SYSTEM OPTIMIZATION APPROACH TO MEDICAL AUXILIARY PRODUCT DESIGN

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ABSTRACT:

This paper reports the overview of a series of medical service design projects in collaboration between a design college and a children's hospital. A system optimization based design approach was introduced to the students. It helped the students to better discover the design opportunities and generate design solutions through structured design information framework. The project with the best outcome and feedback from the hospital was chosen as a case study to further explain the project outcome progresses of applying such design approach.

Keywords: system optimization, children's hospital, medical auxiliary product design

1. INTRODUCTION

Local context has long been recognized as one of the most important issues in design education. This paper sets out to introduce a series of graduation projects at the College of Design and Innovation (D&I), Tongji University, which aims at one of China's biggest challenges, the medical and healthcare system. The limited medical resources and the overwhelming amount of healthcare need in China have put the patients, the patients' families and the medical staff under tremendous pressure. What can design and design education do in order to face such local challenge? Is there any way to improve the current situation with less top-down "power" but more bottom-up solutions? With such questions and intention, a system optimization based approach was introduced to this local design challenge. Working with Shanghai Children's Medical Center (SCMC), which receives about over 5000 outpatients every day, a series of medical auxiliary products have been designed and tested. One specific case is selected to be further explained in this paper.

1. 1. DESIGN FOR HEALTHCARE AT D&I

Design for Health Care is one of the five domain-based research directions at the College of Design and Innovation, Tongji University. The medical and healthcare system and service has become one of China's biggest challenges and even in the world. What can a design college do in order to face such challenges in the era that design has gradually been

recognized as one of the driver of change making? With the medical-based origin in Tongji's blood, designing for healthcare has become the calling that D&I is meant to answer.

1. 2. SHANGHAI CHILDREN'S MEDICAL CENTER

Shanghai Children's Medical Center (SCMC), affiliated to Shanghai Jiaotong University School of Medicine, is a Pediatric Hospital integrated with medical care, scientific research and education. The hospital was jointly established by Shanghai Municipal People's Government and Project HOPE. As the symbolized project of Shanghai's social development and the city's key construction project during the period of the" Ninth Five Year Plan ", SCMC is Project Hope's largest collaborative program in the world. SCMC serves Shanghai, radiates to the whole country.

1. 3. THE COLLABRATION OVERVIEW

In 2014, a series of graduation projects at D&I were set out to help SCMC to enhance the medical service and experience as the first collaboration between the hospital and the college. 4 students and 2 tutors from Industrial Design Department at D&I were involved in these projects with the support by the leadership and nursing department of the hospital.

Students were asked to spend as much time as possible in the hospital to understand the real world problems with a system-based awareness. Each of them was asked to follow a specific treatment journey as their thesis topic according to their discovery and insight in the first round field research. The four topics were IV treatment, atomization treatment, leukemia ward and infant medicine-feeding.

With the support by both the hospital and the college, it took four to five months for each project to reach a feasible end. In the children's hospital context, the students were challenged by the real world problems that are complex and serious. They are very much motivated by the wills of using design approach to optimize the existing systems and their design mindsets and skills are tested and developed during the period.

Each of these projects sets out to enhance a specific medical service experience within a related and unique system that usually involves the hospital, the patients and the parents. Students were encouraged to apply a system optimization approach to the defined problem and to generate an integrated product-based solution that can meet the needs from all sides of the system and throughout the process of the chosen treatment journey.

In the following of this paper, one of the four projects is selected to be further explained. It is Children Intravenous Aided Medical Service Design.

2. CASE STUDY: CHILDREN'S IV AIDED MEDICAL AUXILIARY PRODUCT DESIGN

The IV area of Shanghai Children's Medical Center locates at the hospital's emergency area. It serves around 600 person-time per day, sometimes even around 1000 person-time per day in the busy season. Among the patients, around 52% patients are under 2 years old, who needs to be injected in scalp vein. In order to meet the huge need of medical service with limited medical resources and staff, the hospital designed a special IV process. However,

this process requires the patients and the parents a series of moves among several rooms for injection, infusion, dressing change and needle pulling. Accidents happen during these frequent moves and the needle drop rate even reaches 10% everyday. This efficiency and safety issue has been identified as the origin of this project.

