Using an Ecological Framework to Design Mobile Technologies for Pediatric Asthma Management
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ABSTRACT
Mobile technologies, due to their ubiquitous nature, play an important role in supporting health care. However, it is not easy to design useful integrated mobile services without a systematic understanding of users, and this is especially true for children. Therefore, we propose a new theoretical perspective for generating design concepts in the early stage of the design process. Our ecological model is based on Ecological Systems Theory which approaches development in terms of the child’s relationships and environmental context. It leverages the fact that mobile technologies are deeply involved with users’ circumstances. We argue that the ecological model can provide a heuristic to help researchers understand users’ needs in context and generate concepts logically and creatively. Here we explore pediatric asthma management as a case study for this model. Finally, five promising mobile technology concepts are provided as examples for further development of mobile technologies related to pediatric asthma management.

Categories and Subject Descriptors
H.5.2. [Information Systems]: User Interfaces – User-centered design; H.5.3. [Information System]: Group and Organization Interfaces – Theory and model

General Terms
Design, Human Factors, Theory

Keywords
Mobile technologies, Health, Environment, Design, Psychology, Pediatric asthma management

1. INTRODUCTION
Developing technologies for improvement of our everyday lives is deeply intertwined with the issue of health and environment. As a result, the trend has been that various disciplines such as public health, biomedical engineering, environmental engineering, health science, and medicine have focused on integrated systems related to web-based and mobile technologies [10, 6]. In particular, since mobile technologies are ubiquitous, they have become common and essential tools to communicate with other people and interact with products in managing our everyday lives. For example, SMS or automatic voice message services are provided by many hospitals to remind patients of a doctor’s appointment, and electronic personal health record systems are provided for user centered healthcare services [4]. However, while mobile technologies are getting more popular in our lives, and many researchers are developing mobile applications, there is a gap between mobile technology research and practical usage of the technologies for actual users in terms of readiness to access technologies. This can be especially true when the intended user is a child.

To address this issue, we propose an ecological theoretical framework for understanding users needs based on their environmental and social experience. We use pediatric asthma management to provide concrete application examples. Asthma is a chronic respiratory disease that causes coughing, wheezing, chest tightness and breathing difficulties. In United States, there are more than 22.2 million people with asthma and 6.5 million of them are children. In fact, asthma is the most common chronic disease of childhood and has high medical costs due to different medicines, medical devices, hospitalization, emergency room visits, education, and environment management. There are various asthma triggers from physical activities to environmental or emotional conditions [18]. A host of mobile technologies have been developed for asthma management. However, there has been little attention paid to integrating a holistic approach to understanding it. The need for such an approach is especially pressing when we consider the case of children with asthma, since their health is tied to their relationship with their parents, other caregivers, peers, and healthcare providers. Moreover, the environment both at home and beyond greatly affects their health.

In this paper, we first describe related work. We then explore the traditional process that researchers engage in when they consider new technology for pediatric asthma management. Next, we introduce the Ecological Systems Theory [3] and propose the ecological model. We suggest that this model takes into account many more factors than the traditional design paradigm and that it can lead to new insights for developing mobile technologies. We then provide examples for pediatric asthma management.

2. RELATED WORK
Many studies have explored the medical and psychological aspects of asthma management, and there are a number of relevant technologies from conventional applications to GPS. We found two major themes in the asthma management literature:
Asthma monitoring and information transfer: In chronic disease management, continuous monitoring of healthcare status and regular checkup reminders are major technological solutions. The Peak Flow Meter (PFM) is an important tool that asthmatics use to monitor the current status of their lung health. Based on PFM results, parents can decide what the appropriate course of action is for a given day. Interestingly, research on PFM has focused on their cost effectiveness and reliability [8, 11] rather than how to make them easier for children to utilize.

On the information transfer side, there are several technological studies such as one that used SMS queries to get asthma diary entries and one that was a home automated telemanagement system [1, 7]. Facilitating communication between children, parents, and healthcare providers is important with making sure that the asthma symptom reporting is essential for adequate management [13].

Environmental intervention: While the previous studies were centered on individuals, these set of studies were centered on environmental factors (such as air quality). They also include a ubiquitous warning system using a GPS navigation, a community-driven monitoring system, and vest-based sensors that measure air pollutants in an integrated data mining system [5, 14, 20].

