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Design and Development of a Patting Robot for Infant Caregivers

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This work presents the design and development process of a patting robot aimed at assisting caregivers in their patting interaction with infants. Caregivers often experience stress and fatigue, both physically and mentally while caring for their babies. Patting is a repetitive task performed by caregivers to help with burping a baby, soothing a crying baby, and lulling a baby to sleep. In the conducted survey, 90% of caregivers responded that they have experienced difficulty in or discomfort from patting a baby. Patting a baby can be a painful task related to health and recovery especially for new mothers with weakened wrists. To solve these challenges, a patting robot for infant caregivers was developed through online survey, prototyping, field study, and iteration processes. The developed robot is a wearable robotic forearm, which is a kind of supernumerary robotic limb (SRL), giving implication for new usage of SRL.

INTRODUCTION

Caring for infants takes up a lot of time, with the primary activities being soothing the baby, burping them after each meal, and lulling them to sleep. All of these tasks require caregivers to pat their babies and use their wrist joints repeatedly. Since patting is a fundamental aspect entwined in all of these nurturing tasks, caregivers need to pat their babies' back multiple times a day. However, the repetitive nature of patting induces physical strain on new mothers whose bodies have been weakened due to childbirth, as hand and wrist pain is known as one of the most common symptoms in new mothers [1], [8], [9]. Moreover, patting demands a substantial amount of time, demanding constant attention and effort during the patting. This sometimes results in the physical and mental stress of caregivers, which could lead to a risk factor for mental health problems in their babies [4]. Thus, there is a need for a helping tool, such as a robot assistant, that assists infant caregivers with this activity.

DESIGN PROCESS

To include users in the process, this study referred to overall design process adapted from the User eXperience (UX) design lifecycle [3], which describes the iteration of understanding users' needs, creating design solutions, prototyping and evaluating UX. During the process, user centric approaches such as contextual inquiry and online survey were conducted. Referring to the collected data, a prototype was built and tested in a real-world environment and then iterated.

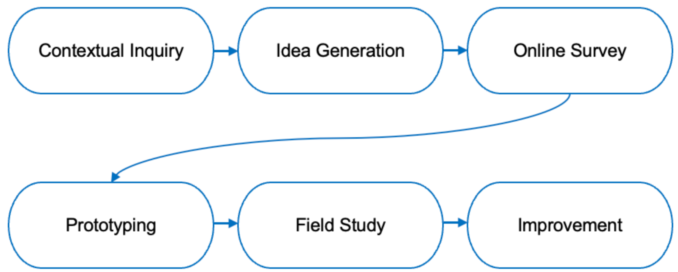

Figure1. Overview of design process

1. Contextual inquiry

To understand the context of caring for an infant, contextual inquiry was conducted. A new mother with a 5-month-old baby was observed at their home. After a 3-hour-observation, the new mother was interviewed describing the daily pattern of caring for an infant. The daily activities includes feeding, burping, changing diapers, soothing, reading books, and lulling the baby to sleep. Among these primary activities, burping, soothing and lulling the baby to sleep required the mother to pat the baby.

1.1. Burping

Burping was conducted after each meal. Since the baby was fed 5 times a day, a 10~15 minute burping process was performed 5 times a day. When burping, the mother put the baby in her arms, while using her right hand to pat the baby's back.

1.2. Soothing

When the baby cried, the mother put the baby on her chest and consoled the baby. It was observed that as the baby cried louder, the mother's patting got faster.

1.3. Lulling to sleep

When it became time to sleep, the mother used patting to ensure her baby of her existence. She said that the posture to pat the baby hurts her back, as she has to reach down low when the baby is lying in an infant bed.

2. Idea generation

Based on these observations, ideas were generated to select the optimal form of the baby patting robot. First, possible locations to attach and wear the robot were considered; the caregiver, the baby, and the chair in which the baby is sitting. According to the location where the robot could be attached to, the robot could be described as one of three types: a sleeve-type worn by caregiver (fig. 2), a backpack-type worn by infant (fig. 3), and an independent chair-type (fig. 4).