2. 1. RESEARCH AND DATA COLLECTION

2. 1. 1. THE THERAPY

IV therapy is a medical method that infuses the liquid directly into the human vein under the circumstance that the infusion system pressure formed by atmospheric pressure and liquid static pressure is higher than the human venous pressure. (Zhao and Ai 2008)

2. 1. 2. THE FACILITIES

There are two therapy rooms, one for injection and the other for needle withdrawing, and 4 IV rooms in the IV area at SCMC. The patients and the parents wait for the therapy period in the IV rooms. Each IV room has around 50 beds, which makes up around 200 beds in total. Each bed equips one stand and every two beds are divided by one partition board in between. The therapy room for needle withdrawing functions at the last stage of the therapy, one bed is used for laying the patient.

2. 1. 3. THE MEDICAL STAFF

The IV area of SCMC takes three-watch system, respectively, in therapy room 1, the IV room and therapy room 2. In each shift, there are 5-6 nurses in therapy room 1 who are in charge of filling the IV bags and venipuncture. In the IV room, there are usually 2 nurses in one shift responsible for handling the emergency and replacement of IV bags. 1 nurse is on duty in therapy room 2 in each shift to take care of withdrawing needles and recycling medical supplies. Shift and duty site are both in turn.

2. 1. 4. THE PROCESS

The whole process of the IV therapy treatment at SCMC can be basically divided into five steps. First, the patient accompanied by the parents need to take venipuncture in therapy room. (Figure 1)

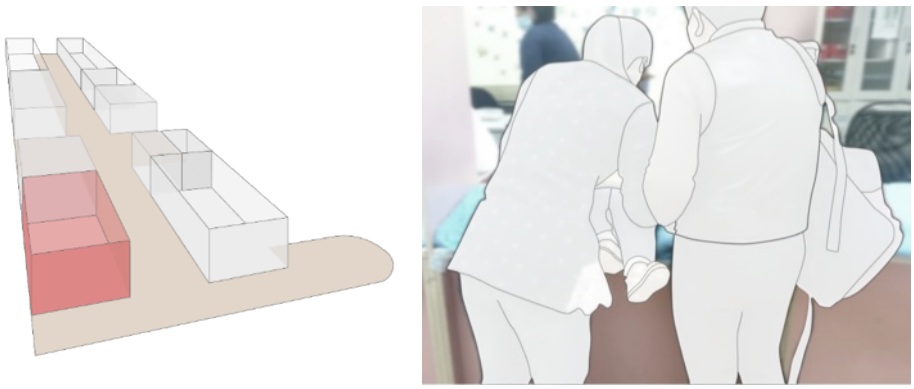

Figure 1: therapy room1 for venipuncture

Then, the parents have to raise the IV bag highly to prevent from blood backflow while moving to the IV room to continue the treatment. (Figure 2)

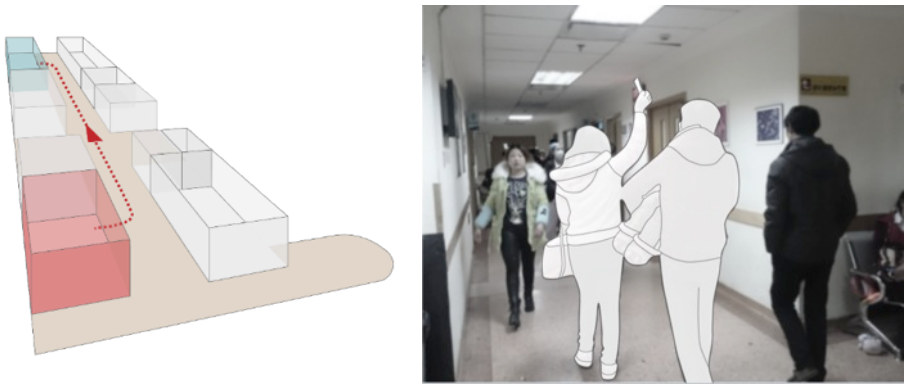

Figure 2: aisle to the IV room

After arriving the IV room, they need to find an IV seat and wait about 0.5–2 hours until the therapy finishes. During this period, the majority of the parents choose to hold the child all the time while pacifying and preventing the child from withdraw the needle accidently. (Figure 3) Meanwhile they also need to pay attention to the IV bag remain.

