

Addressing Medication Nonadherence Using Mobile Phone-Based Tailored Messaging

by

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A dissertation submitted in partial fulfillment  
of the requirements for the degree of  
Doctor of Philosophy  
(Social and Administrative Sciences)  
in the University of Michigan  
2014

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## **DEDICATION**

To the memory of my father, David W. Gatwood

## ACKNOWLEDGMENTS

While this project has spanned many years, this achievement has been a lifetime in the making. From an early age, my parents instilled a deep sense of dedication to studying hard with the message that such devotion would lead to success. Without a doubt, this value and their oversight led me through every endeavor and I would not be where I am today without their guidance. I am thankful for their pushing me to strive to be better in everything, even at times when I was too young to appreciate it.

Over the years there have been a collection of other people, including teachers, mentors, and coaches, that buoyed the message of continuously pushing harder and higher. I am most grateful for the efforts of Carole Laasch, William Hill, Margaret Graber, Joe Myers, J. Matthew Baughan, and Todd Soehner, all of who were overwhelmingly supportive in their own way while also never allowing me to settle for less than my best effort. They likely are unaware of the extent of their impact on my career as well as the appreciation I have for each of them but their lessons have resonated throughout the years and been ingrained in all that I have and continue to do.

While at Michigan several people provided notable assistance and their efforts deserve to be recognized. From my first week, Dean Frank Ascione served as a mentor and encouraged me to remain open-minded to how my research may take shape and to the avenue by which I could make an impact. The inspiration for this project came out of a conversation with Dean Nancy Janz of the School of Public Health who felt a tailored technique could lead to improved medication adherence. At the time it seemed like wishful thinking but I am fortunate that this brainstorming became reality. As this idea developed, I leaned on the insight from Dr. Rachel

Davis to further explore ways to bring this idea to fruition. Certainly, I am thankful for their respective efforts and hope to continue to learn from their perspectives.

Once this dissertation came to be, it was guided by an excellent committee that came together and made the process much easier on me. I am grateful for the logistical and communicative insight provided by Drs. John Piette and Larry An, the latter also offering the services and expertise of the Center for Health Communication Research which was invaluable to our methods. Their respective expertise created a more impactful project and one I hope helps them both in their current and future endeavors. Additionally, Dr. Steve Erickson has been a colleague and mentor since my first year at Michigan and I wouldn't have done this project without his involvement. Specific to this work, he offered his clinical expertise during the message drafting process, something I could not have operated without, and was instrumental in my progression to candidacy status. It was a pleasure working with him on this and previous projects, and I look forward to remaining colleagues and research partners for years to come.

Of course, I am deeply indebted to the guidance and support received from my co-chairs: Drs. Rajesh Balkrishnan and Karen Farris. I may not have made my way to Michigan if it weren't for Raj and he made my matriculation all the more easy. His mentorship over the years has led me to this point and he has always made sure to check in on my needs, both professionally and personally, in a respectful manner. I appreciate the style by which he allowed me to pursue personal interests for this work while also providing pointed advice along the way. We have developed a respectful working relationship and friendship, and I look forward to continuing that in the years ahead.

Since joining our faculty, Dr. Karen Farris has been a great source of support and guidance both for my research and career. Her networking and belief in my abilities provided the

foundation for my ideas to become my dissertation and I am truly lucky to have had the opportunity to develop and run my ideal project. Karen has without a doubt become a lifelong colleague, mentor, and friend and there is much well beyond this research that would not have been possible without her involvement and insight. Her guidance has truly been invaluable and I will miss learning from her during our regular meetings. The manner by which she provided mentorship is something I hope to emulate throughout my career and I appreciate how she balanced providing direction with respect for my autonomy. It has been a joy to work with her on this and other projects and I look forward to continuing to collaborate and making her proud throughout my career.

I would be remiss to not acknowledge the contributions of several bodies without which this research would not have been possible. First, the Rackham Graduate School kindly supplied grant funds so that this project could get up and running, and over the years they have made several conference trips possible. Secondly, this work was supported by a federal grant from the Agency for Healthcare Quality and Research and their contribution provided the lifeblood for all of my ideas. Also, the American Foundation for Pharmaceutical Education kindly awarded me a fellowship over two years of my time at Michigan in order to further support my efforts. I was humbled to receive these funds and grateful that these three bodies saw the potential in me and in my work. Additionally, Charles Mollien of Priority Health made it possible for us to obtain the necessary pharmacy claims, data without which we would not have been able to assess the impact of this study. His participation and cooperation were greatly appreciated.

Certainly, this project would never have been possible without the participation of subjects from the Muskegon, Michigan area. As part of a series of investigations, this study sought to positively contribute to the health of adults with diabetes living in the Muskegon area.

We hope that the approach demonstrated herein will benefit even more patients in the future and that those who participated are better off for having participated. Thank you to all of the subjects for your time, input, and willingness to participate. The collection of projects being conducted in the area was made possible by the effort and interest shown by Jason Barnum. He approached us in the hopes of collaborating and it has been a pleasure working with him and helping make his wishes become reality. Thank you, Jason.

Finally, and certainly not least, I am indebted to the love and support of Katie Kaminski who has been by my side since this project began. She has been an ear for frustration, been a constant source of support, and even donated much of her own time to assist me in areas of this research. She inspires me on a daily basis, not only by her work ethic and dedication to craft, but by the aspirations she has for both of us in the years ahead. Thank you for your patience and understanding over the past two years and know that I love you all the more for having been with me on this journey.

## TABLE OF CONTENTS

DEDICATION .....	ii
ACKNOWLEDGMENTS .....	iii
LIST OF TABLES .....	x
LIST OF FIGURES .....	xi
LIST OF APPENDICES .....	xii
LIST OF ACRONYMS .....	xiii
ABSTRACT.....	xiv
CHAPTER I. LITERATURE REVIEW and BACKGROUND.....	1
Medication Adherence .....	2
Defining Adherence.....	2
Adherence Landscape.....	5
Contributing Factors.....	8
Socioeconomic Factors.....	9
Condition and Medication-specific Issues.....	9
System-level Effects .....	10
Patient Behaviors and Psychological Status.....	11
Factors Influencing Adherence to Diabetes Medications.....	12
Interventions to Address Medication Nonadherence in Diabetes .....	12
Tailoring and Behavior Change .....	19
Elaboration Likelihood Model.....	20
Tailoring Process .....	23
Tailoring Interventions .....	26
Tailoring and Medication Adherence .....	28
Mobile Health and Behavior Change .....	35
Growth of Mobile Health .....	35
Applications to Behavioral Interventions .....	36



Applications to Medication Adherence .....	39
Next Steps .....	47
Gaps and Opportunities .....	47
Theoretical Considerations .....	50
Technology Acceptance .....	51
Health Belief Model .....	52
Self-Determination Theory .....	56
Conceptual Framework.....	61
Aims and Hypotheses .....	63
References .....	65
<b>CHAPTER II. PAPER 1: DEVELOPMENT AND DELIVERY OF TAILORED TEXT</b>	
MESSAGES.....	75
Abstract .....	75
Background .....	76
Methods.....	79
Problem Identification .....	79
Assessment Tool Creation .....	81
Message Creation .....	86
Message Storage .....	88
Tailoring Algorithm.....	89
Discussion .....	91
References .....	95
<b>CHAPTER III. PAPER 2: USE OF MOBILE PHONES AND PERSPECTIVES ON</b>	
<b>TAILORED TEXT MESSAGES IN ADULTS WITH DIABETES.....</b>	<b>106</b>
Abstract .....	106
Introduction.....	107
Methods.....	109
Design .....	109
Subjects.....	110
Data Collection .....	111
Analysis .....	112

Results .....	113
Subject and Mobile Phone Characteristics .....	113
Technology Acceptance .....	114
Perspectives on Treatment and Condition-Tailored Messages.....	116
Discussion .....	118
Conclusions .....	121
References .....	123
<b>CHAPTER IV. PAPER 3: THE IMPACT OF TAILORED TEXT MESSAGES ON HEALTH BELIEFS AND MEDICATION ADHERENCE IN ADULTS WITH DIABETES.....</b>	
Abstract .....	128
Introduction .....	129
Methods.....	131
Results .....	136
Discussion .....	140
Acknowledgments.....	144
References .....	145
<b>CHAPTER V.DISCUSSION .....</b>	
Summary of Study Aims .....	155
Limitations .....	163
Future Directions.....	165
Conclusions .....	168
References .....	170
APPENDICES .....	171

## LIST OF TABLES

### TABLE

Table 1.1 Interventions to Improve Medication Adherence in Patients with Diabetes .....	15
Table 1.2 Tailoring Interventions to Improve Medication Adherence .....	32
Table 1.3 Mobile Text Messaging Interventions to Improve Medication Adherence .....	45
Table 2.1 Focus Group Subject Characteristics .....	99
Table 2.2 Message Themes .....	100
Table 3.1 Tailored Messaging Cohort Demographics .....	125
Table 3.2 Technology Acceptance by Category .....	126
Table 4.1. Study Population Characteristics .....	150
Table 4.2. Baseline Medication Use .....	151
Table 4.3. Subject Health Beliefs and Attitudes .....	152

## LIST OF FIGURES

### FIGURE

Figure 1.1 Elaboration Likelihood Model .....	21
Figure 1.2 Technology Acceptance Model.....	52
Figure 1.3 The Health Belief Model.....	54
Figure 1.4 Self-Determination Theory.....	57
Figure 1.5 Conceptual Framework .....	62
Figure 2.1 Kreuter’s Five-Step Tailoring Process .....	101
Figure 2.2 Framework for Message Development .....	102
Figure 2.3 Tailoring Process and Algorithm.....	103
Figure 3.1 Technology Acceptance Model.....	127
Figure 4.1. Subject Recruitment and Enrollment.....	153
Figure 4.2. Intervention Impact on Medication Adherence .....	154

## LIST OF APPENDICES

### APPENDIX

A. Tailoring Survey Instrument .....	171
B. Endpoint Survey Technology Acceptance Model Items .....	177
C. Mobile Phone Use Survey Items .....	178
D. Focus Group Questions .....	179
E. Post-Intervention Interview Guide .....	180
F. Focus Group Demographic Survey .....	181
G. Focus Group Guide .....	182
H. Theory-Driven Message Library.....	183
I. IRB Documentation .....	193

## LIST OF ACRONYMS

A1c	Hemoglobin A1c
AIDS	Acquired Immunodeficiency Syndrome
CAT	Cognitive Adaptation Training
CBST	Cognitive-Behavioral Skills Training
CCM	Chronic Care Model
ED	Emergency Department
ELM	Elaboration Likelihood Model
FAME	Federal Study of Adherence to Medications in the Elderly
HBM	Health Belief Model
HIV	Human Immunodeficiency Virus
HMO	Health Maintenance Organization
IM	Internal Medicine
IMB	Information-Motivation-Behavioral
MEMS	Medication Event Monitoring System
mHealth	Mobile Health
MI	Motivational Interviewing
MPR	Medication Possession Ratio
MTM	Medication Therapy Management
NS	Non-significant
PCS	Perceived Competence Scale
PDC	Proportion of Days Covered
SCT	Social Cognitive Theory
SDT	Self-Determination Theory
TAM	Technology Acceptance Model
TSRQ	Treatment Self-Regulation Questionnaire
TTM	Trans-Theoretical Model
UK	United Kingdom
VA	Veterans Affairs

## ABSTRACT

While numerous treatments exist to manage diabetes, adherence to guideline-recommended medications remains suboptimal. Both tailoring health messages and text messaging have been observed to improve medication adherence, but analysis of their combined effect is limited. This study aimed to (1) construct a library of and successfully deliver condition and treatment-related tailored text messages to influence medication-taking behavior among adults with diabetes and (2) assess the effect of tailored text messages on diabetes-related health beliefs, technology acceptance, and diabetes medication adherence between patients receiving tailored text messages and standard care alone.

Adults with uncontrolled diabetes were recruited from a western Michigan health system and randomized into two study arms where subjects received either a daily tailored text message or standard care for 90 days. Self-Determination Theory and the Health Belief Model guided message development and a library of 168 theory-driven and 128 medication-specific tailored messages were developed and formatted for automated delivery to mobile phones. An algorithm was applied to determine the order and timing of messages with the aim of progressively influencing diabetes-related beliefs affecting adherence to medication. Baseline responses to a survey instrument were used to establish the series of tailored messages for each participant. Changes from baseline in mean responses to seven theory-driven items and medication adherence were evaluated using endpoint surveys and pharmacy claims data, respectively. Four survey items captured technology acceptance and personal interviews were conducted after the intervention.

A total of 48 subjects were randomized into two cohorts. The receipt of a daily tailored text message was well accepted by intervention subjects and most were interested in continuing

to receive similar messages. Adjusted analysis indicated there were no statistically significant differences between groups in the seven theoretical concepts resulting from the intervention; however, changes for most constructs were in the desired direction for intervention subjects. Similarly, no statistically significant changes in adherence to diabetes medications were observed between or among cohorts after the three-month intervention, and mean adherence values declined over nine months.

The tailoring of diabetes-specific text messages remains an area of opportunity to improve medication adherence and provide motivation to adults with diabetes but larger studies are needed to fully understand their effectiveness.



## **CHAPTER I. LITERATURE REVIEW AND BACKGROUND**

The former United States Surgeon General, Dr. C. Everett Koop, once stated that, “Drugs don’t work in patients that don’t take them.” Although obvious in its observation, this statement sheds light on an issue that has challenged patients and providers alike: a limit of medicinal therapy is the extent by which patients follow what was prescribed. Years later, medication nonadherence remains a prevalent issue, impacting the effectiveness of a variety of medications, both for acute and chronic use, in spite of the mounting evidence connecting high rates of adherence to improved outcomes.<sup>1</sup>

This chapter begins by providing an overview of medication adherence with a specific focus on contributing factors and the extent of this issue in patients with diabetes. Next, it examines what has been attempted by researchers to address nonadherence by describing interventions focused on diabetes, how tailoring has been applied to improve medication use, and how mobile devices have been leveraged to date to improve adherence across conditions. Finally, the need for an intervention using tailoring and mobile communication is synthesized from what is currently understood, the theoretical foundations upon which this study were designed are outlined, and the aims and related hypotheses are described.

## Medication Adherence

### Defining Adherence

Adherence is generally defined as the extent to which patients take medications as prescribed by their health care providers.<sup>2</sup> At one point, the term ‘compliance’ was used to describe this behavior but has been replaced by ‘adherence’, a concept implying a more collaborative process and one that attempts to move away from the stigmatization of behavior as deviant or placing blame on the patient.<sup>3</sup> This transition further suggests a communicative process between providers and patients, stressing agreement on the treatment approach that places the patient at the center of the plan.

The extent of adherence is generally reported in a fashion indicative of the metric used to capture the behavior, meaning our interpretation of adherence may change based on how we measure medication use; however, we typically see adherence described on a continuum from 0 to 100 percent or dichotomized as adherent or not. The latter tends to provoke the most controversy since no gold standard exists to define the point at which one is definitively considered adherent, although a generally accepted value is 80 percent.<sup>4</sup> This value has repeatedly been applied in studies in order to compare outcomes between patients who are categorized as either high or low adherers. Multiple studies have supported this delineation by demonstrating a connection between lower adherence to chronic disease treatment and poorer health outcomes.<sup>5-8</sup>

Properly defining what it means to be adherent, however, must be further differentiated by the stage of treatment in order to be fully understood as it encompasses a range of medication-taking behaviors over time. This process begins at the point of prescription where the health care

provider and patient initially decide upon a particular avenue of treatment for one or more conditions. 'Primary nonadherence' is then a patient's delay or failure to fill a prescription when first written.<sup>9</sup> Relatively little is known about the extent of this problem as significant investigations of this portion of adherence are lacking. A major hindrance to studying primary non-adherence is the difficulty associated with tracking initial fill rates as well as the historical methods by which prescriptions have been written. The recent increase in the use of electronic prescribing (e-prescribing), however, has improved the availability of usable data. A recent database analysis of e-prescribing in a community setting found that 28% of prescriptions for newly prescribed medications were never filled.<sup>10</sup> Other studies have employed survey methods in an attempt to capture this behavior with non-adherence estimates ranging from 4% to 31%.<sup>9,11,12</sup> Regardless of the methods employed, results consistently remind the health community that the initiation of medicinal treatment remains problematic, placing patients whose need for therapy has been identified at risk of further complications by foregoing treatment.

Once the prescription has been received the issue of adherence turns to the regular medication-taking behaviors of patients as instructed by their provider. This includes taking the medication(s) as scheduled, as directed, at the correct dosage, and while avoiding potentially dangerous concomitant drug usage. Arguably, this is the central element of treatment adherence- the repeated and direct taking of medication. While the proper execution of such a prescribed procedure in the course of treating chronic conditions may be done countless times, this behavior is also the most difficult to accurately measure- even direct methods, such as patient observation and blood levels can be misleading. Truly reliable methods of capturing when and how patients take individual medications, and how closely that resembles the initial directions, have proven challenging: both remote monitoring and self-report approaches have been employed, but either

lack clear precision in capturing medication-taking behaviors or are significantly biased.<sup>4</sup> Self-reported estimates rely on carefully crafted survey instruments, diaries, or pill counts to evaluate or record behavior, all of which depend heavily on patient recall and honesty in reporting. The use of diaries or requesting pill counts can be problematic since they can be easily altered but instruments, such as the Morisky Scale and the Adherence Estimator, have proven to be reliable mechanisms of measuring or predicting medication use.<sup>13,14</sup> However, while convenient and economical to implement, such approaches may introduce significant bias to the estimates due to recall and the propensity to report socially acceptable responses.<sup>15</sup>

Alternatively, electronic monitoring of adherence, while precise, is currently prohibitively expensive for widespread use and leaves patients aware that they are being monitored. Additionally, as with retrospective assessment through surveys or pill counts, the actual ingestion of medication cannot be discerned. A recent review of adherence in the past 50 years compared measures of medication-taking behavior and found that a majority of studies employed subjective methods (such as self-report), but, more importantly, that the methods employed to measure adherence can impact the results. The average percent adherent was similar between electronic (69.0) and self-reported (71.8) means; pill counts reported the highest average percent adherent at 85.1%.<sup>16</sup> Considering the inherent flaws of each approach, however, a combination of measures is recommended.

Beyond the regular behavior of taking medication, adherence also encompasses a more global definition of behavior, particularly in chronic disease. Properly addressing chronic disease requires both regular and continued medication delivery; thus, ‘persistence’, or the extent by which a patient remains on therapy over time, is equally important to the treatment process. Refill rates, often provided by pharmacy claims databases, are a commonly used means of

evaluating this ongoing medication-taking behavior, assessing the percentage of days (either as a percent of days covered [PDC] or as a medication possession ratio [MPR]) for which the patient had been provided treatment. Numerous analyses across a variety of chronic conditions have determined that adherence at this level is suboptimal, observing significant stoppages in therapy as early as one to three months post-initiation.<sup>8,17,18,19</sup> Regardless of the point at which medication-taking behavior deviates from what has been prescribed or the means by which this behavior is measured, nonadherence requires significant attention from the healthcare community in order to curb the impact it may have on treatment outcomes. The extent of this issue is outlined in the following section.

### Adherence Landscape

As a whole, adherence is a widespread issue: the World Health Organization has suggested that adherence to medications for chronic conditions averages 50% in developed nations.<sup>20</sup> In the United States, medication nonadherence plagues the healthcare system with avoidable costs and, more importantly, detrimental health outcomes. Recent estimates suggest that medication non-adherence adds \$290 billion in annual avoidable costs and contributes to significant, adverse clinical outcomes, including 10% to 25% of all hospitalizations and nursing home admissions and 125,000 deaths each year.<sup>21,22</sup> A survey conducted by the National Community Pharmacists Association identified the extent of the problem at the patient level, polling specific medication-taking behaviors. Findings indicated that approximately three out of four American consumers reported not taking their prescription drugs, as directed, to some extent; specifically, 31% had not filled a prescription they were given, 29% stopped taking a

medicine before the entire supply had been exhausted, and 49% had forgotten to take at least one dose.<sup>11</sup>

Additionally, estimates of those remaining adherent to long-term medication regimens in the United States has been suggested to range from 17% to 80%.<sup>1</sup> The landscape for adherence in specific chronic diseases is diverse. Estimates suggest that 9% to 47% of patients on therapies to control hypertension are non-adherent, the variation due to the methods employed to measure the behavior- electronic versus self-report.<sup>19</sup> Similarly, across multiple studies, approximately half of patients on lipid-lowering agents were adherent according to generally accepted thresholds.<sup>23</sup> Moreover, adherence to medications prescribed for asthma and osteoporosis have been reported to be 39% and 60%, respectively.<sup>24,25</sup>

The landscape of nonadherence is especially concerning in diabetes. A disease whose prevalence continues to rise at alarming rates, diabetes remains a growing public health threat in the United States.<sup>26</sup> Current estimates suggest the number of Americans diagnosed with diabetes, and the costs required to treat these patients, will more than double in the next 25 years;<sup>27</sup> the cost to treat this condition is already approaching \$200 billion per year.<sup>28</sup> Nonadherence to diabetes medications complicates this economic issue, but, more importantly, places patients with diabetes at an increased risk of detrimental health outcomes.<sup>7</sup>

Numerous investigations have studied the extent of medication nonadherence in diabetic populations throughout the United States, considering how these patients adhere to both oral medications and insulin. A systematic review of studies from 1966-2003 highlighted medication-taking in both of these classes and incorporated both retrospective and prospective analyses. Cramer (2004) found that overall adherence to oral medications ranged from 36% to 93%, for patients completing at least six months of initial therapy, when examined retrospectively.<sup>29</sup>

Moreover, this review observed that adherence to insulin therapy—in patients with type 2 diabetes—was consistently suboptimal, ranging from 62% to 64%.<sup>29</sup> These results highlighted both the wide range of nonadherence rates throughout earlier observations of diabetic medication use as well as the differences in the manner by which patients take different classes of diabetes medications.

A more recent review of studies examining adherence to diabetes medication, spanning investigations from 1990 to mid-year 2007, found similar variability of results. Odegard and Capoccia (2007) reviewed 36 published articles, 28 of which focused on retrospectively or prospectively assessing medication adherence in patients with either type 1 or type 2 diabetes (the remaining studies were active interventions).<sup>30</sup> Adherence rates were found to vary from 31% to 87% in retrospective studies and from 53% to 98% in prospective studies.<sup>30</sup>

Despite the reported range of adherence rates across studies reviewed, average measures of adherence in patients with diabetes have been fairly consistent. Examining studies between 2000 and 2005, Cramer and colleagues (2008) found that average 12-month MPRs were approximately 76% for patients on oral therapy.<sup>23</sup> Similarly, Yeaw and colleagues (2009) reported average 12-month adherence rates of 72% when analyzing oral medication use over a one-year aggregation of health plan claims data.<sup>25</sup> While these reports give us a robust estimate of diabetes medication use, they all share a common theme: adherence to these medications is suboptimal.

Data from multiple studies have suggested that improved medication use in patients with diabetes can be tied to lower levels of circulating blood glucose. Krapek and colleagues (2004) demonstrated a connection between levels of self-reported adherence (4-item Morisky score) and lower hemoglobin A1c for both oral medications and insulin.<sup>31</sup> Similarly, Pladevall and

colleagues (2004) observed that a 10% reduction in adherence led to a 0.14% increase in hemoglobin A1c (A1c).<sup>32</sup> More recently, Rhee and colleagues (2005) found that achieving an adherence level of at least 75% led to a reduction in A1c of at least 1%; a reduction of 0.35% was associated with each increase in adherence of 25%.<sup>33</sup> Differences in resource utilization and healthcare costs have also been tied to varied levels of adherence. Hepke and colleagues (2004) found that higher levels of adherence led to decreased medical costs as well as fewer emergency room visits and inpatient admissions.<sup>34</sup> More recently, Ho and colleagues (2006) observed that patients with diabetes not achieving an adherence level of at least 80% were associated with more hospitalizations and all-cause mortality.<sup>8</sup> Resultantly, more must be done to better understand what leads to nonadherent behavior and how we may better influence medication-taking so that more patients can be put on the path to improved outcomes. Observations from previous studies help us understand what contributes to ongoing medication use and these are outlined below.

## **Contributing Factors**

Beyond describing the prevalence of the issue, research focusing on medication adherence has also extensively studied the individual factors that have a significant impact on this behavior. By and large, adherence has been described as a multifaceted issue where a combination of factors contributes to the ultimate behavior. While varied, these influences may be grouped according to their place within the process of care and the following five sections give an overview of influencers, closing with what has been observed to influence medication-taking in diabetes.



