# Video analysis of parent-child interactions in behavioural sleep disorders: development of a scoring algorithm.

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## Author contribution statement

The study was designed by LG, KB, and CH. Recruitment and data collection was completed by LG. Iterative development of the coding system and the coding of video to calculate inter-rater reliability were done by LG and CH.  Data analysis was completed by LG.

## Keywords

tool, Sleep, Child, insomnia, behaviour

## Abstract

Word count:      243

Introduction: Behavioural sleep disorders, including chronic insomnia (CI), are generally assessed by subjective parent interview. However, evidence suggests that parental report of children's overnight behaviours is unreliable, perhaps due to recall bias or confusion due to sleep deprivation. Video technology has been used clinically to capture complex behavioural disorders in children during the day. However, there is no standardised means of analysing child and parent behaviour at bedtime or during the night. We aimed to create an algorithm for this purpose.

Methods: Child brain tumour survivors (a population previously shown to have a high prevalence of CI) were screened for difficulties initiating and maintaining sleep using sub-scales from the Sleep Disturbance Scale for Children. Those who screened positive (n=3) then completed a detailed parent interview to confirm a clinical diagnosis of CI.  One night of home video footage was obtained from initial settling period to morning waking (SOMNOmedics camera). Footage was imported into BORIS© software and a coding system for parent and child behaviour was developed over multiple iterations until agreeable inter-rater reliability (>70%) was achieved between two independent coders.

Results: The final coding categories were: 1) Time domains, 2) Physical environment, 3) Child global status, 4) Location, 5) Activity and 6) Physical interaction. This achieved 74% inter-reliability in its last iteration.

Discussion: A statistically acceptable behaviour scoring algorithm was achieved. With further development, this tool could be applied clinically to investigate behavioural insomnia and in research to provide more objective outcome measurement.

## Contribution to the field

Chronic insomnia is the commonest sleep disorder affecting children. Its aetiology involves either learned sleep onset associations, which need to be recreated in order for the child to fall asleep, or bedtime resistance whereby the child resists bedtime or makes repeated requests (curtain calls) to delay sleep onset. In both cases, both parent and child behaviour, and their interactions with each other, are critical to the development and maintenance of the child's insomnia. Currently, the mainstay of investigation in children's insomnia is parent interview. However, evidence suggests that parent report of both their child's behaviour and their own behaviour is unreliable. We believe that an accurate understanding of the true factors contributing to a child's insomnia is likely to improve the behavioural management of the sleep disorder. In order to objectively assess parent-child interactions in this context, a standardised methodology to observe and document the bedtime routine and overnight activity must be developed. Modern infra-red video technology lends itself to this purpose. We therefore aimed to create a coding system to document and analyse overnight parent-child interactions as observed on 'video somnography'.

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## Ethics statements

### Studies involving animal subjects
Generated Statement: No animal studies are presented in this manuscript.

### Studies involving human subjects
Generated Statement: The studies involving human participants were reviewed and approved by Health Research Authority and South Central – Hampshire A Research Ethics Committee (reference 18/SC/0012)
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Generated Statement: The datasets generated for this study are available on request to the corresponding author.

# Video analysis of parent-child interactions in behavioural sleep disorders: development of a scoring algorithm.

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## 1    Introduction

Chronic insomnia (CI) is the commonest childhood sleep disorder[1]. According to the Third Edition of

the International Classification of Sleep Disorders (ICSD-3), a diagnosis of CI requires 1) difficulty

initiating and/or maintaining sleep, 2) adequate opportunity to do so, and 3) subsequent daytime

dysfunction. The symptoms must occur at least three times per week and have been present for at

least three months[2]. CI leads to insufficient sleep which can be detrimental to a child's behaviour[3],

cognitive function[4], and brain development[5].

The commonest chronic insomnia in childhood is behavioural insomnia. There are two core sub-

types.

41    1. Sleep onset association disorder, where the child requires specific 'associations', for example a

42    parent/carer present in the room or environmental factors such as music or light, to fall asleep. (From

43    here on 'parent' will refer to any carer with involvement in the bedtime routine). With these

44    associations the child settles to sleep easily but following natural night wakings struggles to resettle

45    to sleep without the same conditions they have associated with bedtime.  Typically the child then

46    signals for a parent by crying or leaving the room[6], this is interpreted as a troublesome night waking.