3. Online survey

An online survey was conducted to understand the real challenges faced by caregivers and gather their requirements about a patting robot. The survey targeted 40 participants (1 male and 39 females) who are caring for infants or have taken care of infants within the past 2 years. Participants were recruited through an online mom cafe. The average age of the participants was 33.65 years.
The survey mainly consisted of two parts: 1. their infant-caring experience related to patting, 2. preferred type of patting robot. Open-ended questions were also asked to collect any requirements/opinion about the patting robot.

3.1. Patting experience

In one part of the survey, participants were asked if they have experienced any discomfort or difficulty from patting. The 90% of participants responded to have experienced discomfort or difficulty related to patting. Among them, 83.33% experienced discomfort from wrist pain and patting posture, followed by the inability to multitask (63.89%) and the boredom from its repetition (47.22%).
When asked about the frequency and duration of patting, it was shown that each 95% of respondents perform patting more than 5 sessions a day, lasting more than 5 minutes per session. 17.5% of respondents were patting their babies more than 15 sessions a day, and 25% of respondents responded to pat over 15 minutes per session.
Participants' responses showed that the main purposes they pat their babies' back are for soothing crying (100%), burping (95%), and putting to sleep (85%).

3.2. Preferred type of patting robot

Among the three types of patting robots (fig. 1-3), participants were asked their preferred form of robot. The sleeve-type robot worn by the caregiver was most preferred with 52.5% of participants, followed by the independent chair-type (47.5%), and backpack-type (25%).
The result was supported by the comments, "I prefer to hold the baby by myself and use the robot only for patting, because the babies move a lot that holding them by myself would feel safe. (P6)", "I want to use both sleeve-type and chair-type robots so that I can use the robots in various circumstances. (P23)"
In the open-ended answers, some participants showed their expectancy for the patting robot. "Patting robot would be helpful for nurturing baby (P5)", "Wrist pain was so harsh while patting the baby's back that made me even consider of buying a moving toy to pat the back instead. (P23)"

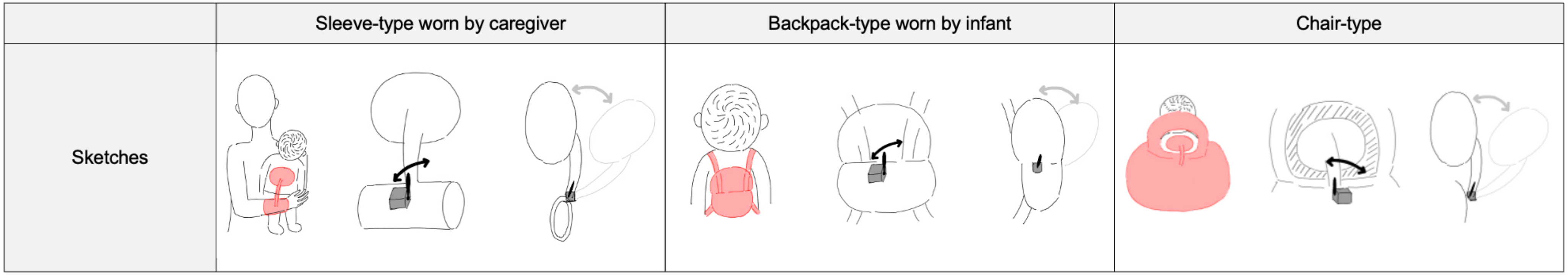

Figure 2. Sleeve-type **Figure 3. Backpack-type** **Figure 4. Chair-type**

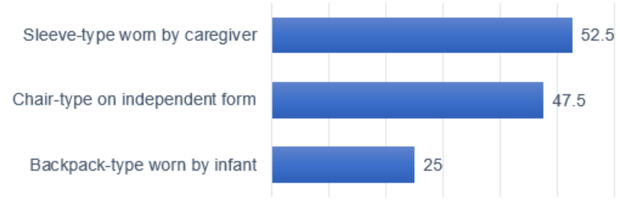

Figure 5. Preferred form of patting robot (Multiple choices question) (%)

Figure 6. Reasons for experienced discomfort or difficulties in patting (multiple choices) (%)

