the proportion of variance accounted for by the 17 successful models ranged from 12.8% (*Speech & Language*) to 62.4% (SASNOS Total Score).

**Predictor Variables:** Twelve of 17 potential predictor variables were included in the ordinal logistic regression analyses: sex; years of education; a history of learning difficulty prior to TBI; neurological history prior to TBI; psychiatric history prior to TBI; relevant medical history prior to TBI; BDI-II score; BAI score; DEX-O score; time since injury; in a relationship post TBI; and WTAR estimated FSIQ. The number of predictor variables entered in each of the initial 18 models ranged from two (*Mental State*) to six (Total SASNOS Score, *Attention and Memory*). The most frequent number of variables considered in the first model was three, with the 17 successful “Final Models” each containing one to three variables (see Supplementary Material for a definitive list of predictors initially entered into ordinal logistic regressions for each SASNOS output).

**Prediction Models Containing a Single Variable:** The most prolific was DEX-O (*Tables 7, 9, 11, and 13*), which had a significant association with NBD severity in all 17 surviving models and was the single predictor in 10: SASNOS total score; *Social Interaction and Relationships*; *Executive Function*; Inhibition and its two subdomains (*Sexual and Social Inhibition*), and Aggression and two of its three subdomains (*Provocative Behaviour, Irritability*).

Parameter estimates confirmed that higher ratings on the DEX-O were associated with increased likelihood of being categorized as having more severe NBD. The best model was for Inhibition (*Table 9*) – the odds of having severe inhibition difficulties increased by a factor of 1.273 for every additional point on the DEX-O. In summary, survivors rated as having more frequent, severe symptoms of executive impairment, were more likely to be assessed as having more severe problems with Inhibition.

**Prediction Models Containing Multiple Variables:** Seven models contained two to three predictors; DEX-O was retained in all of these. Other predictors were sex (4/7 models), BDI-II score (3/7 models), time since injury (2/7 models), and relevant medical history prior to TBI (1/7 models).

*Table 6* confirms the final models (DEX-O, sex, and BDI-II score) evidenced better fit than the intercept-only models for Interpersonal Relationships (chi-square = 42.64, $p < .001$) and one of its subdomains, *Engagement* (chi-square = 38.27, $p < .001$). Parameter estimates (*Table 7*) confirm the odds of being assessed as having severe NBD increased by a factor of 1.090 (Interpersonal Relationships) and 1.067 (*Engagement*) for each additional point on the DEX-O; and by 1.066 (Interpersonal Relationships) and 1.065 (*Engagement*) for each assessment point on the BDI-II. In addition, the odds of a man being in a higher severity category of NBD were .242 greater than a woman for Interpersonal Relationships and .161 for *Engagement*. 
Additionally, final models containing DEX-O and sex also evidenced better fit to intercept-only models for Cognition (chi-square = 51.04, \(p < .001\)) and one of its subdomains, Attention & Memory (chi-square = 47.03, \(p < .001\)) (Table 8). The odds of being in a higher severity category of NBD (Table 9) increased for each additional point conferred on the DEX-O by a factor of 1.115 for Cognition and 1.065 for Attention & Memory. There were also higher odds of men being categorized as having more severe NBD than women (Cognition – .231; Attention & Memory – .165).

Regarding Aggression (Tables 10 and 11), the severity of Overt Aggression was successfully predicted by two variables – DEX-O and relevant medical history prior to TBI (chi-square = 18.19, \(p < .001\)). Higher ratings on the DEX-O increased the odds of presenting with more severe Aggression in general (1.116), and overt aggression particularly (1.108). Additionally, survivors with a relevant pre-injury medical history had 6.361 times the odds of subsequently presenting with severe overt aggressive behaviour.