## Socioeconomic Factors

As is the case for access to care and treatment outcomes, disparities due to patient demographics have been found to play a role in medication non-adherence. Over the course of numerous studies a variety of characteristics have been analyzed, most leading to either varied or conflicting results. Traits such as age and ethnicity have included either results of no effects or findings in one direction: older patients<sup>35-37</sup> and Whites<sup>38,39</sup> tended to have improved adherence compared to younger or minority patients, respectively, if a significant effect was observed. Mixed findings have been reported for a number of characteristics, including educational-level,<sup>38,40,41</sup> gender,<sup>35,42,43</sup> and marital status,<sup>37,44,45</sup> suggesting that the impact of these factors is yet conclusively undetermined. Several socioeconomic factors, however, have been found to consistently affect adherence to medication. Over multiple studies, patients with health insurance as well as those with an established support structure have been connected with improved medication adherence.<sup>1</sup>

## Condition and Medication-specific Issues

Central to the discussion of medication adherence as a whole are the conditions being treated and the medicinal therapies chosen to address them. The complexity of prescribed treatment regimens—addressing issues such as the number of medications and doses required—has repeatedly been connected with poorer adherence as the complication of the regimen increases.<sup>46,47,48</sup> Considering the rate at which the number of medications has observed to increase with age, this is particularly problematic in managing chronic disease. Similarly, embarrassment or the inconvenience of therapy has also been found to reduce adherence,

suggesting that significant stigma may be attached to particular forms of therapy, ultimately leading to problematic levels of medication-taking behavior.<sup>49-51</sup> Additionally, fear of side effects, even as medications have become safer, remains a prevalent issue and one that negatively impacts adherence to prescribed regimens.<sup>52-54</sup> Likewise, if patients are unaware of or believe that a treatment effect is not being realized then subsequent medication-taking behavior may suffer.<sup>55</sup> Also, the cost of the medications themselves is a significant deterrent to adherence in patients both with and without adequate prescription drug coverage. Analysis of patient populations across a range of out-of-pocket medication expenses has demonstrated that adherence suffers as prescription drug cost-sharing increases.<sup>56-58</sup>

Disease-related factors have also been shown to play a role in the medication-use process. Both the number and even a lack of symptoms connected to the disease(s) being treated significantly impact adherence to the prescribed medications.<sup>37,59</sup> Studies examining the severity of disease have produced mixed effects on medication adherence, suggesting that such a connection may be condition-specific or rely on the presence of other factors.<sup>44,60</sup> Additionally, the extent to which the patient is knowledgeable about their condition has been shown to affect the degree to which they remain adherent to their prescribed therapy, but conclusive evidence of the direction is still yet undetermined.<sup>37,50</sup>

### System-level Effects

Several characteristics of the health system at large have been observed to affect the manner in which patients take their medications. Multiple studies have demonstrated that the patient-physician relationship is a particularly strong predictor of adherence: supportive and positive relationships with healthcare providers, where a significant level of trust has been

established, are more likely to lead to improved adherence.<sup>61-63</sup> Further, the regularity with which patients are seen by their physicians also has been connected with higher rates of adherent behavior.<sup>40,50</sup> Relationships with healthcare providers other than physicians have been shown to affect adherence. The Federal Study of Adherence to Medications in the Elderly (FAME) demonstrated the impact the pharmacists may have on medication-use behaviors, suggesting that pharmacists take a more active role in encouraging adherence to prescribed treatment regimens.<sup>64</sup> Collectively, these findings suggest that effective communication and interaction with patients is an important mechanism through which a number of other factors known to influence adherence may be addressed.

#### Patient Behaviors and Psychological Status

The regular and ongoing taking of medications has also been studied with a host of patient behaviors and attitudes in mind. Among this list of contributing factors, several have emerged as the most prominent and significant. The subject of numerous adherence interventions, forgetfulness has become a plague on adherent behavior, contributing to declines in the regular medication-taking performance of many patients, potential solutions for which have been addressed from multiple angles with limited success.<sup>51,52,65</sup> Adherence also suffers due to the comorbid presence of psychological disorders, primarily depression,<sup>66-68</sup> but other conditions, such as bipolar disorder,<sup>69</sup> have been observed to negatively impact the ongoing taking of medications. Additionally, impaired cognitive function, independent of age, has also been tied to decreases in adherent behavior. Conversely, favorable mood attributes, such as a positive attitude or a 'fighting spirit', have been shown to improve adherence to medications.<sup>52,</sup>

## Factors Influencing Adherence to Diabetes Medications

Considering the complexity of treating, prevalence of, and known level of nonadherence related to diabetes, numerous studies have sought to uncover the barriers to and influential factors of medication taking in patients with this condition. A recent review of 36 studies published between 1990 and 2007 synthesized the most common influencers of diabetes medication nonadherence. Odegard and Capoccia (2007) found that the most often cited issues included: the complexity of the regimen, dosing frequency, product education, cost, self-confidence, depression, and experiencing or a fear of adverse effects.<sup>30</sup> Beyond those most commonly cited a host of additional patient factors were described that had been observed in previous investigations. These included condition-related fears (disease severity, needles, stigma, and weight gain), self-efficacy, remembering doses, education, and health beliefs. Additional barriers identified by adherence studies include patients' health beliefs,<sup>71</sup> reading the medication label,<sup>72</sup> and issues with taking the medications as well as understanding the need for ongoing medication use.<sup>73</sup> Such variety in the reported barriers to medication adherence in diabetes suggests that multiple angles must be taken to address this issue and need to consider challenges including, but not limited to, regimen complexity, self-efficacy, and patient education. The following section examines what has been attempted in interventions aimed at improving medication taking in patients with diabetes.

### **Interventions to Address Medication Nonadherence in Diabetes**

Multiple studies have aimed to curb the problem of medication nonadherence in patients with diabetes using a variety of approaches. Results have been varied but provide guidance for

future studies with a similar aim in mind. Table 1.1 provides an overview of the methods and key results observed in these investigations and this section provides highlights from these investigations.

Of those reviewed, the studies ranged in length from as little as three months to as long as three years in terms of an active intervention. Most used standard care as their comparison; however, active controls were used in several cases which included the use of nurse management, lowered medication coinsurance, or educational materials; only two studies lacked a specified control group of patients. To assess the impact of each intervention on medication use, a range of approaches were applied by study investigators to measure medication adherence. The most commonly used metrics were either self-reported measures or MPR/PDC, but other approaches included adherence scores (e.g. Morisky), visual analog scales, active monitoring through MEMS caps, or simple counts of refills over the course of the study. While these studies all included patients with established diabetes, several studies limited their adherence analysis to medications other than those indicated for diabetes, examining the indirect effects that medication-taking in this condition may have on other concomitant disorders (e.g. depression). Additionally, both type 1 and type 2 diabetes were represented across these trials and both adolescent and adult patients were the focus. The most commonly applied method of intervention was contact from a healthcare provider (nurse, physician, or pharmacist) involving either adherence support, counseling, coaching, or care plan follow-up. Disease management, either through case managers, pharmacists (with or without MTM services), or nurses, was common or could have been either in-person or over the phone. Other commonly applied methods of behavior change included reminders, family or community-based programs, and education. The majority of these studies tested only one interventional approach but several studies either had

multiple methods applied to the active arm or had multiple active arms with differing approaches being investigated.

No single type of approach employed by the included investigations led to consistently improved adherence to medications, meaning that both positive and null differences were observed across each type of behavioral technique. The results were mostly mixed for trials employing simple reminders,<sup>74-76</sup> condition or treatment education,<sup>77-82</sup> and family, peer, or community-based programs.<sup>80,81,83,84</sup> However, when limited to pediatric or adolescent patients, family-based or combined contact and educational programs did lead to improved adherence when compared to standard care.<sup>79,80</sup>

While no single intervention method was universally successful, two types of behavioral approaches did lead to more consistently improved levels of medication adherence: increased patient contact and case management. Successful mechanisms of increased contact included the application of telephone assessments/follow-up,<sup>85-90</sup> monitoring,<sup>88</sup> and adherence support.<sup>89</sup> Case management ventures that proved successful included the use of disease management,<sup>91</sup> MTM,<sup>90</sup> health coaching,<sup>86,92</sup> counseling,<sup>87</sup> and simple case management.<sup>78,79</sup> These results suggest that patients with diabetes appear to respond favorably, albeit to a small degree overall, to regular interaction with a healthcare provider or case manager, either through direct follow-up or during interactive management sessions, at least in terms of improving medication use. Future studies should consider incorporating frequent patient contact, either in person or by phone, and leverage disease or case management approaches into their mechanisms of behavioral influence in order to realize improved results.

Table 1.1 Interventions to Improve Medication Adherence in Patients with Diabetes

First Author, Year	Study Population	Length	Intervention	Control	Effect on Adherence	Limitations
Smith, 1986	Diabetic patients of a university IM clinic (N=859)	7 months	Increased contact and visits, including mailings, phone calls, and home visits	Standard care	Nonsignificant difference in prescription refills	Total fills only, no separation of effect between interventions
Skaer, 1993	Diabetic patients covered by Medicaid in South Carolina (N=258)	1 year	3 active arms (all included pharmaceutical care): refill reminder, unit-of-use packaging, or both	Standard pharmaceutical care	All arms improved MPR compared to control; both interventions outperformed either individual intervention	Generalizability, limited to one medication
Piette, 2000	Patients with established diabetes, <75 years of age, and an active prescription for a hypoglycemic agent (N=248)	12 months	Automated telephone assessments and nurse follow-up	Usual care	Fewer self-reported issues with medication adherence	3-item self-reported measure of adherence
Grant, 2003	Adult patients with type 2 diabetes (N=232)	3 months	Pharmacist tailored education	Standard care	No difference between groups (already high)	Only self-reported measures
Katon, 2004	Adult patients with diabetes and major depression or dysthymia (N=329)	12 months	Enhanced education and support from case management	Standard care	Improved odds of antidepressant adherence	No measures of diabetes medication adherence
Krein, 2004	VA patients with uncontrolled diabetes (>7.5%) (N=246)	18 months	Collaborative case management including contact and goal setting	Educational materials and standard care	No difference in treatment intensity or use of other medications	No direct measure of diabetes medication adherence

Rosen, 2004	Nonadherent patients with diabetes of a VA clinic (N=33)	4 months	Smart Caps (MEMS) cue training	Standard care	No significant differences	Small sample size, singular focus, MEMS monitoring
Yopp, 2004	Adolescents with type 1 diabetes (N=53)	7 months	Home-based psychotherapy	Usual care	No difference according to the Diabetes Management Scale for insulin; Better insulin use according to 24-hour recall	Generalizability and conflicting results
Ellis, 2005	Adolescents with uncontrolled type 1 diabetes (N=127)	6 months	Intensive, family-centered, community-based treatment	Standard medical care	Nonsignificant effect on adherence to insulin	24-hour recall for adherence
Howe, 2005	Ages 1 to 16 with uncontrolled type 1 diabetes (N=75)	6 months	Education only; education and telephone case management	Standard care	Education and telephone case management improved the adherence score	Physician sourced measure of adherence
Odegard, 2005	Adult patients with uncontrolled type 2 diabetes taking one or more oral medications (N=77)	6 months active and 6 months follow-up	Pharmacist-driven diabetes care plan	Normal care with the primary physician	Nonsignificant	Self-reported, two question recall used for adherence
Wysocki, 2007	12-17 years, type 1 diabetes at least 1 year, and a qualifying family member (N=104)	3 months	Group educational and social support meetings; Behavioral-Family Systems Therapy	Current therapy	Behavioral-Family Systems Therapy significantly improved adherence versus standard care and at two time points for education and support	Indirect estimate of adherence
Gazmararian, 2010	Adult patients	6 months	3-part pharmacy-	Usual care	Slight improvement	Adherence



	with diabetes taking at least one medication (N=173)		based health literacy program: reminder calls, prescription cards, pharmacist communication training		in refill adherence but NS between groups	measure not specific to diabetes
Heisler, 2010	Men with diabetes being seen in a VA clinic (N=244)	6 months	Peer support program	Nurse care management	No difference in self-reported adherence	Self-report, no true control
Wolever, 2010	Adults with type 2 diabetes (at least 1 year) and taking oral medication (at least 1 year) (N=56)	6 months	Integrative health coaching (14, 30-minute telephone sessions)	Usual care	Significant improvement in self-reported adherence (8-item Morisky)	Likely acquiescence bias
Gibson, 2011	Enrollees of employer-sponsored insurance with diabetes (N=2,204)	3 years	Disease management and lowered medication co-insurance	Lowered medication co-insurance	Higher adherence and percent adherent in all 3 years of the study for insulin and orals	Voluntary program enrollment (self-selection), single employer
Brennan, 2012	Enrollees of a single employer-sponsored plan with diabetes (age > 39) (N=29,247)	6 months	Counseling, follow-up calls, and a free testing kit,	Standard care	Increase in days' supply during intervention period; greater effect in retail versus mail order	Single employer study
APhA, 2012	Adult, nonadherent patients with diabetes on at least one medication (N=216)	6 months	Motivational interviewing	Standard care	Small improvement in PDC over 6 months	Potential selection and acquiescence biases

Bogner, 2012	Adults (age>30) with type 2 diabetes and depression with oral medication for both (N=180)	12 weeks	Personalized in-person and phone-based monitoring	Standard care	Higher proportion achieved 80% or higher adherence at 6 and 12 weeks	MEMS used for tracking
Collins-McNeil, 2012	African American adults with diabetes (N=12)	12 weeks	Church-based, culturally targeted self-management education	None	Significant improvements in medication and insulin administration	Small size, visual analog scale of management
Crowley, 2013	African American women with type 2 diabetes (N=359)	12 months	Nurse-led telephone self-management education	Standard care	Improved odds of self-reported adherence	Recall bias and generalizability
Odegard, 2013	Patients with type 2 diabetes (age>60 years) (N=120)	12 months	Pharmacist-initiated phone adherence support	None	Modest reduction in refill gaps over 12 months	No control group, limited reasons approached
Moore, 2013	High risk, adult enrollees of an employer-sponsored plan (N=4,500)	Up to 12 months	MTM program with follow-up	Standard care	MPRs were unchanged for diabetes medications	Control group matched from dissenters, high risk only, single firm

Moreover, the reviewed studies also provide guidance on the how interventions may layer their approaches. Across these investigations it was found that the use of only a single approach to behavior change led to mixed results in terms of altering medication nonadherence. However, the most consistently favorable results were observed in studies employing multiple approaches to behavior change (e.g. counseling and follow-up, lowered cost-sharing and disease management), a notion that has been previously suggested.<sup>93</sup> Considering the multifaceted nature of medication adherence, these results should be of little surprise. Moving forward, studies aiming to improve medication use should consider the effectiveness that more complex interventions have had on adherence and approach this issue from multiple perspectives, either by using several separate and concurrent approaches to behavior change or by addressing multiple reasons for nonadherence. Overall, what these studies tell us is that much work remains if we are to more effectively influence the taking of medications in patients with diabetes. The next section examines a specific approach that has been taken to improve the specificity by which nonadherence may be addressed.

### **Tailoring and Behavior Change**

Health behavior interventions have become increasingly specific in recent years, attempting to concentrate on more precise factors that may hinder or reinforce change. Historically, this has involved the application of targeted messaging whereby a particular population (generation, disease, etc.) received the same type of message aimed at eliciting a particular behavior based on that group's assumed shared characteristics.<sup>94</sup> There is some evidence that this level of communication can lead to individual behavior change but the effects are limited.<sup>95</sup> Studies using targeted interventions have focused on conditions including

hypertension, diabetes, and hyperlipidemia with mixed results reported in a review by Cutrona and colleagues (2010).<sup>96</sup> They reported on a host of studies aiming to improve medication adherence, including those with patients thought to be more sensitive to targeted messages due to their condition or point in treatment (e.g. post-hospitalization or following a surgical intervention). Among the strategies mentioned, targeted messages were automated and built using patient feedback.<sup>85,97</sup> While some strategies reported were successful, these results suggest that more precise approaches, particularly focusing on increased receptivity, should be explored.

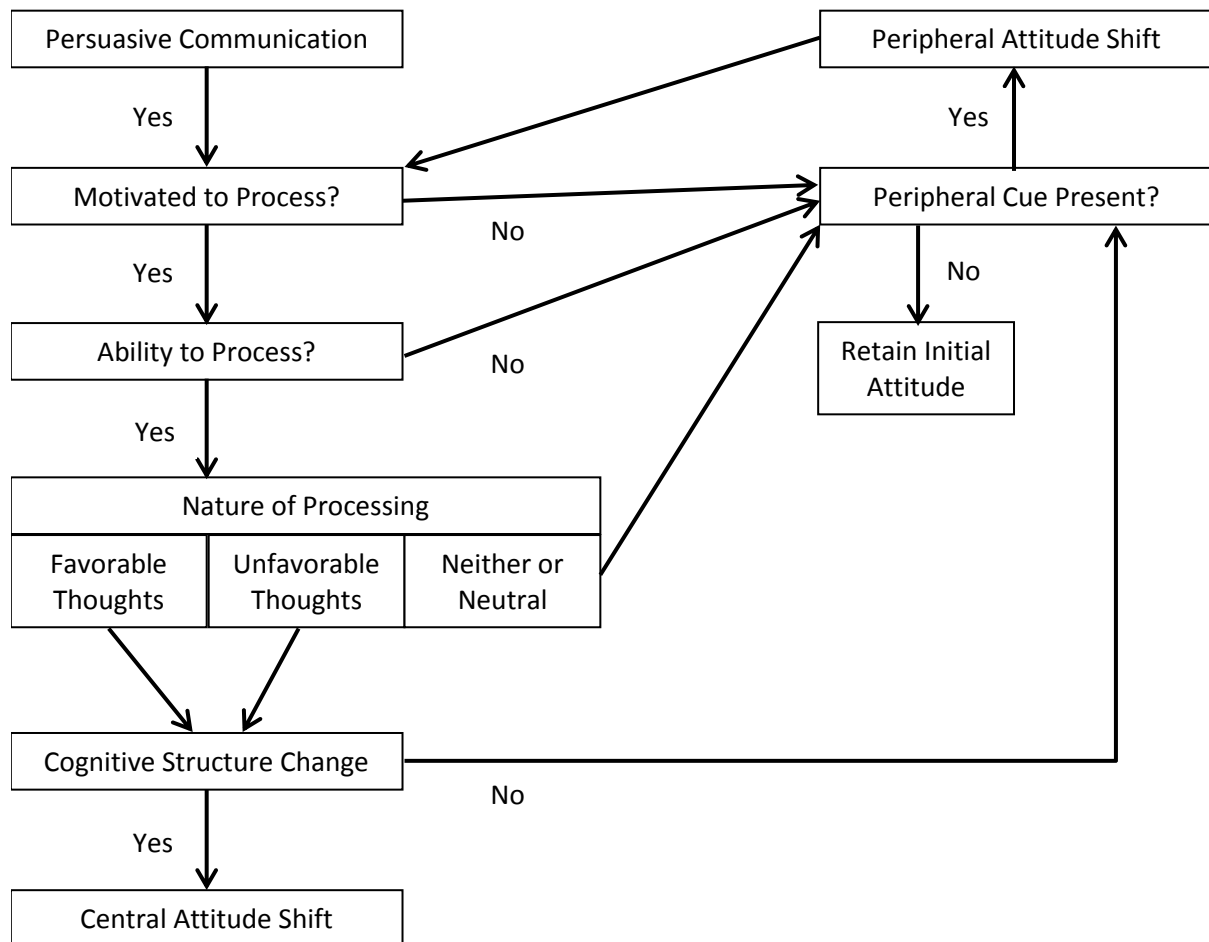
The pursuit of improved processes by which to change health-related behavior led to means of tailoring messages for individuals. This method identifies person-specific barriers and factors related to a particular behavior or outcome and then crafts individualized messages that are concurrently focused on multiple factors. Tailoring improves the specificity by which individuals are targeted based on their personal characteristics (e.g. age, gender, or race), preferences, beliefs, condition, or treatment, and is regarded as the most precise method by which subjects may be messaged. Tailoring follows a precise process, grounded in theory and having been robustly tested, the result of which is a set of messages that are personally relevant to each subject.

#### Elaboration Likelihood Model

The basis for tailoring is rooted in information processing theory specifically that people are more likely to thoughtfully process information when they perceive that information to be more personally relevant. Petty and Cacioppo (1986) argue that personal relevance may be the single most important influencer of the receiver's likelihood to elaborate a particular message.<sup>98</sup> Building off of findings surrounding information processing, Petty and Cacioppo developed a

dual processing model describing the management of information: the Elaboration Likelihood Model (Figure 1.1). The model describes a general framework of the processes underlying persuasive communication and how they may be best applied to an individual. Several concepts interact to form the framework, beginning with the receiver's motivation for processing the message.

Figure 1.1 Elaboration Likelihood Model



Adapted from Petty & Cacioppo, 1986<sup>98</sup>

The argument holds that messages perceived to have higher personal relevance are more likely to be thoughtfully considered and processed.<sup>99</sup> Moreover, a person's need for cognition, or the level of or desire for effortful analytic activity, helps dictate the type of processing most likely to be individually persuasive.<sup>100</sup> An individual's need for cognition may be evaluated using an instrument developed and validated by the model's authors.<sup>100,101</sup>

At this point, the suggestion is that two separate routes of processing influence how individuals manage the receipt of information. The peripheral route relies on cues present in the message, such as the credibility or attractiveness of the source, the use of a catchy slogan, or the repetition of a particular message.<sup>98</sup> Comparatively low levels of elaboration are applied in this case and weaker or shorter lived effects are more often realized.<sup>102</sup> On the contrary, the central route is thought to be used by those requiring a high level of elaboration, relying on careful scrutiny of the message and the underlying argument made.<sup>98</sup> Along this route, if the individual is motivated to process the message and has the ability to process the message, meaning they are not distracted and may have been repeatedly exposed, then favorable (or even unfavorable) thoughts toward the message, and ultimately persuasion, are more likely. However, as can be seen from the model, such central processing requires a continuum of processes for this level of elaboration to be realized; otherwise peripheral cues may be better suited to deliver the message to the individual.

Tailoring exploits messaging processing and follows the ELM by first increasing the personal relevance of a particular message using inputs from individuals. Further, it creates a type of message that is most likely to be considered by the intended audience, either through thoughtful consideration of an argument (the evidence behind a particular behavior provided by research) or the use of peripheral cues (reminders to perform an activity provided by celebrity

figure). Regardless of the route taken, the combination of personally relevant details with identified levels of elaboration has been effective in delivering specific messages to target audiences. However, a defined approach has been suggested by thought leaders in tailoring and is outlined below, followed by results from key studies involving nonadherence.

## Tailoring Process

Considering the specificity with which tailoring interventions are working, the building of deeply tailored messages can be cumbersome. To streamline the process, experts in the field of health communication have suggested a step-wise procedure. Such steps have been developed with a wider range of health professionals in mind, so that tailored communication may be applied to a larger host of patients and by a variety of practitioners.<sup>95</sup> As described by Kreuter, five general steps have been suggested when tailoring messages with computer assistance.

### 1. Analyzing the problem

The initial step is gaining or confirming a thorough understanding of the problem to be addressed. Often this will include searching the literature for the concepts, constructs, or correlates observed by previous research that have shown to be associated with particular conditions, health behaviors, or treatments. This step may be best approached with established behavioral theories in mind, such as the Transtheoretical Model, the Health Belief Model, or Social-Cognitive Theory; the specific theory and their included constructs are dependent on the target behavior(s) and population(s) to be addressed. Since these concepts will form the backbone against which the intervention will eventually rest, it is essential to methodically

investigate the issue at hand and balance the number of concepts with those known to have the highest likelihood for behavioral change.

## 2. Assessment tool development

Once concepts relevant to the target behavior have been identified and agreed upon, an instrument that will assess baseline values in the study population must be developed. While some subject details may be obtained without the use of an assessment tool (e.g. through electronic medical records), information related to latent, theory-driven items (e.g. beliefs and attitudes) will require surveying. This may be done by either adapting an established and tested instrument to the target population or by creating an original battery of items that adequately evaluate the included concepts. Either way, each included set of items should have reliable psychometric properties with close-ended options to improve the efficiency of tailoring. The length of the instrument and mode of data collection are important considerations as sufficient details need to be extracted from the target population without undue burden placed on the respondents. Careful planning paired with a sufficient understanding of the target population will ease both the creation of an appropriately sized instrument that is conducted in a manner convenient to the subjects.

## 3. Message creation

At this stage, a host of messages must be drafted to include all possible response options to the items in the assessment tool. For instance a 7-item Likert scale item may require the drafting of up to seven individual messages that correspond to each of the available responses. This may also include determining cut points for message options relating to responses that



indicate a relative value, such as “high”, “medium”, and “low.” The general approach is to list each response option for each survey item and draft messages connecting the concept with the target behavior. Messages should then be drafted with the behavior and the chosen concepts in mind as a framework for how the intervention will encourage change. A sound understanding of how each concept (e.g. beliefs, attitudes, barriers, and knowledge) relates to the target behavior or how related strategies may be employed is necessary at this stage as a range of possibilities exists in any target population. For example, when targeting medication adherence, messages focused on strategies may suggest the use of pill boxes or reminder triggers while conceptual messages may focus on the subject’s understanding of their condition (disease knowledge), their treatment (medication mechanism of action), or potential hindrances (cost, access, etc.). Moreover, the magnitude of each influencer must be considered and built into the drafting process as the importance of each concept is likely to vary between and within subjects. Ideally, potential messages would be pre-tested by representative members of the target population, allowing for editing prior to implementation. The result is a library of “message stems” (individual phrases that can be amended with other details) that will later be combined with other subject characteristics (name, age, gender, etc.) to more deeply tailor each message.

#### 4. Database development

At this stage, it is vital to create a coding system by which the message stems may be connected with the appropriate item in the assessment tool. For example, a medication use intervention including messages about cost may code an item as “barrier\_cost” in both the survey and message library so that the respondent’s answer would indicate to the system the level at which cost was a barrier to them and they may then receive the appropriately tailored message.

## 5. Algorithm development and programming

The final step in creating tailored messages is to link the responses with the message stems to create a fully tailored message. This involves the writing of code that can take the survey response for each item and properly match it with the appropriate stem from with the library. Often, depending on the chosen software or program, this may be accomplished through the use of simple “IF/THEN” statements that look up the appropriate message based on the response level. Common programs to do so include Microsoft Word and Excel; however, open-source software, such as the Michigan Tailoring System (University of Michigan Center for Health Communication Research) exists for research purposes. The purpose of the algorithm is two-fold. First, it determines the basket of messages that will and will not be delivered to each individual based on the responses given in the survey instrument. This provides for the most accurately tailored set of messages and intervention for each subject. Secondly, the algorithm may also determine the order in which the messages will be received, if a longitudinal approach is to be taken by the intervention and if the order or timing of the messages is important to the chosen mode or model of behavior change.

