Understanding Clinicians' Requirements, Perception and Acceptance of Clinical Decision Support Systems: User Study for Implementation of Sepsis Best Practice Advisory in General Paediatric Care

by

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

Clinicians are faced with ever-increasing patient data as well as medical evidence which are all required for them to make the best possible decisions. Clinical Decision Support Systems (CDSS) are widely used to support clinicians' information processing and decision making. However, clinicians as end users are hardly involved in the design and development of these decision support tools. In addition, some of these CDSS designs and processes are not properly implemented to fit into the clinicians' workflow.

The study specifically investigated clinicians' decision-making regarding Sepsis, design and workflow requirements as well as their perception and acceptance of the Sepsis best practice advisory (BPA). Sepsis is a life-threatening disease, and it is important to identify early manifestations rapidly and reliably for timely interventions as every hour of delay increases mortality by 5-10% (37). The aim was to identify the factors that can aid the implementation of the CDSS such that there is no reduced or incorrect usage and interference with clinicians' decision making. Successful implementation of the CDSS can further improve patient's safety especially with regards to Sepsis care.

The study was in two phases, a user interview and a moderated usability testing. Both phases were qualitative studies obtaining data from a total of 13 participants from a target population of clinicians working in the general paediatrics unit of the hospital. Decision ladders from control task analysis (ConTa) and cognitive work analysis (CWA) were used to model clinicians' decision making and the support provided by the Sepsis BPA. The unified theory of acceptance and use of technology (UTUAT) was used to measure clinicians' satisfaction and acceptance of the tool.

The first phase of the study discovered the general experience, knowledge, challenges caring for patients with Sepsis as well as experiences with CDSS and clinicians' projections or expectations of the Sepsis BPA. Key findings were translated into user requirements which were checked against the minimum viable product (MVP) of the Sepsis BPA and recommendations provided. The second phase discovered particular design feedback and usability issues on the

MVP with more recommendations provided. The UTAUT survey results showed highly positive feedback on satisfaction, acceptance and intentions of clinicians to use the Sepsis BPA.

Acknowledgements

I would like to sincerely appreciate my supervisor, Catherine Burns, who consistently believed in me right from accepting me as her student to this very point at the University of Waterloo. Her guidance, encouragements, understanding, availability despite busy schedules all significantly contributed to the success of this thesis and my MASc degree.

Next, I would like to thank members of the Advanced Interface Design Lab (AIDL) who have contributed to my academic and professional development particularly Murat Dikmen, Reicilis Casares Li, Harjot Singh Parmar, Fan He, Ece Uereten. I would like to especially thank Ryan Tennant who was always willing to answer my numerous questions, for all the encouragement and drive. Another amazing human is Sana Allana, who assisted me every step of the way even when she had no obligation to. Thank you for all the help and your contributions to the success of this thesis.

Special thanks to the Sepsis team at SickKids hospital particularly Erica Patterson and Kathleen Andres who agreed to have me on board the Sepsis project and provided every necessary help to make my study a success. It was a wonderful and seamless experience working with them.

Thanks to Systems Design Engineering for the funding and support for this project.

Dedication

This thesis is dedicated to my family, MD J and all my loved ones.

Table of Contents

List of Figures

List of Tables

Chapter 1: Introduction

Clinicians need to keep up with and be aware of the constantly growing medical data and knowledge to make informed decisions on patient's care. Clinical decision support systems (CDSS) are continuously developed to assist in the information processing and decision making of clinicians in various areas such as preventive care, diagnosis, planning or implementing treatment, patient management and administration [1]. Best practice advisories (BPAs) in particular are incorporated in EHRs/EMRs to bring clinicians' attention to particular elements of a patient's care. However, studies have shown that these alerts are often ignored or overridden by clinicians defeating the purpose [2]. Many healthcare organisations encounter significant challenges regarding implementing user-friendly alerts that fit into clinicians' workflow. Clinicians' workflow can be affected by the presentation or appearance of alerts such that they can be highly intrusive with poor interface design, erroneous information and other usability issues. Alerts that fit into the workflow are most likely to be used by clinicians and drive high adoption rates of the tool.

Sepsis is a life-threatening disease with a study estimating about 25% hospital mortality in paediatric Sepsis patients [3]. It occurs when an infection triggers a chain reaction throughout the body as an extreme response resulting in tissue damage, organ failure and ultimately death if not treated early. It is important to identify early manifestations of Sepsis rapidly and reliably for timely interventions as every hour of delay increases mortality by 5-10% [4]. To this end, the goal of the study includes investigating clinicians' requirements for identification and management of Sepsis at a children's hospital. The results will help drive the successful implementation of a Sepsis BPA in the hospital's workflow.

The study was in two phases, a semi-structured one-on-one interview and a moderated usability testing phase. The study applied User Centered Design (UCD) and human factors principles for eliciting clinicians' requirements, perception of the Sepsis Best Practice Alert (BPA) tool, and discovering possible usability issues, acceptance. Suggestions and

recommendations were also provided for both design customization and workflow process improvements.

1.1 Objectives of the thesis

1. Explore clinicians' decision-making regarding identification and management of Sepsis.
2. Elicit user requirements, perceptions, and expectations of clinicians regarding the Sepsis BPA to be implemented through Semi-structured user interviews.
3. Discover usability challenges of the minimum viable product of the Sepsis BPA, clinicians' satisfaction, acceptance and intention to use the Sepsis BPA through moderated usability testing.
4. Use results from 1-3 to provide recommendations for the design and implementation of a Sepsis BPA in general paediatric care.

1.2 Structure of the thesis

This thesis is structured as follows:

Chapter 1 - Introduction, presents an introduction to the thesis, discusses a little background and motivation behind this work, provides objectives and structure of the thesis.

Chapter 2 - Background and literature review, presents some background on clinical decision support systems, best practice advisories in paediatric care, design and implementation challenges, and Sepsis. The chapter also provided a quick look at related work and the system overview of the hospital for this study.

Chapter 3 – Phase I – semi-structured user interviews, presents the first phase of the study showing methodology, study procedure, results and discussion (including decision ladders and recommendations) from the semi-structured user interview.

Chapter 4 – Phase II – Moderated usability testing, presents the methodology, study design, procedure (including the UTAUT survey), results and discussion from the moderated usability testing.

In Chapter 5 – Conclusion, presents the conclusion of the user study, limitations, implications for research, design and future research opportunities.

Chapter 2: Background and Literature Review

This chapter provides a description of CDSS, its types and various uses. In addition, the chapter includes a background on CDSS and BPAs in paediatric care, design and implementation challenges. Then, I presented a general background on Sepsis and included particularly paediatric data on the disease. After this, I discussed the related work that has been done regarding Sepsis CDSS in general and also in paediatric care. This discussion helped identify the gap in research on Sepsis care in paediatrics and the design of decision support for timely interventions. Lastly, I provided a quick overview of the system at the children's hospital where this research took place including the current practice for Sepsis in comparison with the new huddle, the contents of the screening tool to identify patient at risk, and a quick view of the dashboards of the Minimum Viable Product (MVP) of the Sepsis BPA that had been developed prior to this study.

2.1 Clinical Decision Support Systems

Clinical Decision Support Systems (CDSS) aid clinical decision making by providing case-specific advice based on analyzed data to healthcare providers to improve patient care [5]. Based on the type of interaction, CDSSs can provide aid in form of solicited information, unsolicited information, physician order, disease management systems and integrated information systems (Electronic Health Records (EHRs) or Electronic Medical Records (EMRs)) [2],[5]. Good examples are alerts about dangerous health situations, reminders for preventive care, order sets, and documentation templates[2]. They can be knowledge-based or non-knowledge-based. Knowledge-based systems work with IF-Then rules, evaluates data against the rule and produce an output while non-knowledge-based systems have a data source with decision leveraging on Artificial Intelligence, Machine Learning and Pattern Recognition. However, both systems have common components of such as the communication interface. CDSSs improve patient safety, clinical management, cost containment, administrative functions, diagnostics support, and patient-facing support [2].

Target Area of Care	Example
Preventive care	Immunization, screening, disease management guidelines for secondary prevention
Diagnosis	Suggestions for possible diagnoses that match a patient's signs and symptoms
Planning or implementing treatment	Treatment guidelines for specific diagnoses, drug dosage recommendations, alerts for drug-drug interactions
Follow up management	Corollary orders, reminders for drug adverse event monitoring
Hospital, provider efficiency	Care plans to minimize length of stay, order sets
Cost reductions and improved patient convenience	Duplicate testing alerts, drug formulary guidelines

Figure 1. **Examples of CDS interventions by target area of care** [1]

2.1.1 CDSS in paediatric care

Various CDSSs have been widely implemented in paediatrics medicine for different target areas of care and patient populations. There are varying decision support tools for medication prescribing and utilization [6]. With the goal of reducing the use of Computed tomography (CT), CDSS were developed and implemented to guide emergency care clinicians on the management of patients with appendicitis and Traumatic Brain Injury (TBI) [7],[8]. The use of antiinfective decision support tool in a paediatric ICU setting was effective in the reduction of erroneous drug orders, decrease in the estimate of antiinfective costs per patient and an improvement in therapeutic dosage targets [9]. Computerized physician order entry (CPOE) and decision support systems substantially reduce the rates of medication errors in paediatric care [10].

CDSS for automatic detection of systemic inflammatory response syndrome (SIRS) has also been designed with an approach to achieve interoperability of paediatric systems [11]. This problem space is like that of this thesis as SIRS is part of the criteria used in the design of the Sepsis tool.

2.1.2 CDSS design and Implementation challenges.

There has been a slow but increasing adoption of health IT decision support systems [1],[12]. As seen in the previous section, studies show that CDSSs can improve outcomes and reduce medical errors. However, some studies also demonstrate that CDSSs are falling short of their full potential [13],[14]. Major Improvements in quality and cost of care may become difficult to realise without proper implementation and use of CDS [1]. Research has discovered some reasons for this shortfall are focused on the healthcare provider's willingness, perception and ability to use the CDSS [13],[15].

According to Osheroff, et al. in [16], a CDSS should be designed to 'deliver the right information, to the right people, through right channels, in right intervention formats and at the right points in the workflow'. CDSS must be integrated into healthcare organisation's workflow or it would have no beneficial effect [17]. Healthcare providers begin to underutilize or improperly use CDSSs if steps were not taken to ensure CDSS usability and fit in their workflow. CDSSs can also disrupt workflow if designed without human information processing and behaviors in mind [1],[2]. Disrupted workflow can lead to increased cognitive effort, more time required to complete tasks, and less time face-to-face with patients. When a system is poorly designed, clinicians may begin to practice workarounds that compromise data, an example is generic or incorrect data entry. Poor quality of data consequently results in poor quality of decision support [2]. The Agency for Healthcare Research and Quality (AHRQ) concluded in a report that improperly using a CDSS can be more harmful than not adopting the CDSS at all. Therefore, it is very crucial to involve clinicians in the development and rigorous evaluation of these systems. Clinicians can best decide how CDSSs should be implemented in their local care environments [5].

During the development of CDSS, well-recognised best practices such as review, feedback, and integration into workflows are not routinely followed. Clinical informatics resources are usually allocated to other priorities [14]. As one of the first steps in developing a CDSS, an assessment of the workflow and how to fit CDSS in it should be executed. If any process is discovered to need a redesign, it should be fixed before implementing the tool [1]. In a systematic review of research literature, Kawamoto, et al. identified the design characteristics that resulted in the successful deployment of CDSS [18]. These characteristics are outlined below:

i. Computer-based decision support as opposed to manual.
ii. CDSS interventions are presented automatically and fit into the workflow.
iii. CDSS that recommends actions and next steps.
iv. CDSS that provides needed information at time and place of care.

There are effective strategies for implementing decision support systems as described by Bates and Colleagues in the ten commandments for effective CDSS [19] that help overcome some of these barriers and help change clinician behaviour [20]. Some of these strategies applicable to this research are listed below:

1. No delays in reminders to avoid slow workflow.
2. Delivering information to clinicians without the need to search for them.
3. Prioritising usability
4. No interventions that require clinicians to stop but can possibly change their direction.
5. Emphasis on simplicity.
6. Avoid requesting additional information or input from clinicians as much as possible.

2.2 Best Practice Advisory (Alerts)

Best practice advisories, also known as best practice alerts (BPA), are CDS tools incorporated in EHRs/EMRs of a healthcare organization to bring clinicians' attention to particular elements of a patient's care [21]. Valvona N.S et.al. [22] in a systematic review found that these alerts served as reminders that improved clinicians' adherence to recommended processes of patient care.

Some of the BPAs that have been developed in paediatric care aid in the early identification of deteriorating patients [23], children in need of immunizations or influenza vaccinations [24] and complications in children with type 1 diabetes [25]. In surgical units, alerts have been developed for multimodality neuromonitoring in high-risk paediatric spinal deformity surgery [26] and identifying patients with septic shock in surgical inpatient units [27].

2.2.1 Alert design and implementation challenges

Alerts are usually more encountered as a CDSS but one of the most challenging to implement successfully. Implementing alerts effectively such that they are raised when needed and not inducing alert fatigue is very challenging [1]. Alert fatigue is defined as the "Mental fatigue experienced by health care providers who encounter numerous alerts and reminders from the use of CDSS". In human factors alert fatigue is regarded as poor signal to noise ratio [2].

If physicians must encounter excessive and unimportant alerts, they can suffer from alert fatigue. Sometimes physicians disagree with, distrust, or just ignore these alerts. Studies have shown that alerts in EHRs are often ignored or overridden by clinicians [2],[22],[28] which defeats the purpose and can potentially be harmful. Some of the main reasons for these are low specificity, unclear information, and unnecessary workflow disruption [17]. Clinicians' workflow is usually affected by the presentation or appearance of alerts such that they can be highly intrusive. Some of these alerts possess poor interface design with erroneous information linked to usability issues which in turn affects accessibility to adequate information [29],[30].

As mentioned in the previous section on CDSS implementation, customizing alerts to reflect real-world habits of the clinicians in their local environments is a driver for high adoption rates of the tool [28]. Alerts that fit into the workflow are most likely to be used by clinicians. Process improvement methods can be consistently practiced in the healthcare system to ensure that CDSS alerts continue to support workflow [31].

2.3 Sepsis

According to the CDC, Sepsis is a life-threatening medical emergency that happens when an infection triggers a chain reaction throughout the body as an extreme response. According to the most recent definition (Sepsis -3) developed in 2016, Sepsis is a "life-threatening organ dysfunction caused by a dysregulated host response to infection" [32]. Sepsis can lead to tissue damage, organ failure and ultimately death if not treated early.

Below are the definitions for common terms used to describe Sepsis and its subsets [33]:

i. **Severe Sepsis**: occurs when Sepsis becomes complicated by organ dysfunction. The term was used in previous Sepsis definitions (Sepsis-1 and -2) but not in the current one (Sepsis-3).
ii. **Septic shock:** occurs when there are acute circulatory, cellular and metabolic abnormalities associated with a greater risk of mortality than having Sepsis alone.
iii. **Systemic inflammatory response syndrome (SIRS):** exaggerated response of the body to defend against a noxious stressor (infection, trauma, surgery, acute inflammation, ischemia or reperfusion, or malignancy) localising and then eliminating the endogenous or exogenous source of the insult.

According to the WHO report on global epidemiology and burden of Sepsis released in 2020, 20% of global deaths are due to Sepsis. Sepsis affects individuals of any age and sex but there are significant disparities in the burden. It disproportionately affects vulnerable populations like pregnant women, neonates, young children, older people, the immunocompromised and people with underlying chronic health conditions [33]. It can occur in any community, long-term care, and among inpatients admitted to a hospital [34].

For this study, we would be looking specifically at paediatric Sepsis. According to WHO, almost half (about 20 million) of all estimated Sepsis cases in the world occurred in children under 5 years of age in 2017. In 2018, an estimate of 15% of all global neonatal deaths were due to Sepsis. About 15 out of 1000 hospitalized patients develop Sepsis as a complication of receiving healthcare with the neonatal population being 7 times higher [34]. In the largest global

paediatric point prevalence (2013-2014) study to date, there is an estimated 8.2% severe Sepsis in children less than 18 years of age admitted to ICUs across 126 countries that are primarily in North America and Europe. The study estimated 25% hospital mortality and 17% moderate-to-severe disability among paediatric Sepsis survivors [3]. It is also very costly to treat Sepsis as the average hospital-wide cost was estimated at $32,000 per patient [33].

In Canada, there have been several recent high-profile deaths from Sepsis in children calling for the need to identify early manifestations of Sepsis rapidly and reliably for timely interventions. To provide the best care for Sepsis, early detection is of utmost importance. With every hour of delay of care, mortality is increased by 5-10% [4]. There are manual scoring systems that exist to identify paediatric patients with Sepsis such as SIRS, Paediatric Sequential Organ Failure Assessment (pSOFA), Paediatric Early Warning Score (PEWS), and Paediatric Logistic Organ Dysfunction Score (PELODS) [35]. However, automatic trigger tools (alerts) can be very useful to identify children at risk of Sepsis and support healthcare teams in the treatment and care of a Sepsis patient [36]. Using these alerts with defined treatment procedures has been shown to reduce mortality in paediatric settings [37]. When designing these tools, it is important to consider the context such as inpatient setting, emergency department or surgical specialties as they have unique requirements. The tool must smoothly integrate into the current workflow of the healthcare organisation with minimal training or additional efforts required of clinicians [36].

2.4 Related work

There are varying decision support tools that have been developed and tested for identifying Sepsis in patients. Several studies have investigated the accuracy and sensitivity of systemic inflammatory response syndrome (SIRS) criteria and Sepsis-related organ failure assessment (SOFA) score for detecting Sepsis in patients. Other studies focus on the performance of Sepsis CDSS after implementation. In [38], a retrospective multicenter study was done on 6200 patients in a period of one year to determine clinimetric performance of a Sepsis CDSS and discover opportunities for quality improvement. The tool had an acceptable activation rate (10

per day in a 500-bed hospital) and simultaneously achieved good clinimetric performance. Another retrospective analysis confirmed that the implementation of CDSS incorporated into the medical information system reduced the number of septic shock cases from 26% to 7.5%, reduced duration of stay in intensive care unit and Sepsis treatment by 13% [39].

Machine learning and Artificial Intelligence (AI) approaches have been applied to develop some of these Sepsis tools to make them smarter. In [40], a machine learning model was able to derive optimal policy for individual Sepsis patients based on their trajectories. The model was able to provide suggestions for favourable actions (focusing on antibiotic combinations), predict with very high accuracy the length of stay and mortality. Zhang et al. developed an interpretable model for the early prediction of Sepsis in an emergency department 4h before it occurs achieving high prediction performance across all the subpopulations [41]. Many more machine learning models have been successful in predicting Sepsis, but adoption of the tools and patient outcomes have not been equally successful. It is therefore important for healthcare organisations to deal with these foundational human factors challenges by focusing on the end user's requirements in the design and implementation process for decision support tools.

This study will focus on the design of these systems and the impact on adoption, use and successful application especially in paediatrics care. The impact of the design and fit of these systems on performance is often underrated. Some studies have shown that executing user studies and employing human-centered design principles to decision support tools can contribute significantly to optimal performance [42]. In [43], the study explored literature guidelines on CDSS for supporting Sepsis care together with results from interviewing four healthcare providers. The study identified a few guidelines for the development of CDSS for Sepsis such as interactive patient data investigation, usage of dashboards, visual and audio warnings, collaboration between lab personnel and clinicians and inspection of the knowledge base of evidence supporting recommendations. However, all practitioners in the hospital were not well represented considering only four were interviewed in the study.

Another study investigated the optimization of Sepsis alert design with human factors best practices and recommendations [44]. Ansel Aakre et al. used the user-centered design

methodology to develop the interface that met clinicians' requirements as end-users. All three usability domains that were assessed (interface quality, information quality and system usability) received favorable ratings. In [45], participatory design-based prototyping was used to create user interface concepts for neonatal Sepsis risk decision support. The designs were tested in an iterative format and evaluated using the system usability scale before software development.

In the pool of research, the detection and prediction of paediatric SIRS is underrepresented [35]. In addition, there is very little research including human factors or user studies to inform the design of Sepsis CDSS, especially in general paediatrics care. However, it is expected that more research is performed on health care alert usability and design. This will result in their evolution to better facilitate providers' decision making in an effective and efficient manner. It should equally be stressed that CDSS should undergo further user-centered design development and testing to establish their effect on provider action in health care settings [46]. Also, it is not quite prevalent to find healthcare organisations who are purchasing or customizing these tools executing user or usability studies in the implementation process. This is important to assess how well the system is going to work in their practice and workflow [47].

This study focused on applying UCD and human factors principle to the design customisation and implementation of a Sepsis CDSS tool into the general paediatrics practice in the hospital. This study investigated the needs and requirements of the clinicians regarding the Sepsis clinical decision support tool to be implemented. The project was in two phases, a semi-structured one-on-one interview, and a moderated usability testing. The project successfully applied human factors principles to drive the implementation of the Sepsis BPA in the organization.

2.5 System Overview

The research was conducted at SickKids Hospital, Toronto. It is a paediatric care hospital with many different subspecialties. Management of the organization was looking to pilot a Sepsis

BPA at general paediatrics which is an inpatient ward at the hospital. It is important to note that a Sepsis alert of a different design and development has been in use at the emergency department (ER) of the hospital before this study. However, different subspecialties have different workflows and functions thereby resulting in the need for the design and development of a new BPA.

2.5.1 Sepsis score and criteria

The Sepsis BPA tool will be integrated in the hospital's EHR system, Epic. A version of the tool has been successfully implemented in a children's hospital in the US and was adapted to the hospital's system. The score and criteria were also adopted but properly tested and evaluated by experts in the Sepsis team to fit into the hospital's EHR. The table below shows the contents of the Sepsis screening tool.

***Table 1*. Sepsis screening tool contents**

High-risk conditions	Such as sickle cell, malignancy, solid organ recipient, on immunosuppressants, had a bone marrow transplant procedure in the last 180 days
	Has any of the following Active LDAs Types: Central Venous Catheter, Peripherally Inserted Central Catheter Line, Urethral Catheter, Hemodialysis Catheters,
Temperature	<35.9 or >38 within 24 hours
Heart rate	Tachycardic based on age within 24 hours
Respiratory rate	Tachypnea based on age within 24 hours
Systolic BP	Hypotensive based on age within last 8 hours
Cap refill	Delayed cap refill in last documented flowsheet value
Skin Exam	Dusky, flushed, mottled, cool, cold, in last documented flowsheet value
Mental Status Exam	Difficult to arouse in last 24 hours
Behaviour	Delirium, withdrawn, lethargic, confused, or disoriented in last 24 hours
Labs	ALT, ANC, WBC

LOS	Length of stay < 12 hours

2.5.2 Sepsis early management pathway and new huddle

There is a Sepsis early management pathway in use at the hospital. The pathway consists of the STAR (stop, think, act, review) to identify, SBAR (situation, background, assessment, recognition) for communication and a flow chart showing step-by-step procedure to treat and manage patients. The pathway has not been supported by any tool until now.

