Explanation Patterns for The Sleep Adherence Mentor (SAM)

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Abstract

Sleep disorders impact more than 13% of Australian children. To provide timely advice to paediatric patients and their families, we have created a website that triages patients on the specialist waiting list to provide tailored recommended treatments. To enhance adherence, the child and their family can discuss the recommendations with the Sleep Adherence Mentor (SAM) for each treatment. Recommended treatments may include sleep diary, sleep hygiene, settling routine, caffeine, snoring, and night terrors. To personalise the discussions, the dialogues use explanation patterns where the explainable virtual agent first elicits the beliefs that act as barriers to following the treatment, the goals that are driving their behaviours and the user's information to better understanding the user context. SAM is implemented using the UNITY 3D game engine which is integrated in an authoring tool developed in our lab. Interacting with SAM is only available through the eADVICE website. We have initial feedback on the conversations and have obtained ethics approval for a pilot with 50 paediatric patients at The Children's Hospital at Westmead, Sydney - Australia.

Keywords

Explanation patterns, Explainable virtual advisor, Behaviour change, Pediatric sleep disorders

1. Introduction

Poor sleep among children and adolescents poses a significant and widespread health challenge, impacting around 14% to 31% of Australian children [? ?]. Despite the prevalence of sleep problems, the availability of clinical services is limited but due to the condition not being life-threatening, resulting in long wait times precluding patient access and limiting the capacity to assess patient priority. Despite its prevalence, limited clinical services and long wait times restrict access to treatment. Sleep difficulties impact children's well-being, quality of life, and their families as well [?].

Sleep challenges become particularly pronounced in the early years of a child's life, affecting their behavioral and emotional well-being throughout the initial school years [? ?]. The

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implications extend into adolescence contributing to negative outcomes such as depression, decreased academic performance, and risky behaviors like substance abuse [?].

Given the profound impacts of sleep disorders, early identification and treatment are imperative. However, existing services face constraints, leading to delayed interventions. In 2013 alone, sleep problems among children aged up to seven years incurred costs of approximately AU$27.5 million for the Australian Federal Government [?]. The primary driver of these costs is the delayed access to prompt treatment attributed to inadequate professional services catering to the overwhelming demand for patients' assistance. Even when medical advice is readily available, adherence to treatment guidance, regardless of the health condition, hovers around 50%, whether delivered through human interaction or technology-mediated interventions [? ?]. The challenge goes beyond providing timely advice. It also involves encouraging people to follow the advice. In Australia, children's sleep services are limited to public hospitals and private practices. Public hospitals have long wait times, averaging eight months at The Children's Hospital at Westmead (CHW), for instance. Additionally, there's a wait of nine to twelve months for sleep studies. Therefore, initial screening is crucial to identify children who need urgent attention [?].

Recognizing that sleep problems can stem from medical (e.g. sleep apnea) or behavioral factors (e.g. poor sleep hygiene) [?], this paper focuses on the latter—behavioral problems that can be effectively treated through behavior change. To tackle these challenges, we introduce a technology-driven solution: the Sleep Advisor Monitor (SAM) to promote health behavior change for children with sleep disorders. Section 2 establishes a foundational context by presenting relevant research in both psychology and human-agent interaction. Section 3 introduces the eADVICE system, which served as the platform for the proposed explainable virtual agent (XVA) under investigation. Section 4 presents the design of the XVA, SAM, including the treatments and the explanation patterns design. The feedback obtained from children and parents who evaluated the system and interacted with SAM, as a first evaluation round, is presented in Section 4. The paper concludes in Section 5.

2. Background

Technology-based interventions for health behavior change have gained significant attention in recent years due to their ability to provide accessible support anytime, anywhere [? ?]. These interventions have proven to be particularly effective in enhancing adherence to the treatment plans when they are grounded in psychological theories such as Cognitive Behavioral Therapy [?], social judgment theory [?] and incorporating dialogue support [?]. Dialogue support can range from simple reminders to more complex conversational agents that assume a social role, acting as coaches.

In psychology, Theory of Mind (ToM) refers to the ability to understand the mental states of others, including their beliefs and desires [? ?]. This concept, also known as belief-desire psychology, emphasises the significance of beliefs (what someone thinks is true) and desires/-goals (what someone wants) in explaining and predicting human behavior [?]. Drawing from Bratman's model (1987), beliefs-desire-intention (BDI) agents implement ToM as means to reason about their own behaviour or to understand other agents' behaviour in multi-agent envi-

ronments. By explicitly representing internal beliefs, desires (goals), and intentions, BDI agents can provide explanations for their actions, linking their decisions directly to the underlying reasons. These explanations, known as reason explanations [**?** **?**], shed light on the mental state of the agents.

