

# Sleep–Wake–Behaviour App

Towards developing a database for informing e-coaching solutions for  
neurodevelopmental disorders in children

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## ABSTRACT

Sleep plays an essential role in the overall health and well-being. Sleep quality might adversely affect neurodevelopment disorders such as cerebral palsy, autism spectrum disorders, and fetal alcohol spectrum disorders. However, the effect of sleep quality on the different neurodevelopment disorder is not clear. We developed a web app, called Sleep–Wake–Behaviour Application (SWAPP) which allows caregivers and

clinicians to log and analyze sleep and daytime behaviours of children with sleep disorders. SWAPP is developed to serve two purposes. First, it allows the caregivers and clinicians to collect and analyze data whenever it is necessary. Second, it allows clinicians an opportunity to analyze the collected data to understand the relationship between sleep, tailored interventions, and neurodevelopmental disorders better. We present the design of the SWAPP and discuss how it can be used for implementing e-coaching for caregivers of kids with neurodevelopmental disorders.

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## CCS CONCEPTS

• **Applied computing** → **Consumer health; Health care information systems; Health informatics;** • **Human-centered computing** → *Information visualization*; Mobile devices;

## KEYWORDS

sleep logging, children, neurodevelopmental disorders, web application

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**1 INTRODUCTION**

Most children with neurodevelopmental disorders experience disrupted sleep, which further affects their daytime activity adversely [5, 7]. The sleep disorders are not consistent across the different disorders, and there is a lack of understanding of the causes of the sleep disorders [3, 7]. It is important to improve sleep quality for the overall health of the children.

Sleep hygiene is one of the ways to improve sleep quality. Doctors recommend different habits and practices that the children should do to improve sleep quality. When sleep hygiene alone fails to improve the sleep quality, doctors recommend a pharmacological approach [2, 3]. However, the effects of these medications are also not understood in depth. There is a need to understand how different factors, including medications, affect sleep and how sleep, in turn, affects daytime behaviours [6].

When caregivers notice a disruptive sleep or daytime behaviour, it is not always possible to get immediate medical advice. E-coaching solutions can support caregivers better by providing them with an accurate and efficient course of actions to take in certain situations. With implemented e-coaching solutions, caregivers can have the support they need when it is not always possible and efficient to get medical advice from doctors. For instance, when a caregiver notices that a child wakes up more than usual during the night, the system can make suggestions on what the caregiver to do to help the child sleep better. Caregivers can always bring up their concerns during the doctor visit, however, at specific times when immediate medical advice is not possible, e-coaching solutions can come in to help. Developing e-coaching solutions for children with neurodevelopmental disorders requires high-quality datasets to understand the relationships between the neurodevelopmental disorders, medications, sleep behaviours, and daytime behaviours. As there is a lack of such datasets, it is first required to develop the dataset which researchers can use to design usable e-coaching solutions [1].

We developed a web app called Sleep–Wake–Behaviour Application (SWAPP) to allow caregivers of children with sleep disorders to log sleep and daytime activities. SWAPP

also allows multiple caregivers of children with sleep disorders to log sleep and daytime behaviours. SWAPP allows the caregivers to share this data with their doctors. Health care professionals can look at this data to gain an improved understanding of a child's behaviours and relationships between different aspects of the child's everyday life.

We aim to use SWAPP to develop a database of daytime and sleep behaviours, and medications which can be used by clinicians to understand relationships between different factors, and for researchers to use this new understanding to develop e-coaching solutions for caregivers of children with neurodevelopmental disorders.

**2 DESIGN & IMPLEMENTATION**

SWAPP is a responsive web-based application that allows caregivers to log sleep and daytime activities of children with neurodevelopmental disorders. Caregivers can access SWAPP through personal computers or smartphones using a web browser. The app was built to be responsive to allow caregivers to have flexibility in how they choose to log sleep and daytime activity data of children under their care.

The application allows for two different account types: caregiver and clinician. Caregiver account is intended for those who are caregivers of children with sleeping disorders so they can log any observations that make while taking care of those children. The clinician account is intended for health care professionals to have access to the children's data logged by the caregivers.

**Timeline & Logging**

In SWAPP, each child's profile includes the main timeline page where all events logged are visualized on a vertical timeline showing a 30-hour period (Figure 1). The timeline shows events logged from 6 PM the previous day to 12 AM of the selected day. By showing the timeline that encapsulates a 30-hour timeframe, the users can see sleep logs that span across the night on a single visualization.