3. MOTIVATION
Designing relevant technological solutions requires that researchers understand the recent literature and existing technologies. These solutions must be focused on users' needs and how users interact in the environment. The latter is an important consideration in pediatric asthma management because physical factors can trigger asthma attacks.

Recent trends on converging paradigms encourage us to consider the interfaces in environmental and social system as a way of improving the quality of public health [16, 17]. With this in mind, we consider Urie Bronfenbrenner’s Ecological System Theory and its five interactive levels. It highlights the child’s social and cultural context and her interactions with her surroundings [3]. The Microsystem embodies the child’s direct experience. This has been the focus of most research in asthma management. The Exosystem shows the relation between Microsystems, for example, how a child’s asthma status has influence on her school activities. Social factors indirectly related to the child are part of the Exosystem. The most far removed influence in the child’s life is the Macrosystem, but it can still have profound effects on the child. This might include EPA regulations concerning emission levels. Finally, since asthma is a chronic disease, it is important to manage children’s asthma symptoms over time, and this relates to the Chronosystem in Bronfenbrenner’s updated ecological model (Table 1).

Table 1. Applying Bronfenbrenner’s Ecological Systems Theory to pediatric asthma

<table>
<thead>
<tr>
<th>Levels</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microsystem</td>
<td>Child’s immediate environment: Family, School, Hospital (Individual entity)</td>
</tr>
<tr>
<td>Mesosystem</td>
<td>Connections between immediate environment: Family to hospital, Hospital to School (Relation between Microsystems)</td>
</tr>
<tr>
<td>Exosystem</td>
<td>External environment setting: Parents’ workplace, Activities of the local hospital services (indirect relation in Microsystems and Mesosystems)</td>
</tr>
<tr>
<td>Macrosystem</td>
<td>Larger cultural context: Culture, Ideology, Healthcare policy, Health insurance status</td>
</tr>
<tr>
<td>Chronosystem</td>
<td>Change over time: Implications for managing healthcare over time</td>
</tr>
</tbody>
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We propose that Ecological Systems Theory can provide a helpful model to develop mobile technologies for children with asthma. Moreover, when we compare the territory diagram (Figure 1) with the ecological model (Table 1), we see that the territory diagram neglects the role of culture (i.e., the Macrosystem) and how the passage of time affects pediatric asthma management (i.e., the Chronosystem).

Figure 1. Initial diagram for understanding the physical environment of children with asthma

Figure 1 shows an initial conceptual diagram of the child’s surroundings. However, this diagram neglects the fact that when children grow up (mentally and physically), they interact with people, products, and the environment in various ways.
natural relationships and frequency of interaction. We can see that
the five levels refer to the individual, family, local community,
society, and the environment. The order of these five layers
indicates how extended relationship ranges from an individual in
close and direct environment to social groups in indirect context.
It is important to note that the ecological approach is socio-
culturally sensitive in that not all children and their environments
are perceived to be the same (nor the interaction between the
layers). This is important when we consider the negative effects
of living in an urban or poor setting for asthma management.
Thus, it reminds the designer to consider the user and the context
in which the technologies may be used.

![Figure 2. Ecological Model for designing mobile
technologies for children with asthma](image)

In Figure 2, the center of an ecological framework is the child (or
children) with asthma. This level includes the severity of their
asthma. Here children may consider themselves as asthmatics and
recognize the necessity to manage their asthma status. Children
may have products such as an inhaler or a PFM, but they are still
under the supervision of care providers. In the second level, there
is the family in the home environment. Most parents support their
children’s physical and emotional wellbeing and desire to take
care of their children’s health. Parents are also largely responsible
for monitoring their child’s asthma status. This may include
keeping track of their child’s lung capacity on a daily basis and
making sure that their prescriptions are filled, that the children
know where their inhalers are, and how to use them. However,
parents may also be responsible for environmental (second-hand
smoke) or emotional conditions (familial discord) that can
increase the number of asthma attacks and severity of asthma
symptoms [19]. On the other hand, the third level consists of local
institutions such as hospitals and schools. At this level, children
interact with teachers, friends, and healthcare providers. They
have routines in different contexts, which may include meeting
with healthcare providers for regular checkups or emergency
visits to the hospital. They also spend some time with peers inside
or outside of the home. The fourth level is similar to the
Macrosystem (see Table 1). It also takes into consideration of
economic trends in society. In this level, children with asthma are
affected by current government’s healthcare policy, public health
status, and parents’ economic levels. Environment is in the fifth
level, and it includes natural and artificial environments including
outdoor and indoor air quality. In addition, a broad range of social
and cultural context is in the fifth level.