### Tailoring Interventions

In recent years, tailored interventions have become increasingly popular and applied across a wide variety of health behaviors. To date, the vast majority of these interventions have either been print-based, involving the sending of physical materials, web-based, requiring online interactions, or a combination of these two channels. Targeted health behaviors of these interventions have included, but are not limited to, weight loss, smoking cessation, physical activity, and preventive screening. A large majority of published studies were theory-driven, and

multiple theories have been applied by investigators of these studies. Most often, researchers relied on the Stages of Change/Transtheoretical Model, Social Cognitive Theory, or the Theory of Planned Behavior/Reasoned Action. In multiple cases, the Health Belief Model was applied and resulting effect sizes have been seen to range from small to moderate.<sup>103</sup>

Reviews of these investigations have demonstrated the impact that tailoring can have on particular behaviors and provide guidance for future studies. The overarching findings suggest that tailoring is effective with effect sizes varying due to the nature of tailoring, the method of message delivery (web versus print), and the conditions or behaviors being targeted.

Noar and colleagues (2007) summarized the results of print-based tailoring interventions that addressed behaviors including smoking cessation, diet, screening, and exercise. An overall small effect size across all included studies was found (0.074) and significant heterogeneity was described by the study authors.<sup>103</sup> Aside from this overall magnitude of effect, other moderating variables and methodological features related to tailoring were detailed. For studies involving print-based tailoring, larger effect sizes were observed in studies outside of the United States, focused on preventive or screening behaviors, using messages delivered by pamphlets or leaflets, when more than one contact was made, and using shorter follow-up periods. It was also reported that tailored messages outperformed both simple control groups as well as other types of messages (e.g. targeted or generic). Importantly, it was also observed that studies involving 4-5 theoretical concepts as well as those employing theoretical, demographic, and behavioral concepts in the tailoring outperformed interventions using 3 or fewer theoretical concepts and only tailoring on behavioral or theoretical concepts alone, respectively.<sup>103</sup>

More recently, Krebs and colleagues (2010) built upon Noar's earlier analysis and reported a meta-analysis regarding the evidence of computer-based tailoring- the use of computer

systems to create and deliver tailored messages via the Web. Similar to the review highlighted above, this more recent review included behaviors ranged from smoking cessation to physical activity, diet, and exercise. A modestly higher overall effect size (0.17) was determined across the 88 studies assessed with the largest effects observed in interventions involving smoking cessation or diet.<sup>104</sup> Additionally, effects were found to peak between four and 12 months post-baseline and decrease over time, particularly after the first year; however, when tailoring was dynamic (involving feedback/assessment iteration) the effects remained significant after 12 months.<sup>104</sup>

Taken together the results summarized by these two reviews help us understand what may be most effective across the types of tailoring most often employed and the direction future studies may consider when applying tailoring as a mechanism of behavior change. Although comparative results are not available, it appears that a larger effect size may be realized by leveraging computer-based tailoring by employing electronic means of message delivery or participant interaction. Moreover, multiple contact periods should be considered as should more deeply tailored messages—those incorporating multiple behavioral, theoretical, and demographic characteristics—both of which are likely most easily accomplished by using the advanced means of communication afforded researchers by computers.

### Tailoring and Medication Adherence

A limited number of studies have involved the tailoring of messages aimed at improving medication adherence, the vast majority of which having been published in the past decade.

Table 1.2 summarizes the approaches taken and findings of recent tailoring investigations aimed at improving medication-taking in patients with chronic conditions.

The majority of these interventions targeted improving behavior in patients with cardiometabolic conditions or AIDS, but asthma and schizophrenia were also represented. Trials ranged in length from as little as 12 weeks to as long as 18 months and all involved adult patients. Most used standard care as their comparison but educational materials or generic feedback was also employed.

To produce tailored materials nearly all studies used one or several baseline survey instruments; however, interview responses (some motivational) were employed, as was reported treatment progress. In some cases, specific, established instruments were used to collect subject information, such as the Summary of Diabetes Self-Care Activities,<sup>105</sup> the Problem Areas in Diabetes scale,<sup>106</sup> the Rapid Estimate of Adult Literacy in Medicine,<sup>107</sup> the Structured Clinical Interview for Positive and Negative Syndrome Scales,<sup>108</sup> the Barnes Akathisia Rating Scale,<sup>109</sup> the Schizophrenia Outcomes Module,<sup>110</sup> the SF-36,<sup>111</sup> the CAGE questionnaire,<sup>112</sup> the Frontal Systems Behavior Scale,<sup>113</sup> and the Perceived Control of Asthma questionnaire.<sup>114</sup> The direct mentioning of framework or theory-driven items being incorporated to the tailoring of messages was limited, but several investigations did specifically report the application of behavioral theories. Among those that did so, the theories or frameworks applied included: the multifactorial framework for adherence in clinical research and clinical care,<sup>115</sup> the Transtheoretical Model,<sup>116</sup> the Information-Motivation-Behavioral Skills Model,<sup>117</sup> the Health Decision Model,<sup>118</sup> the Health Belief Model,<sup>119</sup> Social Cognitive Theory,<sup>120</sup> Self-Regulation Theory,<sup>121</sup> and the Chronic Care Model.<sup>122</sup> Other established techniques included Motivational Interviewing and Cognitive Adaptive Training.<sup>123,124</sup> Commonly used collection methods for adherence included a 7-day or 14-day self-report, the AIDS Clinical Trial Group-Revised Total

Score,<sup>125</sup> the Morisky Scale,<sup>13</sup> pill counts, MEMS, metered-dose monitoring, and pharmacy claims (either PDC or MPR).

By and large, these tailored interventions observed significant differences in adherence as a result of the approaches taken. Importantly, those interventions that employed a defined technique (Motivational Interviewing or Cognitive Adaptive Training) or an established theoretical framework showed almost universal improvement in adherence from baseline, increasing adherence, from 4-22%, when specifically reported. Only the Ickovics and Meisler framework failed to show a significant difference.<sup>126</sup> Print,<sup>124,127,128</sup> in-person,<sup>129-131</sup> and telephone-based<sup>132-134</sup> approaches showed positive impact; those that incorporated nurse-led counseling<sup>130-133</sup> were also generally associated with improvements in medication taking. These results paint a positive picture of the effectiveness of tailoring on improving medication taking in patients with chronic disease, particularly when such interventions are rooted in specific theories, frameworks, or techniques. Future studies aiming to improve adherence should universally employ established models to improve the odds of positive outcomes.

Only two of the included studies focused on patients with diabetes and both failed to observe statistically significant changes in medication adherence between study arms; however, positive improvement was observed in patients taking insulin when directed by a health educator over the course of one year.<sup>135</sup> It should be noted that both of these studies lacked a clear theoretical foundation for the tailoring of material, findings that add support for the need to base a tailoring intervention in an established model. As a result, future studies aimed at improving medication adherence in patients with diabetes should base the tailoring of their materials on a well-established theory, particularly one associated with multiple, positive findings (e.g. TTM, HBM). These studies may also consider leveraging emerging techniques and technologies to

more efficiently reach subjects. The following section describes how the prominence of one piece of technology—mobile phones—may be an appropriate and effective means by which behavior may be influenced.

Table 1.2 Tailoring Interventions to Improve Medication Adherence

First Author, Year	Study Population	Length	Intervention	Control	Tailoring Channel (framework)	Adherence Results	Limitations
Grant, 2003	Adults with type 2 diabetes (N=232)	3 months	Drug-specific patient education, identified adherence barriers, and additional services	Standard care	Pharmacist-led interviews based on medications and a survey	Nonsignificant differences in adherence after 3 months	Indirect tailoring, limited contact
Holzemer, 2006	Adults taking antiretroviral medications (N=240)	6 months	Structured nurse counseling	Standard care	Nurse counseling based on survey responses (Ickovics & Meisler framework)	No differences in adherence across multiple measures	Dose variation
Johnson, 2006	Adult members of an HMO taking antihypertensives (N=1,227)	18 months	Stage of change-based manual and tailored feedback	Standard care	Printed materials using stage-based feedback from surveys (TTM)	Significantly lower nonadherence at 12 and 18 months	Likert-based adherence measure, high dropout
Johnson, 2006	Adults taking cholesterol medication (N=404)	18 months	Stage of change-based manual and tailored feedback	Standard care	Printed materials using stage-based feedback from surveys (TTM)	Some differences at 6 months but consistently better adherence at 12 and 18 months	Likert-based adherence measure, high dropout
Parsons, 2007	HIV positive adults taking antiretroviral therapy (N=143)	12 weeks	Motivational interviewing and cognitive behavioral skills training	Didactic health education	Repeated counseling using MI and CBST (IMB, MI)	Improvements in percent dose and day adherent at 3months; dissipated by 6 months	Recall bias



Bosworth, 2008	Adults with hypertension (N=636)	12 months	Needs-based counseling across several behaviors; blood pressure monitoring; both	Standard care	Telephone, nurse-led counseling using a needs-based assessment (HDM)	Increase in self-reported adherence at 6 months	Reliance on self-report
Hudson, 2008	Adults schizophrenia patients of VA clinics (N=349)	6 months	Adherence barriers and domain-based strategies	Basic education	Nurse counseling using interview responses	Significant improvement in odds of adherence, especially if already adherent	Scale used for adherence
Reynolds, 2008	Antiretroviral naïve enrollees of an AIDS clinical trial (N=109)	16 weeks	Structured, proactive, nurse-led phone calls	Patient Education	Telephone nurse counseling	Significant improvements over 64 weeks	Self-report measure
Velligan, 2008	Recently discharged and outpatient schizophrenia patients (N=95)	9 months	Cognitive adaptation training (all behaviors or medication-focused)	Standard care	Manual-based behavioral change using a series of assessments (CAT)	Both interventions showed significant differences in adherence (pill counts); no difference between these groups	Established condition (in years), selection bias
Janson, 2009	Adults with moderate to severe asthma (N=280)	24 weeks	Scripted sessions with asthma educators and respiratory therapists	Standard care	Nurse counseling using treatment progress (HBM, SCT)	Mean adherence remained consistently higher over time	Monitoring of doses, generalizability
Stacy, 2009	Currently taking a statin (N=497)	Variable	Tailored feedback from interactive voice response and mailed guide	Generic feedback	Interactive telephone based on theory-driven items (TTM, HBM, CCM, MI)	Significantly higher adherence rate at 6 months	Selection bias-subjects opting in

Walker, 2011	Adult diabetes patients (age>30) of a health care worker union (A1c>7.5%) (N=526)	1 year	Calls from health educators	Printed educational material	Telephone (unspecified)	Mixed results of change in adherence due to intervention	Differential dosing, different outcomes for adherence based on measure
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## Mobile Health and Behavior Change

### Growth of Mobile Health

In the past decade, ownership and use of mobile phones in the United States has grown from approximately 255 million units to over 326 million units.<sup>136</sup> Currently, 91% of American adults own a mobile phone, up from just under 80% in 2008.<sup>137</sup> Moreover, roughly \$185 billion was spent last year on operating mobile phones.<sup>136</sup> Unlike many technologies, mobile phones do not exhibit disparities in ownership across age, race, and socioeconomic status.<sup>137</sup>

While use of these devices was originally dominated by “talk time”, the majority of mobile phone use is now dominated by more immediate and brief means of communication, such as text messaging and instant messaging. In 2012, more than 2 trillion text messages were sent by mobile phone in the United States, a five-fold increase from 5 years earlier.<sup>136</sup> As of earlier this year, 79% of mobile phone owners use their device for messaging, suggesting that there is a strong preference for many Americans to communicate by means easier than placing direct phone calls.<sup>137</sup>

As this technology has become more popular, the functionality of mobile phones has increased dramatically. Most prominently, smartphones—those devices capable of operating and exchanging information across web-based applications—have grown in popularity and use: as of 2013, 56% of American adults own a smartphone, making these devices the most widely owned and operated mobile phone on the market.<sup>137</sup> Considering such widespread use, opportunities have emerged to apply mobile phones to the daily conducting of health-related activities. This has included applications housing medical information, personal health records, and trackers for diet, exercise, and other self-care activities. Additionally, tools have been developed to improve

the means by which communication is relayed between patients and providers. As early as next year, estimates suggest that the mobile health market will reach \$4.6 billion, significantly expanding the use of mobile devices in health care and boosting the ability of both patients and providers to manage disease and treatment.<sup>138</sup> As this market continues to grow, it is anticipated that mobile phones will also be further introduced as a means to deliver health-related interventions; the following sections describe how this has been done to date.

### Applications to Behavioral Interventions

Although still relatively new to the health care field, mobile devices have begun to be tested as a means to instill behavior change in patients with a variety of conditions, including diabetes, hypertension, obesity, and smoking. Target behaviors of these interventions have included medication use, self-care, diet, and exercise, and tested means of altering behavior have included education, direct patient-provider communication, reminders, and patient tracking. While multiple communication channels using mobile platforms have been applied, text messaging has emerged as the most predominant delivery mechanism to date. Results of these studies have varied but their findings remain important to our understanding of how mobile phones may be used to influence health-related behaviors.

Three recent systematic reviews highlighted the results of published studies involving the application of mobile phones in behavioral interventions, two of which focused solely on the use of text messaging. Krishna and colleagues (2009) reviewed 25 investigations where mobile phone communication was used to encourage behavior change; channels included voice, text message, Internet, e-mail, and personal devices. Targeted behaviors included smoking cessation, medication adherence, appointment keeping, vaccination, and disease management- nine studies

specifically focused on diabetes. Nearly all of the reviewed studies employed some level of text messaging and relied on one-way communication to do so; when applied, the frequency of messaging varied considerably from once daily to once daily, although some were dependent on the subjects' prescribed treatment regimen. The study authors concluded that improvements were realized in medication adherence, clinical outcomes, quit rates, and appointments kept.<sup>139</sup> Specifically, conditions requiring ongoing support or care, such as asthma, diabetes, and smoking cessation, benefitted the most from a mobile intervention. Although positive improvement was not universal, these results suggest that mobile device-driven interventions can show positive effects; however, trials targeting medication adherence were underrepresented. Importantly, all but one of the studies focusing on patients with diabetes showed positive results.

Fjeldsoe and colleagues (2009) reviewed 14 studies focused exclusively on the effect of text messaging in behavior change interventions, seven of which were not included in Krishna's review. Foci of these studies included smoking cessation, physical activity, disease management, and medication use; again, diabetes was well represented as seven studies specifically targeted patients with this condition. Twelve of the studies applied tailoring techniques to improve the individualization of the messages and the majority of these trials (7) utilized two-way communication to vary the messages over time to sync with the patients' ongoing treatment. The frequency of messaging varied by study and ranged from weekly to daily, and study length ranged from six weeks to one year. Among the studies reviewed, a majority (8) showed positive improvement and nearly all of the remaining studies demonstrated positive trends- the lone study that reported null results focused on symptom improvement in patients with bulimia nervosa.<sup>140,141</sup> The evidence presented in this review provides strong support for the application of tailoring as nine of the 12 studies using this level of communication observed positive

improvements in outcomes, including five studies involving patients with diabetes. However, only three studies focused on medication adherence, limiting what may be gleaned about the effectiveness of text messaging to encourage this behavior. The review authors concluded that the included studies demonstrated the potential that text messaging can have on improving a range of health-related outcomes but future trials can improve upon what has been done, including the application of more tailoring, larger sample sizes, explicit use of theory, increased interaction between patients and providers, and the evaluation of process measures.<sup>140</sup>

More recently, Wei and colleagues (2011) reviewed 24 published studies involving the application of mobile phones, specifically using text messaging; 16 of the included studies were not summarized in Krishna's or Fjeldsoe's publications. Targeted behaviors of Wei's review included smoking cessation, weight loss, disease management, and condition self-monitoring, and a larger share of the reviewed trials focused on adherence to medication while five specifically targeted diabetes. Similar to what was observed by Krishna and Fjeldsoe, the frequency of communication ranged significantly, from daily to monthly, and even mirrored dosing schedules. More studies were seen to employ feedback mechanisms and some incorporated subject preferences into the messaging. Most of the studies reported positive results or trends but a majority of trials involving medication adherence did not observe significant improvement, perhaps due to the host of methodological flaws reported by the authors (e.g. inadequate sample size, adherence metric, experimental design).<sup>142</sup> The review authors concluded that, by and large, studies to date that have used mobile messaging demonstrate that positive change can be realized across a host of behaviors; three of the five studies that included patients with diabetes showed positive improvement in outcomes.<sup>142</sup> However, the varied results reinforce the need for further inquiry.

Taken together these reviews paint a mostly positive picture of the impact that mobile phone interventions can have on particular conditions and behaviors. While positive results were observed in numerous studies, the applications to medication adherence were limited. Moreover, the main mechanism of behavior change for interventions using text messaging was a simple reminder message, which limits the extent to which other reasons for health-related behavior may be addressed. Additionally, the application of tailoring was limited- only three of the 42 studies specifically mention this level of communication. Also, a major limitation of most studies was a lack of adequate sample size as many were underpowered to determine statistically meaningful differences. Resultantly, opportunities to expand the specificity of messaging remain prevalent.

#### Applications to Medication Adherence

While still relatively scant, researchers have begun leveraging the utility of mobile phones in the pursuit of improving medication adherence. Considering the ubiquitous nature of messaging platforms across all types of mobile phones, texting has been a popular channel by which messages aimed at changing medication-taking behavior have been relayed. Table 1.3 summarizes the methods and findings observed across recent investigations aimed at doing so which includes several studies previously reviewed but also highlights studies overlooked in previous reviews.

As can be seen, a majority of published studies to date have been conducted outside of the United States and nearly all of which concluded within the past decade, most of which since 2008. Nearly all studies employed a control group who generally received no message (standard care only) although simple beeper messages and real-time monitoring were applied in one case

each. In most cases, chronic conditions (two involved diabetes) and associated medications were targeted and studies were as short as three weeks and as long as one year. Similar to what has been observed in other types of studies, adherence in these investigations was measured in several ways: pill counts, visual analog scales, self-report, electronic monitoring, and responses to the Morisky scale. Additionally, a majority of studies involved adult patients of both genders but pediatric, younger adults, and only females were also specifically enrolled in some cases.

Across all studies reviewed the frequency of text messages received by participants varied considerably by study. In some cases the number of texts was dependent on the dosing regimen of the study subject; other studies sent messages only weekly, two times a week, or, most popularly, daily. As many as 12 messages per day<sup>143</sup> were delivered and one study sent subjects messages three times each day.<sup>144</sup> Interestingly, one study explored the option of varying the amount of messaging throughout the 18 weeks of the intervention.<sup>145</sup>

The studies represented present a dichotomy of approaches to improving medication adherence: simple reminders versus tailored content. The majority of studies (n=6) opted to send simple reminders, with or without accompanying educational material. Results of these studies were mostly positive; improvements in medication-taking were observed in four of the seven studies where reminder messages were the focus.<sup>144,146-148</sup> Texts that were delivered daily were mostly effective although weekly messages were shown to outperform them in one instance<sup>148</sup> and thrice daily messages also showed positive improvement in adherence,<sup>144</sup> but the long-term implications of this latter approach are yet to be determined. As can be seen, the use of simple reminder messages was not universally successful in improving adherence. However, in cases where nonsignificant results were observed it is possible that the nature of the medication class involved (oral contraceptives)<sup>149</sup> or the use of active monitoring in the control group<sup>150</sup> may have



contributed to these null results. The latter of these two studies involved patients with diabetes, the findings of which were conflicting. What we may glean from this is that simple text reminders may not provide added value to patients with diabetes above ongoing monitoring in terms of motivating medication-taking behavior. Rather, a deeper messaging channel may be required to more adequately influence this population.

In four of the reviewed studies, tailoring was also applied to the messaging, improving the level of individualization beyond the capability of simple reminders and expanding the extent by which other factors affecting adherence may be reached. Four separate conditions were represented in these trials (diabetes, asthma, schizophrenia, and HIV) as were a range of patient ages, including children. Feedback from the subjects was employed in two of the investigations and texting frequency was different in each of the studies. Importantly, unlike what was observed in studies using simple reminders, universal improvement in adherence was realized in each of these investigations.

The earliest of the studies was an intervention conducted by Franklin and colleagues (2006) where a technique called “sweet talk” was tested in a group of pediatric patients (ages 8-18) with type 1 diabetes. Patients were randomized to one of three groups: 1) conventional insulin therapy; 2) conventional insulin therapy and Sweet Talk; and 3) intensive insulin therapy and Sweet Talk. The messages were guided by Social Cognitive Theory,<sup>120</sup> leveraging goal setting (established at baseline) and social support, and focused on insulin injections, glucose testing, diet, or exercise. A weekly message reinforcing the established goal was sent as were daily messages providing tips, information, and reminders related to this goal. Control subjects received only the standard care required of all participants. By the end of the study (1 year), patients in the Sweet Talk group scored higher in diabetes self-efficacy and demonstrated

significant improvement in self-reported adherence (visual analog scale) when compared to control.<sup>151</sup> Additionally, the vast majority of subjects felt the messages helped their diabetes self-management and nearly all indicated they wanted to continue receiving messages. The frequency of messaging was also well received but a chief complaint was the repetition of some messages throughout the study. As a first study investigating the viability of tailored text messages to improve medication adherence, Franklin and colleagues demonstrated that this channel and level of communication can be effective, at least in a particular patient population.

In a smaller and briefer investigation, Hardy and colleagues (2008) examined the use of tailored messaging, with feedback, in a population of adults with AIDS who had self-reported nonadherence to antiretroviral therapy. However, tailoring in this investigation was less defined (subjects merely selected, and could change, the theme of their messages) and lacked a theoretical foundation- patients selected a timely theme for their messages (e.g. weather, news, sports, etc.) that coincided with their reminder. Subjects in the active arm requested feedback acknowledging receipt of messages and the frequency of messages was dependent on the subjects' treatment. Comparisons were made to a group of patients receiving a beeper reminder over a 6-week period. Results indicated that the use of this messaging system improved adherence over six weeks according to multiple measures (MEMS, adherence score, and pill counts). This investigation also indicated that a feedback system may not be sustainable over time but that the system's persistence in receiving a response was a main factor in adhering to a medication regimen.<sup>152</sup> Moreover, similar to before, most subjects enjoyed receiving the messages and indicated they would continue to use a similar system. While these results also paint a positive picture for tailored text messaging, what we may extrapolate from this study may

be limited as the methods mirror more of a “preference-based” messaging system rather than true tailoring and the small sample size restricts the generalizability of findings.

Two additional tailored text messaging studies were published last year, one set in the United States and the other in New Zealand. Granholm and colleagues (2012) ran a pilot test of tailored messaging in a group of community-dwelling adults with schizophrenia. Over 12 weeks, subjects were sent 12 messages per day (6 days per week), randomly distributed, that focused on three separate domains: adherence, socialization, and hallucination. The messages were written in a manner to apply cognitive behavioral therapy techniques and were tailored using baseline responses and ongoing feedback to multiple choice response messages. No control group was employed. The study authors concluded that this tailored text message system was effective at improving medication adherence, particularly in those adults with schizophrenia that were living independently.<sup>143</sup> Additionally, there was evidence that, over the course of the study, participants increased their belief in their medication to help them stay healthy. Subjects also appeared to be receptive to providing feedback as response rates exceeded 80% for all metrics.<sup>143</sup> While these results again support the effectiveness of tailored text messaging they should be taken with some caution as the adherence metric employed (prompted, daily, single-item multiple choice question) was likely to have been impacted by acquiescence bias and related results were dependent on the living situation of the subject; the lack of a control group also limits the interpretability of the findings.

Focusing on young adults (ages 16 to 45) with asthma, Petrie and colleagues (2012) compared messages tailored by patient beliefs to the receipt of no messages to improve adherence to controller medications. Tailoring was performed using responses to the Brief Illness Perception Questionnaire,<sup>153</sup> which is theoretically rooted in Leventhal’s self-regulatory

model,<sup>121</sup> as well as medication belief ratings.<sup>154</sup> Messages were designed to push subjects in a target direction based on their baseline responses and the direction believed to be most consistent with higher adherence. The frequency of messages varied throughout the study: two per day during weeks 1-6, one per day during weeks 7-12, and three per week for weeks 13-18. Medication adherence was determined using self-report over the phone at multiple periods. The study observed that subjects receiving the tailored messages had an increase in their perceived control over asthma and necessity of controller medication as well as held a more chronic view of their condition.<sup>145</sup> Both mean adherence rates and the number of those achieving 80% or higher was significantly higher in the intervention group. Moreover, a dissipation of effect was not observed even several months after the intervention had ended. This study provides guidance on several fronts, mostly providing additional evidence of the effectiveness of theory-driven tailored messages but also that their effects can be sustained beyond the time of active receipt. However, the varied dose schedule fails to assist future studies in understanding at what frequency subjects should be reached.

While positive results have been observed in the limited number of studies combining tailoring and mobile text messaging, much opportunity exists to better leverage these methods to improve adherence, specifically in patients with diabetes. The next section summarizes what gaps need to be filled in this area and how the current study was designed to address these needs.