However, the Sepsis decision support tool comes with a new huddle. The huddle represents the step-by-step flow designed into the Sepsis tool to identify and manage patients with suspected Sepsis as seen below:

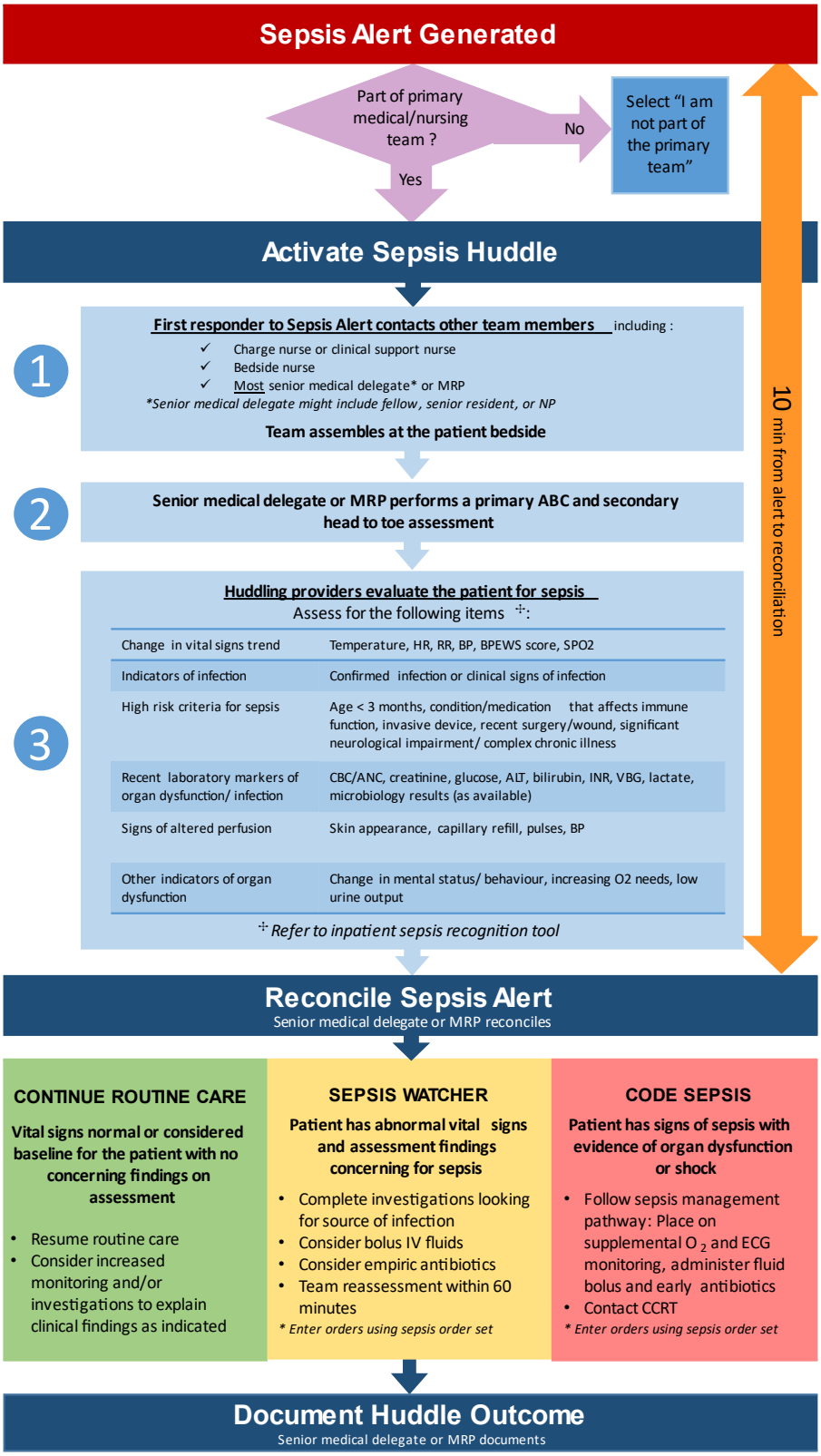

Figure 2. **New Sepsis huddle**

2.5.3 Sepsis Best Practice Advisory

A minimum viable product of the tool had been developed at the time of this study. The tool was designed for two user types, nurses and providers. Users would encounter the Sepsis BPA whenever they open the patient's chart. The BPA is acknowledged and activated resulting in a Sepsis banner in the patient's summary chart. The user clicks on the summary chart and the Sepsis navigator is opened. There are few differences in the sections and functions available in the Sepsis navigator to the two users. Nurses can document vital signs but the physicians can only view the vitals graph. However, only physicians can document focused assessments, sign Sepsis orders, and document a Sepsis event note.

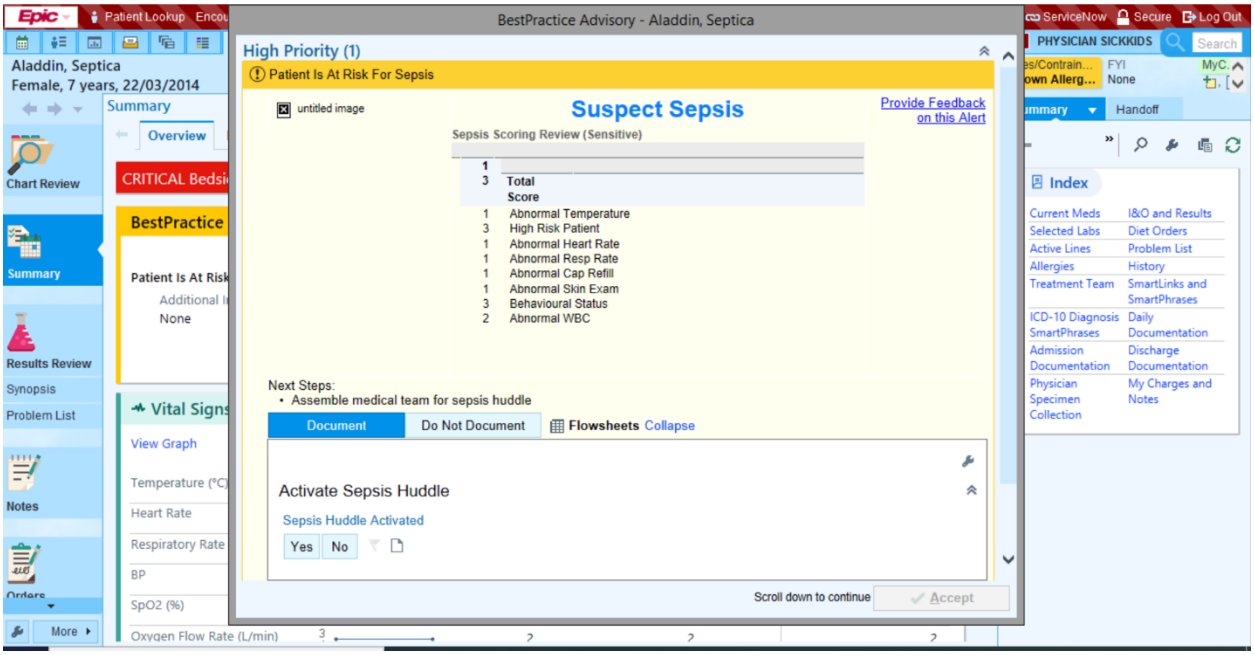

Figure 3. **Pop-up display of the Sepsis BPA**

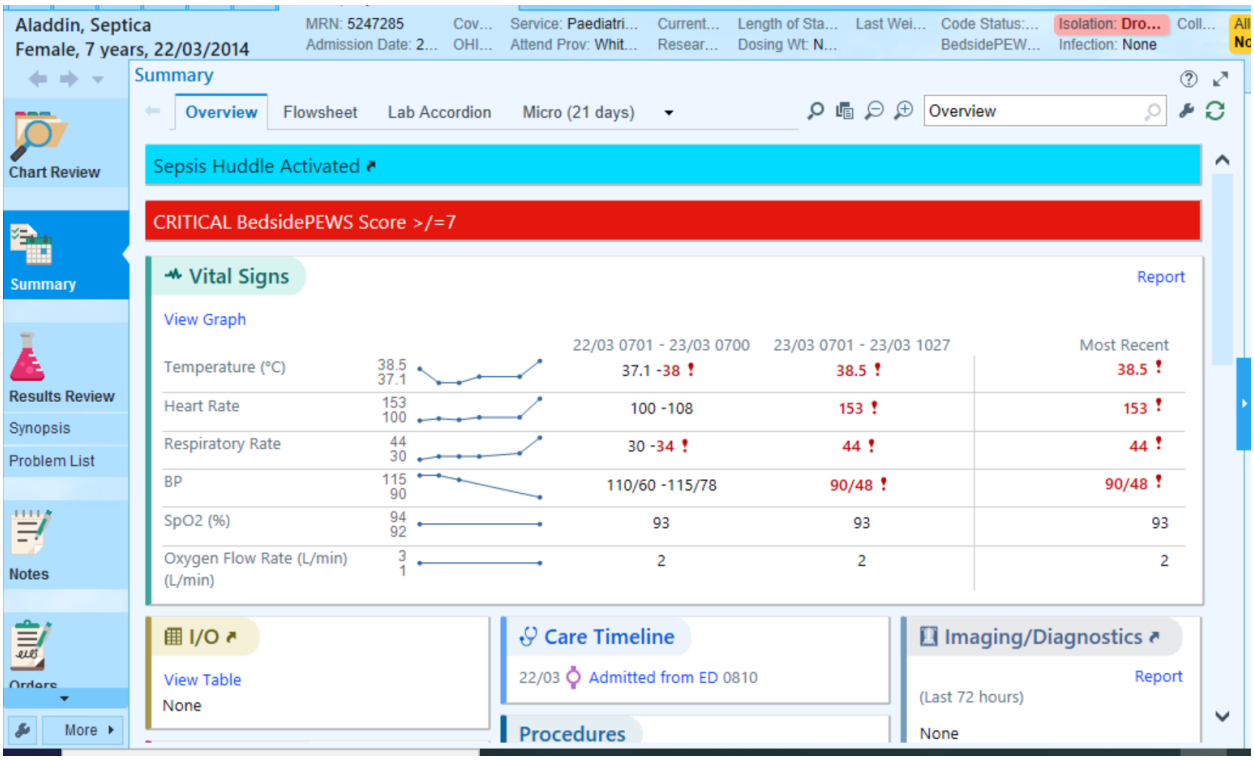

Figure 4. **Sepsis banner on patient's summary page**

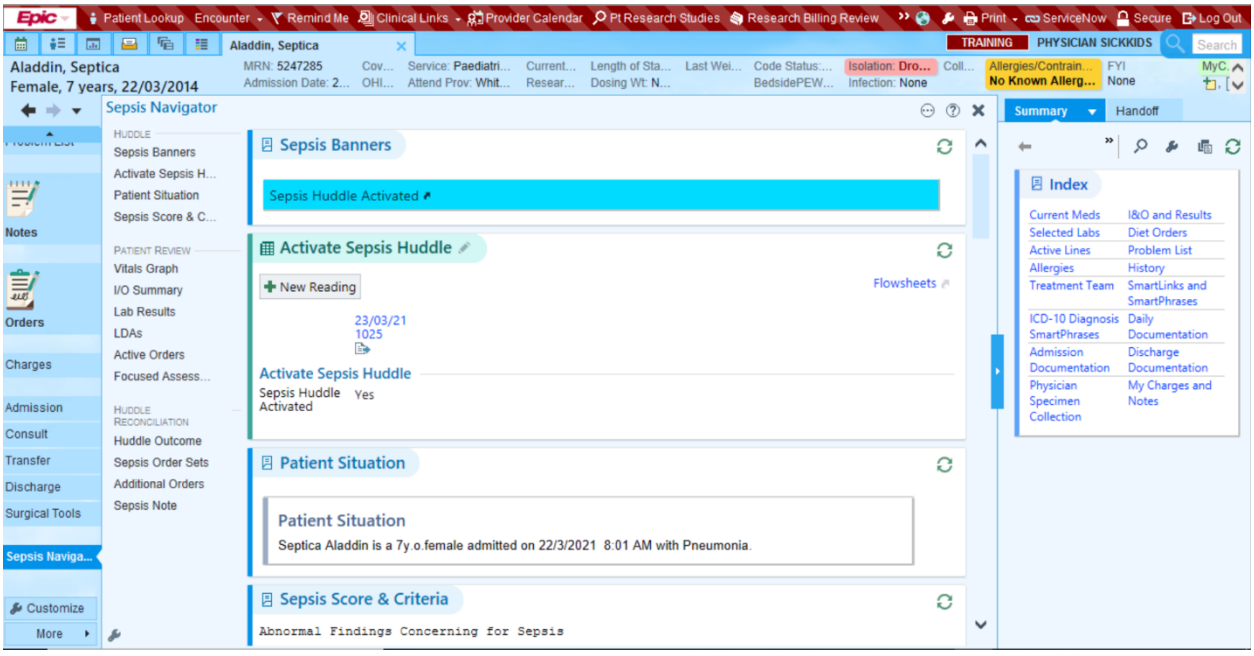

Figure 5. **Navigator of the Sepsis BPA**

2.6 Chapter Conclusion

Clinical decision support systems should be designed and implemented to optimally deliver on their functions. This chapter provided an understanding of the various challenges that clinicians have faced using these systems and a possible reason being the lack of clinicians' involvement in the design and implementation of these systems into their workflow. The section on Sepsis was able to provide details on the definition and terms in Sepsis care, history, data for paediatric Sepsis and established the need for automatic alerts to identify patients at risk for Sepsis. The review of related work also provided insight into the focus of research on outcomes of Sepsis tools interventions with little on user studies showing involvement of clinicians in the design and development. There was also particularly little research on Sepsis or SIRS tools for paediatric settings. This chapter was able to provide precedence on the need for this research and the possible contributions to both the hospital and research in general.

Chapter 3: Phase I – Semi-structured User Interviews

This chapter presents the first phase of the user study for the Sepsis BPA. Here, I used a semi-structured interview approach to elicit user requirements for the Sepsis BPA. In addition, I also explored the clinicians' decision making and experiences regarding Sepsis. The methodology, study procedure, participants' demographic data for the study was also provided. The results showing the thematic categories, themes, subthemes, charts to visualize the frequency of participants' responses were provided. Afterward, the MVP was checked against the user requirements, key findings and concerns of clinicians with recommendations provided to correct or improve the tool.

3.1 Methodology

Qualitative semi-structured interviews were used in this phase with the intention to allow clinicians to share a wide range of viewpoints regarding decision making with Sepsis, clinical decision support and their expectations of the Sepsis BPA. Questions to guide the interview were drafted by the author after careful consultation with stakeholders and principal investigators at the hospital.

3.2 Study setting

The interviews took place remotely on Microsoft teams. Meeting times were scheduled with participants a week before. All participants were clinicians from the general paediatric unit at Sickkids hospital, a paediatric care hospital in Toronto. Present at the interviews were the facilitator (author), another researcher who was the note-taker, and the participants.

3.3 Participants

The target population for recruitment was the general paediatrics unit at the hospital, considering that the Sepsis BPA was being developed for the unit. The recruitment of participants was purposive. A wide range of years of experience and different healthcare professions were considered in selecting participants. Clinicians were contacted by principal investigators at the hospital about the study while the author followed up with interested participants. The research was approved by the institutional review board at the author's university (the University of Waterloo).

Ten participants were interviewed and provided with background and demographic questions which included age, gender, healthcare profession, and years of experience with Sepsis. The range of years of experience was 24.5 with a median of 7. A summary of this data can be seen in the table below:

Table 2. **Summary of participants' demographics in semi-structured interview**

Participants	Age range	Gender	Healthcare Profession	Years of Experience
P1	20 - 30	Female	Physician Assistant	3.5
P10	51 - 60	Female	Physician	27
P11	31 - 40	Female	Physician	11.67
P12	31 - 40	Female	Registered Nurse	7
P2	41 - 50	Female	Nurse Practitioner	20
P3	31 - 40	Female	Registered Nurse	7
P5	31 - 40	Female	Physician	7
P7	20 - 30	Female	Resident	2.5
P8	20 - 30	Male	Resident	3
P9	20 - 30	Female	Resident	3

The chart below shows the distribution of the healthcare professions sampled from the general paediatrics unit at the hospital:

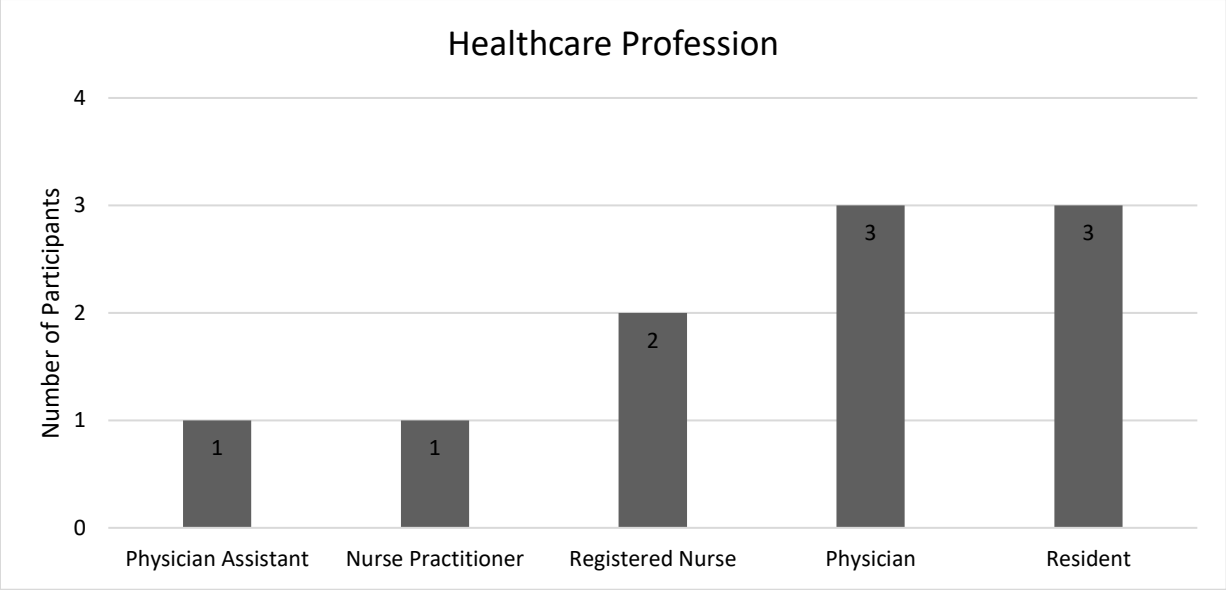

Figure 6. **Participants' healthcare profession demographics.**

3.4 Study procedure

The participants received an information letter prior to the interview. The interviews began with the facilitator introducing participants to the study and taking verbal consent. Responses to background and demographic questions were also taken verbally. Participants were asked questions centred on their decision making regarding identifying and managing Sepsis, the challenges they encounter, expectations of the tool and design and interaction preferences. The session was audio-recorded to facilitate data collection.

3.5 Data analysis

Thematic analysis of the data was performed by two researchers using NVivo. The coded data were grouped into a hierarchy of resulting themes. It was a combination of inductive and deductive approaches for the thematic analysis. It was predominantly deductive as some of the main themes were expected concepts of the researcher. However, the approach to analysing and placing the sub-themes were much more inductive. According to Braun and Clarke in [48], coding and analysis of research data can involve a combination of inductive and deductive approaches in reality, but what is most important is the coherence and consistency of the overall analysis.

The coded data from the two researchers were compared in a total of three meetings with similar codes merged and others added or revised as agreed after deliberation.

3.6 Results

3.6.1 Coded data

The data were coded into the following hierarchy:

Thematic category – Themes – Subthemes.

The table below shows the summary of the results:

Table 3. **Thematic categories, themes and subthemes**

Thematic categories	Themes	Subthemes
General experience and knowledge caring for patients with Sepsis	Identifying Sepsis	Clinical judgement, level of consciousness, start shift identifying patients more at risk, organ dysfunction, Epic and bedside PEWS scoring, physical exam, patient history, labs, different approach for complex and risk factor patients, look for signs of infection, vital signs
	Managing Sepsis	Maintain good perfusion status, anticipatory tasks by nurses, lumbar puncture, vasoactive medications, approach based on patient history, find source of infection, maintain blood circulation, lactate, hemodynamic status, collaborate with medical team, escalate to ICU and Critical Care Response Team (CCRT), maintain breathing, identify response to treatment, iv access, bolus of fluids, chest x-rays, watch, reassess frequently and intervene when needed, blood work and cultures, antibiotics
	Experience with Sepsis	Advocating as a nurse, knowing when to get CCRT or ICU, better to intervene early even before identifying, CCRT support, patient's typical state at inpatient wards, how physicians are notified of Sepsis, always looking for Sepsis, watching vitals, challenging and complex patient populations

	Assessments and actions very specific to Sepsis	Different types of blood work and cultures, extremities, frequency of assessments, gases, high temperature and fever, history of antibiotics, hypotension, lactate, level of consciousness, nail bed, neurological changes, patient not right or off, perfusion, Sepsis has many different presentations, tachypnea & tachycardia, watch the patient
Challenges of caring for patients with Sepsis in local paediatric setting	Barriers to identifying Sepsis	Access to examine patients, anchoring bias before actual identification, challenging or complex populations, delay in bedside nurse notifying physicians, delay in labs and diagnostics, no SIRS notification, Sepsis pathway not followed, Sepsis symptoms similar to MIS-C (covid), vital signs inaccurate or not available.
	Barriers to managing Sepsis	Delay in action, delay in getting resources, everyone has varying levels of concern, hard getting access, knowledge of antibiotics made in the unit, mobilising and communicating with medical team about administration of interventions, night call staffing and support, no knowledge of patient's history before intervention, no order sets
	Most Challenging experiences with Sepsis	Challenges gathering information, discontinuing antibiotics, getting access, late identification, managing patient not recovering, mis-c vs. Sepsis,

		night call staffing and support, quick decline in vitals
Experience with CDSS and projections of the Sepsis BPA	Experience with CDSS	Brushing off or not considering CDSS, CDSS for novices or training, experience with bedside PEWS, following algorithms to treat patients, helpful for ordering medications, knowledge of Sepsis BPA in ER.
	Expectations of the Sepsis BPA	Alert all members of the medical team assigned to patient, awareness and education on use of Epic, decrease time to antibiotics or managing Sepsis, help to determine when to call CCRT, most helpful at night with less staff or resources, screening tool, simplify and standardise process, support collaboration between teams, tool will not replace clinical judgement, training or teaching tool for new clinicians. **More subthemes with subthemes:** • concerns about the tool, • documentations accompanying alert, • interaction preference, and • types of additional information with alert
	Perception of department that may benefit the	Allied ancillary services, CCRT, departments where most patients have Sepsis, departments with

	most from Sepsis BPA	trainees, inpatient team or unit with admitting privileges, the emergency.