Caregivers can log five different event types:

- *Prepare for bed*
- *Asleep*
- *Awakenings during night*
- *Daytime Activity*
- *Medication*

Each of the events is colour-coded which is represented on the child's timeline. When logging a sleep-associated event (*Prepare for bed*, *Asleep* or *Awakenings during night*) or a *Daytime Activity*, caregivers can specify the child's mood (Figure 2), disruptive behaviours and any general note observed during the event [8].

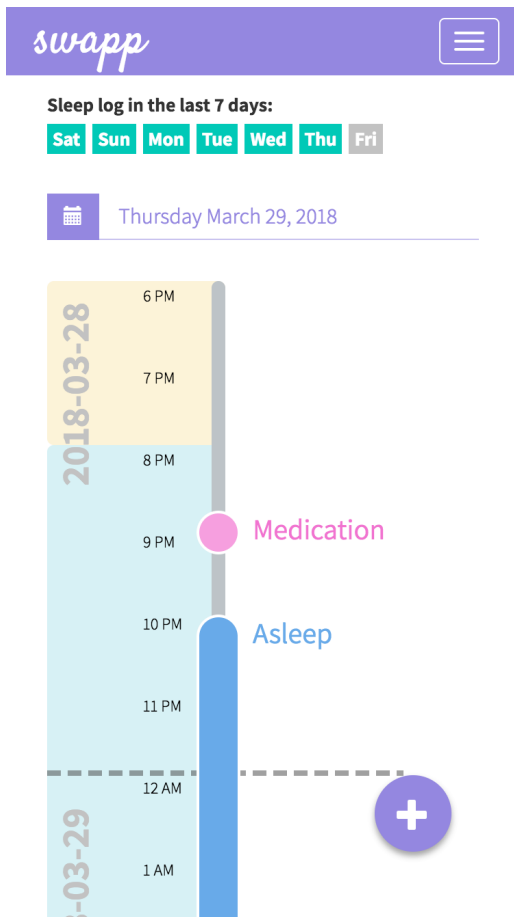


Figure 1: SWAPP timeline page showing a child’s sleep data on mobile

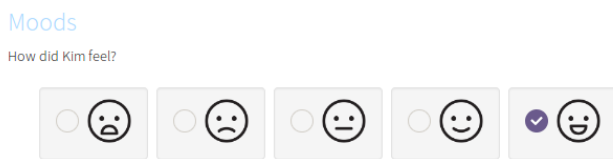


Figure 2: A range of moods that can be logged with an event

For *Medication*, caregivers can specify the medicine and the time that the medication was taken as well the dosage and side effects [6].

**Shared Data for Collaboration**

SWAPP was designed as a platform that can accommodate one caregiver account logging for multiple children while at the same time allow a clinician access to those children’s data through the same platform (Figure 3). For example, there can be multiple children profiles linked to a single caregiver

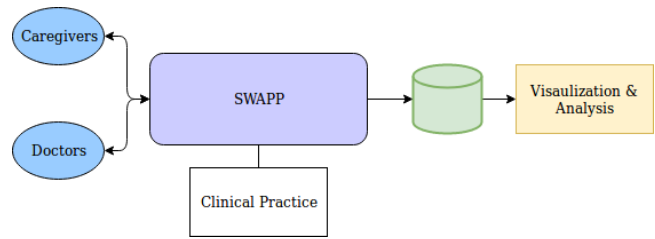


Figure 3: A flowchart showing caregivers and doctors can both use SWAPP as a sole data-point to access sleep and daytime activity information

account. This caregiver account can be shared by multiple users. For example, parents can share a caregiver account to log data about their two children’s sleep-wake information.

**Shared Dashboard**

As mentioned earlier, clinicians can also access a child’s data through SWAPP. When a clinician logs into SWAPP, they would see a different user interface which provides them with the summary of a child’s data from the last 30 days (Figure 4).

Clinicians can also fill out the *Sleep Disturbance Scale for Children* (SDSC) for a child in which the filled form and the score of the assessment are shown on the dashboard for the clinician to view (Figure 5). The SDSC’s purpose is to characterize sleep disorders in children by using a 27-item inventory on a 5-point Likert-scale [4]. On the dashboard, the clinician can see today’s assessment and the previous assessment side by side. This design choice allows clinicians to easily compare if the assessment scoring has been improved compared to the previous visit.

This dashboard can also be viewed from the caregiver side where it can be accessed by clicking on the “Dashboard” tab on the child’s timeline page. With this shared dashboard, both clinicians and caregivers can have access to the child’s data from one platform. This approach provides them with a platform that both can use to support their sense-making process of the logged data and clinicians can efficiently analyze digitally logged data as opposed to the current pen and paper journal.