Table 1.3 Mobile Text Messaging Interventions to Improve Medication Adherence

First Author, Year (Country)	Study Population	Length	Intervention	Control*	Text Frequency	Results	Limitations
Marquez-Contreras, 2004 (Spain)	Adult patients with hypertension (N=104)	4 months	Text reminders and information	No messages	2 times per week	All measures of adherence nonsignificant	Limited to reminders
Franklin, 2006 (UK)	Pediatric patients with type 1 diabetes (N=92)	12 months	Tailored text messages with or without intensive insulin therapy	Standard care	Daily	Improved adherence with both insulin therapy groups	Visual analog scale measure
Cocosila, 2009 (Canada)	Adults willing to take Vitamin C (N=102)	1 month	Text reminders and acknowledgement	No messages	Daily	Improved adherence in both groups; correlation between acknowledgments and adherence	Single item self-report question
Hou, 2010 (USA)	Females taking oral contraceptives (N=82)	3 months	Timed reminder	No messages	Daily	No difference in missed pills	Electronic monitoring, generalizability
Strandbygaard, 2010 (Denmark)	Adults with asthma (N=26)	8 weeks	Daily text reminder	No messages	Daily	Double digit difference in adherence rates	Sample size and duration, limited to reminders
Hardy, 2011 (USA)	Nonadherent adults on antiretroviral therapy (N=23)	6 weeks	Tailored content with feedback	Beeper messages	Based on dosing frequency	Significantly higher adherence over multiple measures	Sample size, different results based on metric, unrelated content
Pop-Eleches, 2011 (Kenya)	Adults recently started on antiretroviral therapy (N=428)	12 weeks	1) daily reminder, 2) daily long message, 3) weekly reminder, 4) weekly long message	No messages	Daily or weekly	Weekly reminders showed higher rate of adherers; no difference versus control in the daily groups	Dropout rates, known monitoring
Arora, 2012 (USA)	Adults with diabetes visiting	3 weeks	Motivational, reminder, and	None	3/ day	Improvement in 8-item Morisky Scale	Small sample, no control

	the ED (N=23)		educational messages			from baseline	
Granholm, 2012 (USA)	Community-dwelling adults with schizophrenia (N=42)	12 weeks	Adherence, socialization, and hallucination messages with feedback	None	12 messages / day, 6 days / week	Improved for those living independently	No control, unclear adherence metric
Petrie, 2012 (New Zealand)	Nonadherent young adults being treated for asthma (N=147)	18 weeks	Beliefs tailored text message	No messages	Weeks 1-6: 2/ day Weeks 7-12: 1/ day Weeks 13-18: 3/ week	10% increase in adherence and significant difference in percent adherent	Unclear self-report methods, varied dose
Vervloet, 2012 (Netherlands)	Nonadherent adults 18-65 with type 2 diabetes (N=104)	6 months	Real-time medication monitoring and text reminders	Real-time medication monitoring	Dependent on dose and forgetfulness	Days without medication did not differ; texting improved dose taking within the assigned window	Known monitoring, no inactive control

\*Control groups included standard care, the same as each active group, unless noted

## Next Steps

### Gaps and Opportunities

In summary, medication nonadherence continues to be an ongoing issue in patients with diabetes and, while progress has been made, much opportunity to improve this problem remains. Considering the dramatic growth expected in the incidence and related costs of diabetes in the decade ahead,<sup>28</sup> it is paramount that improved means to alter medication-taking behavior be explored so that better adherence can lead to improved disease management.<sup>31,33</sup>

Over the course of multiple investigations, researchers have observed that patients with diabetes are especially influenced by the perceived severity of their condition, their self-efficacy, their ability to remember to take their medications, education provided, and their beliefs about diabetes;<sup>71</sup> results have also indicated that understanding the need for ongoing medication use can be influential.<sup>73</sup> Attempts to influence medication-taking in populations of patients with diabetes have shown mixed results using a host of approaches, including simple reminders, education, and group-based programs; however, leveraging ongoing contact (e.g. provider follow-up, adherence support, monitoring) or case management (e.g. disease management, counseling, health coaching) showed consistently positive improvement. Such results indicate that frequent contact and approaches that incorporate a particular patient's treatment may best improve medication adherence. Moreover, the notion to combine approaches has been voiced for over a decade and consideration to do so should be made by future interventions.<sup>93</sup>

Fortunately, over time our methods of improving medication adherence have been more specific. While targeted intervention—those communicating a message to a group sharing particular characteristics—have shown some benefit, the results are not conclusive enough to

suggest this approach is best suited to instill reliable behavior change. Resultantly, the tailoring of interventions has become more prominent and results have been promising, particularly when computer-based tailoring is employed.<sup>103,104</sup> Over the course of its application, we have seen limited application of tailoring to medication nonadherence; however, these interventions have not always been solidly founded in theory. Evidence from those studies leveraging theory-driven has been promising and improvements in adherence have been realized in these cases. Such results have further indicated that the most significant improvements have been observed when tailoring on at least four to five concepts.<sup>103</sup> However, a significant gap exists in our understanding of how theory-driven tailoring may improve medication-taking behavior in patients with diabetes as the evidence has been less conclusive in this population, perhaps due to the inadequate application of theoretical methods in these studies. This does not definitively indicate that such an approach is inadequate in this population but rather that more robust methods of applying tailoring in patients with diabetes is needed, specifically those that leverage theory-driven methods.

The use of mobile phones in behavioral interventions has become an increasingly popular communication channel as the ownership and use of these devices has become widespread. Reviews of interventions leveraging mobile communication have shown improvements in the management of disease, particularly chronic conditions including diabetes.<sup>139,140</sup> In recent years, we have seen the combined use of mobile phone communication and tailoring become an increasingly used mode of delivering behavioral interventions. A limited number of studies have explored tailoring mobile interventions in patients with diabetes, using a range of mobile communication options, and several have specifically focused on improving medication adherence. Results of these investigations have been promising, but several limitations have



emerged. Primarily, many interventions have been limited by the use of reminders, the vast majority lacked a solid theoretical framework, sample sizes have been relatively small, and focusing on medication nonadherence has been underrepresented, although its presence in some studies is evidence that the leveraging of mobile devices in medication nonadherence is taking place.<sup>139,140,142</sup> Future interventions can certainly build off of what has already been done keeping in mind what has limited the interpretability of previous studies.

Across studies using mobile phones, text messaging has emerged as the clear favorite among interventional researchers addressing medication nonadherence. However, within this area of research, approaches have relied heavily on merely sending reminders to patients and some positive results have been observed but change has not been universally realized and findings have been conflicting in patients with diabetes. Conversely, when tailored text messages have been used, positive improvements in medication-taking have been consistently realized, suggesting that this level of communication may be most appropriate when aiming to address nonadherence by mobile phone. Moreover, tailored text messages have been shown to lead to improved levels of self-efficacy, perceived disease control, perceived chronic nature of disease, and medication necessity.<sup>145,151</sup> Additionally, subjects responded favorably to the receipt of messages and nearly all indicated they would like to continue to receive messages; however, considering the pediatric population involved and their use of text messaging, acceptance of this communication channel in older patients deserves investigating.

In spite of these consistently positive results, gaps remain in our understanding of how to best apply tailored text messaging. While patients with diabetes have been included in a study using tailored texting, it was limited to pediatric patients.<sup>151</sup> Although still dominated by younger Americans, text messaging has shown to be a regularly used communication channel across age

groups, and, as such, may be a viable means to reach nonadherent patients regardless of age;<sup>155</sup> positive results using such an approach was observed in nonadherent adults with asthma.<sup>145</sup> Additionally, the founding of tailored text messaging interventions in sound behavioral theory has shown to lead to reliable, positive results, but, as studies have been limited, more research is needed.<sup>145,151</sup> Finally, the frequency of messaging has varied across studies and no reliable estimate of what should be sent has been determined.

In summary, what we have observed in studies is that tailored text messaging can lead to positive improvements in medication adherence. Additionally, the messages used should be grounded in theory, not be limited to simple reminders, and include multiple concepts in the framing of the messages. What remains to be understood is the applicability of tailored text messages to improve adherence in adults with diabetes, how yet untested behavioral theories may function in the development of tailored messages, and how adults accept the mobile phone into their treatment process as a communication tool.

To address this we must first consider how theory may be best applied in this context. The following section highlights theories that are applicable to adherence and how they guided this study. Also, as the use of mobile technology in healthcare is in its infancy, a theory explaining how technology may be accepted is applied. Finally, how these theories come together to form the conceptual framework is detailed.

## Theoretical Considerations

Considering the positive results observed in the theory-driven studies outlined previously, our study will incorporate elements of several established behavioral theories to frame messages and assess outcomes. The combination of concepts from the Health Belief Model and Self-

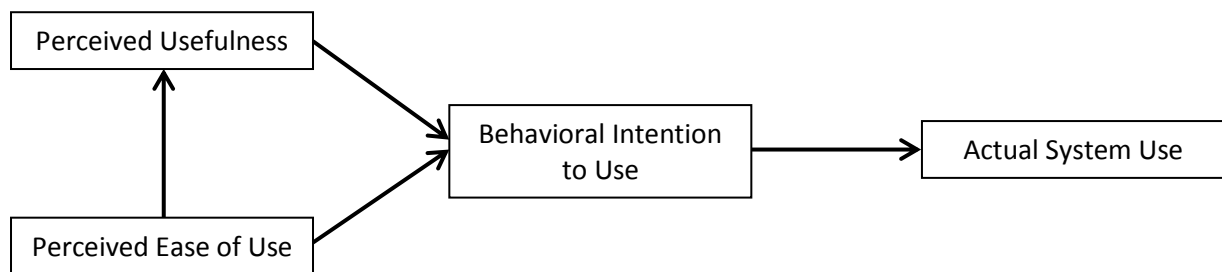
Determination Theory formed the foundation of the conceptual model guiding this intervention. The next section provides an overview of each theory, indicating the rationale for its selection in this study. Additionally, a third model is described, elements of which were used to assess the study population but not applied to the message-development process. Insight gained from including this model in the study will focus on how adults with diabetes incorporate the mobile phone into their regular care, and the results will provide perspective on the feasibility and demand for future mobile messaging projects.

### Technology Acceptance

An extension of the Theory of Reasoned Action, the Technology Acceptance Model (TAM) is an information systems theory that attempts to explain the acceptance and use of various technologies. Davis and Bagozzi developed this model; the main elements include the concepts of perceived usefulness and ease of use. According to Davis (1989), perceived usefulness is defined as “the degree to which a person believes that using a particular system would enhance his or her job performance”; perceived ease of use refers to “the degree to which a person believes that using a particular system would be free of effort.”<sup>156</sup> Davis posited that these two concepts were fundamental determinants of user acceptance of a particular technology. The extent to which the user perceives these concepts influences their attitude toward using the technology, which influences their intention to use the technology. This model has been used to explain a wide variety of technologies including mobile devices. Kim and Park (2008) applied TAM to better understand consumer adoption of short message service (text messages). Their findings suggest that perceived ease of use and usefulness are both major factors influencing intention to use mobile text messaging.<sup>157</sup> While these findings suggest that TAM concepts can

help us understand the likelihood of text message adoption, their findings were mostly driven by younger respondents- a population already understood to readily use such a communication channel.<sup>155</sup> Moreover, the application of mobile phones, particularly text messaging, in the context of healthcare delivery has well outpaced the research behind this technology; therefore, our understanding of patient perceptions of these messages in the course of their treatment is severely limited. As a result, what remains to be better understood is two-fold: 1) how do older patients interpret text messaging as easy to use and usefulness and 2) how are these concepts perceived in the context of healthcare-related information? Answering these questions is paramount to the future development of mobile health-related platforms.

Figure 1.2 Technology Acceptance Model



Adapted from Davis, 1989<sup>156</sup>

### Health Belief Model

The Health Belief Model (HBM), first introduced in the 1950s, is one of the most widely applied behavioral theories. When originally devised, HBM was designed to predict responses to treatment by ill patients; more recently, it has been applied to more general health behaviors. As

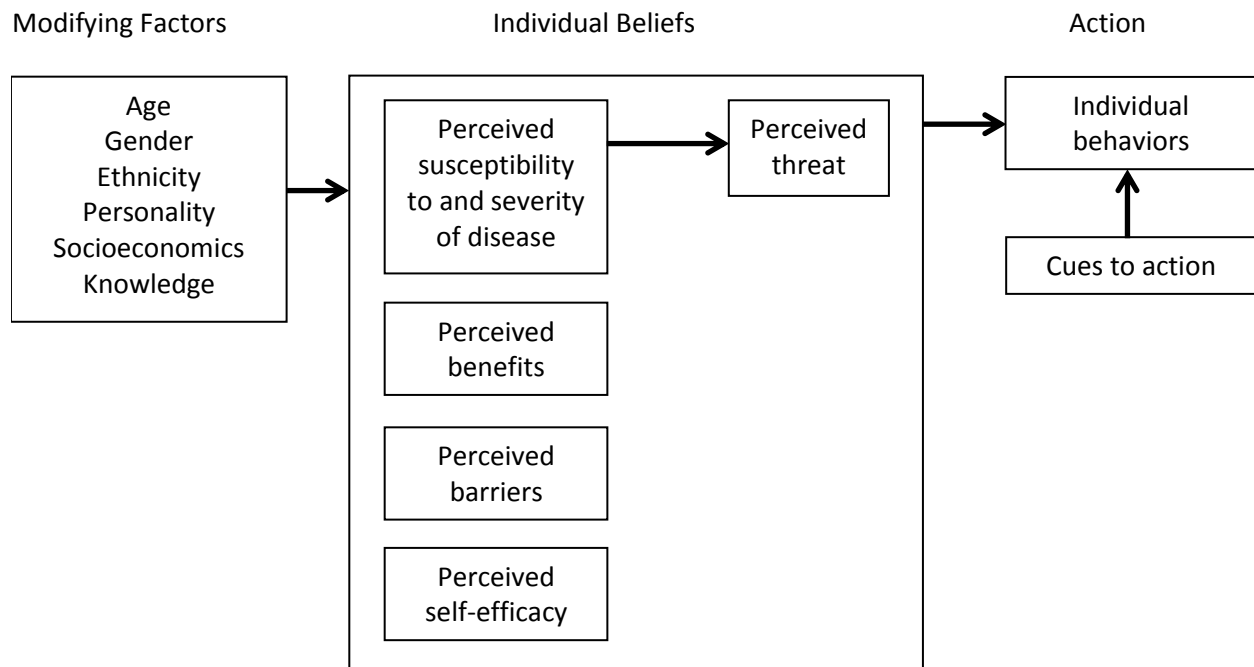
a result, over the course of the past 40 years, the theory has undergone multiple iterations and additional concepts have been inserted over time. Figure 1.3, depicts the components and linkages suggested by the most recent version of the theory.<sup>158</sup>

At its core, HBM posits that a health-related action will be taken if a negative health condition can be avoided, a positive expectation of the behavior exists, and that the recommended behavior can be successfully taken.<sup>158</sup> The model suggests that behavior is influenced by a combination of factors:

- Perceived susceptibility: beliefs about the likelihood of an outcome or condition
- Perceived severity: the seriousness of or consequences of an outcome or condition
- Perceived benefits: results of actions to reduce threats related to a specific condition
- Perceived barriers: impediments, perceived or real, to particular behaviors
- Perceived self-efficacy: personal competency to carry out a particular behavior
- Cues to action: behavioral triggers that may increase the likelihood of action

It should also be noted, as can be seen in the depiction of the model, that perceived susceptibility and severity are often combined to create the concept of perceived threat: the level of risk imposed by not acting on the condition. The combination of all of these constructs attempt to predict why action to prevent, screen for, or control illness will be taken in a manner that builds off of the belief an individual has in each of these concepts. As indicated by the model, modifiers, such as age, gender, and ethnicity, may exist differentially impact the predictability of a particular behavior in specific populations.<sup>158</sup>

Figure 1.3 The Health Belief Model



Adapted from Champion & Skinner, 2008<sup>158</sup>

When taken into context for medication use, the likelihood of an individual to take their medication would be made more likely if they sense they are susceptible to a specific condition, believe that condition would have serious potential consequences, believe that taking the medication would reduce the probability or severity of a condition, and understand that these benefits outweigh any costs of or hindrances to taking the medication. Additionally, the likelihood of taking the medication would be increased if the individual believed in their ability to take the medication as directed and may also be improved if triggers to taking the medication (such as symptoms or encouragement) are introduced.

Across conditions and health-related behaviors the Health Belief Model has been rigorously tested or applied, this has included investigating the role of this model in treatment

adherence. Becker and colleagues (1978) were one of the first to show that perceived severity, susceptibility, benefits, and barriers observed in mothers were each found to be significantly associated with both measures of adherence to asthma medications assessed in their children.<sup>159</sup> In 1985, Becker and Janz reviewed applications of HBM to patients with diabetes. Results from reviewed studies indicated that positive associations between HBM components and insulin treatment exist, some reaching statistical significance: severity and barriers.<sup>160,161</sup> These findings suggest that components of the model may be predictive of adherence but the model as a whole, to this point, may not have empirical support.<sup>162,163</sup> A recent meta-analysis highlighted the association between perceived disease severity threat—the combination of perceived susceptibility and severity—and adherence (not limited to medication use). DiMatteo and colleagues (2007) observed a significant and positive association between adherence and perceived disease severity threat across 27 studies. The authors further suggested that these findings are suggestive of the need for improved health education, the building of patient-centered health messages, and the assisting of patients to recognize when disease threats are most severe.<sup>164</sup>

Taken together, the results of studies incorporating elements of the Health Belief Model provide guidance on how this model may help us predict adherence as well as the constructs that are most likely to be associated with improved medication use. Considering the complexity of medication adherence, specifically the range of identified influencers, it may not be particularly surprising that the entire HBM framework would be supported empirically.<sup>165</sup> However, its individual constructs have shown to be predictive of levels of medication adherence, particularly perceived susceptibility and severity. Such support suggests that health messages should consider

the role that health beliefs play in ongoing medication use when seeking to encourage improved adherence.

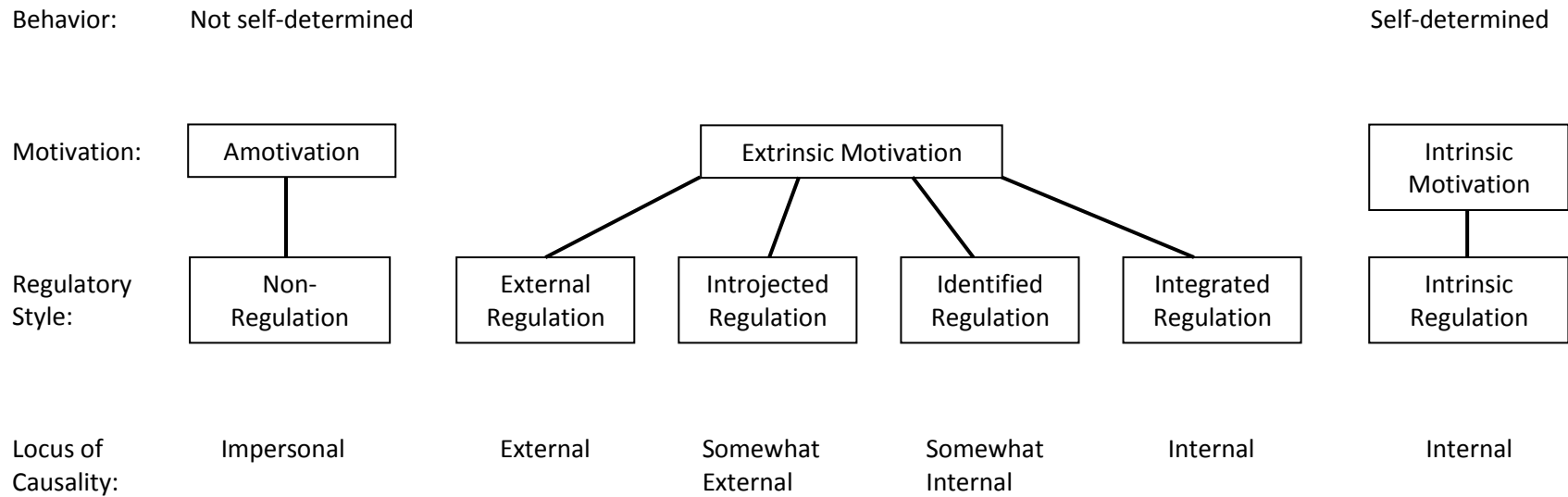
## Self-Determination Theory

Developed by Deci and Ryan, Self-Determination Theory is a theory of motivation, suggesting that people are driven by three essential needs: competence, relatedness, and autonomy.<sup>166</sup> The pursuit of these needs is reflected in a continuum of motivation, ranging from amotivation, or a complete lack of motivation resulting from the absence of value in an activity, to intrinsic motivation where one is completely self-determined.<sup>168</sup> The theory focuses on identifying specific types of motivation within this range as a compilation of five mini-theories that evaluate the continuum:<sup>166,168,169</sup>

- Cognitive Evaluation Theory addresses the social contexts of intrinsic motivation and highlights the roles of competence and autonomy supports.
- Organismic Integration Theory is focused on extrinsic motivation and specifically outlines the continuum of internalization and the relationship this has with autonomy.
- Causality Orientations Theory differentiates between three types of orientations (autonomy, control, and amotivated) based on individual tendencies.
- Basic Psychological Needs Theory addresses the basic tenet of SDT that well-being and functioning are influenced by autonomy, competence, and relatedness, and that support of these needs should impact wellness.
- Goal Contents Theory dichotomizes goals by their extrinsic and intrinsic natures and how they are individually related to wellness.



Figure 1.4 Self-Determination Theory



Adapted from Deci & Ryan, 2000<sup>166</sup>

With these sub-theories in mind, Self-Determination Theory operates under the assumption that humans are active organisms that interact with and are either socially supported or thwarted to achieve particular needs. The theories then attempt to explain motivational-related behavior observed across investigations. On one end of the continuum, intrinsic motivation describes the internal tendency to seek challenges but it has been observed that unsupportive conditions can inhibit this state.<sup>166</sup> Resultantly, maintenance of this state by social and environmental factors, such as positive feedback, is needed;<sup>168</sup> however, it is important to remember that this level of motivation will only be reached for things that hold intrinsic value for them.

In the middle of the continuum we see a range of regulation types that define extrinsic motivation which aide in the understanding of motivation when applied to activities lacking intrinsic value. Motivation for performance of these activities lies in some definable outcome, and Organismic Integration Theory helps explain the differences in types of motivation that are extrinsically driven, varying in the extent of autonomous regulation.<sup>166</sup> Here, external regulation is that controlled by an outside force or influence beyond the control or cause of the subject. Next, introjected regulation includes those activities performed to avoid guilt or anxiety and done so with only partial, personal acceptance of the behavior.<sup>166</sup> More plainly, these activities may be performed to demonstrate worth to others or to enhance one's ego which demonstrates ability but also the external nature of the motivation.<sup>170</sup> The third form of extrinsic motivation—identified regulation—is one in which the individual consciously values a behavior and sees it as personally important. This demonstrates some development toward more autonomous, yet still extrinsic, motivation. Finally, integrated regulation is when the behavior has been fully accepted by the individual as being completely compatible with their values and needs but are yet still

motivated by some defined outcome. While demonstrated across a continuum, Deci and Ryan (2000a) do not suggest that the process of improved autonomy occurs in defined stages but rather that internalization may increase over time through facilitation- providing support for autonomy furthers the process of transforming values from an external source to individual ownership.<sup>166</sup> However, it is important to remember that all three needs require servicing to facilitate greater internalization and integration as has been observed by the theory's authors.<sup>166</sup> Therefore, support for autonomy must also be met with reinforcement of competence and the personal relatedness of the behavior.

In the context of medication taking, SDT may assist us in understanding the motivation one may or may not have for ongoing adherence to a prescribed regimen. The theory suggests that motivation to take a particular medication may either be driven internally, if one has established intrinsic value for the medication, or by an external force against which the individual places the medication's value. Beyond this, the degree to which motivation is driven is related to how competent one feels they are in adhering to the regimen and how closely related the taking of the medication is to the values of the individual. Efforts to promote medication-taking using SDT as a framework should consider all three of these needs in its design and also recall that changes in motivation may be driven over time by addressing the individual's source of motivation and guiding them in a desired direction.

Applications of SDT have been led by Williams and the results of the integration of this theory to the taking of medication have important implications for future studies. Williams' earlier investigation applying SDT (1998) did so in a population taking prescription medications for at least 3 months; diagnoses varied considerably between subjects (31 in sum) but the vast majority were diagnosed with either hypertension, symptoms of menopause, or hyperthyroidism.

The objective was to assess the relationship between autonomous support and medication persistence. Medication adherence was assessed using two pill counts separated by two weeks. Results indicated that autonomous motivation was related to and directly predicted medication adherence at least when accounting for it by self-report.<sup>171</sup> Moreover, autonomy support was found to indirectly affect adherence; motivation was seen to mediate this relationship.<sup>171</sup> Other significant findings provided support for HBM, through a negative correlation between adherence and perceived barriers, and the suggestion was made that autonomy may mediate the relationship between barriers and adherence. Overall, these results indicate that motivation, support, and barriers play a role in adherence, but, given the cross-sectional and short duration of follow-up, a deeper analysis was necessary.