47    2. Limit setting sub-type, where the child makes repeated requests to the parent in an attempt to delay

48    his/her bedtime, that is, "curtain calls". This is accommodated by the parent, who fails to enforce

49    sufficient boundaries[6].

50    Where elements of both sleep onset association insomnia and limit setting insomnia are present, the

51    term 'combined type insomnia'[6] is used.

52    The standard diagnostic assessment of CI is through a clinical history, which has some limitations.

53    Firstly, whilst parental recall of their child's *sleep schedule* (i.e. sleep onset and duration) has been

54    shown to correlate with objective measures (actigraphy), overnight *sleep quality* (the child's

55    overnight activity including number of night wakings[7]) is less reliably reported[8,9]. Parents are only

56    able to report activity of which they are aware. If the child does not disturb the parent, these wakings

57    may be overlooked[9]. While the child's own account is relevant, many children with CI may not have

58    the developmental skills to provide an accurate history. Furthermore, parental recall may be restricted

59    by their own memory of events, which may be impaired when tired, particularly after repeated

60    awakenings[9]. On occasions the sleep problems may be exaggerated, thus misleading any intervention

61    put in place by the clinician[10].

62    An important aetiological factor in the development of CI is parent behaviour. This is usually

63    communicated by self-report so is dependent on the parent's awareness of his or her own actions.

64    Additionally, parents have been shown to sometimes be untruthful when asked to give a self-report of

65    their parenting due to social desirability bias. For example, they may tell clinicians that their child is

66    up-to-date with their vaccines when they are not[11]. An objective measure of both child sleep and

67    parent-child interaction would therefore be of value.

68    Actigraphy is the commonest objective measure of sleep in the child's home environment. It detects

69    overnight activity by measuring limb movement via a wrist-worn device[12]. However, it does not

70    detect wakeful stillness, therefore its validity as an objective measure in insomnia patients is

71    limited[13].

72    Direct observation of parent behaviour is more accurate than parent self-report[14,15]. However, the

73    presence of an observer influences both child and parent behaviour and it is costly and impractical in

74    most clinical settings. Home video somnography (HVSG) is a simple technique using an infra-red

75    camera set up in the child's bedroom that measures sleep and captures information about the child's

76    usual sleep ecology (sleep setting and parent behaviours) without the need for body worn sensors.

77    HVSG was pioneered in the 1970s by Anders and colleagues[16-18] to assess developmental changes in

78    infant sleep. In these original studies basic sleep states were scored (awake, active sleep, quiet sleep).

79    VSG has been since used across multiple applications, principally to assess episodic movement

80    disorders[19] in sleep. The advent of smartphone cameras and low cost motion sensitive night cameras

81    has brought this application into every household and increasingly parents and clinicians are

82    exploiting this technology in the clinic to report sleep related symptoms[20].

83    However, the use of HVSG for behavioural analysis at bedtime and during the night is new. Only one

84    case study has been published to date using HVSG to observe and code parent and child behaviour in

85    CI[21]. The authors used a basic coding system to analyse the child's sleep quantitatively. Only one

86    coder assessed the footage, therefore no inter-rater reliability was calculated. There are a number of

87  established coding systems for daytime parent-child interactions[22-24] designed for specific situations,

88  such as to measure infant soothing and distress[22], or to code parent and child interactions over a short

89  duration, such as the Iowa Family Interaction Rating Scale[23]. A recent study investigated the scoring

90  of motion detection video recording to measure sleep disturbance in three children aged three to five

91  years with autism spectrum disorder[25]. This study found that there was 100% agreement between two

92  observers who scored night wakings and sleep disturbance (within a five second interval of each

93  other) using the video footage. The authors acknowledged that this technology could be applied to

94  monitor parent-child interactions which might contribute to problematic sleep behaviour.

95  We have previously reported that sleep problems are prevalent in survivors of childhood brain

96  tumours[26]. In a clinical population of brain tumour survivors, 37/55 (67%) of participants aged 3 to

97  27 years were at risk of having a sleep disorder based on validated questionnaires [Children's Sleep

98  Habits Questionnaire, Pittsburgh Sleep Quality Index, and the Epworth Sleepiness Scale]. The study

99  indicated that the commonest sleep disorder experienced in this population was likely to be CI,

100 independent of both the type of treatment received and the tumour's location in the brain. We

101 therefore hypothesised that CI in brain tumour survivors had a behavioural aetiology. However after

102 some preliminary research, we found that there was no standardised method to analyse sleep-related

103 behaviour. Therefore for this study we selected childhood brain tumour survivors, a population we

104 knew were likely to have a high proportion of behavioural sleep disorders, to produce and test a tool

105 to analyse sleep behaviours.