**Visualization**

On top of the summary of the child’s data from the last 30 days, SWAPP also provides clinicians and caregivers with different visualizations to represent the child’s data from the last 30 days. Information about the lowest, average and highest duration for sleep associated and daytime activity events are visualized on the dashboard with bar charts (Figure 6). The application also depicts the overall sleep quality

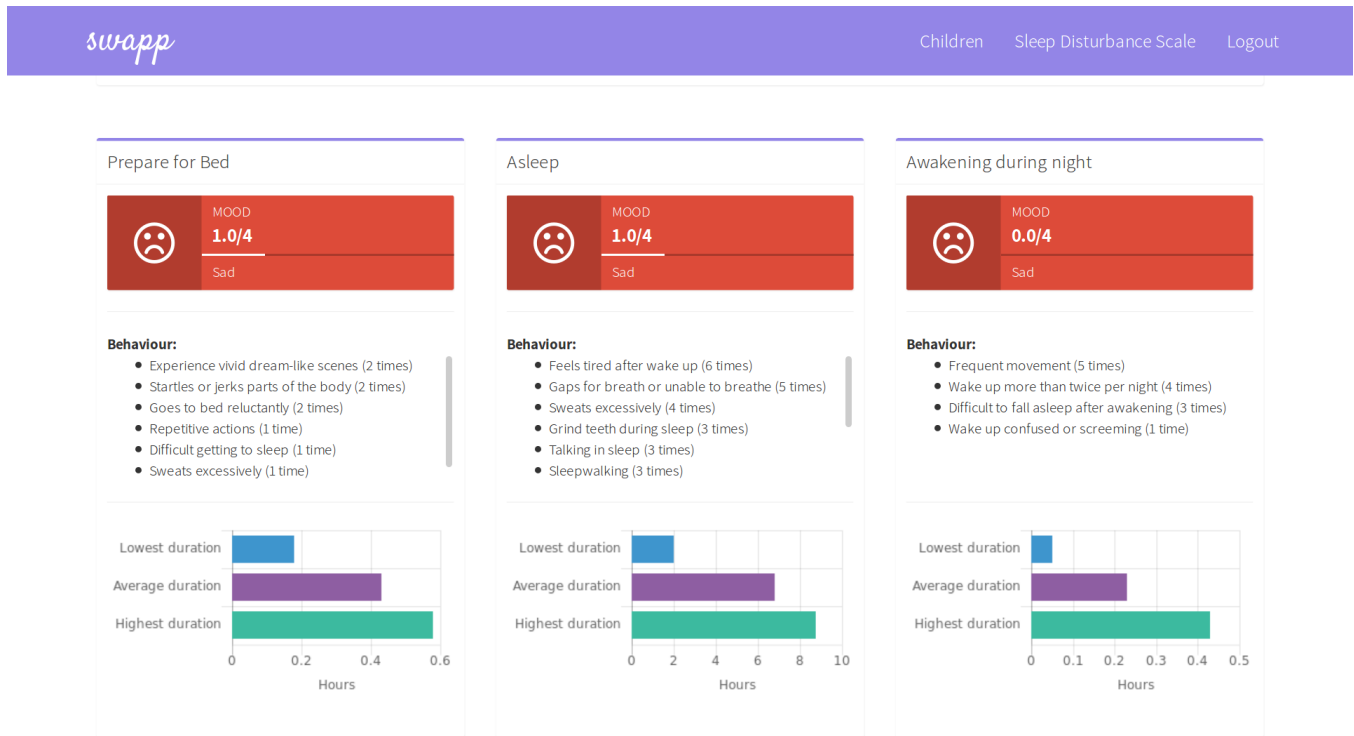


Figure 4: SWAPP’s dashboard on the clinician side

Today's result

DIMS: Disorders of initiating and maintaining sleep	12
SBD: Sleep Breathing Disorders	8
DA: Disorders of arousal	9
SWTD: Sleep-Wake Transition Disorders	11
DOES: Disorders of excessive somnolence	15
SHY: Sleep Hyperhydrosis	5
<b>Total score</b>	<b>60</b>

Figure 5: A Sleep Disturbance Scale assessment

of a child from the last 30-days by plotting the data on a line graph to show the change in sleep quality.

### 3 USE CASE SCENARIO

To better understand how SWAPP can help in a medical practice and facilitate efficient communications between caregivers and clinicians, we provide a use case scenario of SWAPP by parents who have a child with sleeping disorders.