A more robust analysis was conducted by Williams (2009) in patients with diabetes. The purpose of this study was to further explore the application of SDT to adherence by extending a hypothesized model to include other constructs of the theory to this particular behavior. Both self-reported and medical claims data were used to assess medication adherence, the Treatment Self-Regulation Questionnaire was given to assess self-regulation and support, and the Perceived Competence Scale was used to assess the subjects' perception of their ability to manage their diabetes.<sup>172</sup> The authors concluded that their hypothesized model showed adequate fit: support related positively to regulation, which related positively to competence, which related positively to medication adherence.<sup>173</sup> Moreover, these results provided support for earlier findings that indicated these same SDT constructs may play an important role in diabetes management.<sup>174</sup>

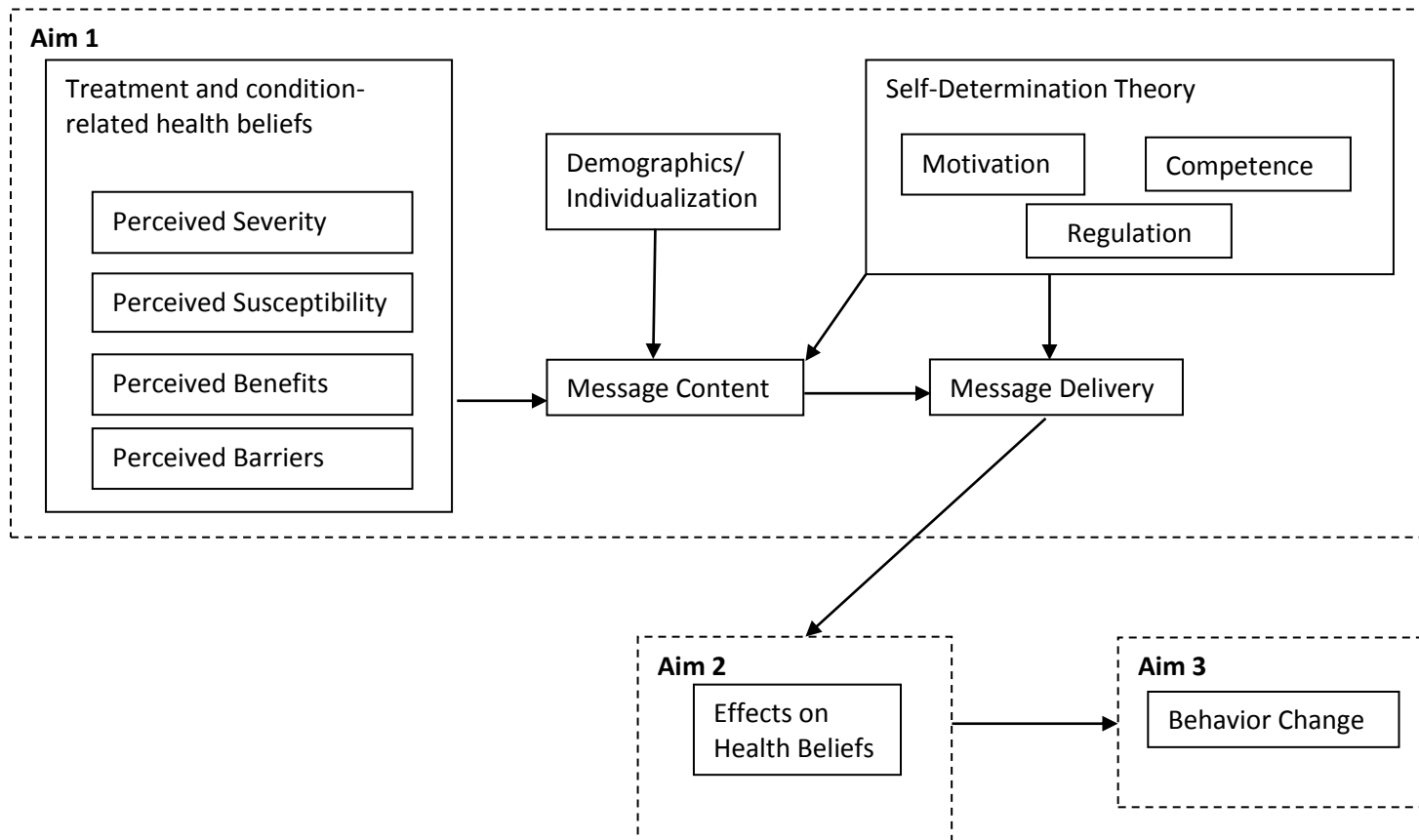
Taken together, these applications of SDT to medication adherence provide evidence that autonomous support and regulation as well as competence are important factors in the decision to take medications. Strong evidence in support of the application of this theory to diabetes was

observed and the suggestion made that motivation be addressed in clinical encounters to improve the odds of better self-management, an aim in line with recommendations made by the American Diabetes Association.<sup>173,175</sup> Additionally, the Treatment Self-Regulation Questionnaire and Perceived Competence Scale were both tested and shown to be significantly relevant to medication adherence in patients with diabetes, evidence that the concepts inherent to these two instruments should be considered by future interventions.

### Conceptual Framework

Our basic conceptual framework for the study is detailed in Figure 1.5 which describes how the elements of each theory coordinate to explain and contribute to medication adherence, how personal elements aid the message development and delivery process, and how the process of message receipt is ultimately intended to lead to behavior change. Using responses to items related to HBM<sup>176</sup> and SDT (Treatment Self-Regulation Questionnaire;<sup>177</sup> Perceived Competence Scale<sup>172</sup>), each included concept (perceived severity, susceptibility, benefits, and barriers, and sources of motivation, autonomy, and perceived competence) is evaluated to determine the perceived level of each concept in individual subjects and then the impact that these constructs may have on treatment adherence. These theories were chosen based on the evidence, such as that highlighted above, that showed the concepts described by these models were related to medication-taking behavior and were appropriate for an intervention to address.<sup>160,161,164,171,173,174</sup> By including these concepts, we aim to address the perceived level of health belief or attitude with the intent of shifting these beliefs and attitudes in a direction known to increase the likelihood of medication adherence. For instance, increased perceived susceptibility and severity

Figure 1.5 Conceptual Framework



have been found to be associated with an improvement in medication-taking;<sup>164</sup> by encouraging an understanding of the importance of these concepts in the treatment process over time the aim is that improved adherence will ultimately be observed. Additionally, recognizing the need to guide subjects over time toward a target belief level, messages incorporate a developmental element, assuming that progress will be made as a result of the message content.<sup>166</sup> Thus, Self Determination Theory is shown to apply to both how its concepts explain the target behavior as well as how a gradual progression may be incorporated.

The eventual result of addressing HBM and SDT concepts over time is hypothesized to be improved levels of health beliefs and attitudes, which have been supported by previous research in this area and by the proposed means. Ultimately, our goal is to relate the changes in beliefs and attitudes to changes in behavior, in this case the levels of medication adherence, adding to our understanding of how concepts of HBM and SDT relate to medication-taking in patients with diabetes

### Aims and Hypotheses

The overall objective of this project is to test the effectiveness of individually tailored messages delivered by mobile phone text messaging in a sample of patients with diabetes. The central hypothesis is that tailored text messages will improve treatment-related beliefs and adherence to the prescribed treatment regimen beyond that observed in adult patients with diabetes receiving only standard care. This central hypothesis, as highlighted by the conceptual framework, will be tested by the following three specific aims:

1. Construct a library of and successfully deliver condition and treatment-related tailored text messages that can be used to influence medication-taking behavior using theory-driven approaches among patients with diabetes.
2. Assess the effect of tailored text messages on health beliefs related to treatments, conditions, and technology acceptance in patients with diabetes.
3. Analyze changes in diabetes medication adherence between patients receiving tailored text messages and patients with only standard care.

With these aims in mind, we have hypothesized the following:

H1: The assessed beliefs and attitudes will be significantly and positively changed in patients receiving tailored text messages compared to patients with standard care and that mobile phone-based messaging will be perceived as a useful and easy to use healthcare tool.

H2: Medication adherence will be significantly and positively changed in patients receiving tailored text messages when compared to subjects receiving standard care only.



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## **CHAPTER II. PAPER 1: DEVELOPMENT AND DELIVERY OF TAILORED TEXT MESSAGES**

### **Abstract**

Background: Medication nonadherence remains a significant public health problem, and efforts to improve adherence have shown only limited impact. The tailoring of messages has become a popular method of developing communication to influence specific health-related behaviors but the development and impact of tailored text messages on medication use is poorly understood.

Objectives: The aim of this paper is to describe an approach to developing theory-based tailored messages for delivery via mobile phone to improve medication adherence among patients with diabetes.

Methods: Kreuter's five-step tailoring process was followed to create tailored messages for mobile phone delivery. Two focus group sessions, using input from 11 people, and expert review of message content were used to adapt the survey instrument on which the messages were tailored and edit the developed messages for the target population.

Results and Conclusions: Following established tailoring methods a library of 168 theory-driven and 128 medication-specific tailored messages were developed and formatted for automated delivery to mobile phones. Concepts from the Health Belief Model and Self-Determination Theory were used to craft the messages and an algorithm was applied to determine the order and timing of messages with the aim of progressively influencing disease and treatment-related beliefs driving adherence to diabetes medication. The process described may be applied to future investigations aiming to improve medication adherence in patients with diabetes and the effectiveness of the current messages will be tested in a planned analysis.

## **Background**

A variety of interventions have been developed using communication theory to promote health behavior change. Many of these interventions have used targeted messaging whereby a particular patient population (defined by their age, disease, etc.) received the same type of message aimed at eliciting a particular behavior based on that group's shared characteristics.<sup>1</sup> Over time, methods have become more focused, narrowing the emphasis from population-level factors to tailoring according to characteristics that reflect more proximate determinants of health behaviors, such as beliefs about the risks and benefits of treatment. By tailoring, behavioral interventions may highlight condition and treatment-specific influences that are most personally relevant to each subject with a clear, personalized goal in mind.

The general approach to tailoring health communication is to create messages that are individualized for each recipient based on information collected about that user via survey. This information can be used to create original messages or can be added to pre-existing material.

Common survey elements used to tailor health communication include the participant's name, age, gender, race, family structure, and details related to the outcome of interest (e.g. potential consequences of inadequate disease management and the benefits of adhering to self-management plans). These characteristics are strategically placed into a message with the aim of influencing behavior by creating a piece of communication that appears to be relevant only to the recipient.

The foundation for tailoring messages rests on information processing theory, which suggests that people are more likely to process information thoughtfully when they perceive that information to be personally relevant.<sup>2</sup> A prominent example of such a theory, the Elaboration Likelihood Model (ELM) posits that separate routes of information processing (peripheral and central) influence how information is managed and is based on the individual's need for cognition and motivation.<sup>2</sup> The benefits of more elaborated processing include longer message retention and an increased likelihood of permanent attitude change.<sup>3</sup> Therefore, applying ELM, the benefit of tailoring health communication is the improved odds of capturing users' attention through individualization that will increase the likelihood of thoughtful consideration of message content and ultimately a greater impact on health behavior.

Message tailoring has shown promise as a mechanism for effectively promoting individual health behavior change. Reviews of tailored health interventions have concluded that tailoring is useful in a variety of areas including smoking cessation, physical activity, dietary change, and preventative screening.<sup>4-16</sup> Tailoring has also been applied successfully to the problem of medication nonadherence: the inability to take medications as prescribed by a healthcare provider, which may be either intentional (due to motivational or perceived issues) or unintentional (forgetfulness). Positive applications of tailoring to medication adherence have

been observed among patients with hypertension, schizophrenia, hyperlipidemia, and asthma.<sup>17-23</sup> However, the vast majority of these studies were conducted using either print or computer-based materials, limiting their reach and effectiveness. Adherence problems are also common among people with diabetes, resulting in inadequate physiological control and a higher risk of complications.<sup>24-26</sup> Unfortunately, interventions focused on improving diabetes medication adherence have had only limited success.<sup>27</sup> Effective interventions for diabetes medication adherence support likely require an individualized approach addressing each patient's array of health beliefs and other limitations- a problem for which tailored health communication may be ideally suited.

Recently, mobile phone messaging has been increasingly used in tailoring studies. Mobile phones are nearly ubiquitous and could be an effective channel for improving self-management support between face-to-face interactions with clinicians.<sup>28</sup> Most studies focused on improving medication adherence using mobile phones have been limited to improving unintentional nonadherence through reminder messages, and results of these investigations have been mixed in terms of the effect on medication use.<sup>29-34</sup> However, a limited number of studies have incorporated the tailoring of health messages into interventions focused on medication nonadherence. Petrie and colleagues (2012) showed improved medication adherence to controller inhalers among adult patients with asthma by text messaging subjects from 1 to 3 times daily over 18 weeks.<sup>35</sup> Several recent studies have combined mobile phone adherence reminders and tailored messages addressing patients' beliefs associated with intentional nonadherence. For example, using an intervention called "Sweet Talk"—a tailored text messaging support system for patients with type 1 diabetes—Franklin and colleagues (2006) observed improvements in self-reported adherence to diabetes medications after 12 months.<sup>36</sup>

Such results suggest that tailored text communication could improve diabetes-related adherence, but additional testing is necessary to confirm and expand on our understanding of how this messaging channel may be most effectively applied. The aim of this paper is to describe an approach to developing theory-based tailored messages that can be delivered by mobile phone to improve medication adherence among patients with diabetes.

## **Methods**

Kreuter's five-step process of tailored message development was used to produce a library of messages addressing various contributing factors to nonadherence and an algorithm for individualizing each patient's series of messages while customizing this approach for mobile text messaging delivery.<sup>5</sup> This process included the following steps as suggested: problem identification, assessment tool creation, message creation, message storage, and tailoring algorithm development (Figure 2.1).<sup>5</sup> The following section describes the processes taken to fulfill these steps for developing the message library for a diabetes adherence support intervention. This study was approved by the Institutional Review Boards at both the University of Michigan and Mercy Health Partners (Muskegon, MI).

### **Problem Identification**

Recognizing that diabetes medication nonadherence was an important contributor to poor outcomes, Lakeshore Health Network ("Network"), a physician hospital organization with over 300 primary care and specialty physicians, began exploring potential solutions in 2011, including a community-wide medication adherence awareness campaign focusing on consumer

engagement. The Network prioritized strategies using information technology in order to improve self-management support in a way that would be potentially cost-effective. Tailored health communication supporting adherence and delivered via text messages appealed to the community's health leaders, who partnered with researchers at the University of Michigan to develop such an approach.

To clearly define the problem, it was critical to first understand the specific factors impacting diabetes patients' adherence behavior. Two theories of health behavior were chosen to establish a framework for understanding the processes determining diabetes medication use. Self-Determination Theory (SDT) suggests that people are driven by 3 essential needs: competence, relatedness, and autonomy. The pursuit of these needs is reflected in a continuum of motivation, ranging from amotivation to intrinsic motivation, where the latter is completely self-determined.<sup>37</sup> Evidence suggests that the likelihood of long-term maintenance of behavior change is increased if one is intrinsically motivated rather than influenced by external forces.<sup>38, 39</sup> For example, individuals may take medications initially because physicians tell them to do so. Over time, continuing to take medications is likely a decision based on internal motivation that includes an implicit balancing of benefits and costs to the user. Ultimately, medication taking may become habit; however, adoption of such a behavior may be a process for some and, as such, requires that messages encouraging the behavior guide the patient along the way rather than forcing change upon them. Applied to medication-taking, Self-Determination Theory concepts have been found to be related to this behavior: evidence suggests that autonomous self-regulation and perceived competence each play an important role in the ongoing taking of medication.<sup>40</sup>



The Health Belief Model (HBM) has been extensively applied to a variety of health behaviors including medication adherence. Using the model, studies of adherence have identified numerous barriers that contribute to inadequate medication use and several health beliefs (perceived susceptibility, severity, and benefits) have been predictive of this behavior.<sup>18, 41, 42</sup> At its core, HBM posits that a health-related action will be taken if a person believes that a negative health condition can be avoided through that action, the behavior is likely to result in a positive outcome, and they can successfully execute the intended behavior.<sup>43</sup> In the context of medication use, the likelihood of an individual taking their medication may then be increased if they believe that they are susceptible to a specific condition, believe that condition would have serious potential consequences, believe that taking the medication would reduce the probability or severity of the condition, and understand that these benefits outweigh any costs of or barriers to taking the medication. Additionally, the likelihood of taking the medication would be increased if the individual believed in their ability to take it as directed and may also be improved if triggers to taking the medication (such as symptoms or encouragement) are introduced. Multiple studies have observed the role that HBM constructs may play in the medication-taking process, suggesting that levels of each of the incorporated concepts may be predictive of resulting adherence or nonadherence.<sup>44-49</sup> Applying this model allows the crafting of messages to be based on the particular constellation of beliefs for individual patients and the level of belief individuals have in each construct

## Assessment Tool Creation

### Initial concepts and items in the assessment tool

The first step in message development is the selection of a proper survey to capture patient characteristics that can guide the tailoring process. In the current study, the tailoring process was guided by instruments incorporating Self-Determination Theory and the Health Belief Model. (Figure 2.2)

Concepts related to Self-Determination Theory were captured using the Treatment Self-Regulation Questionnaire (TSRQ) and the Perceived Competency Scale. The concepts of motivation and support as measured in the TSRQ have acceptable internal consistency (Cronbach's  $\alpha > 0.80$ ) and validity has been verified in diabetes.<sup>50,51</sup> Perceived competence was measured using items from the Perceived Competence Scale, allowing messages to be based on initial competence that can be adjusted over time. Cronbach's  $\alpha$  for this scale is 0.94 and support for its construct validity has been demonstrated.<sup>52</sup>

The extensive application of Health Belief Model (HBM) to health behaviors has produced validated survey instruments specific to conditions and modes of treatment. We used a diabetes-specific instrument developed by Given (1983), and then by Becker and Janz (1985), to capture diabetes and treatment-related health beliefs.<sup>53,41</sup> The Cronbach's  $\alpha$  ranged from 0.70 to 0.89 depending on the domain of the scale and content validity was verified by a separate study.<sup>53,54</sup> Using this instrument, 4 HBM concepts were assessed including perceived disease severity, susceptibility to negative outcomes, benefits of medication use, and barriers to medication use.

In addition to these theory-driven items, 2 other domains of questions were added to the instrument to more deeply tailor the messages. The subject's name was used in every message

and their age was used sporadically. In addition, we included details about the subject's current diabetes medications, including the name of the medications (as written on the bottles), number of times taken each day, number of pills taken at each dose, and time of day the medication was to be taken. This information was used to time text message delivery and craft messages that would be specific to each subject's treatment (benefits, safety, and mechanism of action). The name of medications was also included in some theory-driven messages.

#### Assessment tool adjustment

To incorporate specific perspectives from the target population in the message design, 2 focus groups were held on separate days including patients with diabetes from the Muskegon, MI area. These sessions were led by the study's primary investigator and guided by questions focused on issues related to diabetes treatment adherence and mobile phone use. The goal of the focus groups was to uncover any medication-taking problems specific to this community and not already considered in our theories, as well as inform the study on how adults in the area use their mobile phones to text message and access health-related information. Recruitment was done with advertisements in area physician offices, pharmacies, and community health practices using flyers and word-of-mouth. The target population for these sessions was intended to represent the population of interest for the larger, proposed study: adults with diabetes currently under treatment for diabetes and who had an active mobile phone. Basic demographic information on the participants was collected by an anonymous survey given at the end of each session. Sessions were audio recorded, dictated by a research assistant, and lasted approximately an hour each. Transcriptions were analyzed by the principal investigator following each session. Emerging

themes and concepts were noted and used to inform potential changes to the proposed assessment tool and the message development process.

Two sessions were held including 11 people with diabetes. All but 3 of the participants were female, most were Caucasian, and most had been diagnosed with type 2 diabetes (Table 2.1). Most participants reported that they have been treated for diabetes for 5 years or less. Participants' ages ranged from 48 to 69 and the number of medications being taken for diabetes ranged from 0 to 4.

Several themes were identified from the focus groups. First, participants reported that their mobile phone use was relatively limited. Most indicated that they used their phone for basic functions, generally talking to family members or for emergencies, and if other functions were used it tended to be text messaging. When texting, many subjects indicated that it was mostly for communicating with family members, 1 person specifically mentioned that they "liked the texting because it is faster." For those utilizing texting functions, estimates of the number of messages per day ranged from 1-2 to 9-10. However, not all participants viewed texting favorably: "I don't like reading information on text messages...texting is for the younger people." One subject specifically mentioned that the size of the text in the message made them too difficult to read. Members of both groups reported even more limited use of smartphone applications.

Several participants indicated that they already used their mobile phone to access health-related materials, mostly to gather information about symptoms and treatments. However, the majority of participants indicated that the computer remains their primary source of health-related information, "to see what's wrong, you know symptoms that I have. I just Google it."

Patients who sought health information online did so with varying frequency, some as often as weekly and others less than once every few months. When asked how valuable they would view receiving personalized health-related information on their phone, participants reported mixed feelings. Generally, those already using their phones on a more regular basis reported more favorable interest; however, more consistent support was garnered for receipt of similar information if delivered by “snail mail...a couple times a month.”

Participants indicated that adherence to their prescribed diabetes treatment was generally good: “I don’t see a challenge, just follow the rules. They say just take it 2 times a day and that’s what I do”. When given explicit directions from their physician, these subjects indicated that they were better able to follow the protocol, knowing what the consequences of inaction would be. Moreover, if doses were missed, respondents indicated that these were only on occasion.

However, 1 point was raised by members of both focus groups. When beginning a new medication, participants said that they would have benefitted from learning more about potential side effects of new treatments. Multiple participants mentioned unexpected side effects that were brought on by new medications that were not mentioned by their providers. Specifically, the participants suggested that these details could have been better described to them by pharmacists: “As soon as they gave [it to] me I wish they had told me I would feel tired. It’s three o’clock in the evening and I’m trying to go do something and I was knocked out. They didn’t tell me that right away.”

Based on the information from the focus groups, changes to the assessment tool were deemed unnecessary, as other challenges to the medication use process in this population were not identified. However, 1 item from the original survey was removed as it was specific to changing eating habits rather than medication use; altering this item to fit the study’s aims was

deemed inappropriate. The final assessment tool included 3 sections (a medication list, the theory-based items, and demographic details) and 34 items, 29 of which were used for tailoring (Appendix).

## Message Creation

Based on the items in the assessment tool, text message stems were drafted using each theoretical concept survey item, and the range of answer options for each item was used to develop different messages tailored to the specific response on that item. The assessment tool included Likert-type items with response options ranging from “strongly disagree” to “strongly agree” for HBM constructs and from 1 to 7, ranging from “not at all true” to “very true”, for SDT items. For Health Belief Model items, messages were written for responses deemed “high” or “low”. This was determined using a survey response to each item where responses of “agree” or “strongly agree” (“disagree” or “strongly disagree” for those reverse coded) indicated “high” and responses of “uncertain”, “disagree”, or “strongly disagree” would indicate “low” (“uncertain”, “agree”, or “strongly agree” for those reverse coded). For Self-Determination Theory items, messages were drafted for “low”, “medium”, and “high”, corresponding to 1 and 2, 3 to 5, and 6 and 7 responses, respectively, or the opposite if reverse coded. For example, a response of “2” to the first item related to competence, “I am confident that I can take care of my diabetes” would suggest that this subject had a low level of this construct and that the individual would then receive a “low” message.

Messages within each level were framed with the goal to improve or make more positive the concept/attitude, and the intention of the messages was to guide rather than force change from a less desirable to a more optimal level.<sup>38</sup> Practically, this means that those starting at “low”

or “medium” would receive messages intended to guide them toward a higher level of either “medium” or “high”. This approach may include recognizing the challenges of their treatment or condition, acknowledging the frustrations that may be introduced by external pressures, recognizing small victories, or valuing gradual progress. Conversely, subjects starting at “high” would only receive messages that reinforced this level of the intended concept. These messages were framed with maintenance and recognition in mind to keep subjects at the target level. Each message had a singular theme aligned with the corresponding survey item (Table 2.2). This eased the manner by which subjects may be guided toward more optimal levels of beliefs and self-determination. Two to 3 separate messages per item-level were drafted because of the number of messages required for the study. Consequently, 96 Health Belief Model messages (16 items and 2 levels) and 84 Self-Determination Theory messages (12 items and 3 levels) were created.

Drafts of the message stems were reviewed by an expert panel of health behavior researchers for readability (appropriate reading level), content (matching of the material to the concept), and tone (matching of the messages to the response level). Suggested revisions centered on appropriately structuring messages that included the subject’s age—to avoid inadvertent stereotyping—as well as simplifying the language to an 8th grade reading level. The study team recognized that the medication-specific messages detailed the benefits of each treatment, and the inclusion of medication tailoring in benefits-based messages was redundant. As a result, only 2 messages per item-level focusing on “perceived benefits” were included in the library. After this review, substantive changes were applied to 55 of the theory-based items. Following these changes, a total of 168 potential, theory-based messages were included in the final library.

Messages were also developed that included tailoring based on diabetes treatment with messages addressing medication efficacy, safety, mechanism of action, and reminders. These messages were crafted for 10 therapeutic classes of medications, including 5 combination products and 3 insulin categories, and did not vary for individual products available in each class; however, combination medications were handled by including information about both therapeutic classes. Separate messages were created for short, intermediate, and long-acting insulin. Based on feedback from focus groups, several messages were drafted that focused on communication with providers, specifically pharmacists, to encourage patients to ask for medication-specific information. Up to 3 messages per category were developed resulting in a total of 128 possible messages; a clinical pharmacist reviewed initial drafts for clarity and accuracy. Two of the 128 potential messages were revised and all messages were deemed appropriate for inclusion in the final library.

Finally, messages were edited to limit their length to approximately 160 characters to allow for the inclusion of the subject's age, name, and medication names. Such limitations allowed the messages to be properly delivered by a single mobile phone text message.

### Message Storage

The final library was maintained in a Microsoft Excel spreadsheet, which served as the primary tailoring engine for the larger study. The file was programmed to automatically concatenate the subject's name with the appropriate message stem after all stems (both medication and theory-based items) were pulled from the library.



## Tailoring Algorithm

The tailoring algorithm provides the logic to link the messages with survey responses and places them in a predetermined way that is established by the investigator. Tailored messages for each subject were constructed in a step-wise fashion. First, raw survey information (name, medications, and item responses) was entered into coded worksheets. These responses created coded output that concatenated information based on survey item number and leveling. For instance, a response to the first item indicating “low” competence on the baseline survey would retrieve the appropriately leveled message stem from the library creating a list of the specific theory-based messages for this item (3 in total). This process is then repeated for each survey item until all theory-based messages are created using baseline measures and the message bank is populated for each user. Concurrently, medication codes retrieved all of the medication message stems from the library based on the subject’s reported treatment plan, and all message stems were automatically concatenated with the subject’s name and a randomly selected greeting (e.g. Hello, Hi, Good [morning, afternoon, evening], etc.) Finally, the subject’s age and/or medications were manually imputed to select, randomly determined messages. These additions increase the specificity of the message to the individual, creating a message that is tailored on upwards of 5 characteristics (name, timing, treatment, age, and beliefs). For instance, a subject (Jane) with a baseline competence level of “low” (response equaled “1” or “2”) would receive the following message related to competence: “Hello, Jane. Building confidence in being able to take care of your diabetes takes time. But you make progress every day by following your treatment plan.”