3.6.2 Thematic Category 1: General experience and knowledge caring for patients with Sepsis

This category consists of themes describing the knowledge and experience regarding caring for patients with Sepsis shared by participants during the interview. The themes in this category include:

1. **Identifying Sepsis**

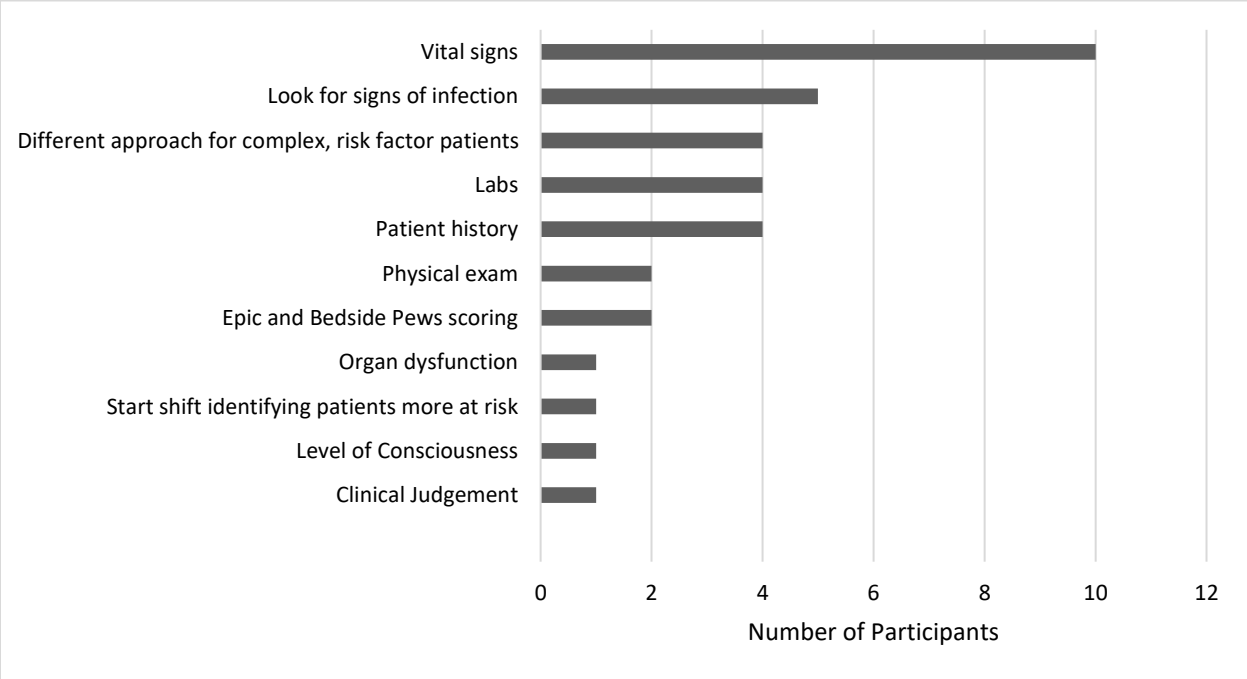

Figure 7. **Identifying Sepsis**

Participants provided a list of approaches they use to identify Sepsis in a patient. All ten participants made mention of diagnosing by checking vital signs with 5 of them clearly stating how important it is.

Participant 8 (resident): *"……then really the **vital signs** are probably one of the most important things."*

Participant 5 (physician): *"……I think the main thing is their **vital sign**."*

Participant 11 (physician): *"……So I think the clinical presentation is probably your key indicator that it's coming, and it starts with your **vitals**."*

Within these vitals are very specific signs such as tachycardia, blood pressure, hypotension, hemodynamics, temperature, fever, hypothermia, perfusion and respiratory status as mentioned by participants.

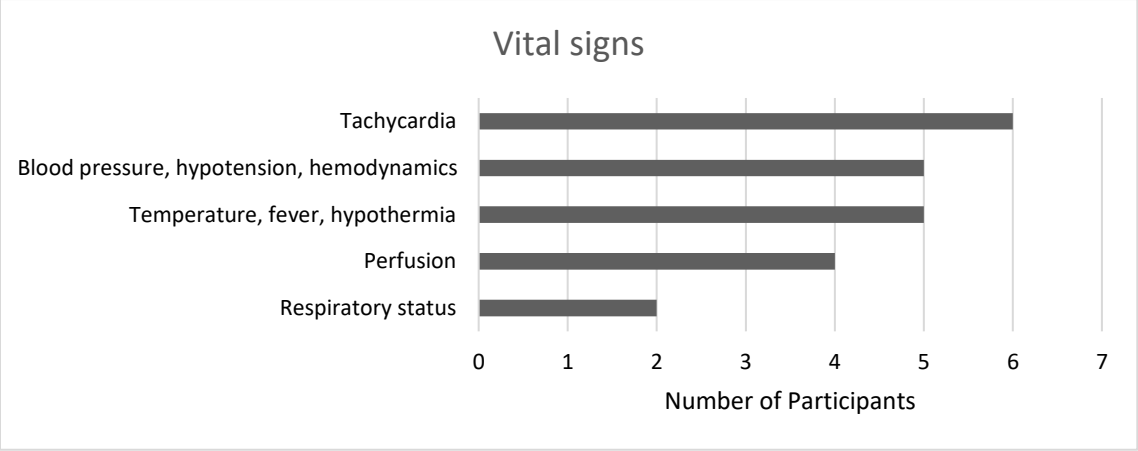

Figure 8. **Vital Signs**

Another popular approach as shared by 5 participants is the search for signs of infection in the patient. Considering sepsis represents a systemic inflammatory response to suspected or confirmed infection, it is important for clinicians to seek out a source of infection in order to effectively treat the patient. Other means of identifying Sepsis mentioned are through physical exams, checking the level of consciousness, assess organ dysfunction and patient history. Four participants mentioned labs, urine output and complete blood count (CBC).

Four participants made mention of how differently they approach complex and risk factor patients. According to participants these patient populations included newborns, patients with complex chronic illnesses sometimes with abnormal vital signs at baseline, patients with

immunocompromise or immunodeficiency, sickle cell disease, or pre-existing neurological impairments.

> Participant 10 (physician): *"……there are some kids that at baseline breathe very quickly or their heart rate is faster, right? or they're on oxygen so you have to sort of know what they are like normally to know what changes."*
>
> Participant 9 (resident): *"I think some of it depends a little bit on a patient population. I think if you had something like in NICU (Neonatal Intensive Care Unit) or like a patient population that is neonatal potentially have more subtle or nonspecific signs."*

Two participants use Epic or bedside PEWS scoring to monitor for Sepsis and 1 participant emphasised personally using a lot of clinical judgement.

2. Managing Sepsis

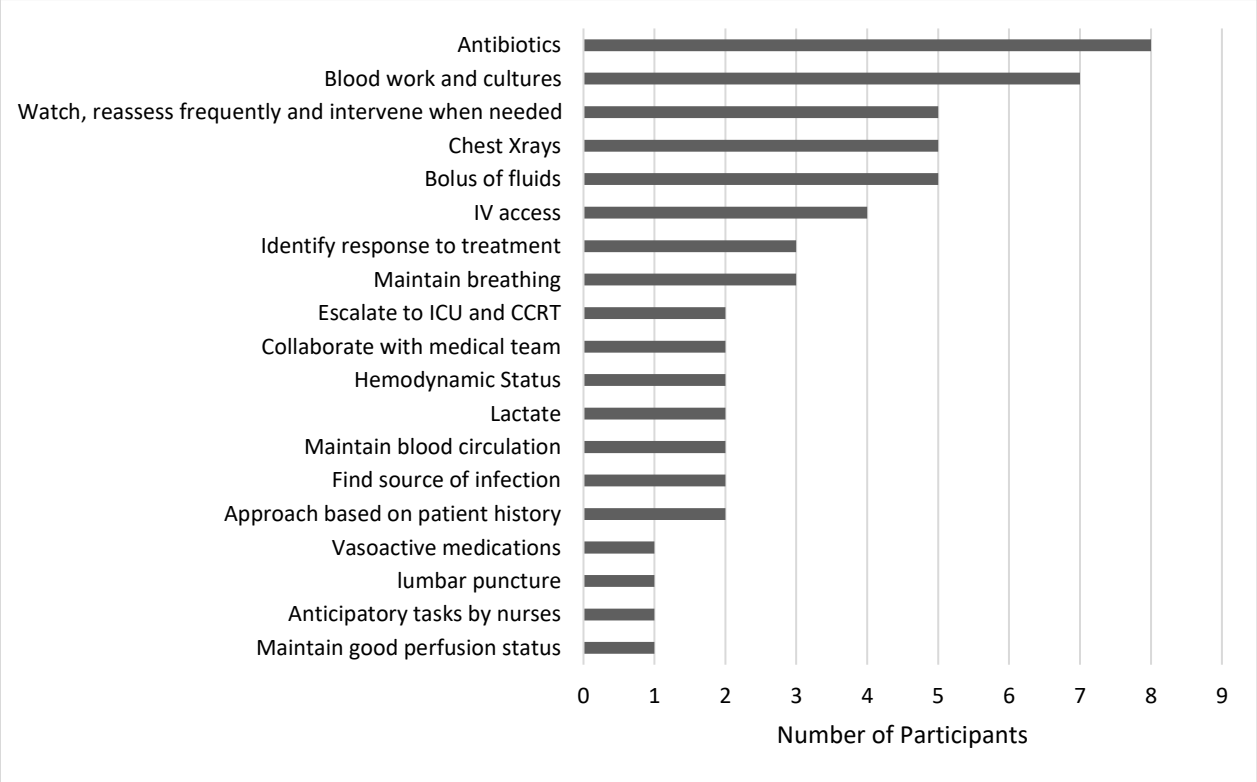

Figure 9. **Managing Sepsis**

Preparing and administering antibiotics came up top of the list in managing Sepsis as mentioned by 8 participants. According to the Center for Disease Control and Prevention (CDC), clinicians should treat Sepsis with antibiotics as soon as possible.

> Participant 12 (registered nurse): *"……We usually would draw cultures and start antibiotics regardless until those cultures are shown."*

A participant further explained how the type of antibiotics depends on the baseline health of a patient.

> Participant 7 (resident): *"……And then I would start them on antibiotic and again that the antibiotic of choice would depend on the baseline health of the patient and if they're already on antibiotics."*

Sending blood work and cultures to the labs is the second most frequent process stated. Examples of the labs mentioned are CBC, inflammatory markers, and sodium. Five participants indicated that they keep reassessing and watching patients to determine the next line of action and intervention. The key point with this is the identification of Sepsis continues with the management of it.

> Participant 10 (physician): *"……So the identification is part of the management, I think because the minute you say this is what I think then everyone else is more in tune with how sick a child might become."*

Chest x-rays and bolus of fluids were also commonly mentioned by 5 participants. Participants mentioned that chest x-rays are done to investigate if it was respiratory or if they suspect pneumonia. Fluid boluses are used for resuscitating patients with Sepsis. According to participant 7, the volume also depends on the baseline health of the patient.

> Participant 7 (resident): *"……and then fluid resuscitation so a normal Saline bolus and the volume of that bolus would depend on again the baseline health of the child."*

Other processes mentioned are maintaining good perfusion status, blood circulation and breathing, checking lactate and hemodynamic status, and a lumbar puncture when necessary.

Patients are also given vasoactive medications and approached based on history. IV access is also commonly mentioned (4 participants) although not as much as fluids, antibiotics or bloodwork were mentioned. IV access is one of the means clinicians use to either get these fluids and antibiotics into the bloodstream or obtain some blood samples.

Managing Sepsis is usually a collaboration in the medical team and the nurses tend to carry out the anticipatory tasks to prepare for the treatment of patients.

> Participant 2 (nurse practitioner): *"……usually you'd start drawing up fluid for boluses If you needed to give boluses, getting vasoactive drips ready just in case, and drawing lab panels and getting blood cultures and antibiotics ready. So anticipatory tasks."*

There is the continuous search for source of infection and identification of patient's response to treatment. Finally, managing by escalating to ICU or CCRT (Critical Care Response Team) if patients are not responding to most of the treatments was mentioned.

3. Experience with Sepsis

Participants shared the personal experiences they have had when caring for patients with Sepsis.

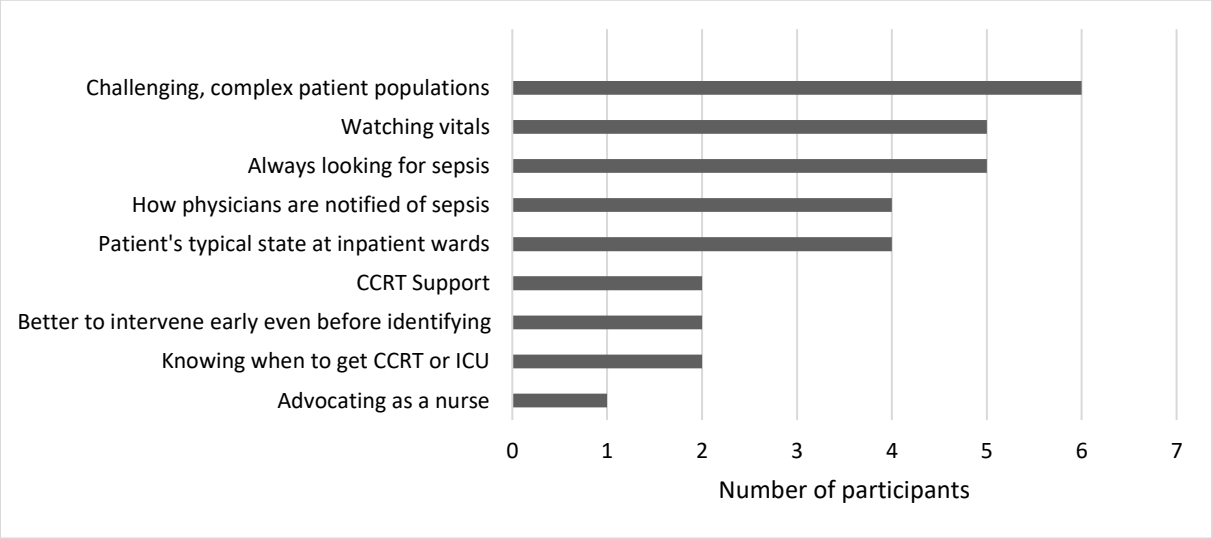

Figure 10. **Experiences with Sepsis**

The most recurring experience mentioned is the treating of complex and challenging patient populations as stated by 6 participants. Some excerpts:

> Participant 7 (resident): *"……they have an underlying immune deficiency, so I find in patients where there's other complexities, it's tough to interpret some of these vital sign changes or other things that might point us towards Sepsis."*
>
> Participant 10 (physician): *"……one of them was just a newborn who was extremely ill. Who you know, even though we identified the infection and we were treating actually deteriorated and we couldn't catch up."*
>
> Participant 8 (resident): *"……kids are febrile for a variety of reasons. For example, like when I'm covering oncology, there are kids with possible neutropenic Sepsis quite commonly, and fevers are really quite routine. And there was this child who was already on antibiotics but was hypotensive and febrile but not tachycardic, so kind of met some other criteria for Sepsis but not all. And it's just deciding what to do in those situations."*

Watching vitals and always looking for Sepsis are the next most mentioned experiences with Sepsis by 5 participants. These 5 participants commonly mentioned how they consistently check the vitals of patients and how they are generally always on the lookout for Sepsis in any patient admitted into the inpatient wards. One important point mentioned mostly by physicians (4 out of 6 physicians plus a physician assistant), is the practice of being notified of suspected Sepsis in a patient by a bedside nurse who calls or pages them.

Participants talked about the patients' typical state at inpatient wards. According to them, patients who are presented to the hospital with Sepsis are often already identified in the emergency department and admitted for continuing management or those imminently in shock are already in the ICU. This means that patients in the wards do not usually look sick, are unpredictable and need to be constantly watched for Sepsis.

> Participant 7 (resident): *"……I find that at general paediatrics ward, by the time the kids are admitted to us, a lot of the initial Sepsis resuscitation management has been done in*

emergency already. So, when we encounter it, it's more a child that's becoming septic as opposed to coming in with Sepsis."

Two participants commented on being well supported by CCRT when escalation of nonresponsive patients is needed. Some participants also mentioned not clearly knowing when to call CCRT and sometimes having their request dismissed because they reached out too early. Two participants expressed how it is important to act early and intervene even before Sepsis is ruled out or not. Lastly, one of the nurses commented on her experience with constantly advocating to other members of the medical team the changes and differences they see in their patients and the need to act on it.

4. Assessments and actions very specific to Sepsis.

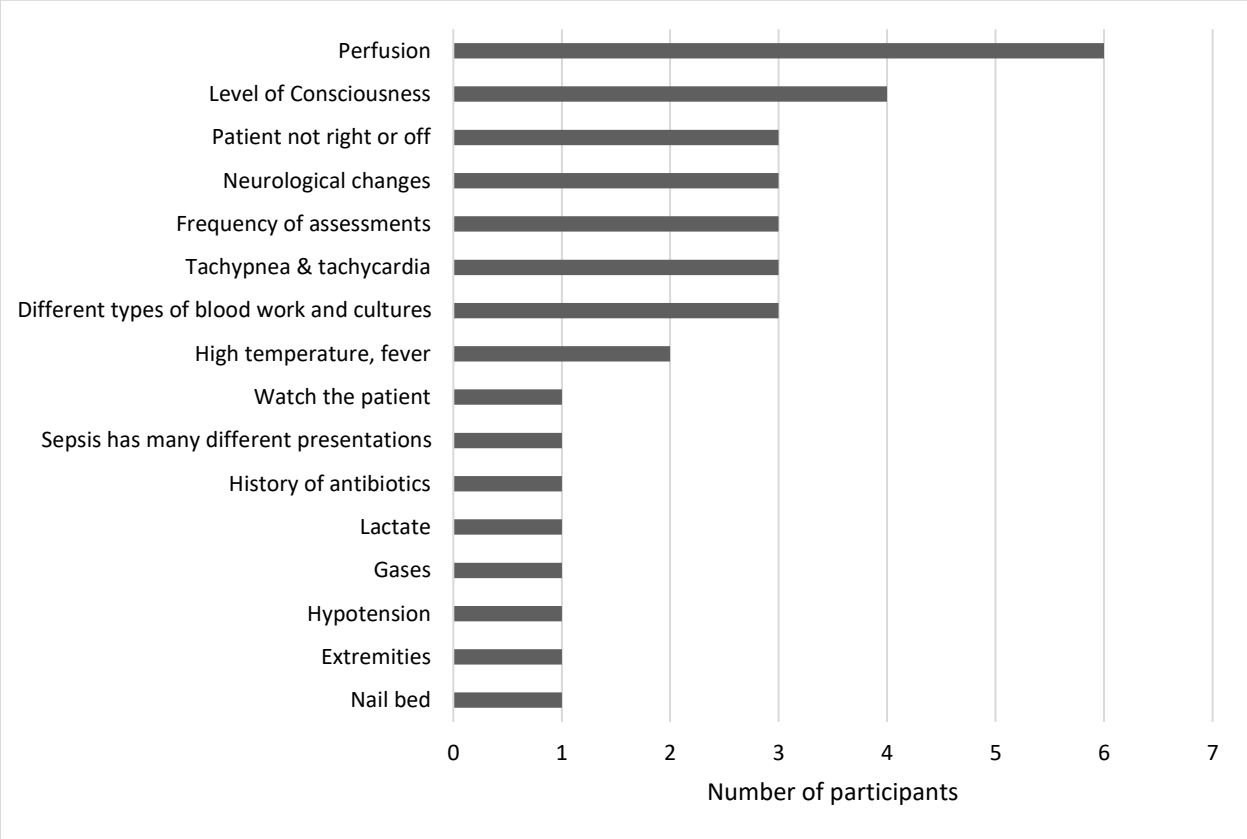

Figure 11. **Assessments and actions very specific to Sepsis**

Participants were specifically asked the symptoms or specific actions they take while suspecting Sepsis in a patient to confirm. These are actions that are not entirely rooted in the regular patient's check-up. Checking perfusion came up top among participants (6) as a go-to for confirming Sepsis. Next to perfusion is checking the level of consciousness mentioned by 4 participants. Three participants each mentioned checking for neurological changes, tachypnea, tachycardia and different types of blood work and cultures.

One of the important points made by 3 participants is the increased frequency of all these assessments when they suspect Sepsis.

> Participant 12 (registered nurse): *"……It's a bit of a knowledge thing. I think something looks off. I should do another set, so sometimes I would say maybe It's less of going with the full set to identify and more like how frequent that is being done."*

Other points mentioned include checking high temperature and fever, history of antibiotics, lactates, gases, hypotension, extremities and the nail bed.

3.6.3 Thematic Category 2: Challenges of caring for patients with Sepsis in local paediatric setting

This category grouped the barriers clinicians face while identifying and managing Sepsis in the local paediatric setting and the most challenging experiences they encounter in the process.

1. Barriers to identifying Sepsis

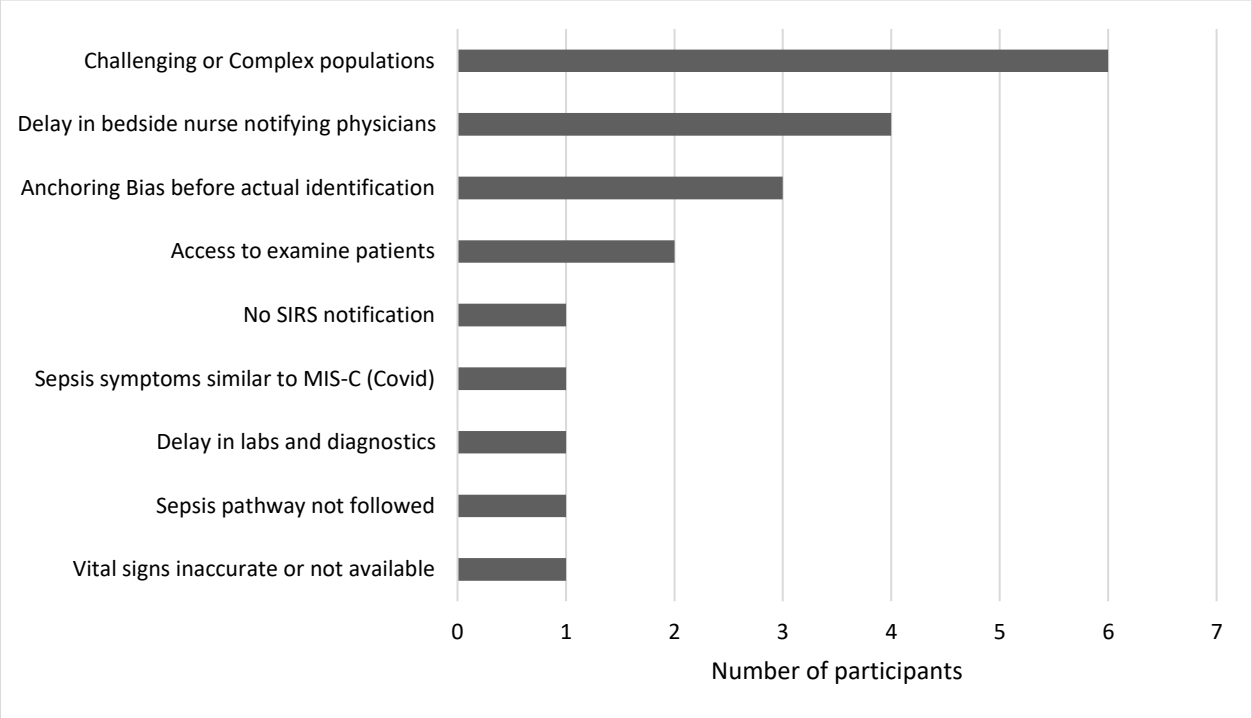

Figure 12. **Barriers to identifying Sepsis**

Six participants stated that they encounter some difficulties trying to identify Sepsis in complex patient populations. As mentioned earlier complex populations can include babies, immunocompromised or risk factor patients.