106 We aimed: a) to develop a reliable (i.e. reproducible), practical parent-child behaviour scoring tool

107 for use with an overnight home video recording of the child's bedtime and overnight activity and b)

108 to compare parent-report of child sleep with HVSG objective measures.

109 **2    Method**

5

110 Ethical approval was obtained from the Health Research Authority and South Central – Hampshire A

111 Research Ethics Committee and research governance approval from University Hospital

112 Southampton NHS Foundation Trust.

**2.1 Materials**

114 Children were screened for eligibility using the Disorders of Initiating and Maintaining Sleep

115 subscale of the Sleep Disturbance Scale for Children (SDSC). This consists of 7 questions rated on a

116 5-point Likert scale pertaining to the previous 6 months with a maximum score of 35. If the child

117 scored 16 or more they were eligible for further assessment.

118 Equipment used for HVSG was the SOMNOmedics infrared camera with SOMNOwatch actigraphy.

119 This is a portable camera designed to capture activity in low light conditions along with audio

120 recording. The data are downloaded to DOMINO Light™ software that synchronises actigraphy data

121 with video footage, allowing the coder to rapidly locate periods of movement. However, this

122 software only allows basic marking of the video in real-time and had limitations for the analysis of

123 multi-layered aspects of sleep ecology.

124 An alternative software, BORIS© (Behaviour Observation Research Interactive Software), was

125 identified. This was developed by researchers at the University of Turin to document animal

126 behaviour. BORIS© offers the requisite features for this study, namely, it was intuitive to use and

127 allowed the coder to classify behaviours as *state* events, which are ongoing (e.g. when the child is

128 asleep), or *point* events which happen at a single point in time (e.g. time at sleep onset).

**2.2 Data source**

130     Eligible potential children (aged 3 to 12 years who had completed brain tumour treatment at least six

131     months previously) were pre-screened for CI using the SDSC questionnaire. Three children who

132     were at risk of CI were recruited.

133     Recruited children underwent one night of HVSG at home. Recording was programmed to begin

134     prior to the start of their normal bedtime routine, and the parent was instructed to stop the recording

135     when the child woke up in the morning. Families were instructed to carry out their normal bedtime

136     routine, therefore the camera captured all interactions happening in the bedroom during the bedtime

137     routine and during the night.

138     The day following the overnight recording, parents were interviewed by the researcher LG (Lorna

139     Galbraith) using a structured clinical interview (Southampton Children's Hospital Sleep Service).

140     This interview was audio-recorded, and the recording was used to confirm or reject a clinical

141     diagnosis of CI and to obtain the caregiver's self-report of overnight activity.

142     **2.3    Coding system development**

143     Crano's principles of coding system development were employed[27]. This specifies that the following

144     options are considered: a) a categorical or a rating system (in this case a categorical system was more

145     appropriate to incorporate a wide range of behaviours), b) an intensive or extensive system (an

146     intensive approach was initially selected to analyse interactions in detail), and c) a non-inferential or

147     inferential system, the latter meaning that the coder must consider the function of a person's action as

148     well as the action itself[27]. A partially inferential approach was adopted, to reflect the fact that the

149     emotional tone of any behaviour was important to the outcome (sleep onset) rather than the action

150     itself. For example, a parent can soothe their child during the bedtime routine by singing a lullaby

151     gently, however if the singing is loud and stimulating this will not help to settle the child. The authors

152     applied their expertise in sleep medicine (Dr Catherine Hill - CH) and psychology of childhood brain

153   tumour survivors (Dr Kim Bull – KB) to the development of the parent-child interaction coding

154   system. A draft version of a coding algorithm was developed using the following headings: 1) sleep

155   schedule variables, 2) events during the bedtime routine, 3) events after lights out, 4) events after a

156   night waking, and 5) parent-child interactions. Parent-child interactions were further dichotomised as

157   either sleep-promoting or sleep-hindering, as determined by the coder. Physical and verbal

158   behaviours were separated. The full list of codes from this first draft of the coding system can be seen

159   in Table 1.