Finally, although potential predictors were no better than the intercept-only model in predicting Communication scores, this was not the case with its subdomains (Table 12 and supplementary material). Severity of NBD symptoms associated with Speech & Language was successfully predicted by age and DEX-O ratings (chi-square = 9.53, \(p = .009\)). For every one year increase in age, the odds of being categorized as having severe Speech and Language difficulties increased by 1.038, and by 1.035 for each additional point on the DEX-O (Table 13). As a model, time since injury and DEX-O scores (Table 12) were predictive of Mental State scores (chi-square = 6.70, \(p = .030\)), although parameter estimates revealed that neither were significant unique predictors (time since injury \(p = .063\) and DEX-O \(p = .700\)).

**Discussion**

The first aim of this study was to use SASNOS to investigate the prevalence of NBD exhibited by survivors with TBI in the community. We hypothesized that our sample would present with significant symptoms of NBD, with most presenting with multiple clusters of symptoms. We confirmed this was the case, with 92% exhibiting “mild” or worse symptoms in at least one SASNOS domain. Thus, in contrast to Soendergaard et al. (2019), NBD was highly characteristic of our sample. We also conducted cross-comparison of our results with those found for NbR participants, as well as stroke and ABI survivors. The headline prevalence rate for our sample sat intuitively where expected, falling between the rate found in NbR (100%) where people with the most extreme challenging behaviour are likely to migrate, and stroke survivors receiving rehabilitation (60%) where a mixture of posterior and anterior lesions are likely.

However, whilst NBD was highly characteristic of our Welsh sample of survivors with TBI living in the community overall, frequency and severity of specific...
symptoms varied considerably. 69% reported “mild” or worse symptoms with Interpersonal Relationships and 83.9% for Cognition, whereas only 40.2%, 18.4% and 8% reported at least “mild” problems for Aggression, Communication, and Inhibition, respectively. Consistent with Alderman and colleagues (2011, 2017), the most common presentation was a combination of NBD symptoms from Interpersonal Relationships and Cognition (49.5% of the total sample), of which nearly half (49.5%) were also assessed as presenting with “mild” or worse NBD symptoms of Aggression.

That said, even though NBD concerning Interpersonal Relationships and Cognition appear generally characteristic of ABI, symptoms were highly non-homogeneous, with disparity commonly observed at subdomain level. Whilst 92% of our sample were assessed as being in the “normal” range for Inhibition, few survivors were assessed as having Sexual Inhibition difficulties (3.4%), but nearly half (46%) were rated as exhibiting difficulties with Social Inhibition. Likewise, 40.2% of our sample were assessed as having “mild” or worse difficulties with Aggression; but 66.7% were rated as having “mild” or worse difficulties with Irritability, the majority (75.7%) of which were “moderate-to-severe”. Similar dissociations were also found within the Communication and Cognition domains. Difficulties with Relationships, Attention and Memory, Social Inhibition, Irritability and Speech and Language were also especially noteworthy; 13 different combinations of SASNOS domains were found which broadly parallels the 10 reported by Alderman et al. (2011). Breaking down SASNOS profiles by subdomain in a large mixed-aetiology ABI sample to identify the range and principal types of NBD profiles would be a useful objective for future studies.

Further, the high overall prevalence rate of NBD in our sample contrasted sharply with the result of 32.3% described by Soendergaard et al. (2019). In the latter, symptoms of NBD were relatively infrequent and predominantly of “mild” severity. In contrast, nearly all survivors here (92.0%) presented with NBD symptoms in at least one SASNOS domain, and most two or more (74.7% of the total sample, with 81.3% of those assessed as having “mild” NBD on at least one domain). Severity was also more variable, ranging from “mild” to “severe” depending on type. Sample representativeness may help to explain these findings, as Soendergaard and colleagues reasoned that the lack of NBD observed in their sample may have been because survivors with the most severe symptoms had been excluded. Interestingly, Stolwyk et al. (2018) suggested this was also the case with their stroke sample, helping to account for the low levels of aggression and disinhibition observed. Therefore, levels of NBD in our sample may be attributable to those survivors with greater difficulties seeking help or financial compensation. Although, results from studies investigating focal NBD symptoms in community samples suggest that such difficulties are present, validating our findings. Indeed, high rates of challenging behaviour have been reported in both community ABI (85% – Kelly et al., 2008) and TBI (54% – Sabaz et al., 2014) samples; and Rabinowitz
and Levin (2014) reported that approximately 65% of survivors with moderate-to-severe TBI experience long-term cognitive impairment, with as many as 15% of mild cases also reporting persistent problems. High rates of alexithymia and low levels of emotional empathy are also commonly described (Williams & Wood, 2010; Wood & Williams, 2007, 2008), with the resulting lack of emotional responsivity, mutual support, and reduction in overt acts of affection contributing to the fragility of close personal relationships and diminishing social networks after injury (Williams & Wood, 2013; Williams et al., 2020). This may help explain why scores on the Cognitive and Interpersonal Relationships SASNOS domains are often reported as being the lowest across studies, as the latter difficulties may be driven to a large extent by social cognition difficulties.