> Participant 1 (physician assistant): *"……I guess it can also be challenging in really young babies to recognize early signs of Sepsis because babies can change so quickly. I guess it's just a matter of recognizing that this baby has risk factors for Sepsis and then keeping a closer eye on the vital signs. Now, keeping a closer eye on the baby, doing*

reassessments. Babies can have multiple sources of Sepsis, so it's just important to keep your mind on all different things."

Participant 7 (resident): *"……I find it tricky in our more complicated patients, so you know patients that have lots of other reasons to be tachycardic. For example, they have pain, anxiety, other issues or a patient that has a little bit of hypotension at baseline. When they're sleeping we see a lot of complex care patients at baseline are hypothermic, so it kind of makes assessing temperature instability a bit tricky."*

Four participants stated that there can be delays in bedside nurses notifying physicians. Sometimes, it can be due to the slow paging system. One of the 4 participants also mentioned that the time lag may be due to bedside nurse's judgement.

Participant 5 (physician): *"……I think the biggest barrier is we're not always aware of the vital sign changes unless we look or unless we're alerted by the bedside nurse. So, it's dependent on whether the bedside nurse identifies it as abnormal and approaches us…… that might contribute to a bit of a time lag."*

Three participants admitted that there might be anchoring bias that comes in the way of identifying patients with Sepsis. Clinicians may hold on to an initial hypothesis based on the first piece of information or data. If a patient seems fine on initial check-up or ward rounds, or clinicians are aware of the initial diagnosis they came in with, they may not see the need to check on them as often.

Participant 10 (physician): *"……I also think that generally once kids are on the ward, we think we know what's going on with them, and so we don't necessarily think of another diagnosis. So, if they come up from emergency or from the ICU with a history of Sepsis, we know that's what they had. But if they come up with a different diagnosis and they have a clinical change, we don't always think about it and that's like an anchoring bias, right? You just sort of think you know what you have in front of you so you don't necessarily think of something else?"*

Two participants mentioned that it is sometimes difficult to examine patients when access to them is obstructed by patients themselves (if irritable), parents of the patients wanting things deferred, or ward nurses.

Other barriers mentioned by one participant each includes the absence of SIRS notification, Sepsis symptom being very similar to MIS-C for covid and how they require different forms of treatments, delay in labs and diagnostics, clinicians not following Sepsis pathway probably because a good number of them are unaware, and vital signs being unavailable or inaccurate.

2. Barriers to managing Sepsis

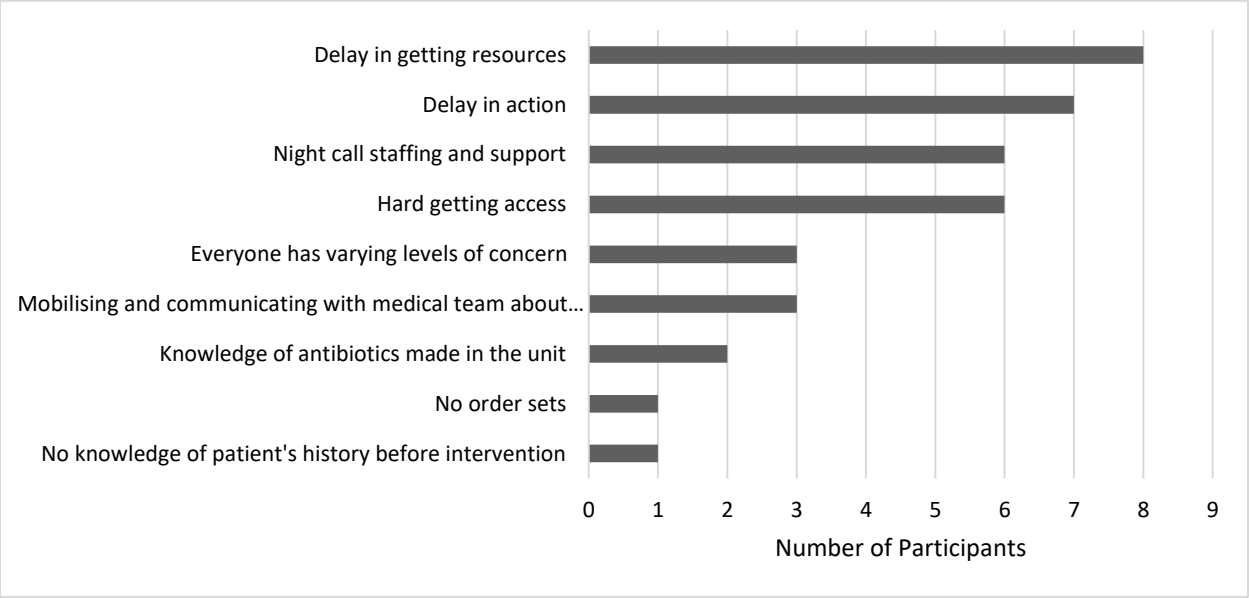

Figure 13. **Barriers to managing Sepsis**

Topping the list of barriers to managing Sepsis is the delay in getting resources as stated by 8 participants. Resources here include members of the medical team, antibiotics, getting IV access, blood work and cultures.

> Participant 1 (physician assistant): *"……Maybe just the time it takes to get everything coordinated. Like, we need IV, phlebotomy, antibiotics to come to the floor. So maybe just delay in getting resources potentially is probably the only barrier, I can really think of."*

Participant 3 (registered nurse): *"…….sometimes it's just a matter of being able to get a hold of the medical team, or whoever is looking after the patient, if it's the nurse practitioner or physician's assistant……"*

Following in the list of barriers is the delay in action by clinicians or ancillary services which was mentioned by 7 participants. Some are due to short staffing at night shifts.

Participant 2 (nurse practitioner): *"…….trying to get labs done in a timely manner. Phlebotomy typically has to come through the unit to draw labs, and sometimes there's a delay while you're waiting for that to happen. So, it's usually just the delay in trying to get the diagnostics done before you can get that first dose of antibiotics in the patient. That is the biggest delay I find."*

Six patients stated that there are usually issues with the night call staffing and support with regards to managing Sepsis because they are mostly short-staffed.

Participant 7 (resident): *"……I would say if it's overnight or after hours. Sometimes, there's delays in getting things done really quickly and it's just hard when you're short-staffed and to be the person to call down and say I want this stat and that sort of thing."*

Participant 3 (registered nurse): *"……especially on night shifts, the doctors look after many different people and they are down in emergency, everybody takes break, sometimes you're paging them. If you can't get a hold of them there's kind of a delay of care."*

Some patients are hard to access as stated by 6 participants. The kids' veins are not the same as adults'.

Participant 12 (registered nurse): *"……I think one of our biggest challenges in paediatrics is getting access for IV, antibiotics, fluids or any of those things because kids' veins aren't the same as adults and a lot of our kids have been in and out quite a bit, have shoddy veins and so are really hard to get access,"*

Participant 3 (registered nurse): *"……Now there would be like access, if they have an IV or a central line, or if they don't. If they're really hard access or you lose the IV, that can really cause a lot of problems,"*

Three participants stated that members of the medical team can have varying levels of concern and that can be interpreted into differences in how to proceed with care. This can be tied to the fact that some of them are unaware of the standard Sepsis pathway or do not follow it.

Participant 11 (physician): "……*And then I think you also have to be prescriptive in how quickly you want your fluid bolus to be administered, because not everybody will necessarily have the same urgency as you."*

Participant 9 (resident): *"……Other people's experience with things, sometimes people's level of concern for things, can be different……"*

The challenge of mobilising and communicating with the medical team about interventions can also be tied to the delay in action and the varying levels of concern in the team. Two participants mentioned that the knowledge of antibiotics that can be made in the unit's omnicell is not available to everyone in the team and can result in avoidable delays. Little or no knowledge of patient's history can be a barrier to managing. Lastly, a participant said that the absence of an order set constitutes a barrier.

3. Most challenging experiences with Sepsis

In this theme, participants shared with us some of the most challenging stories and experiences they encountered while caring for a patient with Sepsis. Some participants had similar experiences as seen in the chart below:

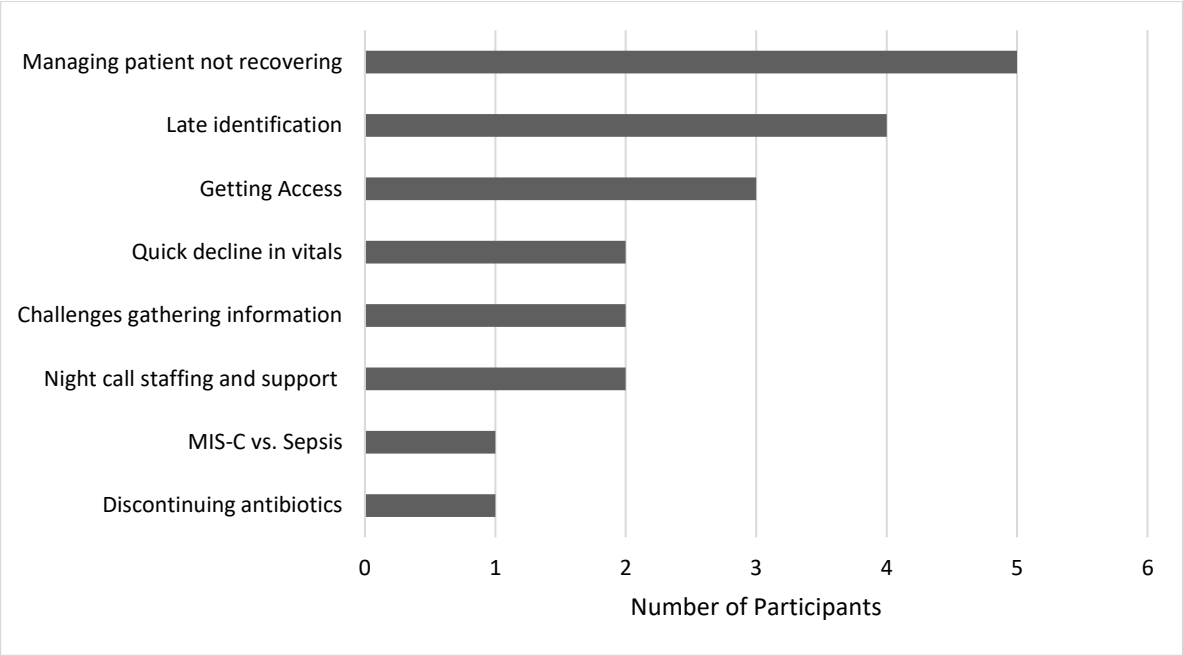

Figure 14. **Most challenging experiences with Sepsis**

Top on the list of these challenging experiences is managing patients that are not responding to treatment.

> Participant 9 (resident): *"……The most challenging time I can really think of would be a time that a patient's blood pressure was dropping and we're trying to get fluid boluses and like they lost their IVs. So, there's your scrambling to get IV access to then continue to provide the care……. …then there's also respiratory involvement, so they're on oxygen and you're kind of trying to see if you can still manage them on the floor or if they need to go to ICU."*
>
> Participant 5 (physician): *"……I do remember once where the children got unwell quite quickly or like they became hemodynamically unstable and this was especially in*

immuno-compromised children, but luckily we had the critical care team and the ICU support, so we were able to manage the patient with their help."

Four participants had challenging experiences relating to the late identification of Sepsis in the patient.

> Participant 3 (registered nurse): *"……so sometimes you are notified of the patients probably likely to be septic and they start showing vital sign changes and you're able to intervene quite early. But then other times, you're kind of getting them in late Sepsis, it can be chaotic and similar to a code,"*

Three participants had challenging experiences with getting access to patients. Two participants mentioned challenges with gathering information, quick decline in vitals and night call staffing and support. Some of the quotes have been provided in the previous sections about the barriers.

Challenging experiences based on the similarity in symptoms between MIS-C (in COVID patients) and Sepsis plus decision making around discontinuing antibiotics were each mentioned by 1 participant.

> Participant 9 (resident): *"……I think an issue a bit more challenging and interesting these days with MIS-C is that often we have children coming in where they look unwell and recovering from Sepsis. But we're actually not sure if it's MIS-C or if it could be a presentation of Sepsis when they first come in. it's quite different in terms of technically the management we're giving for the two. The biggest difference being that if someone does have MIS-C and they are looking quite unwell, the likelihood is that they probably actually had a myocardial dysfunction in which case giving fluids can make them worse and send them over the edge and be detrimental. Whereas in Sepsis we would think about fluid resuscitation as kind of our initial go-to.*

> Participant 11 (physician): *"……the duration or the decisions around discontinuing antibiotics that have been commenced for possible Sepsis is one that gets some conversation."*

3.6.4 Thematic Category 3: Experience with CDSS and projections of the Sepsis BPA

This category groups the experiences of clinicians with CDSS and their expectations of the Sepsis tool.

1. Experience with CDSS

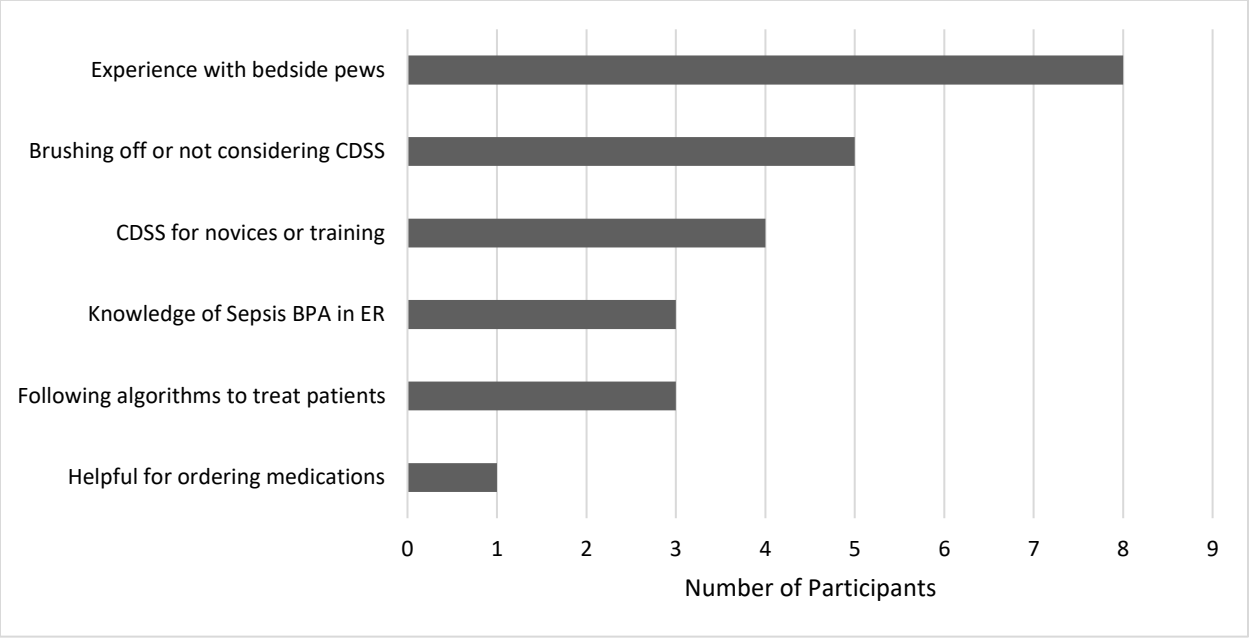

Figure 15. **Experience with CDSS**

Participants were asked about their experiences using clinical decision support systems in their local paediatric setting. Eight participants shared their experiences using bedside PEWS. The bedside PEWS tool is a scoring system to communicate the state of deterioration of patients. It is already implemented in Epic and the most common decision support tool that the clinicians are exposed to in the organisation. A further breakdown of their experiences with the bedside PEWS can be seen in the chart below:

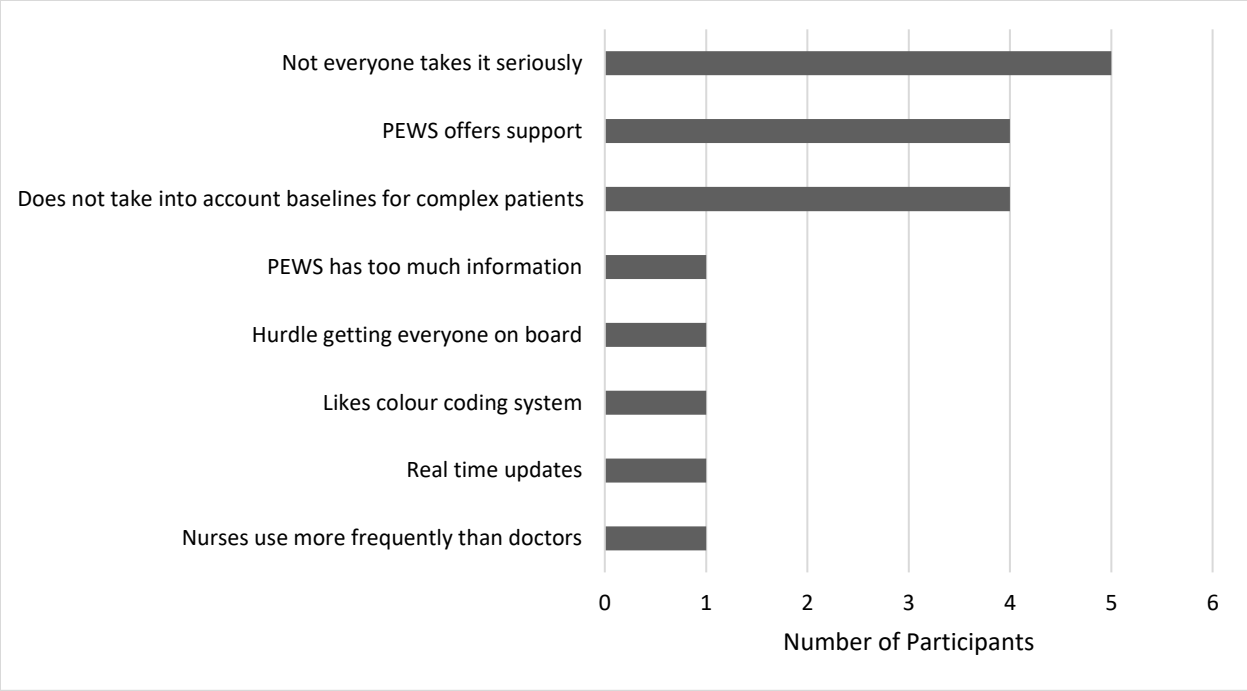

Figure 16. **Experience with bedside PEWS**

Four participants acknowledged that the PEWS offer support. Some participants mentioned prioritising checking up or watching patients with high bedside PEWS after handover or during ward rounds. Some participants liked the colour coding system and the provision of real-time updates to everyone. Others explained how it is a good way of flagging patients and probably a safety net. While providing responses regarding the supports that PEWS offer, participants showed little confidence in it as seen below:

> Participant 3 (registered nurse): *"……I guess it depends who you speak with, but it feels like it has a little bit of less of a strength behind it and that people just kind of brush off their PEWS. They're like Oh, whatever. They don't take that into consideration as much. But I think it's definitely still helpful…"*
>
> Participant 12 (registered nurse): *"……I guess for previously healthy kids, it's like a reminder. It's like a bit of a safety net."*
>
> Participant 7 (resident): *"……The numbers like a bit of a flag for me, but to be honest the number will never change whether or not I do something, it's just support."*

However, Five participants mentioned that the clinicians do not take the bedside PEWS seriously.

> Participant 11 (physician): *"……I think that I've never been told what a PEWS score is for a patient in Sick Kids, and I've been here 2 1/2 years, …….I get told the vitals."*
>
> Participant 2 (nurse practitioner): *"……It's not something I automatically look at. It's not my first thing to look at when I'm looking at a patient. I tend to use that information and tuck it away in the back of my head. What is more important to me is actually seeing the patient and putting the information together."*

Four participants mentioned that the tools do not consider baselines for complex patients. There are some patients who are already scoring high PEWS even on their best days such that they are constantly flagged. One participant noted that the PEWS are too wordy with too much information. A participant said that the nurses use the bedside PEWS more than the physicians.

Generally, participants also mentioned using algorithms to treats patients and for ordering medications. About 5 participants mentioned brushing off or not considering clinical decision support systems. Four of the participants believed that decision support systems are useful for novices and training.

Lastly, three of the participants were fully aware of an existing Sepsis BPA in the emergency department and how it works.

2. Expectations of the Sepsis BPA

This theme encompasses the preferences of the clinicians with regards to the Sepsis tool to be implemented. Participants shared their needs for interactions which include alert design, information and documents accompanying alert, and their general concerns about the fit of the tool in their workflow. Before exploring those needs, we also got some functional requirements of the tool from the participants.