160   The coding system was then tested using the video data from the overnight footage. LG coded 10

161   minute segments of video data with high levels of parent-child interaction using BORIS©. CH

162   independently coded these segments. Any disagreements were discussed and the coding system was

163   modified accordingly. During this process a coding system manual was constructed. This iterative

164   process was repeated multiple times until all observed behaviours were accounted for and defined in

165   a coding manual.

166   **2.4   Reliability of the coding system**

167   The coding system was then tested for inter-rater reliability (IRR). LG and CH each independently

168   coded a 20-minute segment of video during a bedtime routine. A modified percentage agreement was

169   used to calculate IRR by adding up the number of codes with exact agreement between the two

170   coders, within a time frame margin of five seconds, and dividing by the total number of codes. The

171   percentage agreement statistic was selected since it is straight-forward to calculate, given the relative

172   complexity of the multi-layer coding system, and is intuitive to interpret; 0% agreement means

173   complete disagreement, whilst 100% means total agreement. An inter-rater percentage agreement of

174   70% has been reported to be sufficient for complex systems[28]. Alternative statistics for IRR were

175   considered, such as Cohen's kappa, but this can be easily skewed if certain behaviours are more

176  frequently coded than others[29], which we predicted would be the case. Additionally, Cohen's kappa

177  is used to exclude agreement which would have occurred by chance – since the draft coding system

178  was relatively complex, with 46 different behaviours, chance agreement was deemed unlikely.

179  Percentage agreement was therefore calculated for the coding system.

180  **2.5   Comparison of VSG data to parental report**

181  Once reliability of the coding system was considered to be acceptable, LG coded the video footage in

182  full using BORIS©, including the bedtime routines and any night wakings. The coded data were

183  compared to parental interview to assess the accuracy of parental self-report of the child's sleep

184  schedule (i.e. time at sleep onset and morning waking) and the child's sleep quality (i.e. number of

185  night wakings and night waking duration).

186  Following the analysis of the video, each participating family was contacted to discuss any findings

187  of the overnight study and, if the child was found to have a significant sleep problem, the family were

188  offered an appointment with the Southampton Children's Hospital Sleep Service.

189  **3     Results**

190  **3.1    Participants**

191  Three children aged between three and eight years, who were deemed to be at risk of CI following

192  screening, were recruited. Demographic data can be seen in Table 2, though this has been abridged to

193  protect participant anonymity. Parental interview confirmed a clinical diagnosis of CI in participant

194  1, however participants 2 and 3 did not meet the diagnostic criteria for CI.

195  **3.2    The Overnight Parent-Child Interaction Coding System**

196     Thirty-six hours of overnight footage were produced during data collection, of which nearly three

197     hours involved parent-child interaction. These video data were used to develop and test the reliability

198     of the coding system.

199     The final coding system is depicted in Table 3. It comprises twenty-six codes divided into six

200     categories. These categories were as follows:

201     1) *Time domains*. This allows the observer to record 'sleep schedule' variables of the child's sleep,

202     i.e. sleep onset and morning waking, as well as the timing of the settling routine and the time at

203     'lights out' (i.e. when the settling routine finishes).

204     2) *Physical environment.* The observer can record changes in the bedroom environment, such as loud

205     sounds or changes in light which might be disruptive to the settling process.

206     3) *Child global status*. These codes relate to the child's sleep/wake status, including any night

207     wakings.

208     4) *Location*. The observer can record whether the subject (parent or child) is in or out of the bed and

209     their position (e.g. sitting, lying). This was included because frequent changes of the child's position

210     may indicate that the bedtime routine is not having the desired settling effect. Additionally, presence

211     of the parent in the room when the child falls asleep may be indicative of a sleep onset association.

212     5) *Activity*. The observer can record various activities occurring in the bedroom (e.g. reading, playing

213     a game, singing), and indicate whether the behaviour is 'soothing' or 'non-soothing' based on the

214     child's reaction to the activity (i.e. whether they settle or become excited/agitated).

215     6) *Physical interaction*. The observers can record either brief or extended close physical contact.

216     This is significant as physical contact could be a beneficial soothing aspect of a bedtime routine,

217     however it could also be contributing to a detrimental sleep onset association.