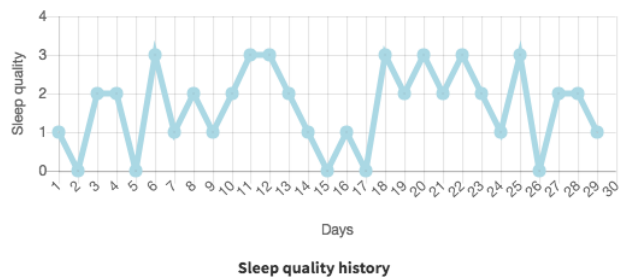


Figure 6: A bar graph showing a child’s Daytime Activity duration from the last 30 days

“Felicity and Stephen are a working couple residing in Vancouver, BC Canada. Felicity is 34 years old and she works as an accountant for a local firm while Stephen is a 39-year-old architect. Their 4-year-old son, Danny, has frequent sleeping difficulties. Danny tends to wake up multiple times a night and the couple also notice that it is extremely difficult to get Danny to prepare for his bedtime.

Felicity and Stephen have been taking Danny to their clinician, Dr Terry, for the past two years. For every visit, the couple brings Dr Terry all the observations and they have been noted regarding Danny’s sleeping behaviours. All their notes and

*observations are handwritten and they usually note down the observations whenever they notice Danny having difficulties going to sleep or waking up multiple times a night. Because the majority of the notes are handwritten with no specific classifications, Dr Terry is required to go through all the notes with the couple regularly and frequently, the couple have to recall specific events that they observing as the notes that were taken are not as always as detailed as they should be.*

*Physical notes and journals have shown to be cumbersome and inefficient for them to use to log information about Danny's sleeping pattern. The couple and Dr Terry have agreed to use SWAPP as a digital platform to log Danny's sleeping pattern. Because SWAPP is a responsive web-based application, the couple can open up SWAPP from either their smartphones or laptops. Felicity and Stephen created a single caregiver account which they both use to record and manage Danny's information. They then created a child profile for Danny which they associate the child profile to Dr Terry. This association allows Dr Terry to access Danny's data on SWAPP from his clinician account.*

*With SWAPP, Felicity now logs information about Danny's sleep from the previous night on her phone while she has breakfast with Stephen and Danny in the morning. Felicity logs the when she started to get Danny to prepare for bed the previous night, when Danny fell asleep and when he woke up as well as all the awakenings during his night sleep. Felicity also takes notes on the quality of sleep and Danny's mood of each sleep associated event that she logs.*

*After two weeks of using SWAPP, the couple pay another visit to Dr Terry's office. This time, however, they do not need to bring any documents with them. Dr Terry has already been viewing Danny's sleep logs before the couple arrives in his office. During this visit, the couple and Dr Terry have more control and confidence in looking at past events that were logged by the couple by viewing the Dashboard. Dr Terry can also see how Danny has been doing for the past 2 weeks as well as making a new assessment regarding Danny's sleep disturbance."*

#### 4 EVALUATION

SWAPP is still at an early stage of development. Once ready, we plan on conducting a pilot study with a group of general users to evaluate the usability of the application. This pilot study will give us a chance to discover and resolve any usability issues before conducting an evaluation study with the target users.

For the evaluation study, we plan to recruit 12 caregivers that are currently taking care of children with neurodevelopment disorders to use the application for three weeks. After the 3-week study, participants will be interviewed about their experience in using SWAPP during the study. We also plan to conduct a separate study with 6 doctors to evaluate

the doctor side of the application and to understand how the application affect their sense-making and diagnosis process.

#### 5 DESIGN CHALLENGES

Throughout the development of SWAPP, we have encountered a number of design challenges that emerged due to some of the requirements that were set out from the beginning of the project.

##### Automating Data Logging

Currently, SWAPP relies on parents and caregivers to observe and log information about a child's sleeping behaviour and daytime activities which might not be sustainable in the long run. Parents and caregivers might find it troublesome to manually log information everyday or might forget to log certain events. To automate this logging process, we will need to use additional wearable devices or sensors. Some of the commercial wearable products today can automatically track the user's sleep however the user is required to wear the device on their wrist when they go to sleep which might cause inconvenience or discomfort to some.

Because SWAPP is intended to be used for children, we need to be careful in how we implement automation with data logging. With wearable devices and sensors, additional equipment needs to be set up or, as mentioned earlier, the child needs to wear a physical sensor to sleep. We feel that this might be intrusive that might cause discomfort and disruption to a child's sleeping behaviour. Having said that, we believe in automating data logging process in the future given appropriate devices can be used to aid the process.