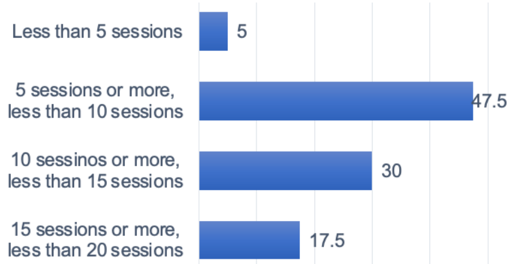

Figure 7. Frequency of daily patting (%)

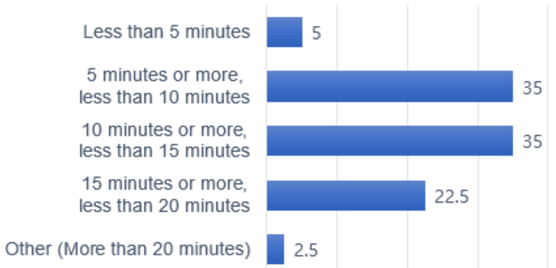

Figure 8. Time taken per patting session (%)

ROBOT DESIGN

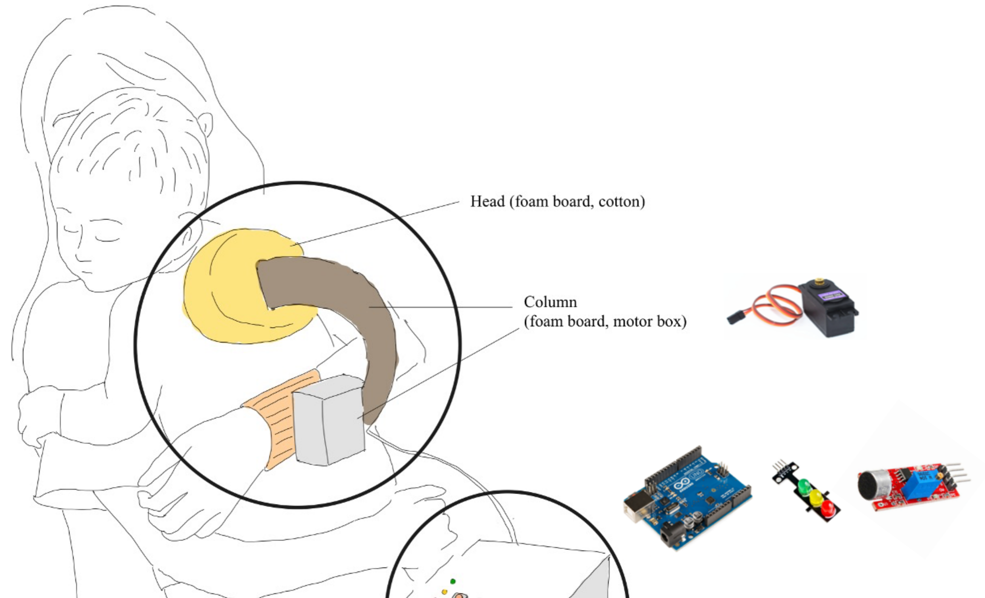

Figure 9. Patting robot design used for field trial

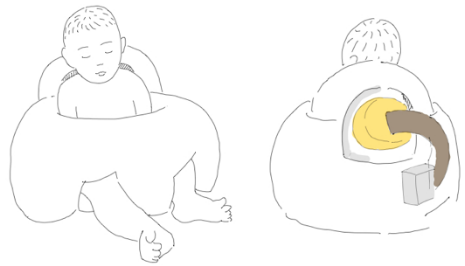

Figure 10. Patting robot attached on a chair (front/back)

1. Hardware

Reflecting the needs of the participants from the online survey, the sleeve-type patting robot type was chosen. The patting robot consists of three main parts: head, column and box. The head part, which directly interacts with the baby's back, is made up of a foam board and cotton. To ensure a safe and gentle patting experience, it is filled with cotton and designed similar to the shape and size of a female hand (oval shape with a size about W150mm X H100mm). The column connecting the motor box and the head part is curved, reducing the risk of any discomfort to the baby. A servo motor, located inside the motor box, allows for the motions of the column in both clockwise and counterclockwise directions. Lastly, there is a box part that interacts with the user. The box contains a button and sound sensor to get inputs from the user, LED lights (green, yellow, red) as visual feedback to the commands, and an Arduino Uno board and batteries. The button is used to turn on/off the robot and switch between the patting modes. Each LED light color shows the current patting mode to the caregiver: green light as lulling mode, yellow light as burping mode, and red light as soothing mode.