Previous studies have highlighted that the reception of explanations incorporating beliefs and goals may vary depending on factors such as age (child, adult) [**?**] or expertise (novice, expert) [**?**]. Building on this understanding, the integration of explanations into behavior change interventions has emerged as an ongoing research area. The goal is to explore new and effective ways to influence user behavior through explainable approaches.

Integrating explanations into behaviour change interventions is a growing research field that seeks new ways to effectively influence user behaviour. Explanation goes beyond simply detailing the recommended behaviour by human or artificial coaches. It aims to elucidate the underlying reasons behind the behavioral recommendations, thus enhancing motivation and behaviour change [**?** **?**]. By providing users with insights into the algorithm's functioning, including its reasoning processes and decision-making mechanisms, explanations can foster trust and transparency in the intervention and address concerns related to data privacy and algorithmic bias [**?**].

Novelly, our work aims to specifically improve behavior change through explanations tailored to the user's beliefs and goals, rather than the agent's. To achieve this, the present paper investigates two key questions: firstly, it explores the design and the utilisation of explanation patterns based on the user's beliefs and goals. Secondly, it seeks to understand how users perceive these patterns within the context of behaviour change.

3. eADVICE System

To address the shortage of specialist care for sleep disorders using XVA, we reengineered the eADVICE (electronic Advice and Diagnosis Via the Internet following Computerised Evaluation). The eADVICE system was tested in the field of paediatric incontinence, a condition that affects up to 20% of Australian children with specialist wait-times of up to two years [**?**].

As illustrated in Figure **??**, eADVICE provides access to families (under the care of their general practitioner (GP) while awaiting a specialist appointment) to a website that asks a set of questions to ascertain the medical status and provides one or more of the treatments personalised for the child. Initial pilots with eADVICE-incontinence found that adherence to the advice was on average 50%, consistent with the literature [**?**]. After adding a virtual coach (called Dr. Evie) to eADVICE-continence, a pilot study with 74 patients who had access to the program over six months resulted in 54% becoming dry during the day and 22% becoming dry at night. Improvements, though not becoming dry, were also experienced by 17% during the day and 33% at night, while only 5% reported becoming worse at night, and 29% reported a resolution without needing a specialist appointment. Adherence to the treatment advice provided by the virtual coach rates was as follows: 100% to reduce caffeine, 97% to fluid advice, 94% to bowel program, 72% to timed voiding, 62% to alarm training and 33% to medication discussion [**?**]. eADVICE-continence has been further evaluated in an RCT with 239 patients showing that the intervention group had significantly lower rates of incontinence than the control group (74.4%

vs 89.7%) and frequent bedwetting (54.7% vs 68.0%) at 6 months. See [?] for more details on the health outcomes.

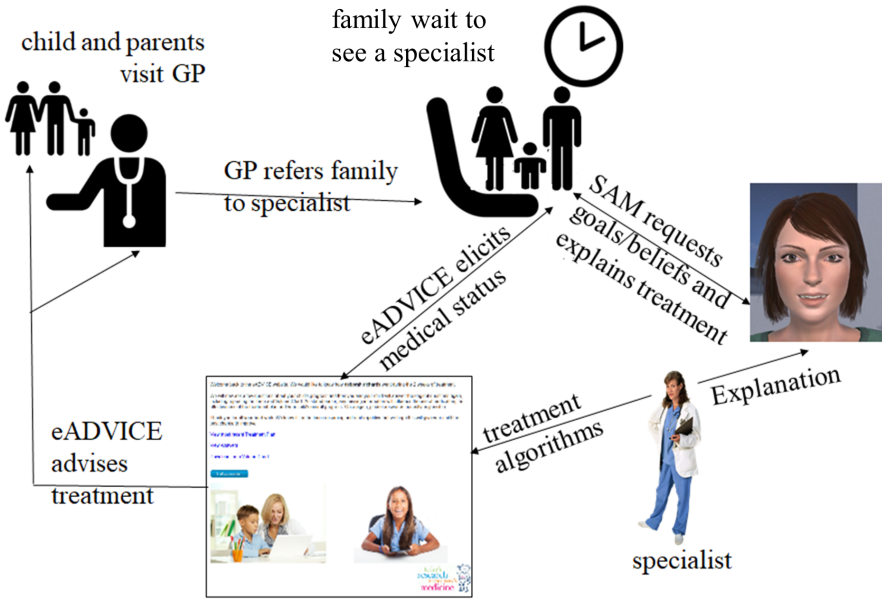

Figure 1: The eADVICE consultation process. The process starts when the family visits their GP (top left) and gets a referral to a specialist. While they are on the waiting list, they are granted access to eADVICE website and interact with the XVA (SAM).