Other factors may also help explain the different rates of NBD across the two community samples. First, there is a difference in mean time since injury: 1.62 years for the Danish sample vs. 2.8 years for the Welsh (ES = .43). A consistent finding in the literature is that NBD is enduring and symptoms can increase over time (see Alderman, 2001; Brooks et al., 1987; Johnson & Balleny, 1996; Juengst et al., 2019; Kelly & Parry, 2008; Thomsen, 1984; Timmer et al., 2020). Second, NBD is also especially associated with damage to anterior brain structures (Wood & Worthington, 2017). Our sample were all cases of TBI, most of whom were survivors of road traffic accidents, where the physical mechanisms of injury incurred through rapid deceleration forces on frontal brain structures are well known (Bigler, 2001, 2007; Wood, 2001). In contrast, the Danish sample experienced a broader range of causes of ABI, with the proportion subject to rapid deceleration forces undocumented. An interesting finding from Stolwyk et al. (2018) in this regard was that NBD as measured by the SASNOS was higher amongst survivors with anterior lesions. Finally, as NBD is the product of interaction between several factors, including the environment and pre-morbid personality traits, local norms and expectations may impact on how it is expressed. Thus, national, and cultural differences across samples may have played a contributory role. A potentially pertinent finding is that people from Denmark have been reported to be the “… world’s happiest people” and those with Danish ancestry more likely to have a “… positive outlook on life”, with a genetic explanation accounting for this (O’Callaghan, 2014).

The second aim of this study was to investigate parity in awareness of NBD symptoms. We hypothesized that survivors would underestimate prevalence and severity of NBD symptoms because of disorders of self-awareness and poor insight, a known outcome of TBI (and a further symptom of NBD). Soendergaard et al. (2019) previously found mixed findings regarding the concordance between SASNOS self- and proxy-ratings. They found several statistically significant differences across ratings, but as mean scores fell within the normal range for neurologically healthy controls, the clinical significance of findings were unclear. We also found that calculating ES as an alternative method of analysis
further undermined confidence in their findings. Results were also mixed in the current Welsh sample. Survivors generally rated themselves as having fewer difficulties than proxies, but in contrast to the Danish cohort, mean proxy-ratings for half of the SASNOS subdomains fell below the normal range, although only two comparisons were statistically significant. Additionally, ES ranged from "trivial" to "small". These results imply differences between raters are insufficient to support a hypothesis of reduced self-awareness. However, when the issue is perceived as the extent of absolute agreement between self- and proxy-raters, weighted Kappa coefficients did not meet the minimum threshold for any SASNOS domain or subdomain. As data variance had been considerably reduced by transforming scores into ordered categorical variables, low Kappa values suggest poor self-awareness may be an issue after all. A future study using a larger cohort with greater range in SASNOS ratings would help clarify this issue.