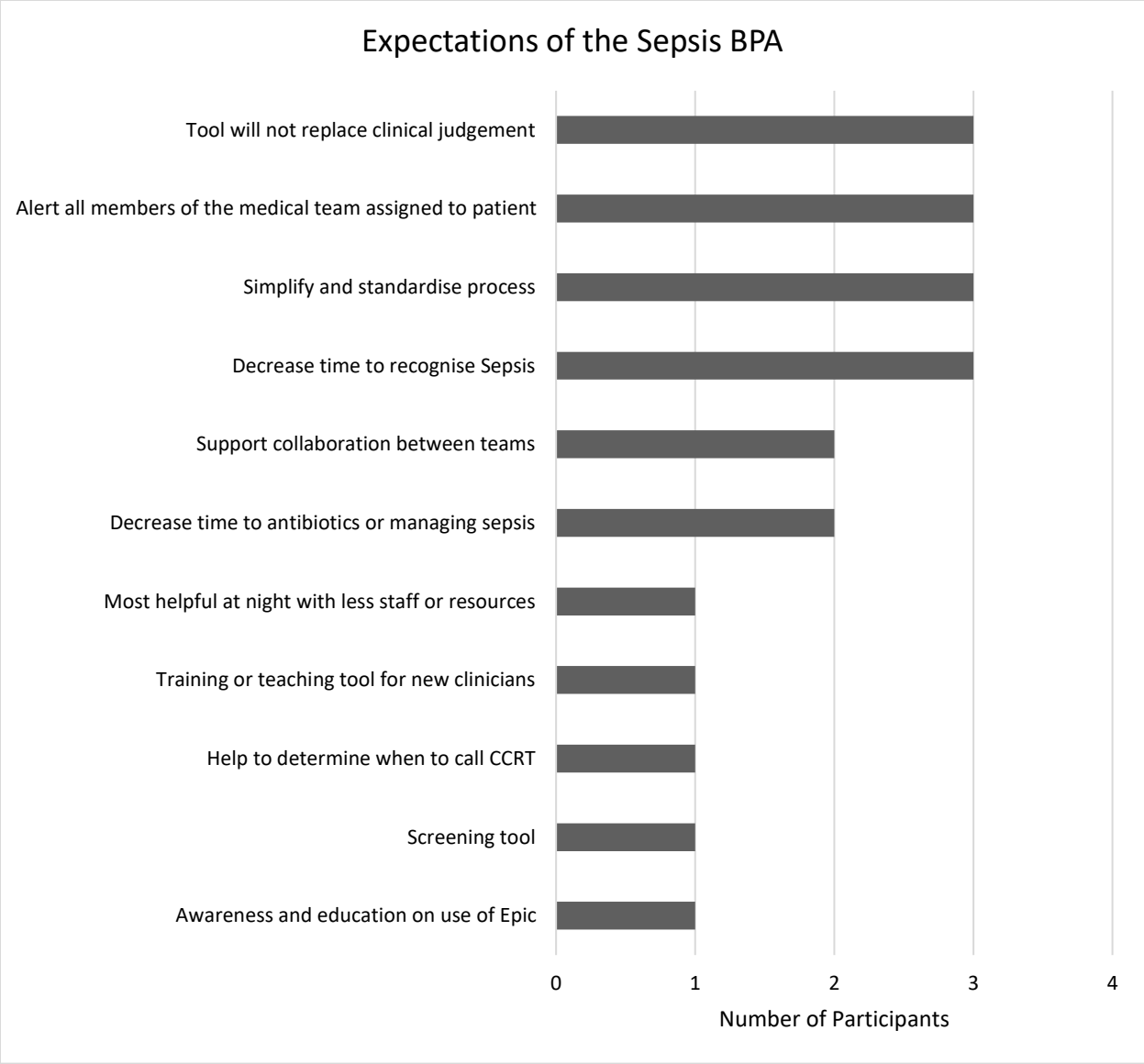

***Figure 17*. Expectations of the Sepsis BPA**

Some of the expected functions of the tool mentioned by participants from lowest to highest as seen in the chart are:

1. Creating awareness and educating clinicians on possible uses of Epic.
2. Functioning as a screening tool for Sepsis.
3. Help to determine when to call for CCRT intervention.
4. Function as a training or teaching tool for new clinicians.

5. Can be most helpful at night with less staff or resources.
6. Decrease time to antibiotics or managing Sepsis.
7. Support collaboration between medical teams.
8. Decrease time to recognise Sepsis.
9. Simplify and standardise the process of Sepsis care.
10. Alert all members of the medical team assigned to the patient.
11. Tool should function as decision support and not replace clinical judgement.

Whether the Sepsis tool meets all these expectations and how it does can be investigated in a pilot study after implementation.

I. Interaction preferences

This subtheme includes all types of interactions that participants expect or prefer on the tool. Within this subtheme is another subtheme that itemises the participant's choices for the design of the alert. First, let us explore the general interaction preferences mentioned.

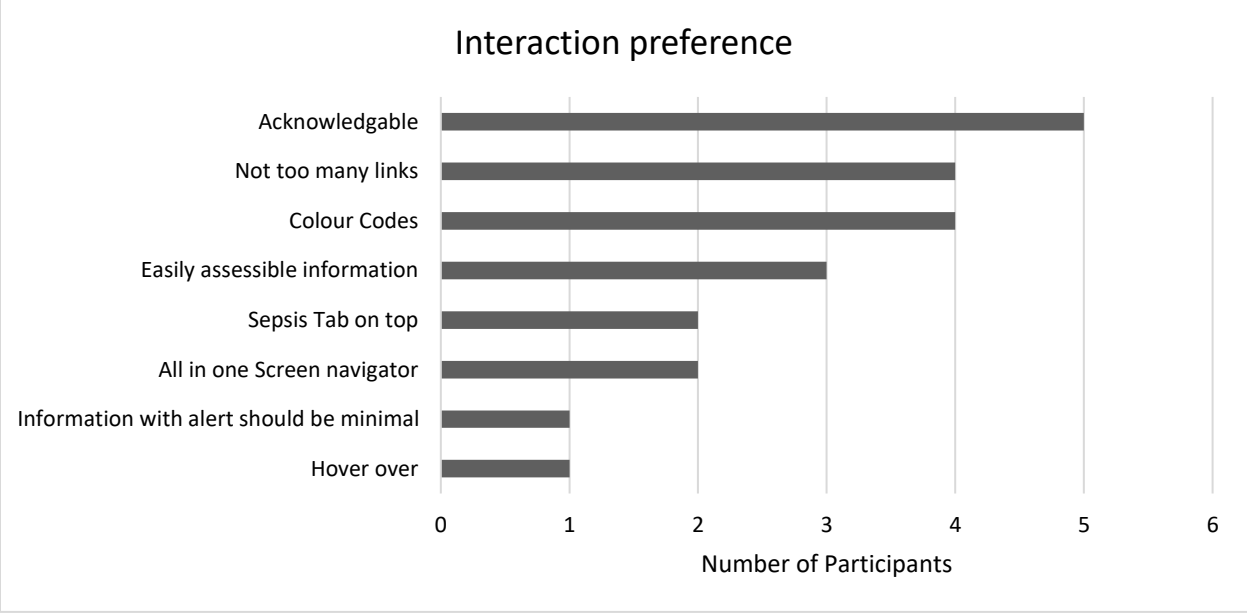

Figure 18. **Interaction preference**

Topping the chart is the desire by participants to have an acknowledgeable alert. They want to be able to interact with the alert in such a way that the system is aware they have accepted or

chosen to investigate the alert. A participant particularly mentioned the need for active interaction with the alert stating the next steps to the tool.

> Participant 5 (physician): *"..... I think as long as it comes up and gives me the opportunity to see why and to put in what action I'm going to follow and with that it's it silences, especially based on what I say."*

> Participant 12 (registered nurse): *".....I want it up in my face. Personally, I want it to be something that I have to click away from."*

Four participants said they would love the idea of colour codes to show severity or guide them through navigating the tool.

> Participant 1 (physician assistant): *".....if there could be something that alerts you that click on your inpatient list, because there's going to be Sepsis alert and that particular color is like associated with Sepsis..."*

> Participant 2 (nurse practitioner): *".....I like the colour-coding system in that if I'm looking at my patient list for the day and I see that I have patients that have yellow and red, those are the ones that I know have increased intensity associated with their care and to keep a close eye on them."*

Four participants outrightly stated that there should not be too many links while navigating the tool. This buttresses the point made by 2 participants who said an all-in-one screen navigator making the needed information easily accessible is best to prevent clicking from screen to screen to get any work done on the tool.

> Participant 7 (resident): *".....I mean, there could be an attachment of links to a few papers for where some of the evidence for this came from. But if I am totally Frank, I'm not about to click those links at 3:00 AM."*

> Participant 12 (registered nurse): *".....I personally find that I do better if it's all in one area than if I'm clicking through. The more you can put things in a spot, the more likely people are going to use..... I think it depends how easy it is to access. With other tools*

that we've had, when there's a lot of clicking people just find it's easier to go on their normal spreadsheets."

Two participants said they would want a Sepsis tab included in their Epic display right at the top of the screen.

Participant 12 (registered nurse): *".....I guess I would think would be if you're able to flag Sepsis and click on it and it's automatic that everybody has the Sepsis tab on top."*

A participant stated that information with the alert should be as minimal as possible which confirms one of the issues that they had with the bedside PEWS being too wordy and easily dismissible.

The chart below shows participants' preferences for alert design:

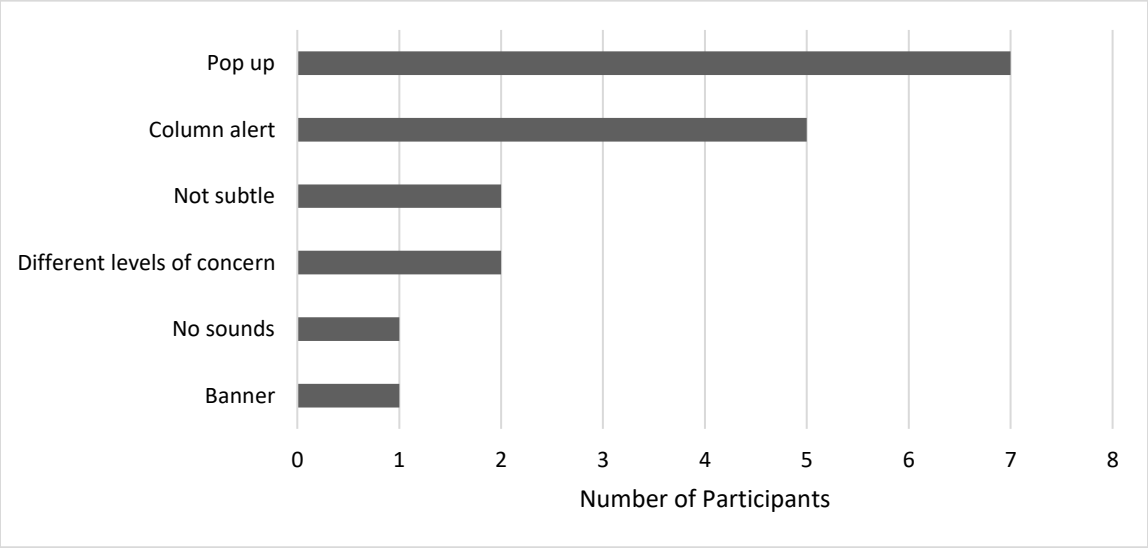

Figure 19. **Alert design preference**

Seven participants preferred a pop-up alert. Some requested that the alert needs to be in their face without necessarily looking for it.

Participant 10 (physician): *".....an alert that you have to acknowledge for at least the people that need to acknowledge it, so it has to pop up."*

Participant 2 (nurse practitioner): *"…..I like the idea of a pop-up. I'm very visual. I would hope that anytime that I was working in EPIC it would pop up."*

Participant 7 (resident): *"…..I want to say like when you click a patient's chart that there's an alert that pops up."*

Participant 8 (resident): *"…..I mean, if there was a patient who there was concerns of Sepsis, I'd probably want a pop-up."*

Next on the list of preferences for the alert type is a column alert in the patient's list on Epic. This idea stems from their experiences with bedside PEWS.

Participant 1 (physician assistant): *"……If it could be like when you click on your patients list beside their name is the score of their bedside pills, maybe like a column that would allow for like a Sepsis alert."*

Participant 8 (resident): *"……I wonder if on a patients list, one of the columns, you know we have the PEWS column, so as part of the PEWS column or a separate column, it could have like a Sepsis sign."*

Two participants mentioned that these alerts should not be subtle but in their faces. One participant made mention of a banner alert type at the top of the Epic screen for the Sepsis tool. Another participant clearly stated that no sound is needed for the alert.

Two participants also mentioned that the alerts could come up with different levels of concern.

Participant 8 (resident): *"……I don't know if it's going to be like different tiers in terms of how Epic is going to triage the level of concern based on the data it gathered for Sepsis and if it's a super high critical level of concern based on the information that is correlating then to pop up a more critical alert versus if it's just a lower level of concern but a possibility. So flag it in a less invasive way than like a massive pop up on the chart."*

II. Documentations accompanying alerts.

Participants shared with us the types of documents they would like to see in the navigator for the Sepsis tool.

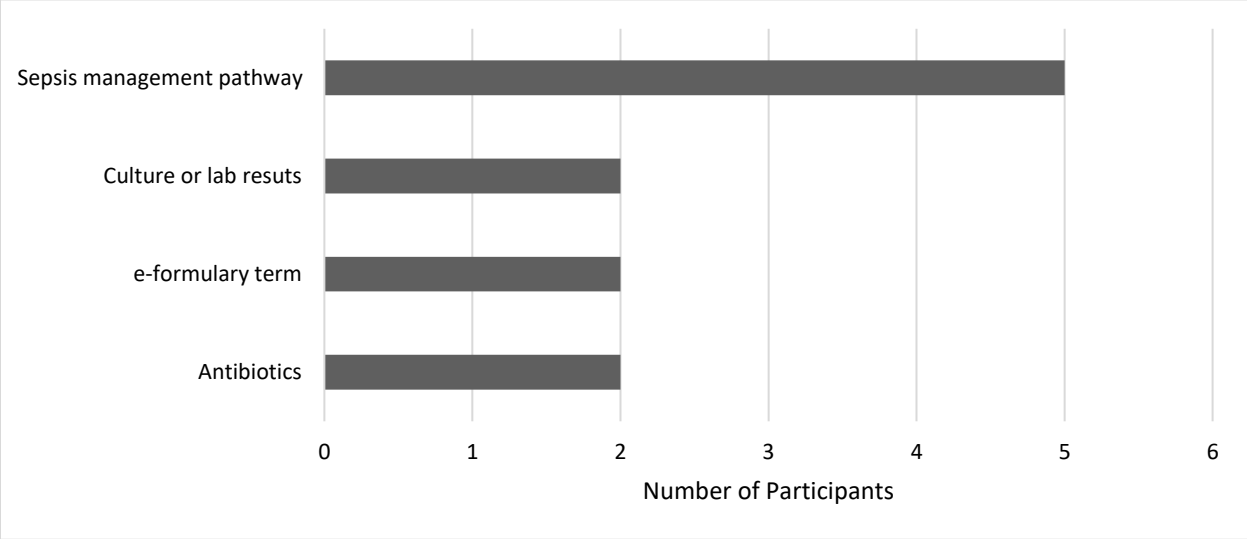

Figure 20. **Documentations accompanying alerts**

Topping this list is the need to see the Sepsis management pathway as stated by 5 participants. This need may be based on one of the barriers in Sepsis care mentioned earlier where clinicians do not seem to be aware of the Sepsis management pathway in the system. Cultures or lab results are also documentations that 2 of the participants mentioned wanting access to. Two of the participants mentioned the need for e-formulary documents and for antibiotics types.

III. Types of additional Information with alert

This includes the information that they would love to see with the alert as well as in the navigator of the tool.

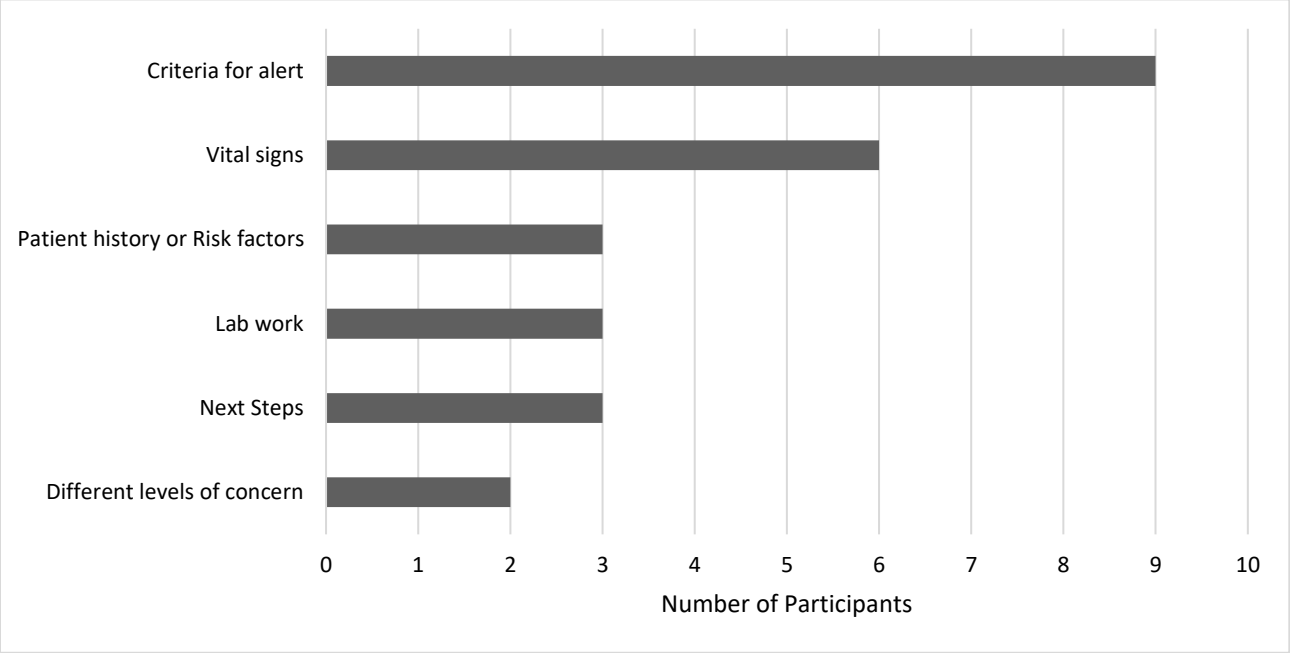

Figure 21. **Additional Information with alert**

Topping this list is the criteria for the alert with 9 participants clearly stating this need.

> Participant 7 (resident): *"……I just want to know what the criteria for the alert is. I think that's how they do it in emergency as well. I want to know if it is just heart rate alone? Is it fever above a certain number plus a high heart rate? Is it a little blood pressure...?"*
>
> Participant 8 (resident): *"……Yeah, I want to know the reasons why they need this Sepsis alert. It could say meets criteria based on heart rate, blood pressure, fever, abnormal lactate. So, I know what they're basing their decision on.*

Six participants mentioned the need to also see the vital signs of the patient.

> Participant 2 (nurse practitioner): *"……vital signs? I want to see a quick summary of the vital signs including temperature, heart rate, blood pressure, saturations."*

Participant 9 (resident): *"……I want to know the blood pressure in the like the most recent vital signs I think would be really helpful, particularly blood pressure and heart rate."*

Three participants each mentioned the need to see the patient's history or risk factors, lab work, and next steps for treating the patient. Lastly, two participants mentioned the need to see the different levels of concerns explained.

IV. Concerns about the tool

Participants were also able to voice a few concerns that they had regarding the incoming Sepsis tool.

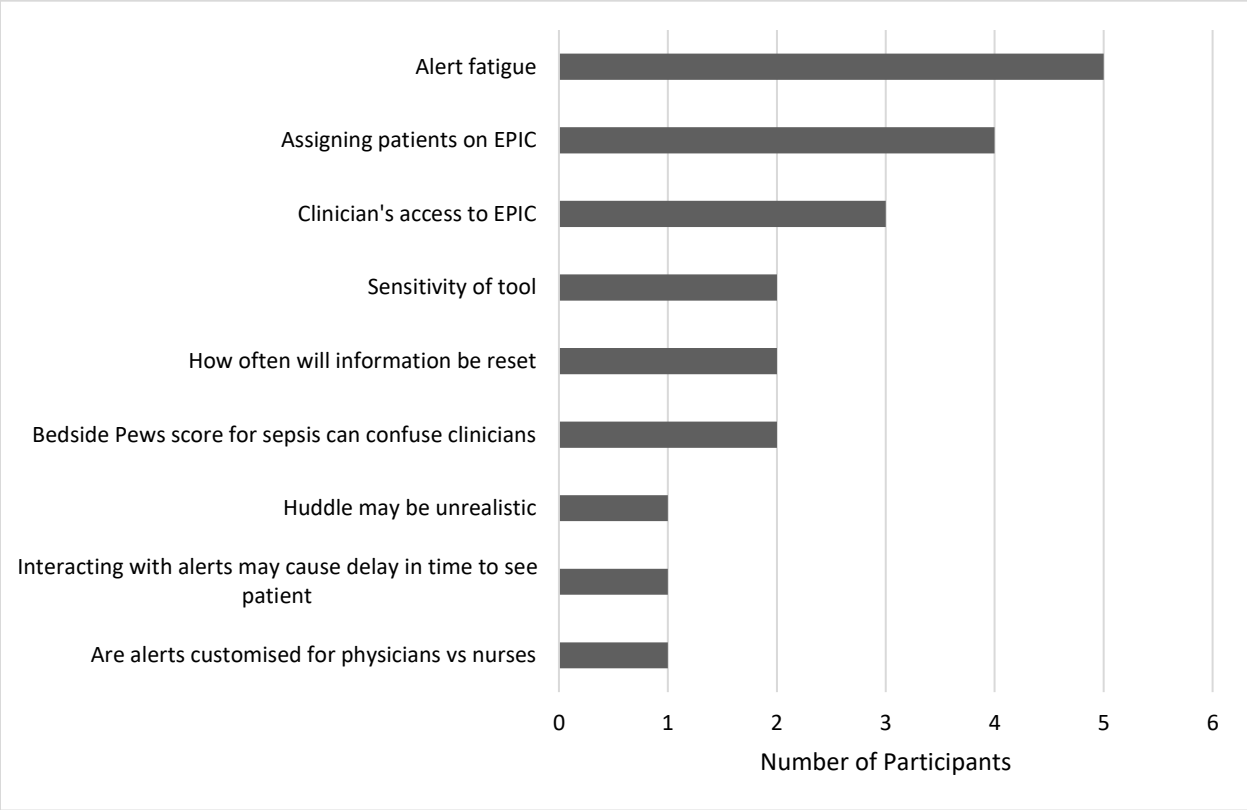

Figure 22. **Concerns about the tool**

Alert fatigue was the biggest concern the clinicians had regarding the tool.

> Participant 10 (physician): *"……But once you acknowledge it, It needs to sleep for a while, whether we can decide how long but the last thing you want is that every time you log on, it pops up because the alert fatigue is definitely something that I worry about."*

> Participant 11 (physician): *"……I just worry sometimes that we get so many alerts and there's so much information coming in that we dismiss."*

> Participant 9 (resident): *"……let's say you're getting this alert because the patient has a fever and they're tachycardic, you get a Sepsis alert and you reconcile the alert. If they are still febrile or tachycardic an hour later, is it going to re alert or not? that has to be thought about because if it's going to re alert, people might get annoyed having to reconcile the alert every two minutes if nothing is changed with the kid at the same point in time."*

Four participants expressed their concerns regarding how patients are assigned in Epic. How would Epic know which physician is working with any patient? Bedside nurses usually assign themselves to their patients, but some physicians could have to oversee as many as 40 patients.