Based on the responses from the online survey, a patting robot was designed to accommodate different scenarios. The motor box was designed to be easily attachable and detachable using a Velcro attachment, so that caregivers were allowed to use the robot worn or put it on a chair to use independently.

2. Software

Based on the primary activities caregivers engage in while patting their baby, the patting robot offers three modes: lulling to sleep, burping, and calming cries. The modes were switched with pressing the button. The lulling mode allows for a slow speed operation, and can be used when lulling baby to sleep. The burping mode offers a moderate speed operation and is for burping a baby after each meal. In the case of the soothing mode, the patting speed is dependent on the cry amplitude. When a baby cries louder, the patting speed gets faster, and the speed gets lower as the cry amplitude decreases. This interactive speed control was observed from the mother and her baby during the contextual inquiry process. This function was included in the hopes that the reactivity to the cries could allow the baby to feel that the robot was responding to their signals.

FIELD TRIAL

To validate the effectiveness of the Patting Robot, a field trial was conducted. One mother (age 30) and her 5-month-old baby participated. After the baby's meal, the mother was asked to use the patting robot for up to 10 minutes to burp the baby, and then an interview was conducted regarding the experience of using the patting robot.

The mother wore the sleeve-type patting robot on her left arm while holding the baby with both hands. The participant responded that it was more comfortable to support the baby, as the patting robot allows her to use both arms to hold the baby. This was possible as the robot would be performing the patting motion, compared to when the participant would be supporting the baby with one arm and patting with the other hand. This confirmed the positive effect of using the patting robot in relieving physical burden of caregivers. The participant mentioned, "The patting robot was easy to use and effective for burping." However, the participant pointed out some discomfort from the motion of the motor in the wearable robot. Due to the location of the motor box on the wrist, there was a sensation of weight and movement on the wrist. Furthermore, she added that it was not easy to operate the robot by pressing the button, while holding a baby with both arms. Thus, it can be concluded that there were needs of alleviating the discomfort from the motor location and difficulty of pressing button.

Figure 11. Field trial of the developed robot

DESIGN IMPROVEMENT

To enhance the usability of the patting robot, few improvements were applied. To minimize the discomfort from the weight and motion of the motor, shock absorbing material in the form of a sponge was added on the wrist. Furthermore, the function to use voice commands to turn on/off the robot and switch the modes was added using mobile application.

IMPLICATION

Based on the aforementioned results, this work has implications for future research as follows.

Firstly, this work suggests a new usage of a lightweight wearable robotic forearm, which can be also seen as a supernumerary robotic limb (SRL), while previous works on SRL were mainly focused on industrial usages [7], [10] and compensation for motor-impaired person [5], [6]. The patting robot can be seen as a type of SRL with a main function, patting, as it adds a degree of freedom to the caregiver's arm.

Additionally, this work observed the needs of caregivers during their interaction with robot. As caregivers are fully occupied when holding a baby, robots should have an interaction method without physical manipulation such as voice command or autonomy.

FUTURE STUDY

The field trial highlighted the need for improvements in comfort, for both caregiver and baby.

First, the robot should evolve to be infant-friendly by adapting parent-like features. According to the previous study, it was shown that applying physiological features such as heartbeat-like vibrations to an object provided comfort to infants [2]. Elements that make the baby feel like they are with their mother, such as a temperature similar to body temperature and a recorded voice of the mother can be added for calming babies.

Lastly, developing intelligent systems for predicting the state of the baby is expected to provide advanced comfort to babies. By utilizing artificial intelligence on the robot, it could be used as an autonomous agent providing suitable modes for the babies.

CONCLUSION

In summary, the design and development of the patting robot presented in this research provides a promising solution to the challenges faced by caregivers. The incorporation of user requirements, as identified through the online survey and interview, and the focus on enhancing usability allowed the development of a robot that meets the specific needs of infants and caregivers. This research contributes to the advancement of assistive technology in the field of infant care and holds potential for positively impacting the lives of caregivers and infants.

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