The ordering and delivery of messages was based on several constraints. First, the associated intervention lasted 90 days with participants receiving 1 tailored message per day.

This allowed for 78 theory-driven messages for each subject; 12 tailored, medication-specific messages were added in order to total 90 messages.

Second, the leveling of items had to be considered as the delivery of messages was intended to guide subjects from lower to higher levels of the concepts over the 90-day intervention. The system was designed so that subjects would receive 2 Self-Determination Theory messages from their baseline level and 1 message from the next higher level with both sets drawn randomly from the available messages in each level. As an example, a subject with a baseline level of “low” for a competence item would receive 2 messages from the “low” category and then their third message would be from the “medium” category. Subjects whose baseline response was high for any item would receive 3 messages from the “high” category in order to maintain their self-reported level. Messages for subjects beginning at “low” for Health Belief Model items—meaning baseline survey response indicated a limited understanding of or belief in their disease severity or susceptibility—would first receive 2 messages to encourage understanding of these concepts and then change to messages focusing on reinforcement as they progressed through the intervention. Following this approach, subjects who were low for any HBM construct would receive 2 messages from the “low” category and then 1 message from the “high” category. For instance, a subject deemed “high” for an item related to severity may receive a message with the following text: “You know how serious diabetes can be. Taking your medications as directed will help you control this condition and improve your health.”

Finally, as stated earlier, medication messages were incorporated into the algorithm to fill the gap created by the number of theory-driven messages and the 90-day study period. All subjects received the same number of medication-specific messages and these were received on defined days that were identical for each subject; however, the mix of the types of medication

messages (efficacy, mechanism of action, and potential side effects) was dependent on the number of medications for each subject. All messages were timed for delivery based on the time of day at which the first dose of any medication was reported to be taken.

The order of messages was pre-determined to alternate between theories and their individual concepts, but an identical scheme for each subject for the order of messages was used (Figure 2.3). The final algorithm specified that theory-driven messages alternated between those based on HBM and SDT until all messages were exhausted. Using the baseline level for each item, messages began with the first message for the baseline level of each corresponding item, cycling through the first message, then the second, and (if applicable) the third item.

Once placed in chronological order, message stems were automatically combined with the subject's name and a randomly assigned greeting. The addition of subject medication and age were completed manually prior to message delivery. Following these steps, the resulting combination of messages was stored in individual worksheets (1 per subject) and formatted to meet the needs for server-based delivery to each subject's mobile phone.

## **Discussion**

Tailored messaging has become an increasingly used means to encourage health-related behaviors, including medication adherence. Only recently has this approach been modified to communicate with patients by mobile phone text messaging. Building effective messages that are sufficiently tailored and formatted for mobile phone delivery poses unique challenges. A repository of theory-driven messages is vital to the success of mobile phone-based and tailored adherence support services. Applying the library of messages built by the methods described here will contribute both broadly, by adding available messages to the architecture of tailoring,

and specifically, by demonstrating how tailored text messages may impact medication adherence.

The applied methods were similar to prior efforts although there were some important differences. Applying “Sweet Talk”, Franklin and colleagues targeted pediatric patients with type 1 diabetes using messages that were informed by Social Cognitive Theory but their approach had a more universal focus on self-management behaviors (e.g. exercise and glucose self-testing) rather than a specific targeting of medication use.<sup>36</sup> Moreover, as an intervention targeting children, “Sweet Talk” involved the use of ‘texting jargon’—the shortening of particular words—that likely improved the resonance of the messages with this younger population.

More recently, Petrie and colleagues focused on improving asthma treatment adherence in young adults.<sup>35</sup> The basis for their messages was a validated Illness Perceptions Questionnaire.<sup>55</sup> Messages were crafted around each illness perception item in order to change beliefs over the course of the intervention. This was accomplished using responses to the instrument’s 11-point scale; messages were tailored to match baseline patient beliefs for those higher or lower than the mean reported values. However, those within the standard deviation of the mean responses for a particular item did not receive a message tailored for that belief and it was unclear whether these messages were replaced with others. It was also not clear to what extent individual patient characteristics were used in message tailoring. In contrast, our message delivery was designed to reach all participants for all concepts of each theory, regardless of baseline values, so that all elements studied were tailored to and studied.

The current methods have limitations. Both the type and number of messages were limited to 2 health behavior theories and daily delivery, respectively. While evidence suggests

that such a “dose” of messages is acceptable to subjects, a truly individualized approach would incorporate patient preferences for the number of messages into the design.<sup>35</sup> Moreover, a host of health communication and behavior theories (e.g. Theory of Planned Behavior, Trans-theoretical Model, Regulatory Focus Theory) could apply to the message creation process, particularly expanding on the role of need for cognition as defined by the Elaboration Likelihood Model. Additionally, messages did not consider the effect of present versus future oriented subjects when framing messages from either a loss or gain perspective- a previous study highlighted the impact that this type of framing may have on medication adherence.<sup>56</sup> Similarly, messages were drafted without specific subject input to the process and content; future studies should incorporate this step into the message-creation process to improve the specificity and content of each message as well as to increase the use of patient preferences. Also, while the theories applied to the current messages supplied sufficient concepts for tailoring, they may not be comprehensive in addressing all factors that influence medication use. Specifically, the cost of medications was not addressed and the concern for side effects, while acknowledged by our medication-specific messages, was not applied extensively in this study. As previous research has suggested the role that these concerns may play in motivating adherence to medication, future studies involving theory-driven messaging should consider including these issues in the message development process.<sup>57</sup>

The process described by Kreuter and demonstrated herein is a practical approach to tailoring messages aimed at changing a specific behavior. This study’s methodology applied such an algorithm with the goal of delivering tailored messages by mobile phone- one of the first studies to do so. The result of this integration is a process that similar studies may duplicate so that further theory-driven tailoring of text messages may be applied to improving medication

adherence and other health-related behaviors. The current library of messages will be tested in a future study among patients with poorly controlled diabetes. Specifically, this will quantify the impact of tailored text messages on patients' beliefs regarding diabetes treatment and their disease as well as the impact of the intervention on users' acceptance of mobile technology and medication adherence.

### Acknowledgments

This research was sponsored by an award from the University of Michigan Rackham Graduate School and by Grant Number HS021976 from AHRQ and the contents of this publication are solely the responsibility of the authors and do not necessarily represent the official views of AHRQ. John Piette is a VA Senior Research Career Scientist and received additional support from grants number P30DK092926 and 1-R18-DK-088294-01-A1 from the National Institute of Diabetes and Digestive and Kidney Diseases. The authors wish to thank Benjamin Korman (University of Michigan College of Pharmacy) and Jason Barnum, PharmD (Mercy Health Partners) for their assistance with the focus groups.

This paper was previously accepted for publication and is reprinted from Gatwood J, Balkrishnan R, Erickson SR, An LC, Piette JD, Farris KB. Addressing medication nonadherence by mobile phone: Development and delivery of tailored messages. *Res Soc Admin Pharm* 2014; doi:10.1016/j.sapharm.2014.01.002, with permission from Elsevier.

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Characteristic	Frequency (n)
Gender	
Male	3
Female	8
Race	
Caucasian	6
African American	4
Hispanic	1
Diagnosis	
Type I Diabetes	4
Type II Diabetes	7
Treatment Years	
<1	4
1-3	2
3-5	1
5-10	2
>10	2

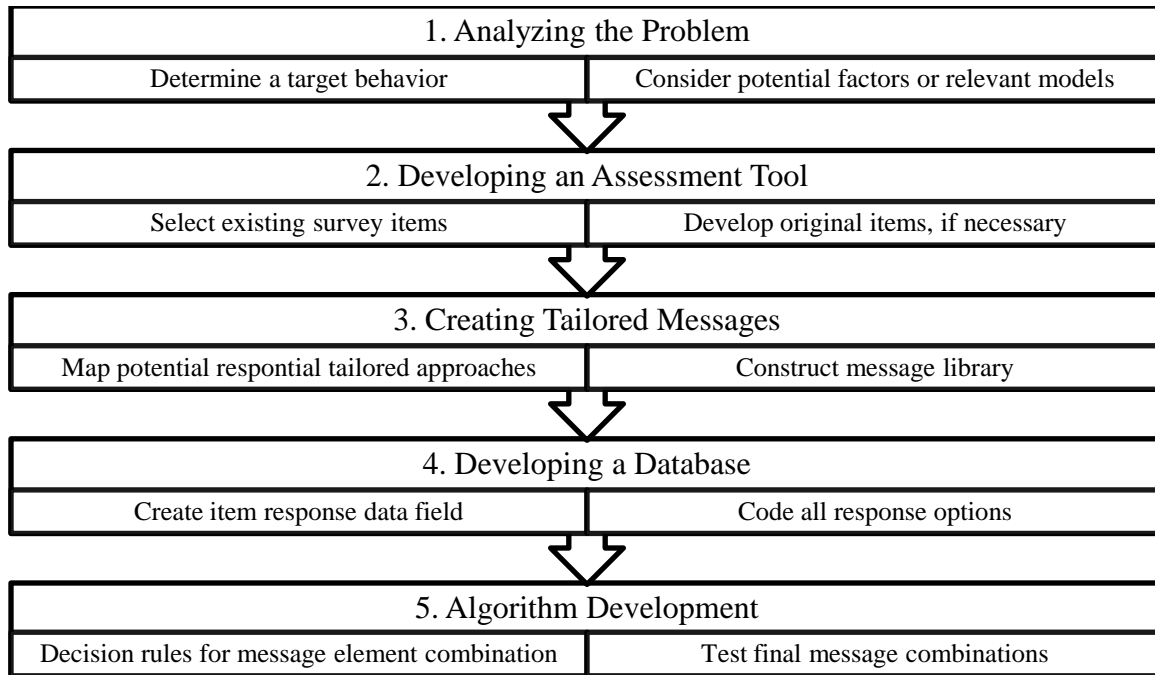
Table 2.1 Focus Group Subject Characteristics

Total n = 11

Table 2.2 Message Themes

Concept	Themes	Example Message Stems
Severity	<ul style="list-style-type: none"> <li>• Condition progress and control</li> <li>• Daily effort to manage diabetes</li> <li>• Role of medications in reducing the risk of future complications</li> <li>• Serious nature of diabetes, now and in the future</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Low:</b> even if your diabetes isn't controlled today, taking your medications, exercising, and eating right will help you reach your goal</li> <li>• <b>High:</b> sounds like you are making progress with controlling your diabetes. Keep up the good work!</li> </ul>
Susceptibility	<ul style="list-style-type: none"> <li>• Treatment adherence even when feeling well</li> <li>• Potential for future health problems</li> <li>• Symptoms of illness</li> <li>• Chronic nature of diabetes treatment</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Low:</b> even when you start to feel better, be sure to stick with the diabetes plan your doctor and you agreed upon. It'll pay off in the long-run</li> <li>• <b>High:</b> recognizing that there is more to treating your diabetes than just feeling ok is a great way to approach your health. Keep it up!</li> </ul>
Barriers	<ul style="list-style-type: none"> <li>• Adjusting daily habits/routines to fit medication-taking needs</li> <li>• Means to ease the process of taking medications</li> <li>• Understanding prescribing directions</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Low:</b> your normal activities don't have to be affected by your treatment. Pair a daily activity with taking your medications to easily fit them in</li> <li>• <b>High:</b> sounds like your doctor gave you great direction on your diabetes medications. Be sure to put that plan in action every day</li> </ul>
Benefits	<ul style="list-style-type: none"> <li>• Belief in self-efficacy</li> <li>• Adjunct therapy to medication</li> <li>• Symptom relief</li> <li>• Tailored treatment plan</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Low:</b> your medications can go a long way in controlling your diabetes. The plan your doctor outlined is tailored to meet your needs and improve your health</li> <li>• <b>High:</b> believing in the power of your medications is great, taking them as directed will show you how much you can control your condition</li> </ul>
Competence	<ul style="list-style-type: none"> <li>• Confidence in self-treatment</li> <li>• Making daily progress toward treatment goals</li> <li>• Acknowledging and managing treatment challenges</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Low:</b> controlling diabetes can be challenging but there's a lot in your control, like following your medication schedule and eating well</li> <li>• <b>Medium:</b> meeting the challenges of controlling your diabetes takes time, but taking your medications as directed moves you closer every day</li> <li>• <b>High:</b> thinking you can meet the challenges of your diabetes head on is a powerful attitude. Stay strong and keep up with your treatment</li> </ul>
Motivation	<ul style="list-style-type: none"> <li>• Importance of medications</li> <li>• Incremental impact of medications</li> <li>• Taking responsibility for own health</li> <li>• Indirect effects of medication taking</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Low:</b> it may be tough to see but taking your diabetes medications is vital to your health. Taking them as directed may help you see their value</li> <li>• <b>Medium:</b> many things are important for your health when you have diabetes. Taking your medications as directed is one of them. See for yourself</li> <li>• <b>High:</b> you're right. Taking your diabetes medications is one of the best things for your health. So, keep taking them as directed to reach even better health</li> </ul>
Support	<ul style="list-style-type: none"> <li>• Limiting external pressure(s)</li> <li>• Upsetting others</li> <li>• Proving self-efficacy</li> <li>• Approval for managing treatment</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Low:</b> when it comes to health the only approval you need is that of your body when it gets the benefit it needs from medications to treat your diabetes</li> <li>• <b>Medium:</b> by focusing on your treatment plan you are gaining the only approval you need: that of your body. Your medications are designed to help with this</li> <li>• <b>High:</b> you're right, the only approval you need is your own and that of the benefit of the good health you'll see from sticking to your treatment plan</li> </ul>

Figure 2.1 Kreuter's Five-Step Tailoring Process



Adapted from process detailed in Kreuter, 1999<sup>5</sup>

Figure 2.2 Framework for Message Development

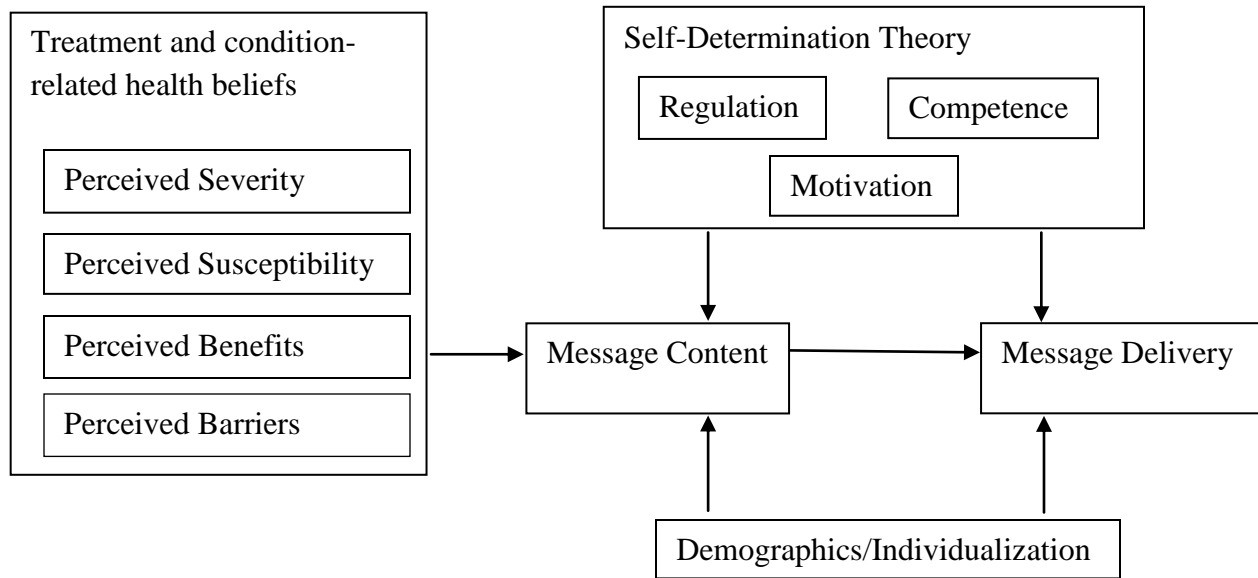
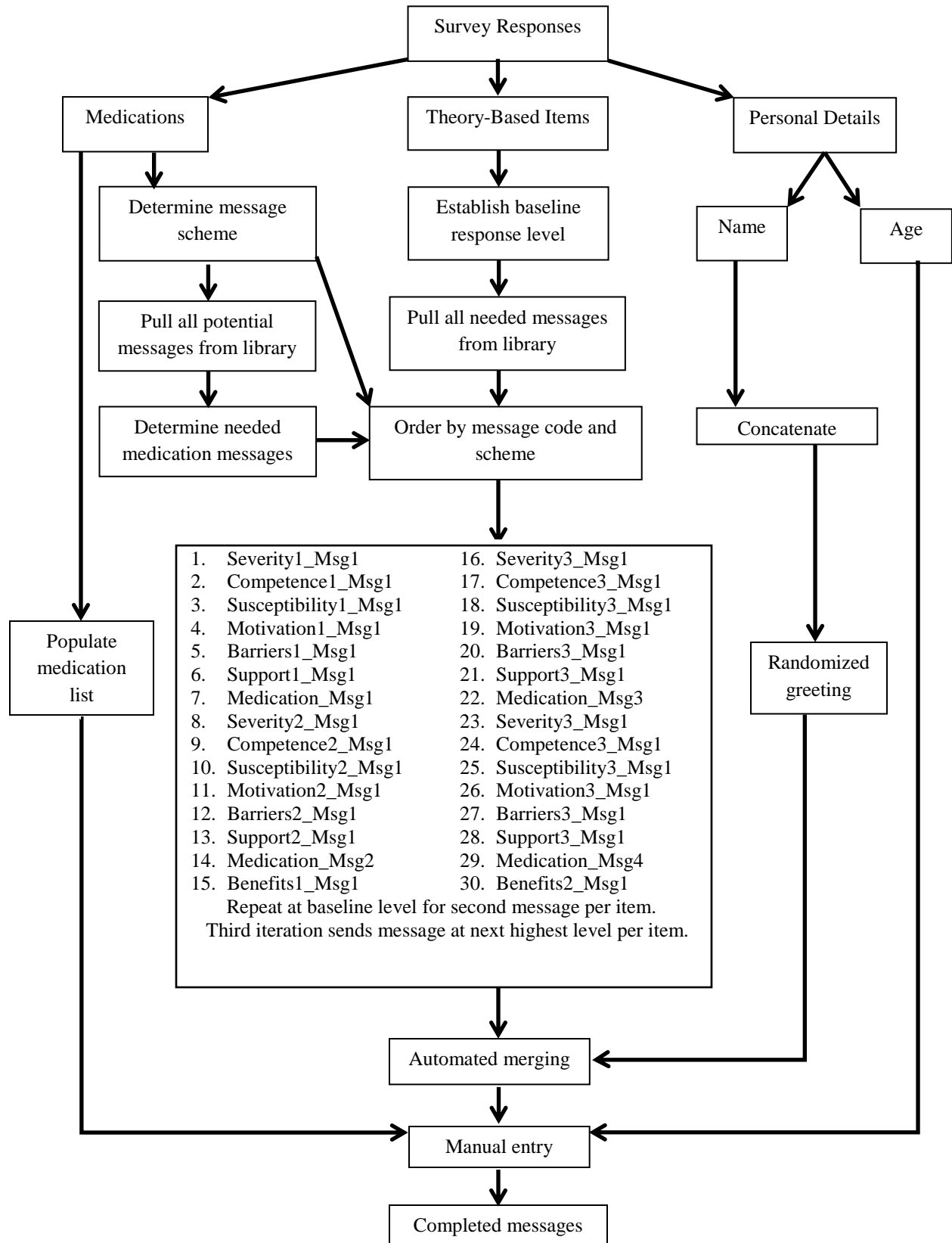


Figure 2.3 Tailoring Process and Algorithm



## Appendix. Tailoring Survey Instrument Items

Section	Category	Item
Medication Use <sup>a</sup>	Diabetic regimen	Name of medication
		Number of pills
		Times taken per day
		Time(s) of day taken
Health Beliefs <sup>b</sup>	Severity	My diabetes is well controlled.
		My diabetes would be worse if I did nothing about it.
		I believe that my medications will help prevent complications related to diabetes.
		Diabetes can be a serious disease if you don't control it.
	Susceptibility	My diabetes is no problem to me as long as I feel alright.
		My diabetes will have a bad effect on my future health.
		My diabetes will cause me to be sick a lot.
		I believe I will always need my diabetes medications.
	Benefits	I believe I can control my diabetes.
		I believe that my medications will control my diabetes.
		My medicine makes me feel better.
	Barriers	I would have to change too many habits to follow my medications.
		It has been difficult following the medications prescribed for me.
		I cannot understand what the doctor told me about my medications.
		Taking my medications interferes with my normal daily activities.
	Self-Determination <sup>c</sup>	Competence
I can handle my diabetes now.		
I can do my own routine diabetes care now.		
I can meet the challenge of controlling my diabetes.		
Motivation		Taking my diabetes medication is very important for being as healthy as possible.
		I personally believe that taking my diabetes medications is the best thing for my health.
		I feel that I want to take responsibility for my own health.
		I have carefully thought about it and believe taking my medications is very important for many aspects of my life.
Support		I feel pressure from others to take my diabetes



		medications.
		Others would be upset with me if I didn't take my diabetes medications.
		I want others to see that I can take my diabetes medications.
		I want others to approve of me.
Demographics	Age <sup>d</sup>	Subject age
	Gender <sup>e</sup>	Subject gender
	Marital status <sup>e</sup>	What best describes your current marital status?
	Race <sup>e</sup>	What race best describes you?
	Income <sup>e</sup>	Total household income?
	Inhabitants <sup>d</sup>	With how many people do you currently live?

<sup>a</sup> Responses were written in by the subjects in the space provided; time of day was indicated among given options.

<sup>b</sup> 5-item Likert scale responses, ranging from "Strongly Disagree" to "Strongly Agree"

<sup>c</sup> 7-item Likert scale responses, ranging from "1 (Not at all true)" to "7 (Very true)"

<sup>d</sup> Open-ended response

<sup>e</sup> Categorical options given

## **CHAPTER III. PAPER 2: USE OF MOBILE PHONES AND PERSPECTIVES ON TAILORED TEXT MESSAGES IN ADULTS WITH DIABETES**

### **Abstract**

Background: Mobile phone text messaging has become an increasingly popular means to exchange information. Little is known about the preferences for and acceptance of text messages by patients.

Aims: To evaluate the use of mobile phones, acceptance of text messaging, and perspectives on receiving tailored text messages in adults with uncontrolled diabetes.

Methods: A total of 48 subjects were recruited into a randomized controlled study to improve medication adherence; 21 individuals provided responses on technology acceptance and 12 personal telephone-based interviews were conducted. Following 90 days of receiving tailored text messages, subjects in the intervention arm were surveyed on technology acceptance and interviewed to obtain personal perspectives on the receipt of tailored materials and preferences for the use of mobile phones during the treatment process.

Results: Text messaging was relatively limited (<10 per day) among most participants and those texting more frequently tended to be younger and own a smartphone. Acceptance of text

messaging in the treatment process, in terms of usefulness and ease of use, was high; only perceived competence and barriers were found to have significant relationships with either acceptance concept. Subjects felt that receiving one message per day was appropriate and generally benefitted from the content but indicated that messages tended to still serve as reminders.

Conclusions: Acceptance of tailored text messages was high in adults with diabetes and subjects felt they could benefit from receiving similar messages in the future.

## **Introduction**

Mobile phones are a nearly ubiquitous piece of technology, the use of which has increased dramatically in the last two decades. Between 1992 and 2012, wireless phone subscriptions in the United States grew from just over 11,000,000 to over 326,000,000.<sup>1</sup> Currently, an estimated 91% of American adults own a mobile phone, up from 78% five years ago.<sup>2</sup> Most of these devices are now smartphones (56%), the ownership of which has increased dramatically, growing by over 20 percentage points in the past two years and penetrating all socioeconomic levels.<sup>2</sup> A higher percentage of American adults now own mobile phones than report using the Internet.<sup>3</sup> Moreover, while minutes of talk time have remained relatively stable, the estimated number of text messages exchanged between devices has more than doubled since 2008: over two trillion messages were sent last year, the majority of which among younger populations.<sup>1,4</sup>

Capitalizing on widespread ownership and advanced connectivity, the healthcare community has begun to leverage mobile phones in the delivery of care. As of 2012, nearly one-

third of cell phone owners reported using their phone to search for health or medical information, the percentage of which having nearly doubled from two years prior and is well distributed across socioeconomic levels. Moreover, nearly one in five adults now own health-related applications on their phone to assist in the tracking or management of their condition.<sup>5</sup> Considering the penetration of mobile applications and operability in the healthcare market, researchers have employed mobile technology in the conducting of behavioral interventions.

To date, text messaging has been the most popular mobile channel used by interventions but direct calling, Internet, and e-mail functions have also been applied.<sup>6</sup> A variety of conditions and behaviors have been targeted across these studies, including smoking cessation, appointment keeping, physical activity, diabetes, hypertension, and asthma.<sup>6-8</sup> Medication nonadherence has also been addressed, primarily using reminder messages to encourage the proper taking of medications, mostly in chronic conditions.<sup>9-14</sup>

Estimates suggest that less than 10% of American adults receive updates or alerts by text message and over 80% of the mobile Internet usage is in adults 49 years of age and younger.<sup>5</sup> Importantly, several studies evaluated the receipt of messages in their subjects to better understand the acceptance of such a system. In these studies, acceptance of and satisfaction with receiving text messages focused on medication adherence was high, and this was observed in investigations with a variety of dosing schemes ranging from one to three daily and even in those employing an adjusting dose.<sup>11, 13-17</sup> However, if mobile platforms such as text messaging and smartphone applications, focused on health and medicine, are to be more widely accepted, more must be understood about the use of cell phones, and their capabilities, as well as the needs and preferences in certain patient populations.