##### Responsiveness

Because SWAPP needs to be responsive to allow caregivers to be able to log events from any devices, we had to think about how information can be displayed on small devices. Our approach to designing is to think "mobile-first" and scales from mobile to larger displays. Where the forms that caregivers can fill out currently are not extremely complex, future implementations might include complex forms that might be a challenge to fill out on a small device. With this in mind, we "wizardify" the event-logging by guiding the user through different steps in order to log an event. Instead of overwhelming caregivers with long forms with multiple fields to fill out, they are guided step by step to log an event starting from selecting the time of the event to selecting the quality of sleep and moods to general note taking.

Designing the visualizations for SWAPP also came with challenges where we had to consider how they would be displayed on small devices. Visualizations that are big in size for big displays need to be scaled down to accommodate smaller devices. Scaling visualizations require making different design choices instead of just resizing the visualizations

to fit a smaller screen, the visibility of labels and how the line or bar graph is displayed need to be carefully considered. In some cases, some labels that are shown on big displays need to be redesigned or hidden on smaller displays.

### Timeline

The child's timeline required more design considerations and more complex than we expected. For most people, sleep is an activity that spans across the night, 2 different days. Our original design mockup that has a 24-hour frame timeline could not communicate the duration and how *prepare for bed*, *asleep* and *awakenings during the night* are connected. With a 24-hour timeline, each timeline tends to start with an *asleep* event with some *awakenings during the night* in between, where *prepare for bed* exists on the previous day's timeline instead.

To overcome this challenge, we implemented a 30-hour timeline which starts from 6 PM the previous day to 12 AM on the selected day. For example, if the caregiver is viewing a child's timeline on a Wednesday, they would see the child's timeline from 6 PM on Tuesday to 12 AM on Wednesday. With this approach, caregivers can see how sleep associated events are or are not connected and how the events might span across the night.

### Scalability & Future Vision

At its current state, SWAPP is still at the early development phase yet still has essential features that can help caregivers and clinicians record and monitor various data about children with sleeping disorders. Moving forward, we can scale the application support more complex form intakes and to collect more complex data like pain chart, blood samples information and x-ray images. We will be able to use our existing implementations like "wizardification" to accommodate complex form fillings.

With more complex data collected, we can implement future versions of SWAPP to be able to make suggestions for the caregivers on what actions to take based on the data collected. The suggested actions will be based on the doctor's suggestion. Ideally, this will require minimal levels of inputs from the doctor. The doctor will be able to make a common set of suggestions that normally appear among children with neurodevelopment disorders. This will help to ease the doctor's workload by offloading some of the interactions that usually occur between caregivers and doctors. Caregivers will be able to get common medical advice directly from the system. SWAPP will be able to make suggestions on how the caregiver can prepare the child for bed to effectively and efficiently put the child to sleep, for example. The application can also make suggestions on what to do in the event of multiple awakenings during the night.

Future iterations of SWAPP will also be able to support multiple caregiver accounts linked to a single child profile meaning that multiple different people may use different caregiver accounts to monitor a child's sleep and daytime activities. For example, a child's parents may have two separate accounts, one for the mom and one for the dad, to log and monitor a child's sleep behaviours at home while a teacher at school has another caregiver account that can log and monitor a child's daytime activities at school.

These features are all part of the e-coaching solution vision we have for future SWAPP iterations to provide a more efficient medical care and communications between caregivers and clinicians.

## 6 CONCLUSION

In this paper, we introduced SWAPP, a web app for caregivers of children with sleep disorders to log sleep and daytime activities. We presented the design choices and implementations throughout the development process of SWAPP. We also presented design challenges and what our future plans are for developing e-coaching solutions into SWAPP to provide efficient medical care for children with neurodevelopmental disorders. We are confident in SWAPP's capability to expand to accommodate complex medical data. Moreover, with high-quality datasets, SWAPP can be an effective e-coaching solution for parents, caregivers, clinicians and others who take care of children with neurodevelopmental disorders by providing immediate medical advice based on the data collected.

### AUTHOR CONTRIBUTIONS

OI provided the project framework (based on his PhD research) and the clinical expertise for the project. MB and NB led the two initial evaluation projects.

CR led the design team for the project. MS was the lead UX designer. NC was the research assistant who conducted the UX and UI design work. DP was responsible for the visual design and graphics development of the project. BZ was responsible for UI and visual design for the project.

CS led the SWAPP application development team. TH was responsible for the front-end interactions and AG implemented the back-end of the application.

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