With these promising rates of adherence to the recommended health behaviours, we proposed to develop eADVICE-sleep, which includes the sleep adherence mentor (SAM) to deliver treatments specific to sleep problems. Users could be children, teenagers or parents of children with sleep problems. As shown in Figure **??**, the family first visits their GP. If the GP is unable to resolve their child's sleep problem, they are given a specialist referral, placed on the clinic's waiting list and given access to eADVICE-sleep. Upon the first access and then each fortnight, the family has access to the website to answer questions about the child's current condition. Accordingly, the website executes a number of age differentiated algorithms which are used to identify one or more treatment plans for a two-week intervening period. See Table **??** in Appendix **??** for a snippet from the infant (8 months - 4 years old) algorithm. The website's algorithms require information including weekday and weekend bed and wakeup times, school-night bedtime, waking during the night, naps during the day and caffeine consumption questions. The algorithms assist in triaging patients with urgent needs by including triggers which send an email to the clinic and which direct the parent to ring the clinic urgently. This is similar to identifying risky situations and when the patient needs to be seen by a human as in the study by [?]. Figure **??** presents an example of the website interface for a patient (Eve) with four treatment recommendations. While patients can only receive treatment advice fortnightly at most so they have sufficient time to try the advice, patients can revisit the discussion at any

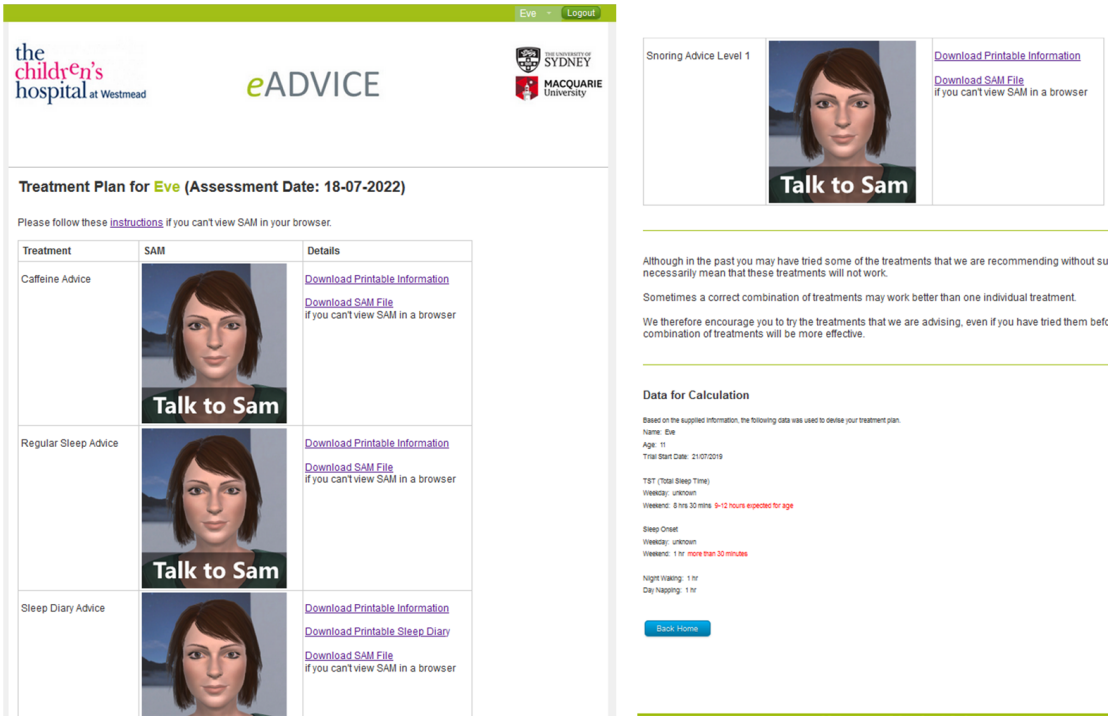

Figure 2: Accessing discussion of treatments with SAM.

time to clarify the process and review the explanations again or to explore alternative flows of the conversation and options provided by the virtual coach to potentially help them in their decision-making and in case they change their mind or find the option did not work as they expected. The system, the virtual coach and the dialogues are designed following evidence based recommendations and the specialists at CHW.

4. The explainable Agent and Dialogue Design

The agent SAM, Figure **??**, is implemented using the UNITY 3D game engine, which is integrated with the designed authoring tool which is a lightweight version of XFAtiMA [**?**]. XFAtiMA (explainable FAtiMA) is an extension version of the belief-desire-intention agent architecture FAtiMA [**?**]. An XVA with XFAtiMA can explain its behaviour (choice of recommendation in this context) based on its beliefs and/or goals. The lightweight version of XFAtiMA is designed so an XVA can be run on internet browsers so that patients and their families would not need to download and extract an application to their computer to interact with SAM.

