# Enhancing Asthma Control through IT: Design, Implementation and Planned Evaluation of the Mobile Asthma Companion

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**Abstract.** The personal and financial burden of asthma highly depends on a patient's disease self-management skill. Scalable mHealth apps, designed to empower patients, have the potential to play a crucial role in asthma disease management. However, the actual clinical efficacy of mHealth asthma apps is poorly understood due to the lack of both methodologically sound research and accessible evidence-based apps. We therefore apply design science with the goal to design, implement and evaluate a mHealth app for people with asthma, the Mobile Asthma Companion (MAC). The current prototype of MAC delivers health literacy knowledge triggered by nocturnal cough rates. We conclude by proposing a randomized controlled trial to test the efficacy of our prototype.

**Keywords:** Asthma Control, mHealth Apps, Asthma Disease Management

## 1 Introduction

Asthma, a chronic airway disease, ranks among the most prevalent noncommunicable diseases with an estimated 334 million people suffering from it globally. The yearly costs of asthma are estimated to be around 56 billion dollars in the US alone [1].

When patients are not able to control their asthma symptoms, it heavily impacts their quality of life and may even have life threatening consequences. However, successful maintenance of well-controlled asthma enables a patient to live with almost unimpaired quality of life [2]. Apart from the personal implications for patients, the degree of asthma (symptom) control profoundly affects the healthcare system from an economic point of view: A patient with uncontrolled asthma symptoms causes approximately 4.5 times the costs of a patient with well-controlled asthma, which is amplified by the fact that more than half of all asthmatics suffer from uncontrolled asthma [3].

In order to achieve asthma control, clinical guidelines emphasize the importance of an empowered patient with disease management skills [4]. Here is where mobile health applications (mHealth apps) can potentially decrease the personal and financial burden of asthma: in contrast to traditional asthma disease management programs, which

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consist of multiple weekly face-to-face sessions guided by healthcare professionals, scalable mHealth apps can empower patients cost effectively by delivering disease management interventions to their smartphones as part of daily routine. Moreover, mHealth apps may exploit built-in smartphone sensors to objectively monitor disease symptoms and as a consequence identify windows of opportunities in which patients are particularly receptive and susceptible to respond to such interventions [5].

However, to prove the potential of mHealth asthma apps, clinical efficacy needs to be demonstrated in relation to the therapeutic gold standard (i.e. traditional asthma management programs). Systematic reviews in this field, which have indicated first promising results regarding the efficacy of mHealth asthma apps, strongly advocate for further research due to the low methodological quality of the available studies [6] and the low average quality of mHealth asthma apps, which often fail to consider clinical guidelines for asthma treatment [7].

We address this research gap by designing, implementing and evaluating our own mHealth asthma app, which is based on design science research [8]. We refer to our app as the Mobile Asthma Companion (MAC). Currently, the prototype consists of a disease management intervention focused on improving health literacy, which is triggered by, among others, automated cough detection.

The remainder of this paper is structured as follows: after introducing the applied justificatory knowledge and deriving the design requirements, we will describe the implementation of our MAC prototype. We conclude this paper by proposing an experimental study design, which will evaluate MAC's efficacy.

## 2 Conceptual Foundation and Design Requirements

Patients are responding particularly well to interventions when they are delivered just in time, or in other words, in the exact moment when patients demand them [5]. A state of demand is characterized, among others, by experiencing adverse health effects. For asthma, we argue that partially controlled or uncontrolled asthma indicate such a state of vulnerability. Thus, nocturnal cough rate, a valid marker for asthma control [9], could serve as an intervention trigger. We already delivered the proof of concept that cough can be monitored fully automated and accurately by means of a smartphone [10].

*Requirement 1: The design artifact has to be able to monitor the nocturnal cough rate fully automated and use it to trigger just-in-time interventions.*

Health literacy, or more specifically asthma education, is a key aspect of asthma disease management [4]. Research has shown that health literacy interventions are clinically efficacious in general and for asthma in specific [11].

For asthma health literacy interventions, first evidence was provided that an asthma mHealth app is able to improve asthma control significantly over the course of five weeks [12]. However, the single-arm study design and the monetary incentives for continuous study participation limit the explanatory power of the study results and the scalability of such an app. Therefore, in order to enable scalability, a user's engagement

needs to be ensured without relying on financial incentives. Gamification features like point systems, badges or achievements are promising options in this regard [13].

*Requirement 2: The design artifact has to deliver a health literacy intervention including educational asthma content implemented through gamification features.*

## 3 Implementation

We implement our MAC prototype as a mobile application for Android smartphones based on the MobileCoach (MC) platform [14]. MC is an established digital health intervention platform, which provides the necessary user privacy and data security features when working with sensitive patient data. Currently, the MC based prototype offers two main functionalities: a chat and an alarm clock.

The requirement of automated nocturnal cough detection is met by expanding our prior work on cough detection [10] in order to detect cough rate overnight. The detection mode is enabled by setting an alarm, which defines a time frame from the moment the alarm is set until it rings. During this period, the detection algorithm operates in the background, automatically detecting and counting coughs.

Users will be instructed to set the MAC alarm directly before going to sleep and to place the smartphone near the bed (e.g. on a nightstand). Based on detected cough rates per night, users will be prompted to interact with MAC through push notifications. The likelihood of receiving such a notification is a function of the standardized cough rate within a user. In order to limit the burden of intervention, users can only receive up to two notifications per day. However, notifications will be sent at least twice a week to users with a particularly low cough rate who otherwise might not receive any notifications at all. Additionally, MAC is also accessible at will.

In order to address the second design requirement, MAC will interact with the user via a chat interface and provide educational material related to asthma health literacy topics in form of knowledge nuggets (e.g. video clips and quiz questions). This chat functionality is enabled by extending the current MC platform with the possibility to communicate with the user via an internet based chat client mobile application instead of a SMS based communication. Furthermore, the educational materials are fully congruent with the content of current disease management programs. The MC rule-based engine triggers the delivery of knowledge nuggets based on the nocturnal cough rate of the user. Finally, gamification features are implemented through badges which users can earn by viewing educational material and answering quiz questions correctly.

## 4 Study Design

We will evaluate the efficacy of our MAC prototype in a randomized control trial, the methodological gold standard for investigating efficacy. Adult asthmatics will be randomly assigned to two different groups: The control group will participate in a traditional asthma disease management program offered by local healthcare entities [4] whereas the experimental group will interact with MAC. The primary endpoint in this

study is asthma control on a monthly basis. Asthma control is measured through a standardized test [15]. Study duration will be three months to account for lagged effects of the intervention on asthma control. Ideally, our study will show that MAC will perform at least as good as the control group in the measurement of the primary endpoint upon study completion (i.e. non-inferiority trial). We will consider seasonal differences in asthma by measuring asthma control additionally at study initiation. A follow-up measurement after three months will account for long-term effects.

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