> Participant 11 (physician): *"……we don't assign trainees we assign MRPS. The nurses add patients to their list."*

> Participant 8 (resident): *"……I just don't know how you can have an alert that pops up for you specifically. It's because I don't know how Epic would know if you're actually looking after the patient or not."*

Three participants talked about how physicians do not have the same level of access to Epic as the nurses, especially the bedside nurses.

> Participant 11 (physician): *"……I don't have Epic. I've never had Epic until now on my phone. And I don't think most people do."*

Participant 12 (registered nurse): *"…….if there's a way to like flag for the physicians the same way that it's in their face. They're not always on the computer……"*

Two participants each talked about the sensitivity of the tool and how the information should be reset to prevent alert fatigue. Some of the quotes have been mentioned above while explaining alert fatigue.

Two participants explained that some of the clinicians also take cues regarding Sepsis from the bedside PEWS score and may begin to confuse the scores with the Sepsis tool.

Participant 1 (physician assistant): *"…….but then that might get kind of muddy because the bedside PEWS also kind of show early signs, like your heart rates climbing so your scoring is increasing."*

Participant 11 (physician): *"…….And used it recently in somebody who I was concerned with Sepsis. The PEWS is one of the things that we are watching,"*

A participant expressed concern regarding the huddle for the Sepsis tool being unrealistic especially in the night shift where there is less manpower. The participant also mentioned how time to interact with the tool may cause a delay in time to see a patient.

Lastly, another participant mentioned that there might be a need to design the alerts differently for nurses versus the physicians.

3. Perception of department that may benefit the most from Sepsis BPA

The researcher particularly asked this question to get the participant's perceived importance of the tool to their work setting. Considering that participants interviewed work in the general paediatrics inpatient setting, these are the results of their responses in the chart below:

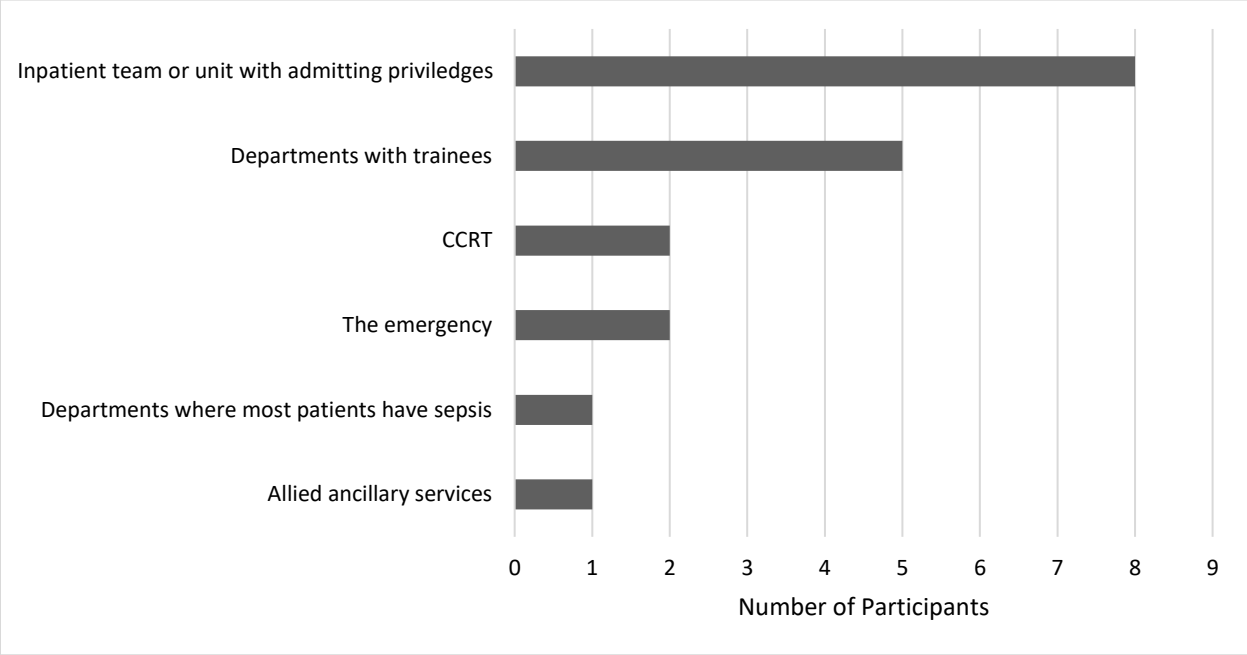

Figure 23. **Perception of department that may benefit the most from Sepsis BPA**

The emergency may have scored low because some of the participants are aware that they have a Sepsis tool of their own.

The inpatient teams or units with admitting privileges were broken down to include the sections the participants mentioned. The general paediatrics and surgical team were equally stated to need the Sepsis tool the most.

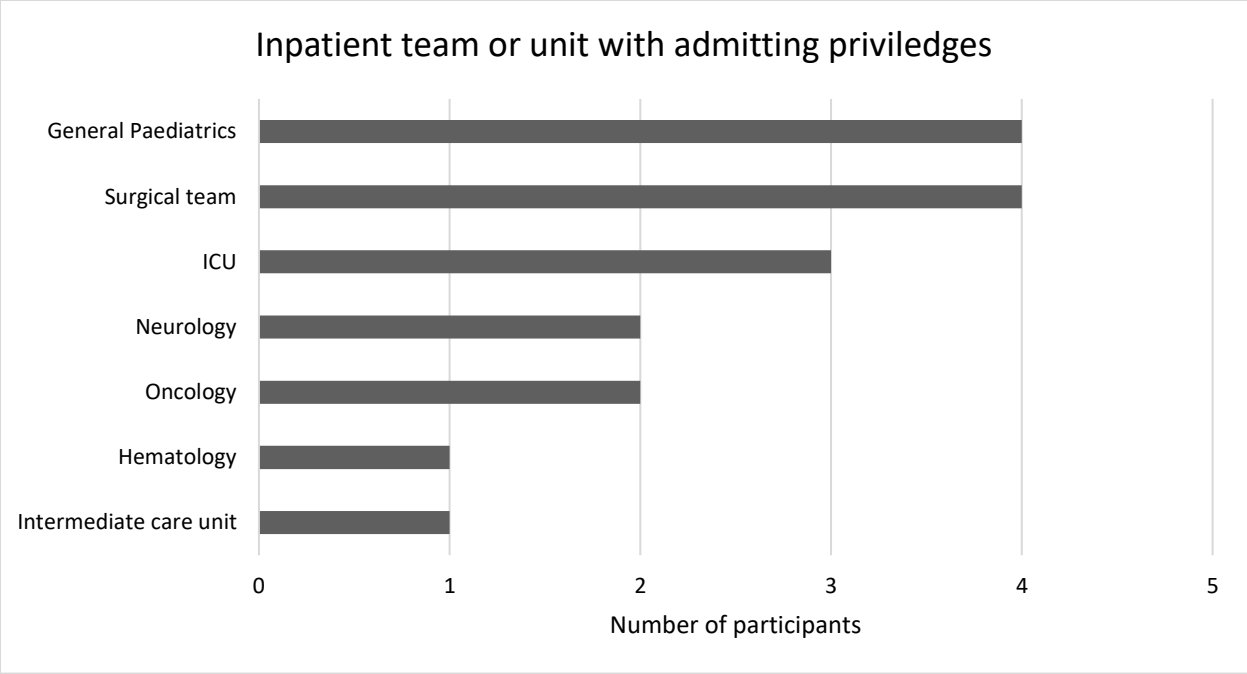

Figure 24. **Perception of department that may benefit the most from Sepsis BPA: inpatient teams or units with admitting privileges**

3.7 Discussion

3.7.1 Decision ladder for Sepsis identification and management in general paediatrics

Control Task analysis (ConTa) was conducted using the results of the interview and the Sepsis early management pathway document for the hospital. Conta is one of the steps of the Cognitive work Analysis (CWA) framework. CWA framework in general provides a systematic approach to understand the work environment, the **control tasks**, strategies taken by the workers, the social and organisation cooperation, as well as worker competencies. Decision ladders are a very good template to identify control tasks. They consist of boxes and ovals. The boxes represent information-processing activities while the ovals represent states of knowledge that are the outputs of these activities. The left side of the decision ladder represents control tasks for identifying systems state while the right side represents control tasks relating to planning and execution[49]. The decision ladder below models the current decision making process for Sepsis treatment and management at the hospital without the Sepsis tool or new huddle:

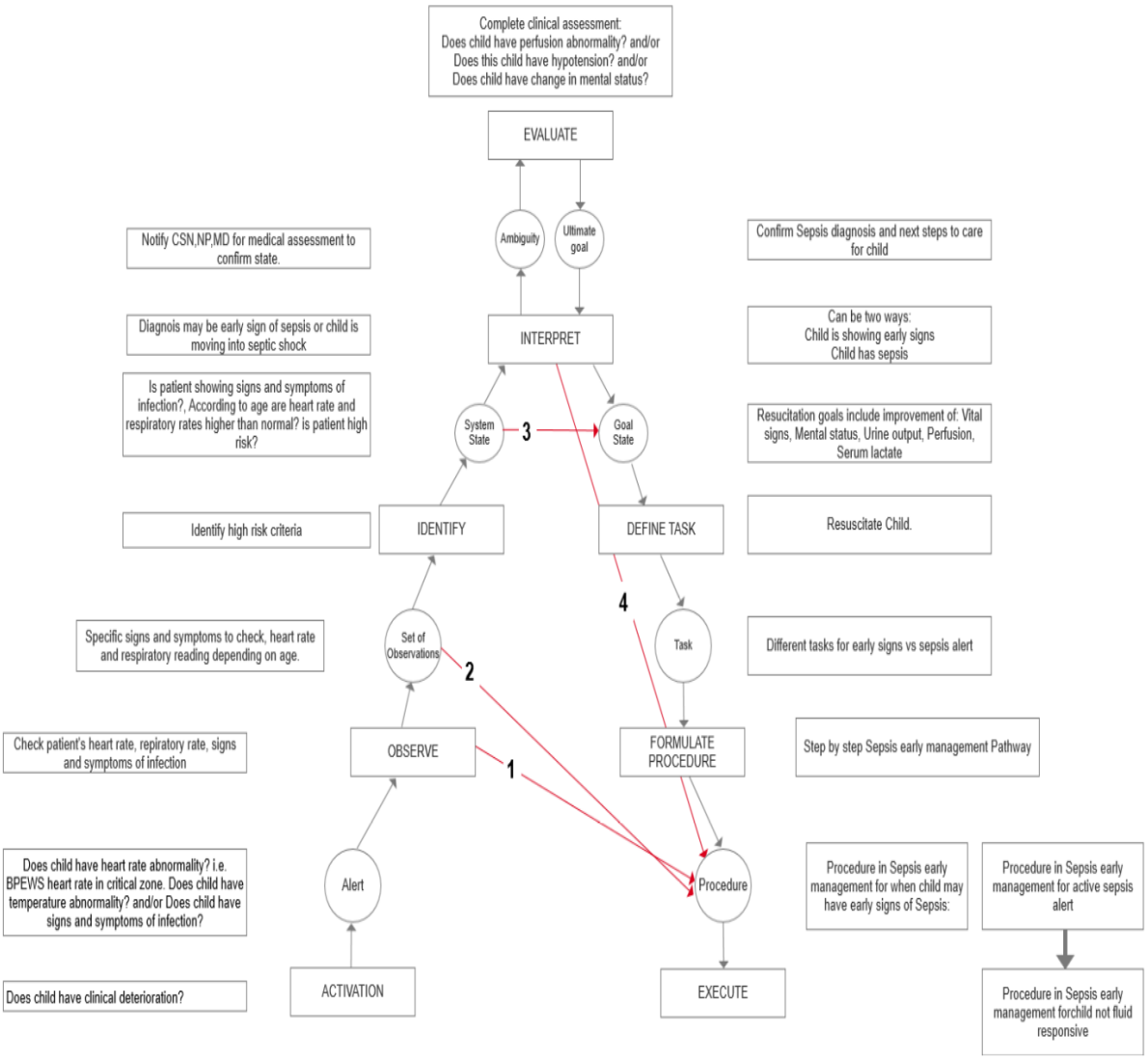

Figure 25. **Decision ladder showing current decision-making process for Sepsis treatment and management in the paediatric hospital**

Among healthcare providers, the junior medical delegates, which includes mostly nurses, are usually more engaged on the left side than the right. Senior medical delegates are more engaged on the right side than on the left. However, any member of the medical team should be able to do some of the tasks on both sides. For example, nurses carry out anticipatory tasks in preparation for the management of the patient.

The red arrows represent leaps (the connection between two knowledge states) and shunts (information processing task to knowledge state) which are included in the decision ladder to model shortcuts in participants' decision making as shared in the interviews.

1. The shunt from observe to procedure is reflected in the interview where participants stated that they start antibiotics immediately especially when patients are actively going into septic shock.

   "*Getting antibiotics in them stat ASAP because that's going to ultimately be what is going to manage the underlying infection*".

2. The leap from the knowledge state of the set of observations (signs and symptoms of infection, heart rate, and respiratory rate) to the procedure also reflects the anticipatory tasks the nurses begin and the need to get antibiotics into the patient.
3. The leap from system state to the goal state shows that the clinicians can become fully aware of the goal to resuscitate once they have the knowledge of the state of the child.
4. The clinicians also do take the shunt from interpreting the situation of the child right into the procedure for treating.

Below is another decision ladder for the purpose of comparison which shows the support that the new Sepsis BPA may provide to the clinicians:

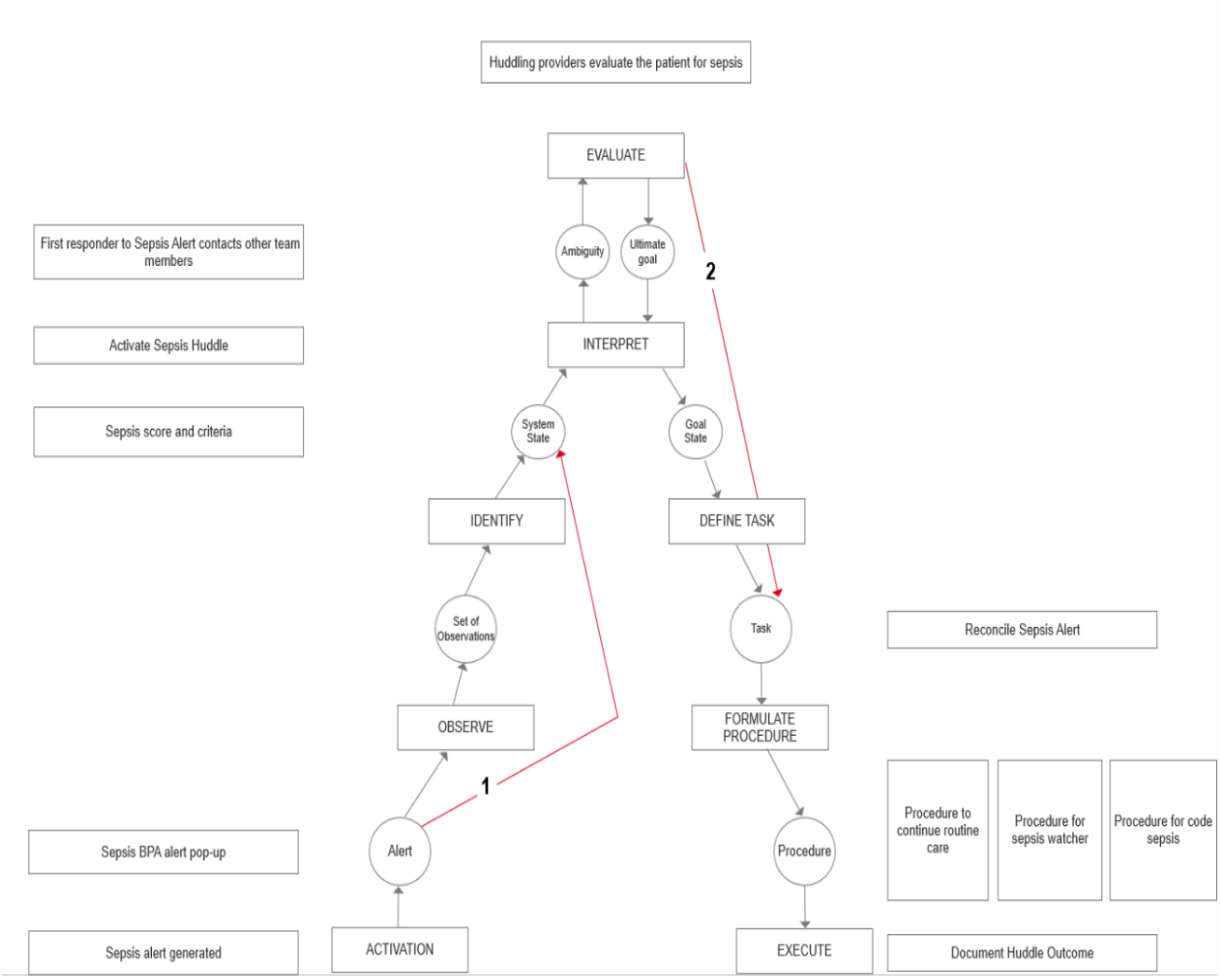

Figure 26. **Decision ladder showing new Sepsis huddle for the Sepsis BPA in the paediatric hospital**

1. The Sepsis BPA supports the leap from alert to systems state as the alerts are accompanied by the Sepsis score and criteria. Immediately clinicians see the alert they become slightly aware of the state of the patient with regards to Sepsis by looking at the criteria.
2. The tool supports a shunt from evaluate to task. After huddle providers evaluate the patient for Sepsis, the alert is reconciled, and the next procedure of care is selected.

These defined huddle stages provided by the tool can help to streamline/standardise the care of patients and to deal with different levels of concern.

3.7.2 Minimum Viable Product (MVP) of Sepsis BPA versus user requirements

From the results above, the clinicians' expectations and key findings are extracted and translated into user requirements. These requirements are checked against the developed MVP and recommendations provided for both future iterations of the product and the hospital's workflow before implementation.

Table 4. **User requirements, MVP verification and recommendations**

User Requirements	Does MVP meet requirement?	Recommendations
Checking vital signs was the highest mentioned for identifying Sepsis by participants (all 10).	A vitals section is the first encountered in the patient review block after Sepsis score and criteria. Nurses have the option to document while physicians can only view the vitals graph and report in detail.	
Antibiotics administration was the highest mentioned for managing Sepsis by participants.	Antibiotics order sets are in the Sepsis order sets section in the huddle reconciliation block.	According to about 70% of the participants, antibiotics are started as soon as possible for a child with Sepsis. Information on antibiotics and the order sets can be made a priority and first encounter in the huddle reconciliation block. Design to provide the option to skip to

		antibiotics and bolus fluids for resuscitating a patient.
Labs including blood work and cultures are also ranking high in requirements by participants for both identification and management of Sepsis	Lab results are presented after Intake/output summary section in the patient review block of the navigator. Labs can be ordered in the additional orders column of the huddle reconciliation block in the navigator	Lab results can be presented after vitals in patient review as the second section. Intake/outputs summary are not as highly prioritised by users as labs. Ordering labs for the management of Sepsis should be better prioritised in the Sepsis order sets after antibiotics. Design can also include the option of ordering needed labs after reviewing the lab results section of the patient review block.
Patient history and risk factors are the 3rd most requested information to accompany alert	A short patient situation section is included in the huddle block. It is the first encountered information after activating Sepsis huddle. Intake/outputs summary and LDAs (lines, drains, airways, wounds) also provide information on patient medication history in the patient review block.	There are still missing pieces of data on high risk factors of patients that can be included in the patient situation section.
Participants mentioned the need to review patient's	Intake/outputs summary, LDAs (lines, drains, airways, wounds), active orders in	

active medications, lines especially IV access to make effective decisions.	that order provide these data in the patient review block.	
Participants stated that the tool can help to determine when to call for CCRT intervention.	Calling CCRT with different levels of urgency is included in the Sepsis order sets.	Tool can also be designed to automatically inform CCRT. The standard situation or time for calling on CCRT intervention can be included in education and training of clinicians. However, knowing when to call CCRT can also be very dependent on clinicians' experience/competencies.
Communication between medical team	No communication support in tool.	Considering how different professionals use Epic in terms of access and duration of use, communication on the tool may not be a priority. The huddle is shared in real time between members of the medical team for each patient to prevent unnecessary tasks and extra workload.
Access to assessments specific to Sepsis including perfusion, LOC, neurological changes, etc. (from theme: Diagnosis and actions very specific to Sepsis)	Focused assessment is the last section in the patient review block of the navigator. Providers can view and fill in new assessments while nurses can only view.	Focused assessments are only physical examination outcomes taken by providers and do not include other data. Assessments like level of consciousness and nail beds can be added from the list provided by users.

Alert all members of the medical team overseeing patient.	MVP alerts all members of the medical team	When alerts are activated by one member of the team, it is suppressed for the rest of the team. Contacting all other members of the team will be done outside the tool. However, that is heavily dependent on the assumption that there is an effective means of communication between bedside nurses and other members of the medical team. From the interview results, this may not be so. Alerts that have been activated can also include a contact feature to automatically deliver a message inviting other members of the team to the patient's bedside.
Acknowledgeable alert	Users must choose to activate Sepsis huddle by clicking yes and then accept to proceed to the Sepsis navigator.	This may be merged into just one click interaction as opposed to two.
Not too many links, all-in-one screen navigator, easily accessible information	The MVP has very few links and an all-in-one screen navigator for Sepsis. All information provided are easily accessible by collapsing or expanding. There is a side bar with all	The mixture of collapsed and expanded sections may send wrong signals to the clinicians about data sections available, prioritised or should be completed.

	the information and interactions in the navigator grouped in three blocks: huddle, patient review and huddle reconciliation.	Collasping and expanding sections may result in too many clicks.
Colour codes	The MVP has colour codes for huddle outcomes Sepsis watch, code Sepsis and continuing routine care as they appear in the banner.	Some participants wanted colour codes to show severity. Management believes clinical judgement should assess the severity and be uninfluenced by the tool. Colour choices seem to blend with the Epic background colour. Although the tool is an advisory, patient safety for Sepsis is crucial and time sensitive. Therefore, colours should reflect a warning or caution. Colour coding should also be different from bedside PEWS as these can easily be mixed up and affect patient's care. Yellow or Orange can be explored for the banner.
Sepsis tab and navigator in clinicians' Epic dashboard.	Not available in MVP	This may be included as an option as some clinicians find it easy to navigate their Epic dashboards by tabs. Epic design includes a navigator button to access all types of navigators in the system. Sepsis may be added to these navigators for

		manual access. Current setting only provides access to Sepsis tool when the alert is fired and a huddle outcome is selected.
Information with alert should be minimal	Alert is accompanied by Sepsis score and criteria.	A usability test can help assess how clinicians may perceive the information (whether minimal or not, importance or understanding)
Pop up was the highest preferred design for alert	In the MVP, alert pops up when clinicians open a patient's chart	For situation awareness and reducing time to identify Sepsis, pop ups should be made to appear immediately patient meets criteria, whether clinicians are in their charts or not. A flag can precede the pop up in the chart.
Additional documents with Sepsis BPA.	The percentage of additional documents requested in user interviews that are included in MVP is 75%. Some of these were not presented as links.	Sepsis tool is missing a link to Sepsis pathway.
Sepsis management pathway was the highest mentioned document participants	MVP has no link to Sepsis management pathway	This should be considered and included as a link to support the clinicians and contribute to the standardisation of Sepsis care.

expect to be linked to from the navigator.		
Additional information with Sepsis BPA	The percentage of additional information types requested in user interviews that are included in MVP is 66%.	Few details on patient history, next steps stated by clinicians are missing and should be included. Information on different levels of concern is not included to avoid influencing clinicians' judgement.
Users (9) expect to see the criteria for the alert as the first piece of information.	MVP displays the Sepsis score and criteria with the pop up before acknowledgment	The display of the Sepsis score can be redesigned to have the digits side by side. Total score can also be included below as opposed to being on top.
Next steps	MVP provides support for orders but do not clearly state next steps	Next steps may be provided as an option which can be in form of the link to the Sepsis management pathway.