The Technology Acceptance Model, an extension of the Theory of Reasoned Action, suggests that the fundamental determinants of acceptance of a technology are its perceived ease of use and perceived usefulness (Figure 3.1).<sup>18, 19</sup> Specific to mobile phones, research has suggested that these two concepts are major factors influencing the intention to use mobile text messaging.<sup>20</sup> While several investigations have considered the influence of external variables on perceived ease of use and usefulness, our understanding of how patients perceive and accept mobile messaging, in the context of healthcare delivery, is severely limited. Considering the rate by which text messaging is used by the general population, it may be assumed that many would adopt this communication channel as a healthcare tool. However, while differences in use by age have been observed, it is possible that condition-related factors may also influence text message use and a better understanding of potential influencers would aide practitioners and developers in the pursuit of improving the exchange of information with patients. As part of an intervention focused on improving medication adherence in adults with diabetes, this research aimed to better understand how patients actually use and perceive using their mobile phone in the treatment process. The objectives of this paper were to describe general mobile phone use, illustrate personal responses related to the receipt of tailored text messages, and evaluate mobile phone acceptance in a population of patients with diabetes. These findings provide insight to the characteristics, health beliefs, and motivations that may influence the acceptance and eventual use of text messaging during the treatment process.

## **Methods**

### Design

Mobile phone use and acceptance in adults with diabetes were evaluated as part of a randomized, controlled intervention using tailored text messages to address medication nonadherence. The intervention employed theory-based individualized text messages focused on condition and treatment-related beliefs as well as medication-specific information over a period of 90 days. The message development and delivery process is described elsewhere.<sup>21</sup> Participants in the active arm received their daily message at the same time each day in conjunction with the time of day at which the first medication was taken; control arm subjects received a monthly “thank you” message throughout their 90-day period. Institutional Review Board approval was received from both the University of Michigan and Mercy Health Partners (Muskegon, MI) for all study components.

## Subjects

Subjects for the intervention were recruited from a community-based primary care network in western Michigan. Eligible subjects for the randomized study included those diagnosed with diabetes, taking at least one antidiabetic medication, and having a hemoglobin A1c of at least 8.0% (according to their most recent test). Patients were excluded if they had experienced a stroke or heart attack, been diagnosed with congestive heart failure, or did not own and operate a mobile phone. Following screening and informed consent, eligible subjects were randomized (using a random number generator) to a study arm where they would receive either one tailored text message per day for 90 days or standard care only. All subjects were then mailed a survey and were considered enrolled once this was completed and returned; a similar survey was mailed after the 90 days of the intervention. All subjects, regardless of study arm, were compensated \$50 for their participation.

The intervention ran from December 15, 2012 through September 24, 2013, and 2,230 study-related messages were sent and 94.3% were delivered properly as scheduled according to the system. Most interruptions in message delivery were isolated incidences (e.g. one missed day, received later in the day) with one exception where a phone was disconnected.

Subjects in the tailored text messaging arm were asked to participate in a brief phone interview (10-15 minutes) at the end of the study to capture perspectives on the receipt of tailored text messages. Subjects were randomly selected until half of the cohort had participated, and oral consent to participate was obtained from each subject prior to participating. All subjects were compensated \$10 for being interviewed.

#### Data Collection

At entry to the intervention, all enrolled subjects (regardless of study arm) were surveyed on general mobile phone utilization and ownership. Items focused on the type of phone owned, including service provider, frequency of texting, and monthly service costs. Among those subjects in the intervention group, technology acceptance was evaluated after 90 days of receiving tailored text messages. Four items guided by the Technology Acceptance Model were included in the endpoint survey and adapted for patients with diabetes from an instrument used to investigate SMS (text) messaging employed previously by Kim and colleagues.<sup>18, 20</sup> The included items surveyed subjects on perceived usefulness and perceived ease of use (two items for each concept), the degree of which, according to the model, influences the user's attitude toward a particular technology and, ultimately, their intention to use the technology.<sup>18</sup> Seven-point Likert scales were used for this study, ranging from 1 (strongly disagree) to 7 (strongly agree). Scale reliability for perceived usefulness and perceived ease of use were demonstrated

previously to be 0.77 and 0.91, respectively.<sup>20</sup> Additionally, subjects were surveyed on their health beliefs and level of self-determination (according to concepts related to the Health Belief Model and Self-Determination Theory) using items from three established sets of instruments, the details of which have been described previously.<sup>21</sup>

Questions in the personal interviews focused on opinions of the messages in terms of content, their role in the treatment process, frequency, and their anticipated use of mobile phones for diabetes management in the future. The primary investigator conducted all interviews and notes were recorded on a standardized form for each response item.

## Analysis

For analysis, responses to baseline survey items were combined with demographic characteristics reported by each subject and descriptively reported using t-tests or Fisher's exact tests for continuous and categorical variables, respectively. To summarize responses for Technology Acceptance Model concepts, mean values were determined using scores from both items within each concept; descriptive statistics and comparisons were made using Mann-Whitney tests.<sup>22</sup> To determine if differences in acceptance varied by or potential relationships existed between subject characteristics or beliefs, mean values for both Technology Acceptance Model concepts were compared between categorical variables by Mann-Whitney tests and among continuous variables by Spearman rank correlation.<sup>23</sup> In cases where multiple categories existed, groups were combined to form dichotomous variables of more balanced cell values to accommodate for the small sample size: low texting (1-10 texts per day) versus high texting (11+ texts per day), lower income ( $\leq$ \$50,000) versus higher income ( $>$ \$50,000), and White versus minorities (African American, Hispanic, Native American, or multiple). These categories were



also applied to Technology Acceptance Model items among interview participants, due to the reduced sample size, in order to examine potential characteristics among those with relatively lower technology acceptance.

## **Results**

### **Subject and Mobile Phone Characteristics**

The final study sample included 48 individuals that were randomized equally at baseline into the two study arms. At baseline, the average age was 47 years, but half of the subjects were aged 50 years and older. Also, nearly all subjects were Caucasian or African American, and just over half were married. Income tended to increase with age but no significant differences were observed between races or genders. Among all subjects, approximately two diabetes medications were taken on average and were being taken across four doses per day; at endpoint the number of medications remained unchanged but the average daily dose dropped below four per day (mean = 3.9, SD: 1.56). The two study arms were well balanced according to the characteristics surveyed (all  $p > 0.05$ ).

Daily texting, type of phone, and phone bill were examined by demographics. Overall, participants reported limited text messaging: two-thirds of the population indicated texting 10 times or fewer per day. Of those texting on a more regular basis (11 times or more per day), a significant majority ( $p < 0.01$ ) were 49 years of age and younger; nearly all of these subjects were aged 39 years or younger. In this population, more frequent texting was observed in women than men ( $p < 0.05$ ) and was more likely to have been done among those owning smartphones ( $p < 0.05$ ). No differences in text messaging were observed across income categories, races, or

between service providers; spending on service was no different between low and high text messaging subjects. At baseline, no difference in texting frequency was observed between study arms ( $p=0.682$ ) and all other mobile phone characteristics were similar.

Smartphones were the dominant phone type, and a majority was owned by subjects 49 years of age and younger (72%). Also, a larger share of subjects who reported annual household incomes of \$50,000 or less (62%) owned these devices. Differences in ownership of the two types of phones were not observed by race or gender.

The average monthly bill for mobile services was approximately \$100 and roughly 80% obtained service through a major provider. While the average bill for subjects with smartphones (\$112.90, SD: 14.55) was observed to be higher than those with basic devices, the difference did not reach statistical significance. Those in the lowest income bracket reported the lowest average monthly bills (\$59.14, SD: 28.33) and were significantly lower than the averages of those in the next highest income category as well as those making over \$50,000—no difference was observed between these latter two groups. Additionally, no significant relationships were observed between the number of medications taken or daily dose and mobile phone ownership, spending, or use.

### Technology Acceptance

Endpoint surveys captured intervention arm subjects' responses to items intended to measure acceptance of mobile phones in the diabetes treatment process. By and large, acceptance was high in this population in terms of perceived ease of use and usefulness of mobile text messaging. Mean values were 6.33 (SD: 0.885) and 5.67 (SD: 1.38) for ease of use and usefulness, respectively. Only two subjects indicated some level of disagreement to the

usefulness items; only one subject did so for the items measuring ease of use. All three of these subjects reported low daily texting, contracted with major carriers, were male, over the age of 50, and taking their diabetes medications at least six times per day.

Among all subjects, 76% moderately or strongly agreed to both ease of use items; just over half (52%) had this level of agreement for both perceived usefulness questions. Those subjects reporting such high acceptance to all items (42%) were similar to the characteristics of all respondents except that they tended to be slightly older than average and reported lower than average monthly mobile phone bills. No significant differences or relationships in either acceptance concepts were identified across subject characteristics, including age, race, income, and gender, or among treatment regimens, including the number of medications or type of regimen (oral medication alone versus other regimens). Similarly, mean values for usefulness and ease of use were comparable for subjects regardless of texting frequency or phone type (Table 3.2).

Responses for usefulness and ease of use were also compared to each of the seven health beliefs and self-determination concepts surveyed. Correlation analysis indicated that only ease of use was observed to have a significant relationship with other theory-driven concepts, demonstrating strong, positive association with perceived competence ( $\rho = 0.6, p < 0.01$ ) and perceived barriers ( $\rho = 0.43, p = 0.05$ ). In this population the two Technology Acceptance Model concepts trended toward a significant relationship but did not reach statistical significance ( $\rho = 0.39, p=0.07$ ); correlation between perceived usefulness and daily doses of diabetes medications also trended toward significance ( $\rho = -0.385, p = 0.08$ ).

## Perspectives on Treatment and Condition-Tailored Messages

Twelve (50%) of the subjects in the intervention arm were interviewed over the phone after they had completed the study. The average interview lasted 12.25 minutes (range: 7—43) and most responded to 17 questions. Characteristics of those interviewed, including daily texting, phone type, and both technology acceptance items, were similar to those intervention subjects not interviewed except that those asked and willing were nearly all Caucasian and twice as many males participated than females. Specifically, two-thirds reported texting 10 times or fewer per day, slightly more than half owned a smartphone, and all income categories were represented.

All but one of the subjects interviewed indicated that they enjoyed receiving a daily tailored text message; the objection was financially driven as that individual specified the messages were, “not worth the cost.” Subjects commonly suggested that they enjoyed the messages because they served as reminders, provided encouragement, or gave helpful tips/information. Most (n=9) reported that they found the information in the messages helpful; specific comments indicated the information was “educational”, “encouraging”, and a “little bit of a confidence booster” or a “pep talk.” The remaining three subjects felt that the messages could have been better tailored to their specific needs or that the information provided was not relevant to their current point in the treatment process. One subject suggested that “[the messages] would have been more handy if based on checking sugars. I struggle with that every day. So, a reminder about sugars would have been helpful.” However, all but one person indicated that the tailoring was appropriate and that the individualization made them more likely to read and consider each message since they, “liked knowing [the message] was for me, not just generic.” Another subject noted, “I could tell they were tailored for me because they mentioned the medications I am on. Made me more likely to take them.”

In terms of the impact of the messages, a majority indicated the messages made them more confident about managing their diabetes (n=8) and more likely to take their medication each day (n=8). However, the most commonly mentioned motivation for taking each dose was the timing of the message serving as a reminder.

The messages focused on motivational and health belief factors and gave medication-specific information tailored to subjects' responses. Those interviewed most commonly indicated that content focusing on motivation was most helpful. One subject commented, "The type that gave encouragement, those ones [were the most helpful]. By remembering to take my meds, like I am supposed to, I can live a longer life. Gave me encouragement to take my meds." The messages focused on medication education were also well-received; comments included, "liked the information about what your medications do, how they react, and why I should take them" and "learned more about my Levemir; how it works throughout the day." No types of messages were specifically identified as bothersome or unhelpful. All subjects indicated that it was convenient for them to receive these messages by mobile phone and that receiving one message per day was sufficient; however, some felt that the messaging dose could be individualized (e.g. additional messages to match dosing schedules) based on demand without being bothersome.

Subjects were also asked about what they would like to see out of a similar, future message-based system. Suggestions varied but were generally suggestive of either increased specificity and/or the inclusion of feedback mechanisms. Participants felt that they would benefit from messages that focused on other ways to control their condition (e.g. diet, exercise), individualization around self-identified areas of difficulty (e.g. checking sugars), and more technical medication information. For example, one subject who was taking two insulins mentioned, "I don't know if the benefits or synergies were discussed. A lot of programs lack

giving an understanding of what the short and long-term insulins are doing together. Need more messages about understanding how the medications are working together- don't think that gets addressed." The ability to relay information back to a provider was commonly suggested to "keep in touch with the doctor" or even finding a way to receive "feedback on sugars: these were my sugars, these were my activities, my insulin doses, and recommendations on what I could do." All but one subject indicated they would want to participate in a tailored messaging program, similar to this one, if available in the future.

In addition to simple messaging, other functions of mobile phones that could be used for health-related purposes were mentioned. The most frequently mentioned functions were the ability to track disease progression, specifically the recording of tests, and the scheduling of reminders. Only one-third of interviewees indicated that they plan to, or already, use their phone to research diabetes-related information. If subjects mentioned they would like to interact with a provider (n=8) they tended to specify this would be with their physician; however, the desire to interact with a pharmacist was indicated. In this case, the pharmacist was specified "because of insurance status, especially about cost."

## **Discussion**

As part of a randomized controlled study, this investigation sought to better understand to what extent adults with diabetes use and accept mobile phone text messaging during their ongoing treatment. In the population studied, messaging was relatively limited and younger subjects were observed to text more frequently; however, even limited levels of messaging were seen across ages. Importantly, acceptance of using this form of communication in the treatment process was high, in terms of ease and usefulness, after 90 days of receiving a daily tailored

message, and was consistent across ages. Following what has been suggested by theory such high acceptance of mobile messaging would indicate a high intention to use this particular technology.<sup>18</sup> While no continuous messaging system similar to what was examined is regularly used in practice, the responses of interviewed intervention arm subjects indicating nearly universal interest in using a similar, individualized system suggests that future tailored messages aimed at improving treatment adherence would be accepted and used. As suggested, such a system may be more highly accepted if it deepened the tailoring to specific treatment needs (e.g. checking sugars, lifestyle management) and the stage of therapy.

A key issue across studies of text messaging interventions focused on medication adherence has been the determination of an appropriate message dose, meaning the desired level of contact the subject has with the system. To date, investigations have employed a variety of dosing strategies; these have included sending messages weekly or twice per week as well as sending messages up to 12 times per day.<sup>9, 10, 24</sup> Approaches have also included varying the number of messages sent either based on the subject's medication dose frequency<sup>11, 15</sup> or by stepping down the number of messages from twice daily to approximately one every other day.<sup>25</sup> However, the most popular dose used in text-based adherence studies has been sending one message per day.<sup>10, 12-14, 16</sup> Our study found that a daily message was an appropriate level for our subjects, corroborating the earlier findings, while also discovering that subjects would be open to variable levels of messaging as at least one other study had determined previously.<sup>14</sup> Moreover, our subjects also voiced interest in continuing to use such a message-based system in the future, a sentiment voiced in previous studies as well.<sup>15, 16</sup>

Several types of messages were applied in this study, adding to our understanding of the most appropriate content for patients with diabetes. In our population, respondents in the

intervention arm were split between finding the medication education and motivational messages most helpful- those preferring medication-specific messages tended to be slightly younger and were taking more diabetes medications, and more often, on average. Overall, this suggests that tailoring could be improved by focusing messaging on either type of message, rather than both, based on patient preferences—something that would need to be done at the outset of any intervention. Such an approach may then be more likely to result in positive behavior change and serve as more of an adjunct to therapy and less like a simple reminder. Interestingly, a strong, positive relationship was observed between perceived ease of use and the theory-driven concepts of perceived competence (diabetes-specific) and barriers—the only external variables to do so. This suggests that those finding text messaging relatively free of effort are also likely to be those who perceive themselves as able to successfully meet the challenge of controlling their condition and those who feel that relatively few barriers exist to effectively manage their diabetes. Future research should investigate how best to leverage mobile tools, such as text messaging, in those with a higher level of competence and with few perceived barriers to reinforce behaviors and further improve the odds of positive health outcomes. Similarly, a deeper investigation into what characteristics may be related to higher levels of acceptance is needed in order to better understand the adoption of mobile messaging and the subsequent influence it may have during the treatment process.

This study was limited in several ways. The sample size for this investigation was relatively small and only a fraction of those who participated were surveyed on technology acceptance and interviewed to obtain personal perspectives. While the responses given provide guidance on how adults with diabetes use their mobile phones and how text messaging studies may be structured, the views reported may not be representative of the general population of



adults with diabetes. Moreover, while half of those receiving tailored messages were interviewed to obtain a representative set of responses and their characteristics were similar to those not interviewed the opinions of subjects within the intervention arm may have differed significantly. Additionally, only a limited set of messages was sent to the subjects throughout the study; the mix of messages may have influenced the extent to which each individual was impacted by and their perception of the usefulness of the messaging program. Furthermore, the subjects recruited could also have had either type 1 or type 2 diabetes and may have had their condition for any number of years; however, the messages were not drafted with either type of diabetes or stage of treatment in mind. Resultantly, the messages used may not have been appropriate for all subjects within the study. The intervention also assumed that individual medication regimens were static for the three months of the study. While only three subjects within the intervention arm reported a change in medications over the 90-day period, the inability to alter medication messages after baseline limited the extent to which these messages could have been tailored, resulting in some inappropriate messaging for those placed on a new medication. Finally, while the system used to deliver all messages could report that a message was sent properly it could not confirm whether the recipient read a message.

## **Conclusions**

This study found that adults with diabetes are accepting of using text messaging during their treatment process and that a daily message focused on behavioral motivations, health beliefs, or medication education was appropriate. The use of a similar system may be of benefit to many adults with diabetes or other chronic conditions and future investigations should evaluate how best to leverage tailored material delivered by mobile phones. Such potential systems should consider individual patient preferences in terms of messaging content and dose,

the relaying of feedback, and direct communication between patients and providers in order to improve the odds of both patient utilization and improved health outcomes.

#### Acknowledgments

The study authors wish to thank Jason Barnum, PharmD (Mercy Health Partners) for his assistance with identifying potentially eligible subjects and Katie S. Kaminski, PharmD (University of Michigan) for her assistance with recruiting subjects for the intervention.

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Table 3.1 Tailored Messaging Cohort Demographics

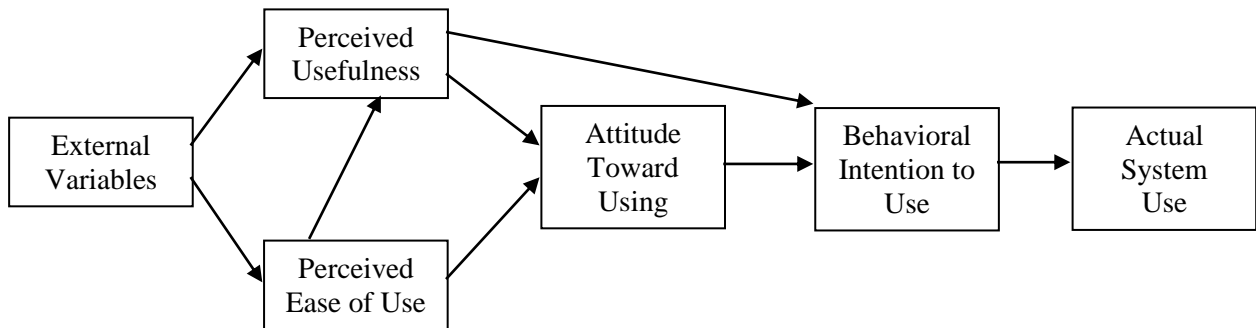
Characteristic	Active Group N (%)
N	24
Age*	46.4 (11.57)
Age Group	
21-29	3 (12.5)
30-39	3 (12.5)
40-49	6 (25.0)
50-59	9 (37.5)
60-64	3 (12.5)
Female	12 (50.0)
Marital Status	
Single	3 (12.5)
Living Together	3 (12.5)
Married	12 (50.0)
Separated/Divorced	6 (25.0)
Race	
Caucasian	14 (58.3)
African American	8 (33.3)
Native American	1 (4.2)
Latino	1 (4.2)
Household Income	
\$0-25,000	7 (29.2)
\$25,001-50,000	7 (29.2)
\$50,001-75,000	8 (33.3)
\$75,001-100,000	1 (4.2)
>\$100,000	1 (4.2)
Daily Diabetes Medications*	2.3 (0.85)
Daily Doses*	4.5 (1.64)
Daily Texting	
0-10	16 (66.7)
11-20	5 (20.8)
21-30	2 (8.3)
31+	1 (4.2)
Phone Type	
Basic	10 (41.7)
Smart	14 (58.3)
Average Monthly Bill*	98.27 (70.36)

\*\*Presented as mean (+/-SD)

Table 3.2 Technology Acceptance by Category

Characteristic	Ease of Use mean (SD)	p-value	Usefulness mean (SD)	p-value
Age Group		0.109		0.886
	21-49	6.7 (0.67)	5.9 (0.77)	
	50-64	6.0 (0.99)	5.5 (1.78)	
Gender		0.590		0.427
	Female	6.5 (0.71)	5.7 (0.67)	
	Male	6.2 (1.01)	5.6 (1.77)	
Race		0.326		0.186
	Caucasian	6.5 (0.92)	6.0 (0.97)	
	Minority	6.2 (0.84)	5.5 (0.50)	
Income		0.313		0.762
	<\$50,000	6.2 (0.93)	5.5 (1.57)	
	≥\$50,001	6.6 (0.79)	5.9 (0.93)	
Texting Frequency		0.226		0.850
	≤10 per day	6.2 (0.93)	5.6 (1.60)	
	≥11 per day	6.6 (0.75)	5.8 (0.91)	
Phone Type		0.218		0.914
	Basic	6.2 (0.75)	5.4 (1.93)	
	Smart	6.5 (0.99)	5.8 (0.83)	
Treatment Regimen		0.961		0.145
	Oral alone	6.4 (0.75)	6.4 (0.95)	
	Combination therapy	6.3 (0.93)	5.5 (1.44)	

Figure 3.1 Technology Acceptance Model



Adapted from Davis (1989)<sup>19</sup>

## **CHAPTER IV. PAPER 3: THE IMPACT OF TAILORED TEXT MESSAGES ON HEALTH BELIEFS AND MEDICATION ADHERENCE IN ADULTS WITH DIABETES**

### **Abstract**

Background: Inadequate medication adherence plagues health outcomes and can lead to increased costs, particularly in patients with diabetes. Efforts to date have resulted in limited effects; approaches leveraging mobile technology have emerged but their focus has mainly been limited to simple reminder messages.

Objectives: To test the effectiveness of tailored messages delivered by mobile phone on improving medication adherence and health beliefs in adults with diabetes.

Methods: Adults, aged 21-64, with uncontrolled diabetes, and taking at least one antidiabetic medication were recruited from a western Michigan health system and randomized into two study arms. Using responses from a baseline survey, intervention arm subjects received a tailored text message once daily for 90 days; control subjects received only standard care. Changes in theory-driven health beliefs and attitudes were assessed by comparing baseline and endpoint survey responses, and the impact on medication adherence was evaluated using pharmacy claims



by calculating the percent of days covered (PDC) prior to, during, and following the active study period.

Results: A total of 48 subjects were randomized into 2 equal study arms. Mean PDC values at baseline were comparable between active and control subjects (84.4% and 87.1%, respectively;  $p>0.05$ ). Declines in adherence were observed in both groups over time but no significant differences were observed between groups or from baseline to the end of the active study period. A trend toward significant improvement in perceived competence was observed in the intervention cohort, and unadjusted tests suggested that both perceived benefits and competence might have improved over the course of the intervention. An effect size for detecting an impact on health beliefs ranged from 0.0 to 0.047 and was 0.035 for adherence to diabetes medications.

Conclusions: The tailoring of mobile phone text messages is a novel way to address medication nonadherence and health beliefs but further investigation to this combined technique is needed to better understand the impact it may have on behavior change in adults with diabetes.

## **Introduction**

Nonadherence to chronic medications is a prevalent public health issue in the United States, contributing to added costs and detrimental health outcomes. The extent of this issue varies by condition with estimates of nonadherence to long-term medication regimens ranging from 20% to 83%.<sup>1</sup> The landscape of nonadherence is especially problematic in patients with

diabetes and is prevalent in those taking either oral medications or insulin. In this patient population, while adherence may be as high as 98%, estimates have been observed to be as low as 31% for oral medications while insulin regimens were found to have been adhered to only two-thirds of the time, on average.<sup>2,3</sup> The implications of such suboptimal adherence include a worsening of health status, as indicated by higher levels of hemoglobin A1c, as well as increased hospitalizations and all-cause mortality.<sup>4,5</sup>

Approaches aimed at improving adherence have evolved over time. Common methods have included provider follow-up,<sup>6-10</sup> patient education and coaching,<sup>11-17</sup> case management,<sup>12,18,19</sup> and reminders.<sup>15,20,21</sup> Across these intervention strategies, improvements in medication adherence have been realized, but consistent change has not been observed among similar strategies and no dominant approach has emerged. Recently, mobile technology has been increasingly used as a means to target improved medication adherence, most commonly leveraging text message reminders to reach patients.<sup>22-27</sup> While improvements in adherence have been realized by solely focusing on such cues to action, this technology affords the medical community the opportunity to relay messages to patients beyond simple reminders and focus on other medication-taking barriers.