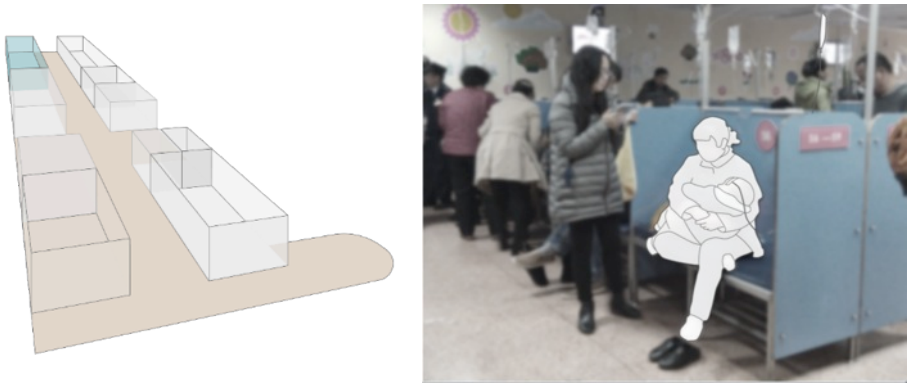

Figure 3: IV room for the treatment period

When the remain of the medicine gets close to run out. The parents need to take the child back through the aisle to therapy room 2 for withdrawing the needle (Figure 4). In the therapy room 2, a nurse will help to withdraw the needle, which finishes the whole process of the treatment.

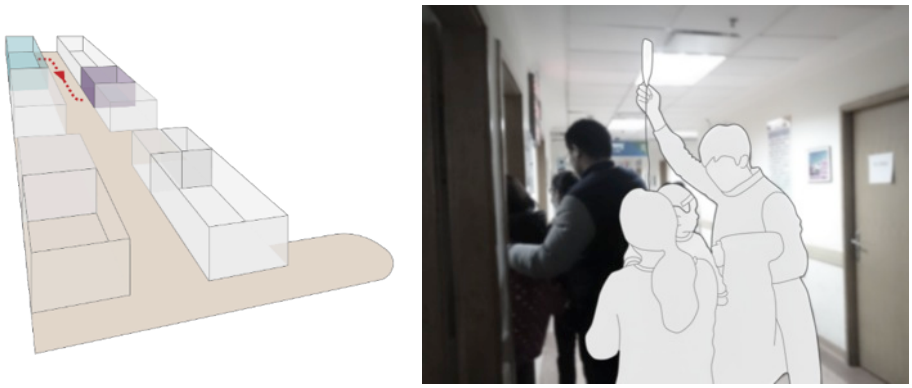

Figure 4: therapy room2 for withdrawing the needle

2. 2. THE INTRODUCTION OF A SYSTEMATIC APPROACH

As stated in 4.2, 4.3 and 4.4, the whole context of IV treatment in SCMC involves different stages of process, spaces, stakeholders and tools. Information and data collected from the field research is quite complex and intertwined. The student was not able to identify the design opportunity easily because there seemed to be “opportunities” everywhere. In order to understand the nature of the problem and solve the efficiency and safety issue in the IV area of SCMC, which is the high needle drop rate as mentioned at the beginning of this chapter, from multiple perspectives, a system-based design information management method is introduced to the student and applied to the project.

The first step of this method is to understand the IV treatment context as a whole process. It systemizes and translates the collected information and data into an entity (Kumar 2013) -task-timeline based scenario. (Figure 5) In this way, it helps the student to understand stand the context comprehensively and to quickly communicate with peers and tutors.

Figure 5: the overall IV therapy process

The second step is to focus on the problem. Desktop research was also applied to this stage in order to categorize the general types of reason for needle drop during children’s scalp IV treatment. In Figure 6, it shows the three main reasons concluded from both the field and desktop research. They are the inappropriate position of holding the child, the inappropriate actions of the patient child and the distance matter during moving with the IV bags.