### 3.3    Reliability of the Coding System

Overall inter-rater percentage agreement the final version of the coding system was 74% which is above the guideline threshold of 70%[28]. 100% agreement was achieved for the categories 'time domains' and 'child global status', in line with Lesser's 2019 study, which found percentage agreement between two observers for sleep onset, sleep offset, and night wakings to be 100%. 'Location' and 'activity' had a lower but acceptable percentage agreement (80% and 74% respectively), though on most occasions when the two coders 'disagreed' in these categories it was because the timestamps of their observations were more than 5 seconds apart. There was 0% agreement for 'physical interaction' due to the coders disagreeing on the start and end time of the behaviour, since the view of the parent and child was partially obstructed by bedding. Agreement for 'physical environment' could not be assessed using the final coding system because there were no changes in the physical environment during the segment of video.

### 3.4    Accuracy of parental report

Parental interview was compared with objective coded data from the overnight video study relating to timing of sleep and number of night wakings (Table 4).  Sleep schedule (sleep onset and sleep offset time) was reasonably accurately reported, but the number and duration of night wakings (determinants of the child's sleep quality) were consistently under-reported. This was generally because the child self-soothed quietly without signaling for the parental attention.

Additionally, we noted that parents tended to omit information about the child's bedtime routine and overnight behaviour. For example, when asked about the physical environment of the child's bedroom, one parent described it as quiet and with dim lighting. However, on observation, the main bedroom light was turned on and off several times, family members walked in and out of the room

240 and a mobile phone in the room started ringing loudly during the settling process. The child was

241 visibly distracted by these events which disrupted the otherwise soothing atmosphere in the bedroom.

242 There were examples of a mismatch between parent report and HVSG observation in all three cases,

243 particularly in regards to parent or child behaviour. A parent whose child did not have CI reported

244 that the child signaled whenever he woke up in the night and that she had to be present in the room in

245 order for him to fall asleep. However, following coding of the child's overnight footage, it was

246 observed that the child was able to self-soothe on multiple occasions following night waking without

247 the presence of the parent.

248 For all participants a graphical visual summary of the bedtime and overnight activity was generated

249 using BORIS© (Supplementary Figures 1 and 2).

250 **4      Discussion**

251 Chronic insomnia (CI) is the most common sleep disorder experienced by children, yet diagnosis is

252 guided by subjective parental report. Despite parent-child interactions at bedtime being key to the

253 aetiology of CI, there is no accepted method to assess these interactions objectively. This study

254 aimed to develop a new tool to objectively assess overnight interactions between children and their

255 parents, which could assist in the identification of behaviours contributing to recurring CI. We have

256 created a reliable and reproducible coding system, the Overnight Parent-Child Interaction Coding

257 (OPIC) System, to fulfil this purpose.

258 The OPIC system demonstrated acceptable reliability. This is particularly significant considering

259 there were 26 behaviours accounted for in the final version of the coding system. The poor

260 percentage agreement for two of the coding categories ('physical environment' and 'physical

261 interaction') can be partially explained by the infrequent use of these codes in the segment of video

262 used to test reliability. Reliability should be tested again using different footage samples.

263 Nevertheless, the reliability of the coding system is a promising starting point for future

264 development.

265 We have shown that this coding system can be applied to three separate overnight videos involving

266 complex, lengthy bedtime routines, and nighttime interactions. The coding system has been used to

267 support parental interview as an investigative tool both in children with CI and without CI and yields

268 additional data to parental report. Applying the coding system to these videos has exposed aspects of

269 the bedtime routine, such as changes in the physical environment, which parents did not disclose

270 during the interview. For example, family members entering and leaving the room and the main light

271 being turned on and off. The parents may have omitted these details from the interview due to recall

272 error, though the clinical interview was undertaken the following day to minimise this risk. It is also

273 possible that parents were selective in their disclosure, either due to an awareness that the

274 behavioural dynamic was inappropriate or because they didn't believe it to be relevant for the

275 interviewer. The significant mismatch between one parental account of an idealised settling

276 environment, despite the observed reality which was noisy and at times chaotic is interesting and may

277 reflect social desirability bias[11].

278 The comparison between parental report and observation of the child's sleep schedule and sleep

279 quality in this small sample supports previous reports that parents are poor historians in terms of their

280 child's sleep quality[8,9]. This finding is significant because problems with *maintaining* sleep are of

281 equal importance as *initiating* sleep in the diagnostic criteria for CI. Therefore, if parents are unable

282 to accurately report their child's ability to maintain sleep, an alternative investigation to parental

283 interview to support a diagnosis is warranted.