Interacting with SAM is only available through the password-protected eADVICE-sleep website. Users could be children, teenagers with sleep problems, and their parents. In the beginning, all the users engage with SAM in an introductory interaction, where SAM introduces itself and explains how the system and process work. SAM is designed to deliver advice/treatments around the most common behavioural sleep problems: sleep diary, sleep hygiene, settling

Figure 3: The XVA SAM.

routines, snoring, night terrors and caffeine consumption. The system can be run in two modes – child-friendly mode and parental mode – with the appropriate language for each group.

4.1. Treatments

The Sleep Diary conversation is designed to encourage and guide the appropriate use of the sleep diary. While this is not a treatment, use of the diary is commonly advised assessment, as it captures essential data such as the patient's daily sleep time (duration and patterns), quality of sleep and sleeps behaviours (e.g. napping), which is needed by eADVICE to calculate other appropriate treatments and to provide self-evaluation for the patient of their sleep. eADVICE-sleep users enter their 14-day sleep diary in the system and then interact with SAM, which explains the importance of the sleep diary for accurate assessment and answers the most frequently asked questions by the users.

Sleep hygiene refers to bedtime-related behaviours. Poor sleep hygiene such as caffeine consumption before bed and excessive electronic device use is one of the main reasons for children's sleep problems, teenagers in particular [**?**]. While sleep hygiene treatment targets adolescents, SAM further delivers two similar treatments specific for infants and children, called settling routines. At this age, sleep can be viewed as a learned behaviour [**?**]. SAM provides advice to parents on how to prepare a sleep environment that can help their children to settle and sleep independently. For example, SAM would advise a mother of a baby older than four months to deal with frequent night wakeups by saying: "*If your baby is older than four months you can start weaning them off night feeds or phasing out bottle feeding. At this age, most babies wake up at night because they are used to eating, but they do not need the night-time calories to grow properly.*"

Night terrors is also a common problem for which SAM provides three alternative treatments for parents to choose from according to their context. The three treatments are a regular bedtime routine (to set a fixed and regular bedtime routine), no touch treatment (to refrain from touching the child when night terrors happen) and scheduled awakening (to record the occurrence of the night terrors for two weeks and then wake the child before they start, according to the schedule for 10 nights). SAM provides the steps of every treatment with explanations and examples.

Breathing problems affect up to 14% of children globally and are linked to many behavioural, cardiovascular and neurocognitive functions [**?**]. Snoring is an indication of having breathing problems, and in severe cases, the child has obstructive sleep apnoea. SAM assesses if the child has a snoring issue and asks the parents to record their child snoring in a log for 14 days. Later, SAM discusses the log with the parents and detects if the child has obstructive sleep apnoea. SAM would advise the parents to use an over-the-counter (i.e. doctor's prescription not needed) nasal spray, which is a common procedure until they can see the doctor. SAM explains the treatment and expected outcome and provides strategies on how to encourage the child to use/accept the spray using rewards and explanation. Time-specific conversations have been designed to allow parents to interact with SAM after two weeks and again after two months of snoring treatments to assess their conditions and advise accordingly.

Finally, caffeine is associated with sleep problems particularly when it is consumed at night [**?**]. Caffeine can be found not only in coffee but in many products such as chocolate, energy drinks, cola and caffeinated snacks. SAM informs children about these products, discusses their beliefs about the products, and recommends alternatives.

4.2. Explanation

Content for the dialogues for the treatments has been provided by the specialist team and from reading relevant literature. A template for the dialogue is designed to provide a structure for the provided treatments as illustrated in Figure **??**. This template has provided guidance for the acquisition of the domain knowledge, including associated beliefs (which are often barriers raised by patients), goals (which are typically the drivers and motivations expressed by patients), education (in the form of explanations and clarifications), and treatments (which are the recommendations provided).

Perhaps more importantly, the template provided a clear way to connect beliefs, goals, recommendations and explanations. An example of the use of the template to design the dialogues is presented in Appendix **??**: the caffeine treatment. SAM starts every conversation by welcoming the user and introducing the treatment topic. Then, it discusses the user's goal of the treatment. It affirms its understanding so the user feels being heard and understood and, consequently, builds mutual understanding. At this stage, SAM chats with the user to elicit more information required to tailor the treatment. Eliciting the user's information and building mutual understanding could appear frequently at any time in the conversation when suitable.