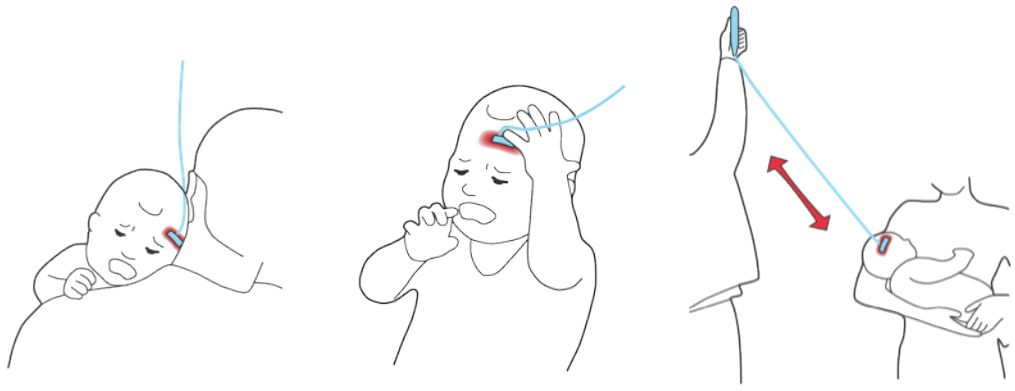

Figure 6: the three categorized main reason of needle drop: position, actions and distance

The third step is to build a more detailed design information framework (Lim and Sato 2006) based on step 1 in order to look into the details at each step of the process from different entity perspectives while not losing the whole picture of the context. By doing this, multilayers of information were integrated into one framework that provides the foundation for design insights and solutions. (Table 1)

Process (P)	**Space** （SP）	**Entity1**（E1） Nurse		**Entity 2**（E2） Patient		**Entity 3**（E3） Parents		**Tool** （T）
		task	status	task	status	task	status	
venipuncture （P1）	therapy room 1 （SP1）	accuracy	being interfered	not to interfere	struggling moving	control pacify	worried	bed needle
moving to IV room （P2）	aisle （SP2）	/	/	not to interfere	impatient uncomfortable	move prevent from backflow	holding the kid raising the IV bag by hand carrying stuff	/
waiting for therapy period （P3）	IV room （SP3）	patrolling respond to emergency	busy occupied	not to interfere	impatient bored	wait check pacify	holding the kid moving around (toilet, fresh air)	seat bracket
moving to therapy room 2 （P4）	aisle （SP4）	/	/	not to interfere	impatient uncomfortable	move prevent from backflow	holding the kid raising the IV bag by hand carrying stuff	/
withdrawing needle （P5）	therapy room 2 （SP5）	quick & safe	being interfered	not to interfere	struggling & moving	control pacify	worried	bed

Table 1: IV therapy system information framework at SCMC

2. 3. THE SYSTEM OPTIMIZATION APPROACH

With the help of the system information framework, a gap between the medical service and the parents' needs were discovered and defined. The design solution used a system optimization based approach to the medical service design. A children's IV therapy treatment aided medical auxiliary product was designed and developed as the key driver to this optimization process.

As shown in Table 2, the stage of P2 and P4 shows the serious lack of medical service support while the parents are overloaded by multiple tasks (as marked in orange in Table 2). The medical service (staff and tools as marked in grey in Table 2) is basically missing in these two stages due to that they are not well considered as IV treatment related from the hospital's perspective.

Process (P)	**Space** （SP）	**Entity1**（E1） Nurse		**Entity 2**（E2） Patient		**Entity 3**（E3） Parents		**Tool** （T）
		task	status	task	status	task	status	
venipuncture （P1）	therapy room 1 （SP1）	accuracy	being interfered	not to interfere	struggling moving	control pacify	worried	bed needle
moving to IV room （P2）	aisle （SP2）	/	/	not to interfere	impatient uncomfortable	move prevent from backflow	holding the kid raising the IV bag by hand carrying stuff	/
waiting for therapy period （P3）	IV room （SP3）	patrolling respond to emergency	busy occupied	not to interfere	impatient bored	wait check pacify	holding the kid moving around (toilet, fresh air)	seat bracket

moving to therapy room 2 （P4）	aisle （SP4）	/	/	not to interfere	impatient uncomfortable	move prevent from backflow	holding the kid raising the IV bag by hand carrying stuff	/
withdrawing needle （P5）	therapy room 2 （SP5）	quick & safe	being interfered	not to interfere	struggling & moving	control pacify	worried	bed

Table 2: the gap between the medical service and the parents' needs

To further understand the relationship between the IV treatment context in SCMC and the needle drop problem, the student integrated the information from Figure 6 with Table 2. The result (Table 3) shows a close link among the lack of medical service support, the overload situation of the parents and the needle drop problem.