Our final hypothesis was that it would be possible to construct prediction models of NBD from the range of demographic, injury and other related variables collected. Models consisting of one to three variables were successfully constructed for nearly all SASNOS outputs, with the extent of executive impairment, depressed mood and sex (male) found to be especially indicative. Consistent with our findings, Stolwyk et al. (2018) found that more severe NBD was associated with greater cognitive impairment and higher levels of self-reported anxiety and depression; and Soendergaard et al. (2019) found a negative correlation between time since injury and NBD in their Danish ABI community cohort. Additionally, Sabaz et al. (2014) previously reported that amongst men post-ABI, challenging behaviour was associated with depression. Of course, we recognize limitations in our current approach as our models were restricted to the range of opportunistic variables available. Consequently, we were unable to consider a range of factors previously identified as predictive of NBD, including known damage to anterior brain structures, pre-morbid difficulties with aggressive behaviour, drug and alcohol misuse, decreased functional abilities, reduced psychosocial participation and increased care needs (Sabaz et al., 2014). Consequently, future studies should consider a more comprehensive range of predictors. We also acknowledge that whilst difficulties with executive function and mood are investigated here as predictors of NBD, other symptoms of NBD can influence these. The data collected here did not enable a more sophisticated analysis to be undertaken to investigate issues of directionality; this would be worthy of inclusion in future studies investigating NBD. One predictor also worthy of further study is learning difficulty, as even though this variable was not retained in our final models, it was associated with several SASNOS domains and subdomains. The proportion of the current sample reporting a history of learning difficulty prior to injury was surprisingly high (17.5%), and Chester et al. (2017) previously found a high self-reported prevalence rate of TBI in a forensic learning disability population. However, a potential limitation
of our study is that it is generally accepted that the WTAR overestimates IQ in respondents with very low scores, a factor which may erroneously have led to learning difficulty not being retained in the predictive models. Furthermore, IQ was low for the sample overall (M = 88.7) despite the overall length of time spent in education (M = 13.5 years). This result might be interpreted as evidence that the sample was not typical, further impacting on the reliability of WTAR results. We recommended that alternative means of estimating pre-morbid IQ are employed in future studies exploring predictors of NBD (see Bright and van der Linde, 2020 for a detailed discussion).

It is also worth noting other potential limitations, including a further reason why our sample may not be wholly representative of the target population. Whilst the number of survivors and their significant others is comparable, and in some instances greater, than other studies utilizing the SASNOS to investigate the prevalence of NBD, survivors included here may have either self-referred to a head injury clinic or been referred for medicolegal assessment. Therefore, our sample may have been biased towards those with the most enduring or severe difficulties. To ascertain representativeness, further study of NBD amongst survivors with TBI living in the community should be undertaken, ensuring participants are drawn from a wide range of contexts. Another potential limitation is the possible loss of meaningful information, as mood and executive function were treated as binary variables to overcome non-normally distributed data. Future studies wishing to identify predictors of NBD might chose to manage this issue differently to retain as much information as possible (for a comprehensive review of methods to address non-normality see Pek et al., 2018).

To conclude, our findings suggest that NBD is highly characteristic of TBI survivors living in the community, highlights the usefulness of comparing both self- and proxy-ratings of behaviour to provide valuable information regarding self-awareness of NBD, and provides useful information concerning potential predictors of NBD. Our findings also demonstrate the usefulness of SASNOS for measuring global, as opposed to focal, symptoms of NBD, and for discriminating between different neurological populations. An estimated 1.3 million people are living with the long-term effects of brain injury in the UK alone, representing a cost to the UK economy of £15 billion per year – equivalent to 10% of the total annual National Health Service budget (All-Party Parliamentary Group on Acquired Brain Injury, 2018). Therefore, if the sample examined here is representative and our results are mapped onto the national population, then approximately 1.2 million survivors in the UK could be enduring mild or worse symptoms of NBD which could reasonably be accounting for much of the associated expense. Given the considerable implications of this number to screening, rehabilitation provision and service delivery to alleviate distress and to reduce costs, further research to confirm the representativeness of the results found here should be conducted to inform the national picture.
Disclosure statement

No potential conflict of interest was reported by the author(s).

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