284  In practice, HVSG and coding of parent-child interactions could be used to aid clinical management.

285  CI is treated using behavioural intervention, with the clinician providing advice based on reported

286  child and parent behaviours[30]. This usually involves removing problematic sleep onset associations

287  and advice on sleep hygjene[31]. However, it seems likely that advice given by the clinician could be

288  improved if the clinician had objective evidence of the nature of parent-child interactions during the

289  bedtime routine. This could facilitate a more targeted family-centred management plan. This plan

290  could be enhanced by focusing on specific examples of problematic and/or constructive parent-child

291  interactions, which could be replayed from HVSG footage. Video feedback has been used in

292  psychological interventions to effectively guide parents with child behaviour management[32-35] and

293  has been shown to improve child attachment security[34], parent mental health status[32], and parent self

294  efficacy[36] (confidence in their own ability to succeed[37]) in comparison to simple verbal feedback.

295  Following behaviour coding using BORIS©, the software was used to create a graphical output of all

296  codes recorded during an observation. This displayed all activity which occurred in the bedroom,

297  including child and parent activity and changes in physical environment. This graph could also

298  provide a visual educational tool for the families of children with CI to demonstrate a complex and

299  excessively long bedtime routine, compared to an appropriate graphical representation of a brief but

300  soothing bedtime routine (see Supplementary Figures 1 and 2).

301  While the OPIC system demonstrated acceptable reliability, further development and testing is

302  warranted as the current version has some limitations. Firstly, coding was time-consuming (the

303  viewing of segments, at times, required up to four times the duration of the whole video to enable

304  scoring where significant interactions between the parent and child took place).  This limits its

305  application in clinical practice.  To overcome this limitation the OPIC system could be further

306  simplified to focus on core behaviours of interest. Alternatively, the clinician could code shorter

307  segments of the video rather than the entire bedtime routine. For example, one minute for every five

308     minutes of video. This would take less time than coding the whole bedtime routine and would still

309     enable video feedback, including examples of undesirable interactions.

310     Another limitation of this study was the approach to IRR testing. Only two coders tested the coding

311     system, both of whom were involved in its development, and were therefore familiar with the coding

312     system. To develop the coding system further and enable its validation as an investigative tool, it

313     should undergo testing by a larger group of independent coders.

314     In the future, HVSG combined with objective coding systems based on OPIC could be a promising

315     supplement to actigraphy as an objective assessment of children's sleep. HVSG could also offer

316     advantages over actigraphy for a sub-sample of children with sensory processing difficulties, such as

317     those with autism spectrum disorder, who might not tolerate a wrist-worn device[38].

318     A systematic approach to quantifying child and parent behaviour in CI would offer an objective

319     outcome measurement tool for CI interventions. The effectiveness of behavioural interventions in

320     childhood CI has only been tested previously using sleep diaries[39], questionnaires[40-42], and

321     actigraphy[39,40,42]. Robust objective assessment of behavioural interventions in childhood CI could

322     provide a more reliable insight into the outcome of these interventions, since researchers could

323     directly observe the extent to which the management plan has been implemented by parents.

324     To conclude, the OPIC system, when applied to home videosomnography, offers the potential for

325     personalised interventions in the clinical management of behavioural insomnia and an objective

326     outcome measurement in clinical research. The paradigm of sleep scoring and video observation is

327     core to mainstream sleep diagnostics and the OPIC system applies similar approaches to a

328     behavioural setting. Software could be adapted within conventional commercial sleep systems to

329     accommodate such an approach.

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337

338 **5    Figures and Tables**

339 **Table 1 -  Initial draft of the Overnight Parent-Child Interaction Coding System.** The first

340 iteration of the coding system, constructed by the research team based on the clinical expertise of an

341 experienced paediatric sleep consultant[1].