Process (P)	**Space** （SP）	**Entity1**（E1） Nurse		**Entity 2**（E2） Patient		**Entity 3**（E3） Parents		**Tool** （T）	**Needle Drop**
		task	status	task	status	task	status		
venipuncture （P1）	therapy room 1 （SP1）	accuracy	being interfered	not to interfere	struggling moving	control pacify	worried	bed needle	
moving to IV room （P2）	aisle （SP2）	/	/	not to interfere	impatient uncomfortable	move prevent from backflow	holding the kid raising the IV bag by hand carrying stuff	/	●
waiting for therapy period （P3）	IV room （SP3）	patrolling respond to emergency	busy occupied	not to interfere	impatient bored	wait check pacify	holding the kid moving around (toilet, fresh air)	seat bracket	●
moving to therapy room 2 （P4）	aisle （SP4）	/	/	not to interfere	impatient uncomfortable	move prevent from backflow	holding the kid raising the IV bag by hand carrying stuff	/	●
withdrawing needle （P5）	therapy room 2 （SP5）	quick & safe	being interfered	not to interfere	struggling & moving	control pacify	worried	bed	

Table 3: the gap and the problem

With this systematic understanding of the context and the problem, the design solution set out to solve the problem by optimizing the system with considerations of multiple aspects to enhance the medical service in SCMC's IV area.

Following the system optimization approach, the design solution had to be embedded in the existing system that goes through the whole process with considerations to the patients' comfort, the parents' easiness and the hospital's order and management. The final design solution came out as a medical auxiliary product that functions as both children's IV treatment aided tool and children's nursing tool.

From the aspect of IV aided function, the design tackled the problems for the parents of moving while raising the IV bags. A non-bracket IV bag carrier solution was generated and introduced to the treatment system. Instead of using gravity and liquid pressure, the solution takes advantage of clip pressure to maintain the treatment temporarily during the

period of moving. In this way, it saves one hand of the parents while moving and holding the child thus makes it easier for the parents to take care of the child. The solution includes a hanging button design, a pressure clip design and tube hanger design as three details of the auxiliary product. (Figure 7)

Figure 7: the IV aided function of the design

From the aspect of nursing aided function, the design focuses on the guide of correct holding position for the parents and the means of appropriate controlling the child's action. A shoulder strap and a hand strap are designed for the parents to better hold the child (Figure 8) while a set of fixing straps (Figure 9) are designed for the child for being better positioned and limited.

Figure 8: the shoulder strap and the hand strap

Figure 9: the child fixing straps

With the integration of both the IV aided function and the nursing function, the final outcome of this project and its service system can be explain in Figure 10.