3.7.3 Is the MVP addressing clinicians' concerns?

The MVP was checked against some of the concerns raised by clinicians about the tool as earlier mentioned in the interview results. Concerns not interpreted into user requirements above are discussed here:

Situation awareness

The tool triggers an alert only when patient's chart is opened. This may not entirely address the need for the tool for situation awareness as clinicians still get to be totally oblivious if they do not open a patient's chart. From the interview results, about half of the participants stated that they would want a concern for Sepsis pop up in their face when they are on Epic. Some

participants also mentioned having anchoring bias regarding Sepsis in otherwise healthy patients. This design of the tool does not address that problem.

Alert fatigue

Alert fatigue is one of the biggest problems with decision support tools in healthcare [31] and top of all concerns shared by participants. There are many factors in the design of the tool that directly or indirectly cause alert fatigue. One that comes top of these mentioned factors is the consideration of baseline condition for complex patients. The Sepsis BPA do not have a smart feature to consider these baselines separately resulting in the following measures:

1. Tool resets every 24 hours for patients that trigger the alert and have an activated huddle.
2. Sepsis score and criteria, although adopted from the US, were customised to the hospital's setting.
3. A background test of the algorithm with real patients have been running in the background for two months and alerting only members of the team to test the sensitivity of the tool. On average, the BPA alerted 1.1 times per 24 hours in total for the unit (about 1 patient a day).
4. Alert fatigue can also be assessed through initial pilot study on implementation of the tool to test the effects of the measures put in place.

Assigning patients on Epic

Clinicians, particularly physicians, expressed concern about how the system knows to trigger a particular patient's medical team. At the hospital, nurses (especially bedside) have a better access to Epic systems than the physicians. The nurses can assign themselves to their patients whereas physicians cannot and may have up to 40 patients in their care.

This concern assumed that the alert pops up without opening patient's chart. However, alert was designed to pop up only when patient's chart is opened making this concern void.

Bedside PEWS may be confused with Sepsis score

From the Sepsis early management pathway in use at the hospital, clinicians have been using the bedside PEWS to assess patient's presentation or deterioration. Clinicians may also not be willing to adapt the score if they believe the PEWS score works just fine to alert them of Sepsis. The hospital can provide education and training that clearly itemises the differences between the scores and the importance of using the Sepsis tool in the identification and treatment of patients.

Data inaccurate or not available

Although mentioned by only 1 participant, it is very important that data is available and accurate to correctly inform these alerts. Design should be in such a way that accuracy of data entered is checked using field rules and should not discourage users from completing.

Interacting with tool can be a form of delay.

The navigator can be designed in such a way that the priority information (e.g. vitals) and reconciliation items (especially ordering antibiotics) are accessible without filling in the rest of the huddle to avoid delay especially with patients that are visibly onset with Sepsis. However, conditions can be attached to this option to avoid abuse.

3.8 Chapter Conclusion

This chapter presenting the semi-structured interview resulted in the identification of themes and subthemes on clinicians' general experience, knowledge, challenges caring for patients with Sepsis, their experiences with CDSS and projections of the Sepsis BPA. Some of these themes include identifying, managing Sepsis, assessments very specific to Sepsis, experience with CDSS, expectations of Sepsis BPA including, alert design and interaction preferences. Control task analysis showed the break down into processes and knowledge states for both identification and care of patients with Sepsis. Clinicians' shortcuts (shunts and leaps) were identified, and another decision ladder developed which modeled the new huddle in the Sepsis BPA showed the support the tool will provide. Lastly, the minimum viable product was checked against user requirements communicated by participants in the interview and recommendations based on design and human factors principles were provided.

Chapter 4: Phase II – Moderated Usability Testing

In this chapter, I provided details of the moderated usability testing in phase 2 of this study. The chapter presents all usability feedback, both positive and negative, provided by participants. These feedback were also grouped to each use types for the Sepsis BPA. Recommendations and suggestions addressing the usability and workflow issues were provided right after. In addition to the results, I included details on methodology, participants, study design, procedure, and post-study survey for the whole study for reproducibility. The chapter ended with a full analysis of the post-study survey with charts showing the responses of participants to each question. In addition, statistical analysis was done to confirm the hypotheses on which constructs of the UTAUT significantly affects the user's intention to use the Sepsis BPA.

4.1 Methodology

The second phase of the user study was a remote moderated usability testing with the aim of identifying usability challenges in the MVP in addition to the user requirements in the first phase. The author decided on remote moderated usability testing because the main objective was to obtain rich qualitative data with deep insights into usability. In addition, COVID restrictions limited in-person testing. The sessions with each participant had two moderators, the author and one of the principal clinical investigators on the Sepsis project at the hospital.

An evaluation identifying EHR usability and safety challenges in paediatric settings discovered two-thirds of safety and medication issues in three hospitals were related to usability challenges. These usability challenges stem from design, customization, implementation and use of the technology [50] thereby establishing the need for usability testing of decision support tools in these EHR systems.

This study was the first usability test for the tool and heavily moderated for qualitative feedback. Participants were asked to think out loud while interacting with the tool providing rich feedback on usability. After usability feedback were elicited, the universal theory of acceptance and use of technology (UTAUT) was used to capture satisfaction and intention to use the Sepsis BPA.

4.2 Participants

Participants were recruited from the same target population as the user interviews (clinicians in general paediatrics unit at the hospital). However, participation of clinicians from the first phase was dependent on continued interest and availability. 3 new participants were recruited and a total of 10 participants to include both types of users (nurses and providers) were planned for the study. However, 3 participants became unavailable at the proposed times for the usability sessions. Given the time constraint, the author proceeded with only 7 participants in total for the study. These 7 participants include 4 registered nurses and 3 providers (2 residents and a nurse practitioner) with varying years of experience caring for patients with Sepsis. This moderated usability testing phase also received ethics approval from the

institutional review board at the University of Waterloo. A summary of the participants' data can be seen in the table below:

Table 5. **Summary of participants' demographics in moderated usability testing.**

Participants	Age range	Gender	Healthcare Profession	Years of Experience
P2	41 - 50	Female	Nurse Practitioner	20
P8	20 - 30	Male	Resident	3
P9	20 - 30	Female	Resident	3
P12	31 - 40	Female	Registered Nurse	7
P13	20 - 30	Female	Registered Nurse	3
P14	31 - 40	Female	Registered Nurse	6.5
P15	20 - 30	Female	Registered Nurse	3

4.3 Study Design

4.3.1 Study setting and summary:

The moderated usability testing was conducted virtually via Microsoft Teams as participants were observed while interacting with the MVP of the Sepsis early recognition tool and navigator. Participants accessed and interacted with the MVP through transfer of control (feature on Microsoft teams) of moderator's shared screen to participants. The study started off with a review of the study's key aspects followed by the participants' verbal consent. After their consent, a moderator asked participants a few questions regarding their demographic and relevant professional information. Participants from in phase 1 already had their consent, demographic and professional information taken. A moderator provided an overview of the tool and its function. The participants were presented with two patient scenarios and told to interact with the tool while engaging in a think-aloud process. Feedback was provided regarding usability challenges, satisfaction and acceptance of the tool through debriefing and post-study surveys administered through Qualtrics.

4.3.2 Case study scenarios.

As opposed to specific tasks, case study scenarios were provided to participants to ensure that the Sepsis BPA supports clinicians' decision making and cognition.

1. You have been assigned patient, Septica. She is a 7yr old female admitted to 7C with pneumonia. You log into her chart and see Sepsis best practice alert (BPA) pop up.

   Using the Sepsis navigator talk out your thought process and how you would use this tool to review your patient and determine plan of care.

2. You have been assigned patient, Septico. He is an 8month old admitted to 7C from the emergency department for fever/UTI. You log into his chart and see Sepsis best practice alert (BPA) pop up.

   Using the Sepsis navigator talk out your thought process and how you would use this tool to review your patient and determine plan of care.

4.3.3 Post-study survey: The Unified Theory of Acceptance and Use of Technology (UTAUT)

The UTAUT was proposed by Venkatesh et al [51] to address some of the weaknesses of the technology acceptance model (TAM). They integrated important elements from other models and theories like theory of planned behaviour, theory of reasoned action, innovation diffusion theory, and social cognitive theory to better predict or explain adoption, acceptance and usage of new technology. The UTAUT model is well suited to this study than the UTAUT 2 because hedonic motivation, price value, and habit constructs do not fit into the current objectives and were not of interest for this research. The UTAUT model has four key constructs:

1) Performance expectancy (PE) - this is the degree to which individual believe that using a system will help them attain better job performance.

2) Effort expectancy (EE) – this is the degree to which individuals associate ease or perception of efforts required with the use of a system.

3) Social influence (SI) – this is the degree to which individuals perceive the importance of other people's belief that they should use the new system.

4) Facilitating conditions (FC) – this is the degree to which individuals believe that organizational and technical infrastructures exist to support the use of the new system.

The model was modified by the author to include questions specific to the Sepsis BPA with the likert scale. Comment boxes were also included in the survey for some qualitative feedback regarding the constructs and the system. In the original model, questions on behavioural intention and usage behaviour are included. Hypotheses are drawn based on the constructs that affect behavioural intention and usage behaviour. Performance expectancy, effort expectancy and social influence are direct determinants of both behavioural intention and usage behaviour while the facilitating conditions are direct determinants of usage behaviour only.

However, usage behaviour was not assessed in this study. The author explored all four constructs to measure satisfaction and acceptance which included an investigation of the effect of all 4 constructs on behavioural intention to use the tool. The following diagram provides the description of the model adapted to this study including the hypotheses:

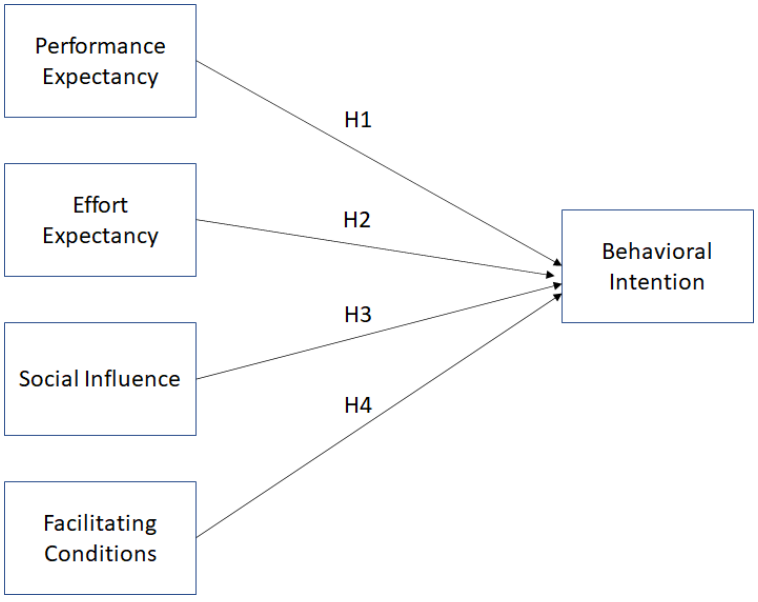

Figure 27. **Adaptation of the UTAUT model to the study**

Hypotheses:

H1 - Performance expectancy positively affects users' intentions

H2 - Effort expectancy positively affects users' intentions

H3 - Social influence positively affects users' intentions

H4 - Facilitating conditions positively affect users' intentions

4.4 Results and Discussion

4.4.1 Usability Feedback

The following usability feedback were reported by participants as they interacted with the Sepsis BPA. Some of these would be split between the two user types to account for the differences in design and interactions. The feedback would also include both features participants liked and the ones they found challenging or missing.

Some elements of the design and interactions participants liked:

Both users (nurses and providers) commented on the following features, functions and interactions they liked:

- Easy documentation of vitals.
- Knowing what had been pulled or ordered from the labs like pending culture or blood work in the active orders section.
- The pop-up alert.
- The colour changes in the banner showing Sepsis activation and the huddle outcome.
- The huddle outcome section.
- The time stamp on vitals and blood work.
- The link to intakes/output summary.
- The criteria provided with the pop-up.
- The vital signs graph report pop-up.

- The time stamp on activated huddle

Nurses

- Viewing the focused assessment section summary documented only by physicians.

Providers

- Urgency included as a note with the Sepsis order.
- The vitals graph.

Usability challenges, interactions or missing components of the tool

After eliciting detailed, specific feedback on elements of the Sepsis BPA, here are some usability challenges that were encountered by users. It includes unexpected interactions, features and functions they found not helpful or missing:

- Navigating to flowsheets outside the navigator after pop-up to review vitals (sometimes more than once). The Sepsis navigator's function includes a vital signs section that allows nurses to document, vitals graph for reviewing the pattern with respect to time.
- Concerned about patients with bad clinical presentation at baseline and the number of times alerts will pop up for them.
- Difficulty accessing navigator after activating huddle. 5 participants could not locate the Sepsis banner showing "Sepsis huddle activated" in the summary page or interpret that it was clickable.
- Too many clicks to expand/collapse sections while getting these tasks done in the navigator. Some participants could not tell that some sections were collapsed on default and skipped.
- Difficulty locating respiratory assessment.
- No information on code status of patients

- Difficulty reading total Sepsis score.
- Difficulty understanding Sepsis score and criteria. The absence of the threshold number.
- No feature to contact the rest of the medical team after activating huddle.
- Sepsis banner in the navigator has no function or link but appears clickable (similar to the Sepsis banner in the patient's summary).
- Exiting navigator to review orders, blood work, fluids, x-ray information.
- Perfusion data not easily accessible in vitals section.
- The need for more information including time antibiotics was ordered and administered in the active orders section.
- Imaging results were not easily accessible.
- No field free notes field for additional details and actions with Sepsis huddle outcome.
- No 24-hour time stamp and quantity information for fluids in active orders.
- No link to Sepsis management pathway after pop-up alert
- Intake/outputs summary in the patient review section not necessarily important for decision making regarding Sepsis.
- Data on differential and inflammatory markers not available in the navigator
- The use of the word report to show more details of a section was not well interpreted by participant.
- Some participants did not know what LDAs mean.

Nurses

- No next steps after reviewing patient information.
- LDAs are more useful to physicians than nurses.

- LDAs not in picture format as in the patient's summary page in Epic. 3 participants prefer the picture display.
- Focused assessments section not clear to nurses.
- Sepsis navigator not included in lists of navigators for access in Epic.
- Vital signs documentation in Epic is similar to documentation during admissions.
- Little understanding of the difference between bedside PEWS and Sepsis score.

Providers

- Exiting navigator to read admission notes.
- There may be too many details in Sepsis note.
- Antibiotics data and access not prioritised in active orders and Sepsis orders.
- No free note option to explain what the option 'other' means when documenting focused assessments.
- Ionized calcium data not necessarily important in orders for Sepsis.
- Participant could not tell if Sepsis notes could be edited or not.
- The term 'increased respiratory effort' as a focused assessment documentation may be too broad. Yes/No response options not enough.
- Orders in the Sepsis order sets should be arranged according to priority.

4.4.2 Recommendations for design to address usability challenges

Starting with the BPA pop-up, the value for the total score should be properly displayed such that the two digits are side by side as opposed to one over the other. The total score can also be moved to display right below the rest of the scores for each criterion. This presentation is for a better flow of the information provided on the pop-up. Participants did not fully understand

what the Sepsis criteria, scores meant or what the threshold value for the Sepsis score is. The threshold value should be included while others may be better addressed in the education and training for the tool as opposed to loading the pop-up alert with too much information. Links can be provided to lead users to the source of the data for each of the criteria. This presentation is for a better flow of the information provided on the pop-up. The two click interactions to activate the Sepsis huddle and accept can be made into one. Accepting the alert takes the user to the patient's summary page which may not be necessary for a user activating the alert. Activating the huddle should lead right into the Sepsis navigator.

Meanwhile, the Sepsis banner which should still display in patient's summary page for the awareness of other members of the medical team should be made easier to locate. Although colour coding is applied to show the different states of the huddle (Sepsis huddle activated, continue routine care, Sepsis watch, code Sepsis), these are all in shades of blue which blends with theme colour of Epic. The banner colours do not reflect alert/warning. Colours like orange, yellow can be explored to properly present the banner. Mouse hover function highlighting the banner can help present as clickable and not just the words on it. There is a Sepsis banner in the navigator which would automatically appear clickable to users who will be conditioned after clicking the banner outside the navigator. However, this banner does not carry out any function but to display the huddle state. This can be removed totally or better presented as just words.

The Sepsis team should explore a function that can automatically page other members of a patient's medical team when a Sepsis huddle is activated. This can contribute further to decreasing the delay in care. An optional link to the Sepsis early management pathway can be provided in the huddle block of the Sepsis navigator after the alert has been activated. It can serve as a guide for the next steps to take in caring for patient. Patient situation summary can include a few more details especially high-risk factors and the code status of a patient.

4 participants (2 nurses and 1 provider) exited navigator to flowsheet which was right beside the navigator in a side bar. Education and training on the tool should properly communicate the full function of the Sepsis tool in general including vital signs and graphs in the Sepsis navigator especially the auto sync function for all data inputs from flowsheets and vice versa. Respiratory

assessment, perfusion data (which is a very important data to assess Sepsis as shown in phase 1) can be better prioritised in the vitals signs section such that it is easily located by the users.

Considering Intake/outputs summary was not mentioned in the interviews and particularly tagged unimportant, it should not be as easily accessible and prioritised as it is on the navigator. Other forms of data like differential and inflammatory markers can be made available and accessible. The LDAs section should have the acronym spelt out. The section should also be changed to a visual display using the picture format as seen in the patient's summary page. Imaging results should also be easily accessible in labs.

Regarding the issue of expanded/collapsed functions for the sections, participants skipped sections that were not expanded while navigating the tool. In addition to the recommendation provided in phase 1 for the issue of too many clicks, a controlled test can be used to check how the expand/collapse function may affect the user's performance.

Time stamps on ordering, administration and the quantity of antibiotics should be added to the active orders section. Antibiotics is very important in the care for Sepsis patients and should be prioritised both in active orders and Sepsis order sets section of the navigator. If possible, antibiotics can be displayed in its own section or a shortcut link to support care for patients with onset Sepsis.

The concern about patients with bad baselines triggering alert too often has been addressed in phase 1. The concern for a mix up between bedside PEWS and Sepsis score has been addressed in phase 1. The colours for the Sepsis banners are different shades of blue showing the different huddle outcomes. However, Epic's interface is predominantly blue making the banner easy to miss. The colours yellow or orange suggested in phase 1 are a good reflection of warning or caution and do not blend with the Epic background.

There should be a free note option while documenting huddle outcome to fill in more details about the situation. The focused assessment section which appears as a summary to nurses should display more information such as timestamps for better interpretation by nurses. It should not only display provider's responses but also the questions for clarity. A free note field to document the reason for picking 'other' option should be provided. The field for 'increased

respiratory effort' should be reframed to provide more details on respiratory assessment as Yes/No options may not provide enough to decide.

The Sepsis navigator should be made accessible in the list of navigators to allow for manual activation of the toll when the need arises. It would also serve as another means of accessing the tool asides from the banner on the summary page. The Sepsis note does not need to include every detail from the navigator. It can be decluttered by grouping some of the data especially labs, microbiology results. The note should also be designed in such a way that its editable function is intuitive.

4.4.3 Post-study survey (UTAUT)

All 7 participants provided feedback through the survey on all four constructs and their intention to use the tool.

Performance expectancy: all responses to the questions in this section are mostly positive with just about 1 – 2 participants providing neutral responses for 3 of the questions. However, most participants agree or strongly agree that the tool will be useful in their job.

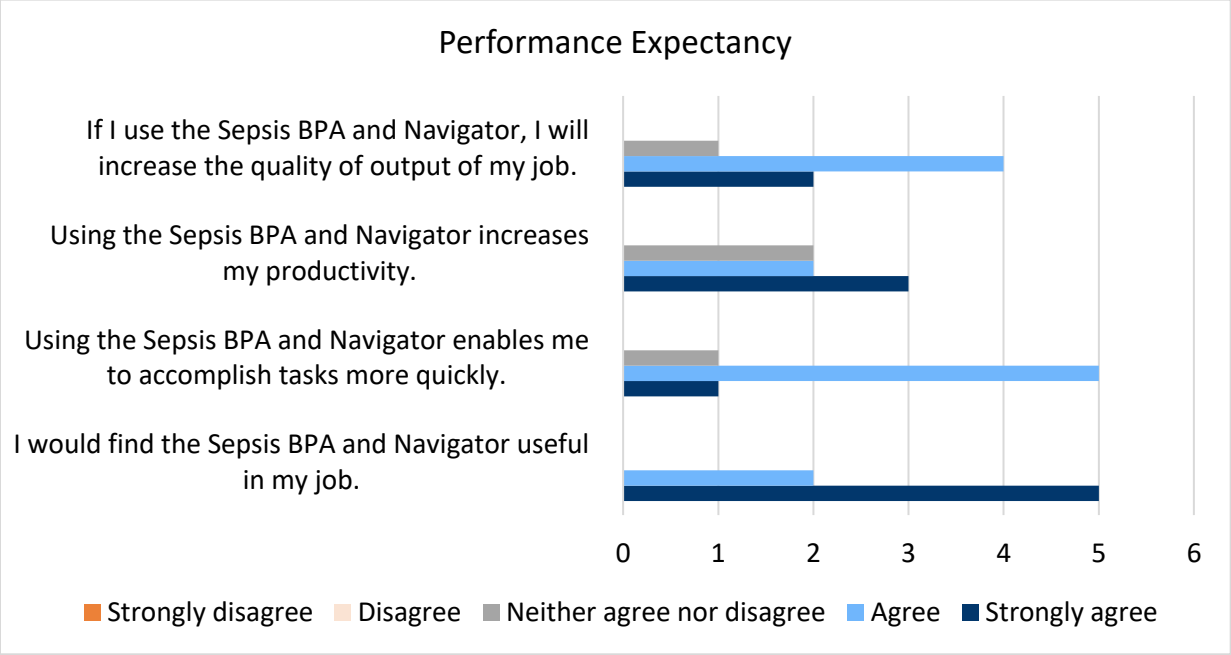

Figure 28. **Performance expectancy**

Some participants provided feedback in the comments box in response to the question “Please comment on how you think the Sepsis BPA and Navigator supports you in doing your work”. Participants expect the tool to consolidate information on Sepsis concisely all in one page, streamline the process of identification, allow for comprehensive review with the medical team, avoid errors that could be overlooked and suggest treatment path moving forward.