Overall, each layer includes physical, social, and cultural
contexts. The main advantage of using this framework for
children with asthma is the fact that each layer interplays with the
others. This framework capitalizes on the dynamically distributed
nature of mobile technologies and facilitates the understanding of
design opportunities for pediatric asthma management.

5. CONCEPT GENERATION

With the understanding of users’ context and viewing the related
works in the framework, we generated five application concepts
for asthma management through mobile technologies. These are
presented in the context of the two themes identified in section 2
and prefaced by general design implications. Each concept needs
to be evaluated by actual users before being implemented.

General Design Implications

Mobile technologies are uniquely suited to deliver appropriate
contents to children and their parents at the various levels of the
ecological approach. This can happen through automatic filtering
and delivery of contents based on a crossing of context of
individuals with their asthma status in the various layers. For
example, automatic text messages of air quality information could
be delivered based on where the child is likely to be during the
week (i.e., her school’s zip/postal code). This could also be
synchronized to the child’s schedule such that on days when she
has soccer practice the information could be sent to her coach. In
addition, relevant pollution index on the weekends could be based
on the parent’s cell phone GPS. Further, GPS and zip/postal codes
can be a correlate to economic and educational status and suggest
individualized information. For example, a tip of the day for
controlling environmental triggers could be different for
individuals living in suburban or urban areas.

Asthma monitoring and information transfer:

- Fun interactive wrist watch game (child level in the
  framework): In order to help children measure the maximum
  speed of expiration or practice breathing exercises, an interactive
game with enjoyable user interfaces can be developed. It can have
interesting metaphors such as pinwheels or candles to keep the
child engaged. The watch is unobtrusive and useful for reminding
the child to take regular measurements.

- Converged smart phone (children and community levels in the
  framework): All-in-one smart phone contains four major
functions: peak flow meter data entry, inhaler usage log, asthma
diary, and test message feedback system. People with asthma can
directly log their peak flow values on the phone and log how
many times they have used an inhaler. This information could be
directly sent to their primary health providers and would allow for
more accurate care (based on timely data). In addition, the
physician could send text messages with relevant information
based on data entry provided by the child.
● Information transfer of personal health record (family and community level in the framework): In case of an emergency hospital visit, all healthcare information related to recent asthma management (i.e., type of reliever or rescue medication) could be easily and quickly retrieved from the patient’s mobile phone to a central information platform via Bluetooth devices.

For environmental intervention:
● Outdoor activity support (children, community, and environment levels in the framework): A mobile phone sends an air quality warning message if children with asthma enter an area with poor air quality. In addition, the phone gives recommendations about good alternative places to move based on current user location. This recommendation service encourages users to continue outdoor activities. An alternative model for low end cell phones would allow the user to simply send a text message with their zip code. They would then get back a text message with data concerning air quality in that area.
● Indoor air quality management (family and environment levels in the ecological framework): People spend 90% of their lives in indoor environments. A mobile device or potable sensor could be set to automatically detect poor air quality and give suggestions as to how to improve it such as opening the window, thermal control, or operating ventilation system.

6. CONCLUSION
The purpose of this work is to introduce a new theoretical model for generating concepts in the early stage of the design process. We suggest that design and psychological perspectives can contribute to Mobile HCI research in terms of generating concepts based on both users’ physical and socio-cultural environments. In our view, the ecological model is well suited to leverage the strength of mobile technology, namely, that they are naturally ubiquitous and deeply involved with users’ circumstances. Our five technology concepts show that the ecological approach can help technologists design better products by encouraging them to view the impact that their technology has at various levels. While we have used pediatric asthma as our case study, we believe that the value of the ecological model extends beyond the health domain and can lead to highly improved and integrated mobile technology design for users of all ages.

7. ACKNOWLEDGMENTS
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8. REFERENCES