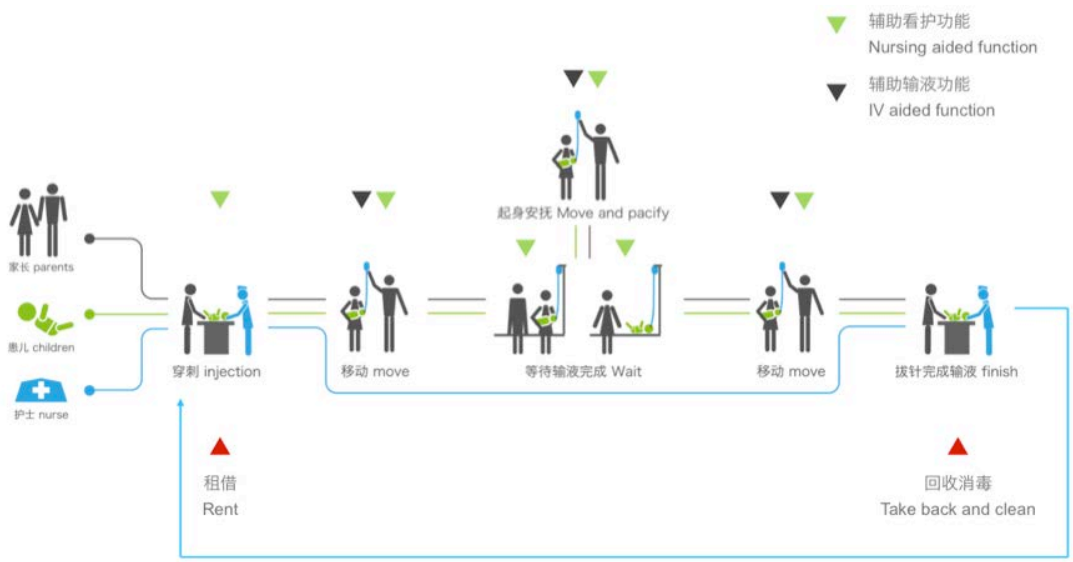

Figure 10: the mechanism of the system optimization approach

3. CONCLUSION

Focusing on the children's IV area at SCMC, the case presented above tried to tackle the real world problem that is complex and related with multiple stakeholders. By introducing the system optimization based design approach, the complicated research and design information was better organized and structured, the design insight was discovered, the design solution was system-integrated to meet needs from multiple aspects and a medical auxiliary product was developed and tested. (Figure 11)

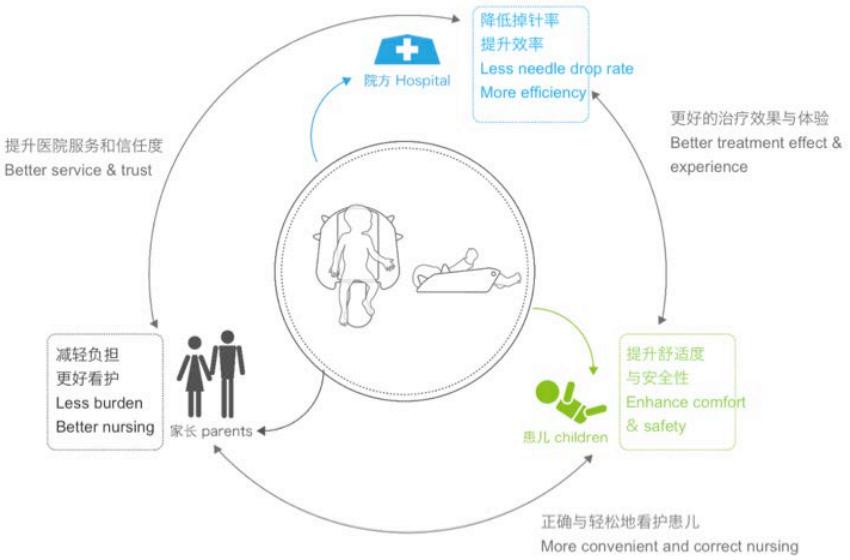

Figure 11: system optimization solution to meet needs from multiple aspects

The prototype of the design was also given a chance to be tested in the real world and positive feedbacks were given from both the hospital staff (Figure 12) and the parents (Figure 13). Meanwhile, some problems were also raised such as the material choice and the self-explain feature so that the parents can quickly understand and learn to use the product without extra instruction.

Figure 12: meeting and on-site testing at SCMC

Figure 13: on-site testing at SCMC with a patient's parents

Three lessons were learned in terms of learning outcomes for the student according to her oral and written reflections. First, the introduction of the system optimization approach efficiently enhanced her understanding of the problem and helped to identify the design opportunity. As she said, "It made the complex information better structured so that they can be presented and analyzed in the same time in stead of one-by-one following the timeline. This helped me to understand better about the whole context and discover the design insight." Second, the system-based approach was reported by the student as a useful design criteria generator that brings the needs from multiple stakeholders together. This was also important to the student because like she reported, "sometimes we don't know what we missed, and this method helped me to check". Third, from the process and the result of the project, the application of systematic service design has been proved to be a good sense-making tool for the student to communicate with both design professionals and non-design professionals.

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