Every treatment consists of a number of recommendations that could be fixed (e.g. recommending caffeine alternatives) or tailored (e.g. recommending a specific sleep routine according to age). As presented in Figure **??**, recommendations could be tailored to the user's information/context (e.g. age), beliefs (e.g. too busy to follow a sleep routine) or goals (e.g. need to give up on caffeinated drinks). The user has the choice to ask for more information after SAM provides a fixed recommendation and to ask for an explanation after a tailored recommendation.

The explanation is designed to explain why the recommendation is given following one of three explanation patterns: belief-only, goals-only or beliefs and goals. These patterns have been evaluated previously in [**?**]. Further, the patterns are designed considering the explanation principles when a human is the target: meaningful, accurate and focused knowledge to serve the desired outcome [**?**].

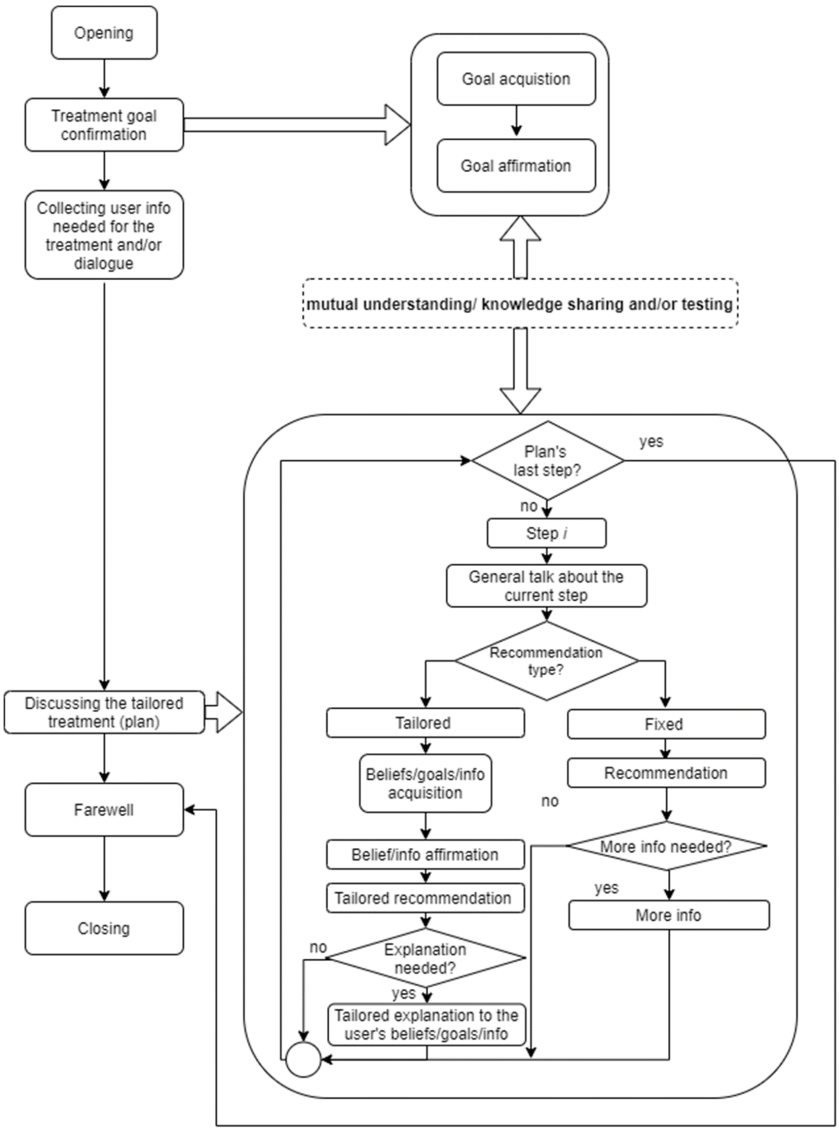

Figure 4: The eADVICE consultation process.

SAM explains how a recommendation is linked to the user's mental state (beliefs or goals) or information provided and may remind the user of the treatment goal before it provides more information/knowledge about why the user should follow the recommendation. SAM refers to the user's belief by stating "you think/find..." and to the user's goal as "you want..." to signify subjectivity as recommended by [**?**]. For example, SAM would explain why a busy mum should follow a sleep routine for her baby by saying: "*You find yourself and your family are very busy* (user's belief), *but it is still important to try to keep regular sleep times* (the recommendation). *You told me you want your child to have a good sleep to develop well* (user's goal). *Actually, you and your child need enough sleep, and being very busy takes a lot of energy* (extra knowledge)."

After discussing all the recommendations in the treatment plan, SAM closes its conversation with a positive note or by encouraging the patient to follow the advice by setting a goal to be achieved in the next two weeks, followed by a friendly farewell.