Effort expectancy: there was only positive feedback about the learning experience (as seen in first and third questions) of participants while interacting with the tool confirming that the tool is intuitive. There are also very highly positive responses for most of the questions confirming that participants found the tool easy to use.

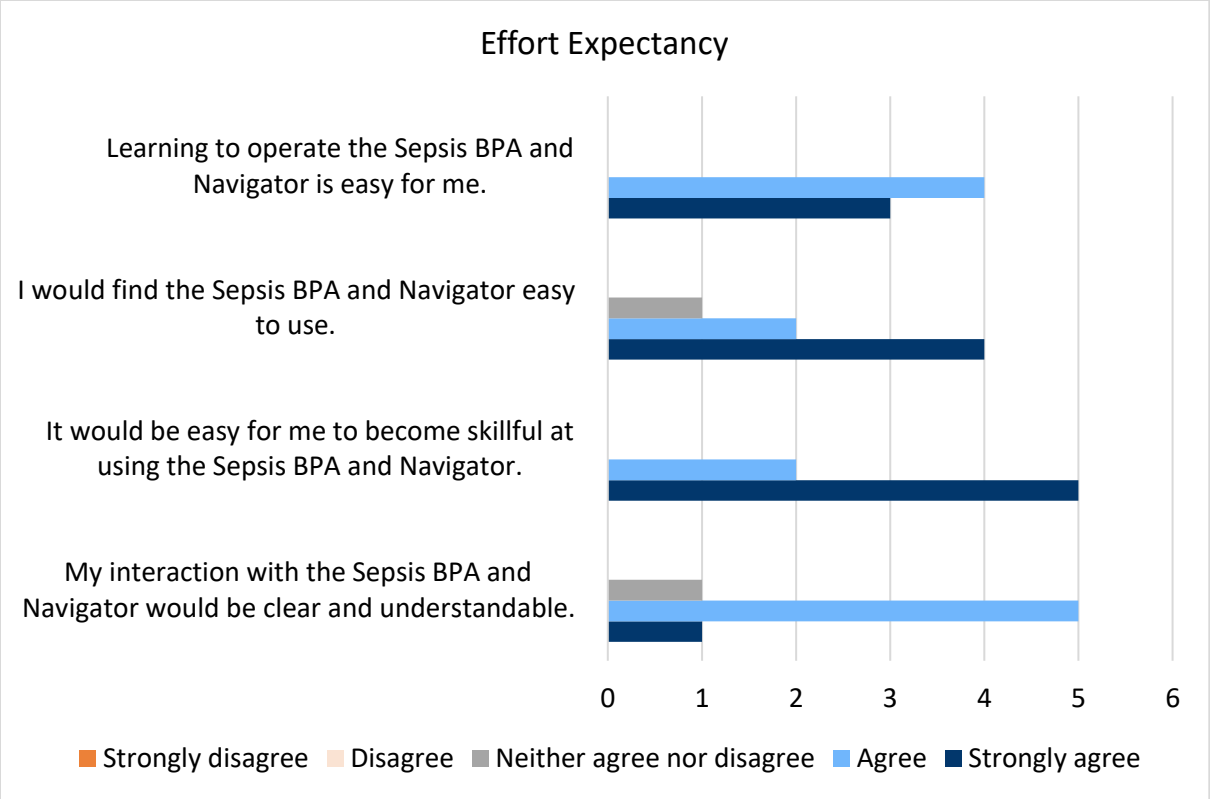

Figure 29. **Effort expectancy**

Here are some of the feedback in response to the question “Please comment on how easy/difficult you find the Sepsis BPA and Navigator is to use”. 1 participant did not find some elements intuitive particularly because of the effort to locate the navigator and having to open

too many tabs. 3 other participants commented on the tool being easy to use. In addition, they also mentioned that ease gets better with exposure and the navigators' similarity with others for admission and transition of care already in use. 1 participant added that the PEWS score being in the navigator was the only confusing part.

Another comment box asking for feedback on the overall experience had positive responses from 3 participants stating that it is useful, user friendly and has a good flow. 1 participant commented on missing pieces of information that should be included particularly on high risk score on the Sepsis criteria.

These responses further confirm some feedback from phase 1 and in phase 2 above.

Social Influence: responses in this section were not as highly positive as other 3 constructs. A significant number of participants provided neutral responses. This means that social influence in the organization may not play a strong role in clinicians' acceptance and use of the tool. However, a good number of participants asked to clarify what the questions mean and may have provided the feedback based on an inadequate understanding of the construct.

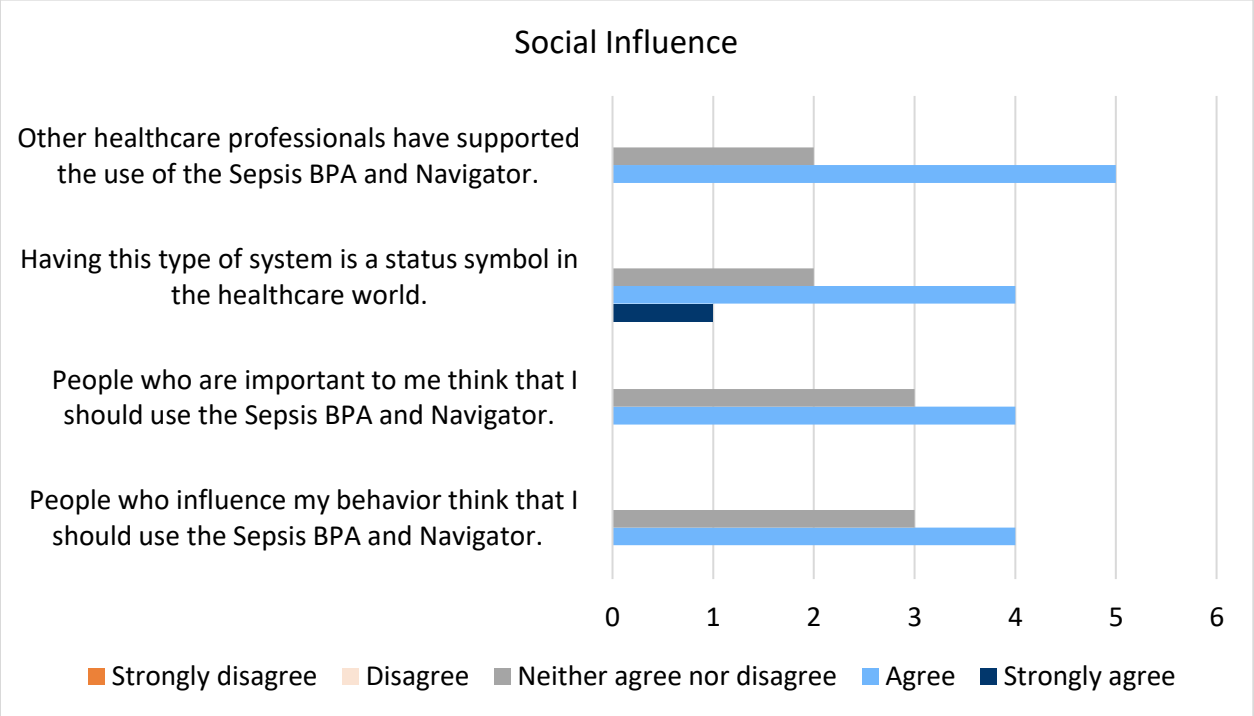

Figure 30. **Social influence**

The feedback in response to the question "Please comment on how others influence your usage of the Sepsis BPA and Navigator" were only 3 in total. Only 1 participant stated that the unit's culture can influence use. Another participant explicitly stated that others do not influence use. These responses further shed lights on the feedback in the chart above showing that social influence may not play a role in influencing the users' acceptance and use of the tool.

Facilitating Conditions: the negative responses in the second question cancels out 'not' which means questions 2 – 5 show highly positive feedback regarding the facilitating conditions for the use of the tool. 6 Participants equally provided positive responses (agree and strongly agree) to the questions on the fit of the tool in their workflow. This provides very good feedback for successful implementation.

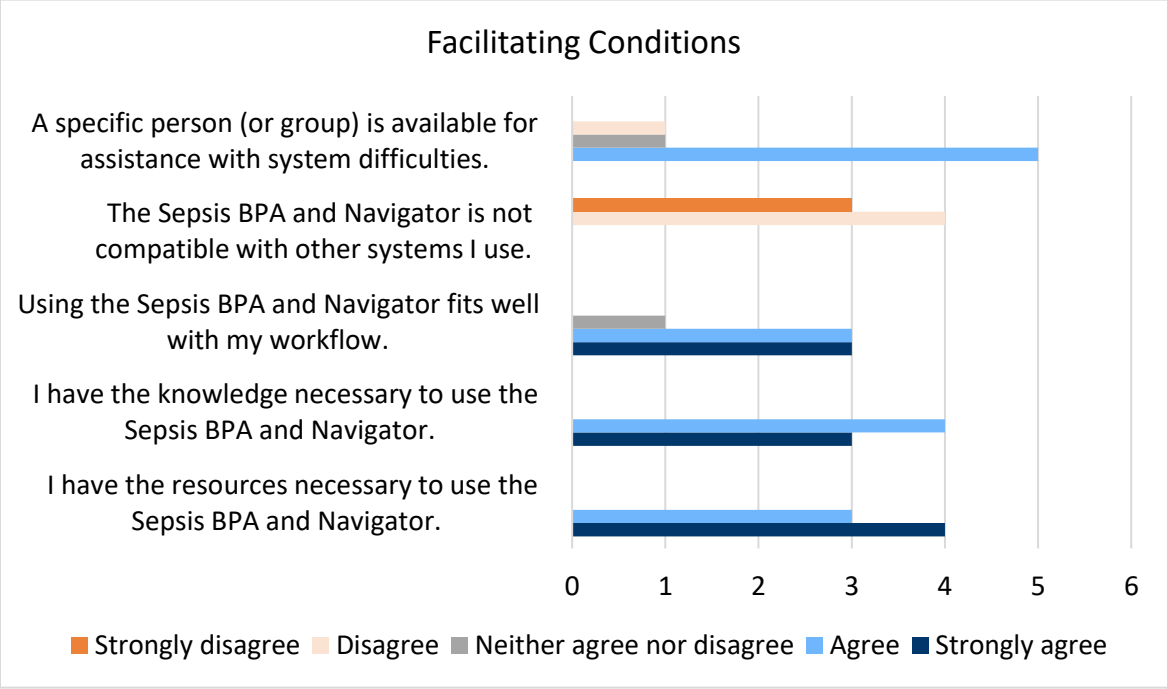

Figure 31. **Facilitating conditions**

Participants provided feedback on the training, support and facilities that have been available for the EPIC system in the organisation. They mentioned the availability of tech support, supervisors, online learning platform and super users who have all contributed to facilitating

learning and use of EPIC. 1 participant suggested that it would be helpful having a unit/floor champion for the Sepsis BPA on roll out.

Behavioural Intention: One question was provided to measure behavioural intention to use the Sepsis BPA.

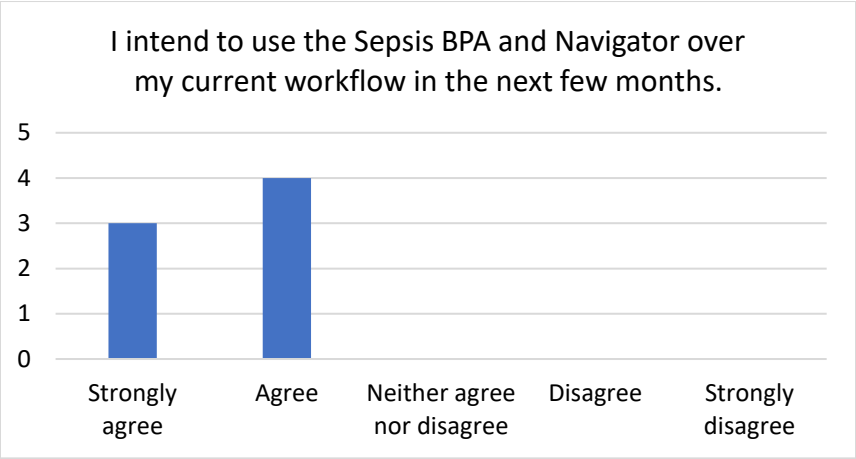

Figure 32. **Behavioural intention**

Participants provided only positive feedback on their intention to use the Sepsis BPA on implementation. All 7 participants either agreed or strongly agreed to use the Sepsis BPA over the current workflow for Sepsis in general paediatrics.

In the last comment box, participants were asked how the Sepsis BPA can be enhanced. Only 3 participants provided feedback which includes:

i. clearly outlining the outcomes and plan of care for routine care, Sepsis watch and code Sepsis.
ii. a timelier process to alert physicians to patients at risk
iii. dealing with the confusing BPEWS score.

To confirm the hypotheses regarding constructs that directly affect the behavioural intention of participants, the following statistical steps were taken to analyse the data.

5 - Strongly agree

4 - Agree

3 - Neither agree nor disagree

2 - Disagree

1 - Strongly disagree

Reliability test

A reliability analysis using Cronbach's alpha was performed on all the variables of the questionnaire, except BI as there was only one question for that variable. Cronbach's alpha can be used to assess the internal consistency, or the extent of which each questions in the construct measure the same concept [52]. Using the psych library in R, Cronbach's alpha was determined for each variable and is shown below**:**

Table 6. **Reliability test**

	Cronbach's alpha	**Number of items**
PE	**0.71**	**4**
EE	**0.87**	**4**
SI	**0.69**	**4**
FC	**0.76**	**5**
BI	**Cannot do**	**1**

PE, EE and FC have alpha values greater than the acceptable threshold of 0.7, which indicates that the variables are robust in terms of their reliability [53],[54]. However, SI is short of the threshold by 0.1, arguably close to 0.70 but may not be as reliable as the other 3 constructs. As mentioned above, some participants may not have had a clear understanding of the questions in these constructs while providing answers which might have contributed to this score.

Correlation analysis

Convergent and discriminant validity were assessed using the Pearson correlation analysis on R. This analysis was performed to learn about the level of association between the variables, as well as its direction. All variables are positively correlated to BI. In addition, FC and PE correlate strongly with BI.

***Table 7*. Correlation analysis**

	PE	**EE**	**SI**	**FC**	**BI**
PE	1				
EE	0.7648 *	1			
SI	0.2415	0.3583	1		
FC	0.7884 *	0.4776	0.1814	1	
BI	**0.7795 ***	**0.6455**	**0.1936**	**0.9366 ****	**1**

*p < 0.05, **p < 0.01

Regression analysis

A multiple linear regression was done to determine the influence of each of the variables on BI. The p value gives the measure of precision against the regression coefficient. The closer it is to 0, the higher its significance. The results do not show any significant influence by any of the constructs on BI at p less than 0.05 and 0.01 respectively. However, it shows that **FC is the most**

significant influence of all 4 constructs on BI. The results also show R^2 value for the equation to be 0.9508 meaning all constructs can predict 95.08% of clinicians' intention to use the sepsis BPA. From the Cronbach's alpha results, SI alpha scores were short of the acceptable threshold. With these results, I may not be able to draw a conclusive inference for SI.

Table 8. **Regression analysis**

	β	t-value	p-value
PE	-0.3576	-0.908	0.4596
EE	0.4634	1.674	0.2361
SI	-0.1044	-0.399	0.7283
FC	1.4024	3.701	0.0659
R^2	0.9508		
Adjusted R^2	0.8524		

*p < 0.05, **p < 0.01

Table 9. **Hypotheses confirmation**

H1 - Did performance expectancy positively affect users' intentions	**No**
H2 – Did effort expectancy positively affect users' intentions	**No**
H3 – Did social influence positively affect users' intentions	**No**
H4 – Did facilitating conditions positively affect users' intentions	**No**

From the regression results, all 4 constructs do not significantly influence behavioural intention at $p<0.01$ and 0.05. Therefore, all 4 hypotheses were rejected. However, all 4 constructs positively correlate with BI with FC being the most significant influence. This means that of the 4 constructs, facilitating conditions are the most important in the implementation process and for continuous use of the sepsis BPA.

4.5 Chapter Conclusion

This chapter presenting the moderated usability testing provided rich qualitative feedback on the elements of the design and interaction on the Sepsis BPA that users liked, found challenging or even missing. These feedback were split for the two user types, nurses and providers. Recommendations and suggestions were provided by the author to deal with the usability challenges communicated as well as further improving the interface and interactions of users. Lastly, the post study survey results were analysed to obtain feedback on the satisfaction and acceptance of the tool. Responses to the four constructs were individually displayed in a chart. The results show an overall highly positive feedback on the Sepsis BPA. The social influence construct scored the lowest on the ratings with the means of scores in the range of 3 – 4. Clinicians rated their intention to use the Sepsis BPA highly positive meaning all participants agree or strongly agree to use the Sepsis BPA over their current workflow. After further statistical analysis, facilitating conditions had the most significant influence on clinicians' intention to use the Sepsis BPA.

Chapter 5: Conclusion

This thesis is an exploration of clinicians' decision-making regarding Sepsis and providing decision support tools to aid the process. The goal of the user study was to apply User Centered Design (UCD) and human factors principles for eliciting clinicians' requirements, perception of the Sepsis Best Practice Alert (BPA) tool, and discovering possible usability issues, acceptance. While there has been considerable research in the past regarding accuracy and outcomes of decision support tools for Sepsis detection, there is very little research including human factors or user studies to inform the design of Sepsis CDSS especially in general paediatrics care. This work was an attempt to provide rich data to guide the design, development and especially implementation of Sepsis CDSS in a paediatric care setting.

In the first phase as presented in chapter 2, the semi-structured interview resulted in the identification of themes and subthemes on clinicians' general experience, knowledge, challenges caring for patients with Sepsis, their experiences with CDSS and projections of the Sepsis BPA. Some of these themes include identifying, managing Sepsis, assessments very specific to Sepsis, experience with CDSS, expectations of Sepsis BPA including, alert design and interaction preferences. Control task analysis showed the break down into processes and knowledge states for both identification and care of patients with Sepsis. Clinicians' shortcuts (shunts and leaps) were identified, and another decision ladder developed which modeled the new huddle in the Sepsis BPA showed the support the tool will provide. Lastly, the minimum viable product was checked against user requirements communicated by participants in the interview and recommendations based on design and human factors principles were provided.

In the second phase as presented in chapter 3, the moderated usability testing provided rich qualitative feedback on the elements of the design and interaction on the Sepsis BPA that users liked, found challenging or even missing. These feedback were split for the two user types, nurses and providers. Recommendations and suggestions were provided by the author to deal with the usability challenges communicated as well as further improving the interface and interactions of users. Lastly, the post study survey results were analysed to obtain feedback on the satisfaction and acceptance of the tool. Responses to the four constructs were individually

displayed in a chart. The results show an overall highly positive feedback on the Sepsis BPA. The social influence construct scored the lowest on the ratings with the means of scores in the range of 3 – 4. Clinicians rated their intention to use the Sepsis BPA highly positive meaning all participants agree or strongly agree to use the Sepsis BPA over their current workflow. After further statistical analysis, facilitating conditions had the most significant influence on clinicians' intention to use the Sepsis BPA.

5.1 Implications for Design and Research

The study aimed to contribute to bridging the gap between the development of Sepsis CDSS in a paediatric setting, its acceptance and successful implementation by providing design requirements and needs of clinicians. In phase 1, findings revealed the important elements and components for a Sepsis BPA. Recommendations for design of the tool as well as workflow improvements were provided. In phase2, possible usability challenges faced by clinicians using Sepsis BPA were highlighted from participant's feedback. These rich qualitative data would inform healthcare systems designers, developers and researchers on the decision-making process by clinicians regarding Sepsis and designing for Sepsis BPAs or CDSS in general. In addition, It would highlight the importance of involving users in the design process and implementation of CDSS tools in their workflow.

The target audience for the outcomes of this work is human factors engineers, software developers, and user experience designers who work on the development and evaluation of software applications in healthcare or health IT systems. Furthermore, this work may be of interest to health care professionals and researchers looking for information on technologies for decision support in their organisations.

5.2 Limitations and Future Work

There were few limitations in this study. The first being the number of participants for both studies. In the user interview phase, more than 10 participants would have provided richer feedback and better theme saturation. Nurses were also not well represented in the sample compared to providers (2 nurses to 8 providers). Due to time constraint, there were only 7 participants in phase 2. There were 4 registered nurses and 3 providers. For the UTAUT analysis, the sample was small and lacked diversity. The sample size may have been too small to conclude with or impact the result considerably. The behavioural intention concept could have included more questions for more data points and better results.

The usability study also took place remotely on Microsoft teams which was not a true representation of the real-life situation and point of use of the tool. The tool is designed to be used by the patient's bedside in collaboration with other members of the medical team that may be present.

Next steps will include implementing the recommended changes and running a second stage usability testing to show more impact of the user study on the experience with the tool. This second stage usability testing can be better set-up as close to the real-life scenario as possible. Measure of effectiveness and efficiency can be considered by taking metrics like time on task, task completion success rate, number of prompts and backtracks. The Sepsis team can also explore testing different design options as suggested in the recommendations provided. Finally, comparing the experience and outcomes of the new tool to the old workflow through randomised controlled trials will be really good feedback for the management of the hospital.

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Appendix A: Semi-structured interview questions

1. Tell us about your typical day at SickKids?
2. Can you describe your experiences caring for patients with Sepsis? *What was your most challenging experience? Walkthrough the experience**?***
3. How do you identify Sepsis in a patient? *Is it a different approach in different departments of the hospital? What barriers?*
4. What types of symptoms are specific to Sepsis that would not normally be assessed, except in the case where Sepsis is suspected?
5. How do you manage Sepsis after identifying? *What barriers? Process, steps?*
6. Are you familiar with or have any experience using Clinical Decision Support Systems (CDSS) (explain the term, provide examples - e.g. bedside PEWS) at SickKids? *What types? What are your experiences/what have you used them for in practice?*
7. What are your expectations of a Sepsis BPA – (may explain)?
    a. *How would you want to be alerted in EPIC? E.g a pop up?*
    b. *What additional information would you want provided with the alert?*
    c. *Would you want any specific documentation also accompanying the alerts? What types of links to documents?*
    d. *How best do you think the Sepsis tool would fit into your workflow?*
8. Which of the departments at Sickkids do you think would benefit the most from the Sepsis CDSS and why?