| Category | Event | Category | Event |
|---|---|---|---|
| Sleep schedule | Bedtime routine (S) | Parent positive commentary | Positive statement (P) |
| | Lights out (P) | | Offers reward (P) |
| | Sleep (P) | | Praise (P) |
| | Night waking (P) | | Reassure (P) |
| | Wake time (P) | | Calm response (P) |
| | Physical contact brief (P) | | Authoritative statement (P) |
| | Parent present not engaging (S) | Parent negative commentary | Raises voice (P) |
| | Sleep onset (P) | Parent positive behaviour | Authoritative action (P) |
| Bedtime routine | Reading (S) | | No response (P) |
| | Singing (S) | | Parent ignoring child (P) |
| | Playing (S) | Parent negative behaviour | Fulfils curtain call (P) |
| | Electronics (S) | | Parent engaging w/ child (S) |
| | Physical contact extended (S) | | Soothing behaviour (S) |
| After lights out | Self soothes (P) | Child positive commentary | Child agrees (P) |
| | Signals (P) | Child negative commentary | Settling environment (P) |
| | Activity (S) | | Settling process (P) |
| | Leaves room (P) | | Anxious comment (P) |
| Night waking | Self soothes (P) | | Disagrees (P) |
| | Signals (P) | Child positive behaviour | Positive behaviour change (P) |
| | Activity (S) | Child negative behaviour | Non-compliant behaviour (S) |
| | Leaves room (P) | | Physical resistance (P) |
| | Drinks (S) | | Tantrum (S) |
| | Movement arousal (S) | | Curtain call (P) |

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[1] P = point event, S = state event. A point event is a brief event occurring in a single moment; a state event is a prolonged behaviour with a marked start and end point.

344 **Table 2 – Participant demographics.**

| Participant number | Age (years) | Years since end of treatment | Co-morbidities | SDSC[2] screening score (/35) |
|---|---|---|---|---|
| **1** | 8.28 | 6.43 | Hydrocephalus, hormone deficiency, epilepsy, developmental delay | 24 |
| **2** | 7.49 | 1.94 | Hormone deficiency | 16 |
| **3** | 3.94 | 2.21 | Hydrocephalus, hormone deficiency, facial palsy, hearing loss, developmental delay | 18 |

345

[2] SDSC = Sleep Disturbance Scale for Children. A score of 16 or more indicates an increased risk of a Disorder of Initiating or Maintaining Sleep. All children were above this threshold.

346 **Table 3 – Final version of the Overnight Parent-Child Interaction Coding System.** The final

347 iteration of the coding system, used to analyse parent and child behaviours at bedtime and during the

348 night[3].

| Category | Event | Modifier |
|---|---|---|
| Time domains | Settling routine (S) | |
| | "Lights out" (P) | |
| | Sleep onset (P) | |
| | Morning waking (P) | |
| Physical environment | Noise intrusion (S) | |
| | Music (S) | |
| | Bright lighting (S) | |
| Child global state | Sleep (S) | |
| | Night waking (S) | |
| | Movement arousal (S) | |
| Location | In bed (S) | Position: |
| | | • Lying |
| | Out of bed (S) | • Sitting |
| | | • Standing |
| Activity | Laughing (P) | Helpful to sleep? |
| | Reading (S) | |
| | Singing (S) | • Soothing |
| | Playing (S) | • Non-soothing |
| | Eating (S) | • Neutral |
| | Drinking (S) | |
| | Verbalisation (S) | |
| | Rocking (S) | |
| | Tidying/housekeeping (S) | |
| | Personal care (S) | |
| | Electronics (S) | |
| | Self-stimulating (S) | |
| Physical interaction | Brief close physical contact (P) | |
| | Extended close physical contact (S) | |

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[3] P = point event, S = state event**.** A point event is a brief event occuring in a single moment; a state event is a prolonged behaviour with a marked start and end point.

19

349 **Table 4 - Parent report vs. objective measurement of child's sleep schedule and sleep quality.**

350 Sleep schedule was accurately reported by parents, however, report of child's sleep quality was

351 poorly reported. All parents under-reported the frequency and duration of night wakings.

| | | Participant 1 | | Participant 2 | | Participant 3 | |
|---|---|---|---|---|---|---|---|
| | Variable | Reported | Observed | Reported | Observed | Reported | Observed |
| **Sleep schedule** | Sleep onset time | 20:30 | 20:37 | 20:30 | 20:15 | 21:30 | 21:04 |
| | Sleep offset time | 06:30 | 06:10 | 07:00 | 06:15 | 06:10 | 06:10 |
| **Sleep quality** | Number of night wakings | 4 | 12 | 0 | 2 | 0 | 1 |
| | Total duration of night wakings (minutes) | 12.0 | 26.0 | 0 | 1.8 | 0 | 3.1 |

352

## 6    Contributions

354 The study was designed by LG, KB, and CH. Recruitment and data collection was completed by LG.

355 Iterative development of the coding system and the coding of video to calculate inter-rater reliability

356 were done by LG and CH.  Data analysis was completed by LG.

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## 8    Acknowledgments

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