While patients can only reassess and receive treatment advice fortnightly at most, patients can revisit the discussion at any time to clarify the process and review the explanations again or to explore alternative flows and options, which might help them in their decision-making if they have changed their minds or find one option did not work as they expected. For this reason, When patients revisit a dialogue we ask their beliefs again, rather than assuming the same answer as before.

5. Initial Evaluation

We have obtained ethics approval to conduct a pilot with 50 paediatric patients at CHW. Further funding is required to conduct the pilot. As part of the development process, we have received initial feedback from parents and children, as well as other health professionals at the hospital. The incontinence specialist has commented on the superiority of the sleep dialogues in terms of structure, content and comprehensiveness in comparison with the continence dialogues that lack a clear connection between barriers (beliefs) and motivations (goals) and explanation and education provided. Some feedback showed interest from teenagers to get more information from SAM by including the option 'more info' in different places in the dialogue. Examples of positive feedback from users are:

• A professional: "*clear, easy, simple to navigate, lots of information broken down into simpler chunks, good examples and transparent language by providing explanations*".

• A mother of a newborn: "*Questions were clear and written well*".

• A father of a 9-year-old and 10-year-old: "*my kids viewed it all as an educational thing rather than a medical thing and thought Dr. SAM wasn't like a real Dr. They thought it would be good to show at their schools, both to teachers & classmates. This perception could be good if the aim is to minimise medicalisation. The kids perceived SAM as a friendly educational tool.*" • More constructive feedback was received from a healthcare professional such as "*my kids suggested pictures & diagrams, for example, they asked what tonsils look like etc*", and "*my daughter wanted to see a video of a night terror (which I showed her) and asked lots of questions mainly about nightmares. Lots of fascination*".

6. Conclusion and Future Directions

In this article, we reported a work in progress to deploy a real application for children (newborns to teenagers) with sleep problems. The system is built as re-engineered version of a previous system (eADVICE-continence) [**?**], which has been proven successful in helping children with incontinence problems. The XVA SAM is designed to deliver tailored treatments to children and parents. These treatments are adjusted every two weeks according to the reported progress by the patient. Sam's dialogues of the treatments were designed following a template that includes delivering advice to change sleep-related behaviours according to the patient's beliefs, goals or context. The explanation templates provided a structured and comprehensive approach

to creating dialogues that ensured beliefs and goals were acquired and discussed. The initial feedback of the system and the XVA SAM by patients and specialists is promising. However, the work is still in its early stages as it was on hold for a while due to a funding issue. A possible future direction, as suggested by [**?**], is to incorporate health literacy measures into the design of the explanation patterns, particularly the knowledge component. This could facilitate personalisation of both the knowledge component and its language, potentially improving patient adherence [**?**]. Tailoring the explanation language and knowledge level to the primary user's age, whether child or parent, is another avenue for personalisation.

Acknowledgments

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A. The website algorithm

Table **??** presents a snippet from the website algorithm used to evaluate the infants' sleep problem. Parents answer these questions on the eADVICE website. The parent can click on a button labelled "more information", to receive a popup window with the reason why we are asking them this question, the reason connected with a specific question is shown in the final column. For older age groups, there is also a "kids" version with simplified language and related pictures/cartoons to make the page look more fun. The responses are used to determine which treatment to recommend.

B. Example of the dialogue

Figures **??** and **??** present part of the dialogue flow and the options available to the user to select. Figure **??** starts with the XVA eliciting the user's beliefs on why to consume a caffeinated drink, which was determined by the user in Step A. The dialogue then continues according to the user's beliefs and goals.

C. What we expect from the workshop

1. **Measurement Validity**: seeking feedback on the appropriateness of proposed methods for measuring behavior change in our target population. This feedback is part of the collaborative effort with healthcare and HCI professionals which is crucial for a robust codesign process.
2. **Recruitment Strategies**: seeking suggestions for alternative recruitment methods or collaborative strategies to increase sample size, particularly for design validation purposes.
3. **Explanation Perception**: identify potential factors influencing the target audience's perception of the explanations patterns provided.

Set	#	Question	Responses	Path	Treatment	More Information
Weekday schedule	1	Does your child have to keep a regular weekday schedule for three or more days per week during school term?	Yes/No	If YES, –> 2a		This could be to attend day-care, preschool or because of the schedule of other family members.
Weekday sleep times	2	Does your child generally go to bed around the same time each night?	Yes/No	If NO, –> 3		
	2a	What time does your child go to bed at night?				
	2b	What time does your child go to sleep at night?		Skip 3 if 1=Y		
	3	Does your child generally wake up around the same time each morning?	Yes/No	If NO, –> 6		
	3a	What time does your child wake up in the morning?				
	3b	What time does your child get out of bed in the morning?				
Weekday vs Weekend	4	Are your child's weekend sleep times the same as your child's weekday (school day) sleep times?	Yes/No	Only ask if 2=Y & 3=Y, otherwise –> 6) If YES, –> 6		
Weekend bedtimes + wakeup times	5a	How much does your child's bedtime differ on weekend nights compared to weekday nights?	A. < 15 minutes, B. Up to 60 minutes, C. > 1 hour, D. They change all the time		If C/D, Regular Sleep Times	This helps us work out what sort of routine your child has for their sleep times so that we can work out which treatment plan might suit them.
	5b	How much does your child's wakeup time differ on weekend mornings compared to weekday mornings?				This helps us to work out how many hours of sleep your child gets on weekend nights. These are more likely to be the nights when they are able to sleep as long as they would like to.

Table 1
Sleep Algorithm Snippet for Infants (i.e. 8 months- 4 years)

4. **Tailored Explanation Design**: Exploring strategies for effectively tailoring explanations and knowledge communication styles for different age groups within the pediatric range.
5. **Challenges and Engagement**: Seeking feedback on potential challenges with the proposed approach, including maintaining children's engagement levels throughout and the complexity of eliciting beliefs and goals through dialogue.
6. **Ethical Considerations**: Addressing and ensuring adherence to all ethical considerations and safety issues related to the workshop and study design.

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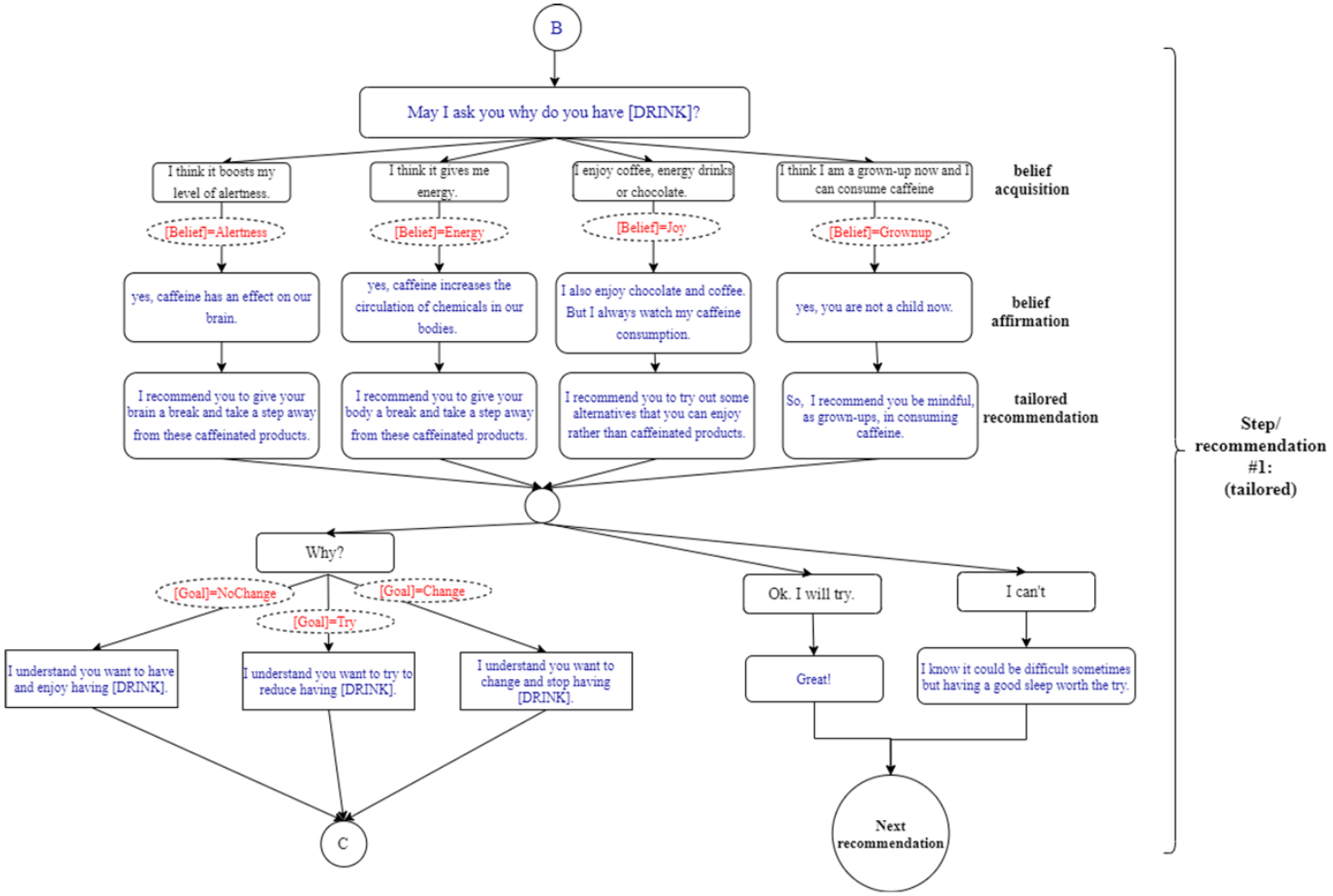

Figure 5: Part1

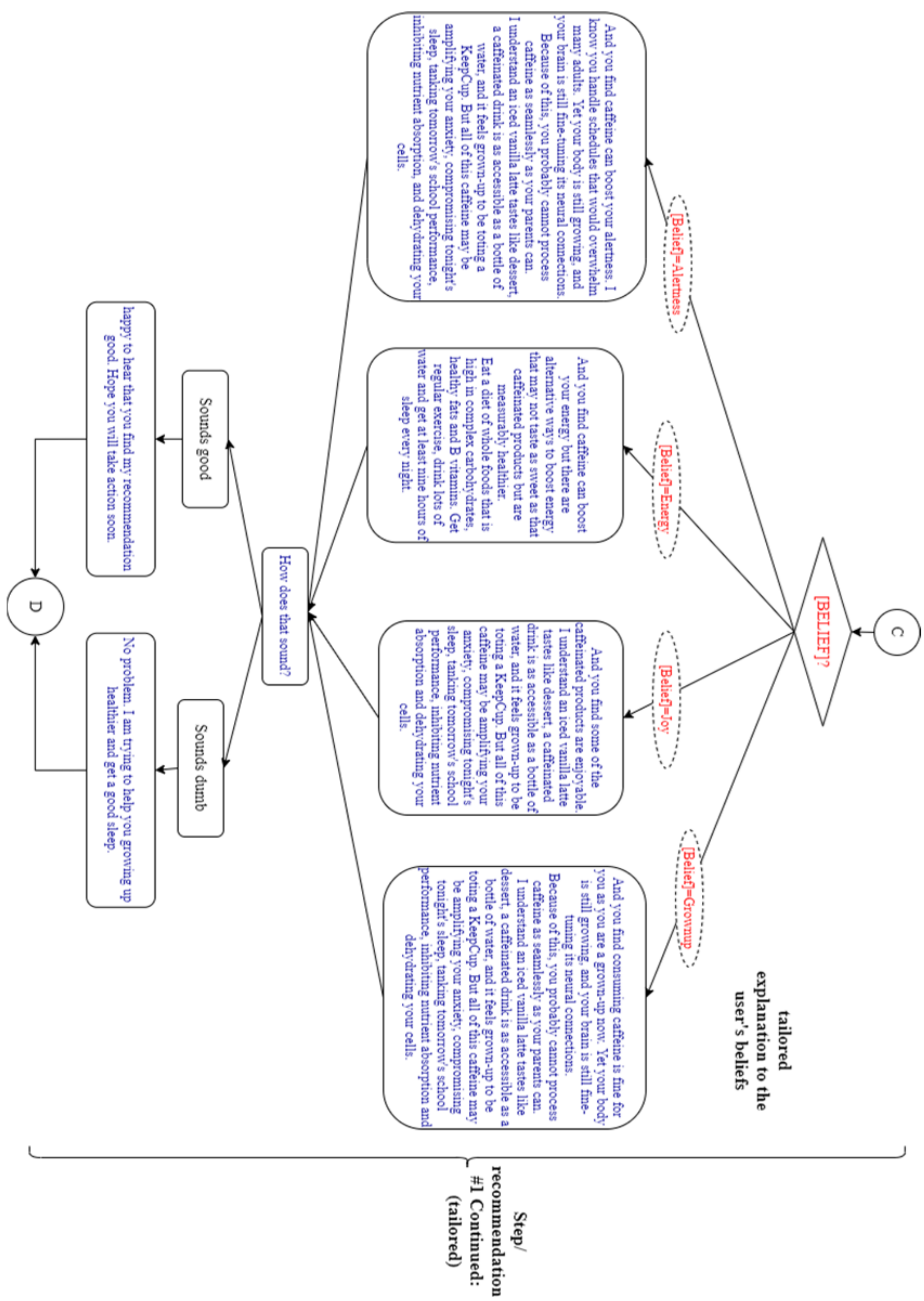

Figure 6: Part2