Having shown positive results in health-related behaviors, such as smoking cessation and dieting, tailored messaging may be an approach to influence patients with diabetes to better adhere to their regimens based on added influences.<sup>28,29</sup> Tailoring identifies and then focuses communication on individual barriers and behavioral factors observed to impact a particular behavior. Studies using tailoring techniques aimed at improving medication adherence have shown mostly positive outcomes, such results having become more consistent in recent years.<sup>30-</sup>

<sup>39</sup> However, in studies involving patients with diabetes, the results have been mixed, suggesting the need for further inquiry.<sup>40,41</sup>

Recognizing the potential of both tailored communication and text messaging, a limited number of studies have investigated the combined effect that these two channels may have on medication adherence and have provided promising results.<sup>42-44</sup> Focusing on type 1 diabetes, Franklin and colleagues examined the use of tailored text messages in pediatric and adolescent patients; results demonstrated that this level of communication was accepted and could be effective in improving self-reported adherence.<sup>45</sup> What remains to be seen is whether the combined approach of tailoring and mobile phone message delivery can be an effective mode of behavior change in older and more diverse populations of patients with diabetes.

As a pilot study, the purpose of this investigation was to test the effectiveness of tailored text messages on influencing patients' health beliefs and attitudes toward their condition and treatment which in turn could lead to improved medication adherence in adults with uncontrolled diabetes. We hypothesize that the sending of daily messages focusing on either theory-driven concepts known to influence medication or specific medication knowledge will lead to increased subject beliefs about their condition and treatment and result in improved adherence to therapy.

## **Methods**

### **Design**

This pilot study was conducted as a randomized controlled investigation using two parallel arms: an active cohort that received a daily tailored message and a control arm that received standard care only. Approval to conduct this investigation was granted by an

Institutional Review Board at the University of Michigan and Mercy Health Partners (Muskegon, MI), and patients gave informed consent to participate after being briefed on the study.

### Study Population

Using electronic health records, adults (aged 21-64) with diabetes and a hemoglobin A1C of at least 8.0% (according to their most recent reading) were recruited from a western Michigan health system. Potentially eligible subjects were drawn from the health system's electronic health record system, contacted by mail, and given the option to opt out of being further contacted and considered. Those not opting out were contacted by phone, introduced to the study, and screened for eligibility, if interested. Subjects were also recruited at a local diabetes health fair during which the study was introduced and interested subjects were screened and consented, if eligible. In order to be eligible, subjects needed to have been diagnosed with diabetes, been taking at least one antidiabetic medication, reported missing at least one dose within the past 30 days, used a mobile phone able to receive text messages, and reported pharmacy coverage through either one of two payer partners or the health system's assistance program. Subjects were excluded if they had suffered a heart attack or stroke, been diagnosed with congestive heart failure, or if English was not their primary language. Once eligible, all subjects were randomized into either the intervention or control arm using a random number generator. Regardless of study arm, all subjects were compensated with a \$50 debit card for their participation at the end of the study.

### Intervention

Using responses to a baseline survey, subjects in the intervention arm received one tailored message by mobile phone each day for 90 days. Content for each message was based on

either concepts of the Health Belief Model or Self-Determination Theory or focused on the medication regimen of the subject. To achieve a more deeply tailored message, subject name and the time of day delivered (e.g. morning, afternoon, evening) was always used; age and medication name were used sporadically or when coinciding with a medication-focused message, respectively. The intent of the messages was to increase patient education, provide motivation, and reinforce existing levels of condition and treatment-related beliefs. Messages were timed to be received at the time of day coinciding with the subject's first dose, and delivery of each message was confirmed by the system used to automate the process- the entire message creation and delivery process has been described elsewhere.<sup>46</sup> Subjects in the control arm received standard care only and a monthly check-in message.

#### Data Collection

At enrollment, subjects were mailed a survey to capture baseline values related to Health Belief Model and Self-Determination Theory constructs as well as information on demographics, mobile phone operation, and medication use. Established instruments were used to evaluate the theory-driven concepts of perceived severity, susceptibility, barriers, and benefits as well as autonomous motivation, perceived competence, and external regulation. Health Belief Model constructs were captured using a diabetes-specific instrument developed by Given<sup>47</sup> and then altered by Becker and Janz<sup>48</sup>, maintaining the original Likert-type response options. Cronbach's  $\alpha$  for this instrument ranged from 0.70 to 0.89 depending on the domain of the scale and content validity was verified by a separate study.<sup>47,49</sup> Individual items were scored and summed to create a composite score for each of the four model concepts; higher scores indicated a higher perceived belief in each concept.

Two separate instruments evaluated items surrounding Self-Determination Theory: the Treatment Self-Regulation Questionnaire (TSRQ) and the Perceived Competency Scale (PCS). As measured in the TSRQ, the concepts of autonomous motivation and external regulation have acceptable internal consistency (Cronbach's  $\alpha > 0.80$ ) and validity has been verified in diabetes.<sup>50,51</sup> Perceived competence was measured by items of the PCS; Cronbach's  $\alpha$  for this scale is 0.94 and support for its construct validity has been demonstrated.<sup>52</sup> Similar to the Health Belief Model concepts, a summed score was created for each of the three constructs with a higher score indicating a higher level of each concept.

Subjects were also asked to provide a complete list of medications currently being taken for diabetes. This included providing the following details: medication name, time of day taken, pills or units per dose, and times taken per day.

To evaluate medication adherence, pharmacy claims were collected from a health insurance company as well as the participating health system. Claims were collected over three, 90-day periods to establish a baseline, study period, and follow-up level of adherence to diabetes medications. The proportion of days covered (PDC) was calculated for each subject, and for each medication being taken, to form an overall composite PDC.<sup>53</sup> For each subject, the first fill date for each medication during the 90-day look-back period served as the index date. For this initial period the number of days between index and the end of the period determined the denominator; the study and follow-up periods each had 90-day denominators. Using the days supply, a count of the number of days each medication was on hand determined the numerator; overlapping fills occurring before the end of a previous fill's days supply were not counted until after the previous fill's supply was exhausted. PDC was calculated as the ratio between total days covered and the days in the period.

## Analysis

Subject characteristics, including demographics, medication use, and mobile phone operation, were described using means and standard deviations or frequencies and proportions, and evaluated using t-tests for continuous variables and Fisher's exact tests for categorical variables in order to account for small cell sizes. The proportion of days covered and responses to theory-driven items for each time period were described by means and standard deviations and compared across cohorts by t-tests and Wilcoxon signed-rank or rank sum tests, respectively.

Comparable to a previous, similar study, differences in medication adherence across the entire study period were evaluated using repeated measure ANOVA, assessing between and within group differences as well as a group by time interaction.<sup>44</sup> ANCOVA analyses were also run in order to control for baseline PDC values in examining potential changes from baseline to the end of the intervention. Comparisons were also conducted to evaluate the proportions of subjects attaining a PDC  $\geq$  80% between treatment and control groups using Fisher's exact tests.

Changes in Health Belief Model and Self-Determination Theory constructs throughout the study, between and within groups, were compared using ANCOVA on those subjects returning the endpoint survey. Pearson correlation coefficients were calculated to describe potential relationships between demographic characteristics and particular theory-driven concepts. Survey data were analyzed using only those who completed both the baseline and endpoint assessments.

The primary outcome measure was change from baseline in medication adherence following 90 days of daily tailored messaging. Effectiveness of the intervention was defined a priori as providing an improvement in adherence comparable to previous studies aiming to

impact medication-taking and health beliefs using mobile phones. Power calculations indicated that 28 subjects in each cohort would allow for 80% power to detect at least a 15% difference (SD: 20%) in medication adherence, which would be comparable to an earlier study examining the impact of text messaging on adherence and treatment beliefs.<sup>44</sup> For all comparisons, a p-value of  $\leq 0.05$  was considered to be significant, and STATA 11.0 (College Station, TX) was used for all analyses.

## **Results**

### **Subject Demographics**

A total of 75 individuals were eligible and consented verbally across both recruitment methods; ultimately, 48 subjects returned the baseline surveys and were randomized equally into the study arms at baseline (Figure 4.1). After the 3-month study period, 43 subjects completed and returned endpoint surveys. During the study, one subject was lost to follow-up due to death and the remaining four failed to return the endpoint survey after multiple attempts; no surveys were returned due to a change of address. Three of the four non-responders were control subjects (limited interaction during the study period); baseline characteristics were similar to the average study subject and no outlying values for health beliefs and attitudes were observed. Similarly, no baseline characteristics of the lone active arm, non-responding subject were suggestive of a cause for not completing the study and all beliefs and attitudes values were similar to the average study subject.

Cohorts were well balanced by all included characteristics although some marginal differences in demographic features were observed in some categories; distribution by gender



was equal and similar by race and age groups (Table 4.1). Mean ages were not significantly different between groups ( $p=0.734$ ) and the average across the entire study population was 47.0 years (SD: 11.7). Just over half were married and nearly all subjects were either African American or White. Also, nearly all participants reported an annual household income of \$75,000 or less with the vast majority reporting a value of \$50,000 or less.

Study cohorts were also well balanced by subjects' mobile phone characteristics. Two-thirds of all subjects reported text messaging 10 times or less each day and a majority were owners of smartphones. Smartphone owners and those more regularly text messaging were more likely to be 49 years of age and under (both  $p<0.01$ ) and basic cell phone owners reported significantly less daily texting ( $p=0.037$ ). No significant differences were observed in phone ownership or operation across other demographic characteristics. Across all subjects the average monthly cell phone bill was \$100 (SD: 72.3). Considering all baseline subject characteristics, the randomization was successful in creating well-balanced cohorts.

### Medication Use

At baseline, a majority of patients (70%) were taking one or two antidiabetic medications and the distribution of the number of diabetes medications taken each day was nearly identical across cohorts. On a daily basis, the average number of doses was approximately four and this was no different between study groups ( $p=0.637$ ). The single most common medication being taken was metformin (62%); however, both rapid (e.g. lispro, aspart) and long-acting (e.g. glargine, detemir) insulin were well represented (49% and 58%, respectively). Nearly all subjects (87%) were on oral medication only, insulin only, or a combination of oral and insulin therapy; a near equal distribution was observed between these types of regimens. While medication

regimen characteristics were fairly similar between cohorts, more than twice as many subjects in the active arm were on an oral and insulin regimen. Among all subjects, the number of doses per day tended to decrease with age ( $r = -0.31$ ,  $p = 0.036$ ); those on an oral only regimen tended to be aged 50 years and older while a majority of those on either insulin or both insulin and oral medications tended to be 49 years old and younger. (Table 4.2)

### Health Beliefs and Attitudes

At baseline, no significant differences existed between treatments groups for any of the included beliefs and attitudes (all  $p > 0.05$ ). Within both cohorts, average scores were highest for perceived severity and autonomous regulation for HBM and SDT constructs, respectively, and were maintained in the follow-up period. No differences in any mean levels were observed between genders while a negative relationship was observed between the number of medications and perceived barriers ( $r = -0.42$ ,  $p = 0.004$ ). Additionally, values for external regulation tended to increase with age ( $r = 0.429$ ,  $p = 0.002$ ) but no significant relationship was found between this construct and the number of reported cohabitants ( $p = 0.194$ ) or by relationship status ( $p = 0.231$ ). Also, in spite of the observed differences in mean values, significant relationships between scores for autonomous motivation and external regulation were not seen at baseline.

No significant differences between cohorts in all beliefs and attitudes following the study period were observed after adjusting for baseline values (Table 4.3); effects on perceived competence trended toward significance ( $p = 0.077$ ). However, unadjusted tests indicated that some significant improvement in perceived benefits ( $p = 0.02$ ) and perceived competence ( $p = 0.033$ ) was experienced in active arm subjects; comparisons between cohorts for endpoint values of these constructs did not reach statistical significance (not shown). Analyses using mean value

replacement and last value carried forward were also conducted but no appreciable differences in results were observed.

### Medication Adherence

Complete pharmacy records over the three time periods were available for 20 subjects (10 in each cohort). At baseline, the mean PDC values were 84.4% (SD: 18.8) and 87.1% (SD: 19.8) for subjects in the intervention and control arms, respectively, and most subjects in both cohorts had achieved a PDC of at least 80%- no statistically significant differences were observed for either metric. Over the course of all three periods the mean PDC for all subjects was 77.2% (SD: 0.276).

For both groups, mean PDC values declined between the three study periods; mean change from baseline to the end of the intervention was -5.7% and -12.4% for active and control subjects, respectively. ANOVA analysis showed a significant overall time effect ( $F(1,18) = 0.03$ ,  $p=0.012$ ), a non-significant cohort effect, and a non-significant cohort by time effect (Figure 4.2). Individual tests indicated that the significant difference in mean PDC values occurred for both groups between values at baseline and at follow-up (both  $p<0.05$ ), but no significant differences were achieved between groups at any time point. ANCOVA analysis showed an adjusted but non-significant difference in PDC values between groups from baseline through the active study period of 5.5% ( $p=NS$ ); the resulting effect size was 0.035. Between groups, significant differences in mean PDC values over the entire three study periods were also not observed. Over time, the number of adherent subjects in the intervention arm did decline but not to a statistically significant degree.

## Discussion

The tailoring of messages is a novel method by which behavior change may be driven and their delivery by mobile phone leverages a nearly ubiquitous communication channel that expands our ability to reach and engage patients. This study sought to pilot test sets of theory-driven and treatment-specific tailored messages in a cohort of adults with uncontrolled diabetes from a single health system in western Michigan over a period of three months. Specifically, we aimed to improve adherence to diabetes medications and alter condition and treatment-specific health beliefs and attitudes by focusing message content on individual treatment regimens and baseline health belief levels.

Results suggested that the methods used by this intervention did not lead to significant success in altering either adherence or health beliefs and attitudes. However, some notable findings were observed that will be helpful in guiding future interventions. Compared to and controlled for baseline values, intervention subjects' mean values for perceived competence trended toward significant improvement versus what was observed in control subjects. This observation may be the result of the overarching themes of the theory-driven messages employed by the intervention: the majority of the content focused on reinforcing diabetes self-management and the internalization of the motivation to do so. As perceived competence has been suggested to facilitate goal attainment and provide individuals with need satisfaction, it may be hypothesized that this individual finding may be reflective of the universal effect of the tailored messages used across concepts in spite of their being a lack of significant change in each concept.<sup>54</sup> Since unadjusted, within-group results suggested that some improvement was realized in the intervention arm, further inquiry to how perceived competence may be incorporated into

and altered by tailored text messages, specifically by the means employed, should be considered in future, larger investigations.

Similarly, results suggested that subjects' perceived benefits might be impacted by focusing some messages on either medication-specific information or theory-driven content with an emphasis on the benefits of treatment adherence. When considering the bulk of content delivered, one in five messages sent to each subject focused on the benefits of treatment; resultantly, we may have expected to see a more dramatic change in mean values from baseline. However, in spite of limited statistical inference, this finding should be taken into consideration by future studies that may more precisely tailor medication information to each patient's regimen, specifically the point at which they are in their treatment and to any changes made over time.

To our knowledge, this was the first study to leverage theory-driven tailored text messages with a specific focus on improving medication adherence in adults with diabetes. While multiple studies have investigated the impact that text messages and tailoring can have on adherence, the combined use of these two methods has been limited and either failed to individually tailor or did not fully describe how tailoring was accomplished. Importantly, this study adds both a precise description of how tailoring was achieved as well as an analysis of the intervention's impact;<sup>46</sup> the results add to a body of literature demonstrating mixed effects from employing text messaging in encouraging medication adherence.<sup>55,56</sup> Such a demonstration, in spite of clearly significant results, can help guide future studies aiming to employ similar methods. However, investigators should also consider the approaches taken by recent studies that demonstrated positive improvements in medication adherence,<sup>42-45</sup> specifically those that focused on adults with diabetes.<sup>57</sup> Considering the extent of nonadherence, myriad reasons for this

behavior, and lack of consistency in what has proven to be effective, future studies may benefit from an individualized yet multifaceted approach that builds off of what has been observed to date.

## Limitations

Most notably, this study was limited by its small sample size, similar to many mobile health investigations to date, as several subjects were lost to follow-up and less than half had reliable pharmacy claims data, further reducing the sample size for analysis. A post-hoc analysis indicated that, for the distribution of data observed, the study would have needed at least 339 subjects per arm to have at least 80% power to detect a statistically significant difference in mean values for health beliefs and adherence (at  $\alpha = 0.05$ ). As a pilot study, the aim of this research was to examine the potential for several types of messages to influence health beliefs and medication-taking, and while the sample size limits statistical interpretation the results still provide guidance on how particular tailored text messages may be used during the diabetes treatment process.

Additionally, the types of messages employed were constructed based on the influence their related theory-driven constructs have been observed to have on adherence while also providing education on reported medications. However, research on medication taking has uncovered myriad reasons for nonadherence, only several of which were the focus of this investigation. Resultantly, the influence of the tailored messages used in this study may have been limited if their focus did not match the needs of the enrolled population. The influence of the messages may have also been impacted by how long each subject had been treated for diabetes: more established patients might have not benefited as much as those who were recently

diagnosed. Also, the intervention only lasted three months and may not have been long enough to make a significant impact on either health beliefs or adherence.

To examine adherence, pharmacy claims data were used to track the refilling of diabetes medications; however, a significant discrepancy existed between the medications being taken as listed by each subject and those for which a claim was observed. Considering the wide availability of generic medications through pharmacies offering discount programs, it is likely that many oral medications were filled in this manner and, therefore, could not be tracked by insurance claims data. As a result, the impact of the intervention on the taking of some medications could not be measured. Similarly, the use of PDC as an adherence metric, while widely used and accepted, is an indirect measure of medication-taking behavior: this method cannot confirm that a prescription filled led to medication being taken by each subject.

Additionally, adjustments to insulin dosing may not be accurately measured by PDC, leading to a bias in how adherence was measured for subjects taking this class of medication. Finally, the study population consisted of mostly insured subjects; therefore, the results may not be generalizable to populations lacking or with dissimilar coverage.

## Conclusions

The tailoring of treatment and condition-specific text messages remains an area of opportunity to improve medication adherence, increase patient knowledge, and provide motivation to patients with diabetes and other conditions. Future research should be certain to improve the exchange of information between patients and providers, seek to enroll large cohorts

of subjects, and improve the tailoring of the messages to further individualize the intervention, advance patient engagement, and, potentially, lead to significant behavior change over time.

### **Acknowledgments**

This research was sponsored by an award from the University of Michigan Rackham Graduate School and by Grant Number R36 HS021976 from AHRQ and the contents of this publication are solely the responsibility of the authors and do not necessarily represent the official views of AHRQ. The study authors wish to thank Jason Barnum, PharmD (Mercy Health Partners) for his assistance with identifying potentially eligible subjects and Katie S. Kaminski, PharmD (University of Michigan) for her assistance with recruiting subjects for the intervention.



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Table 4.1. Baseline Study Population Characteristics

Characteristic	Tailored Subjects (N=24)		Control (N=24)		p-value
	Count	%	Count	%	
<b>Demographics</b>					
Age (years)*	47.54	12.1	46.38	11.57	0.734
Age Group (years)					1.000
21-29	3	12.5	3	12.5	
30-39	3	12.5	3	12.5	
40-49	6	25	6	25	
50-59	8	33.3	9	37.5	
60-64	4	16.7	3	12.5	
Female	12	50	12	50	1.000
Relationship Status					0.204
Single	5	20.83	3	12.5	
Living Together	0	0	3	12.5	
Married	13	54.17	12	50	
Widowed	2	8.33	0	0	
Separated/Divorced	4	16.67	6	25	
Race/Ethnicity					0.406
African American	8	33.33	8	33.33	
Hispanic	0	0	1	4.17	
Multiple	2	8.33	0	0	
Native American	0	0	1	4.17	
White	14	58.33	14	58.33	
Household Income					0.559
\$0-\$25,000	6	25	7	29.17	
\$25,001-\$50,000	11	45.83	7	29.17	
\$50,001-\$75,000	5	20.83	8	33.33	
\$75,001-\$100,000	2	8.33	1	4.17	
>\$100,000	0	0	1	4.17	
Cohabitants (persons)*	2.25	1.67	2.79	2.11	0.329
<b>Mobile Phone Use</b>					
Daily Texting (messages)					0.682
1 to 10	16	66.67	16	66.67	
11 to 20	5	20.83	3	12.5	
21 to 30	2	8.33	2	8.33	
31 or more	1	4.17	3	12.5	
Phone type					0.768
Basic phone	10	41.67	9	37.5	
Smart phone	14	58.33	15	62.5	
Average monthly bill (\$)*	98.27	70.36	101.9	75.48	0.867

\*Presented as mean +/- standard deviation

Table 4.2. Baseline Medication Use

Characteristic	Tailored Subjects (N=24)		Control (N=22)*		p-value
	Mean	SD	Mean	SD	
Diabetes Medications per Day	2.25	0.85	2.09	0.87	0.805
Daily Doses of Diabetes Medications	4.5	1.83	4.24	2.05	0.637
Diabetes Therapy**					0.421
Oral medication only	6	25.0	7	31.8	
Insulin only	7	29.2	7	31.8	
Oral medication and insulin	9	37.5	4	18.2	
Other combinations	2	8.3	4	18.2	
Percent of Days Covered (PDC)	0.84	0.18	0.87	0.33	0.756

\*Includes only those completing the self-reported medication list

\*\*Presented as frequency and %

Table 4.3. Subject Health Beliefs and Attitudes

Theory	Construct	Tailored		Control		Adjusted Difference	p-value
		Baseline	Endpoint	Baseline	Endpoint		
Health Belief Model	Perceived Severity	4.0 (0.53)	4.3 (0.44)	4.3 (0.44)	4.2 (0.43)	0.10	0.447
	Perceived Susceptibility	3.7 (0.58)	3.7 (0.57)	3.6 (0.73)	3.6 (0.53)	0.01	0.968
	Perceived Benefits	3.6 (0.59)	3.9 (0.34)	3.8 (0.48)	3.8 (0.61)	0.20	0.169
	Perceived Barriers	3.6 (0.83)	3.8 (0.63)	3.8 (0.68)	3.8 (0.79)	0.09	0.646
Self-Determination Theory	Perceived Competence	4.5 (1.51)	5.3 (1.14)	4.9 (1.52)	5.0 (1.53)	0.57	0.077
	Autonomous Motivation	6.2 (1.17)	6.5 (0.49)	6.6 (0.43)	6.3 (0.70)	0.17	0.363
	External Regulation	3.3 (1.32)	3.7 (1.63)	3.8 (1.48)	3.6 (1.46)	0.36	0.406

Values are listed as mean (+/-SD)

At endpoint, 23 tailored subjects and 20 controls responded to survey items



Figure 4.1. Subject Recruitment and Enrollment

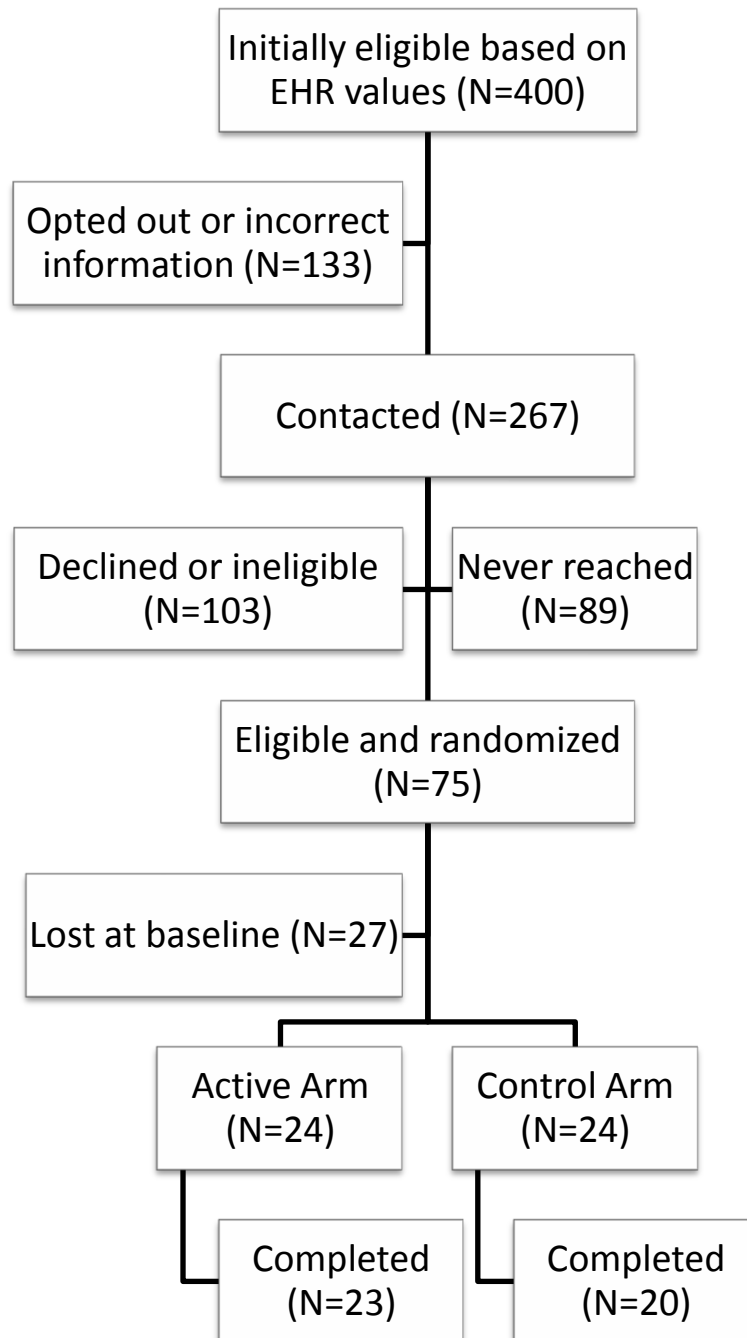
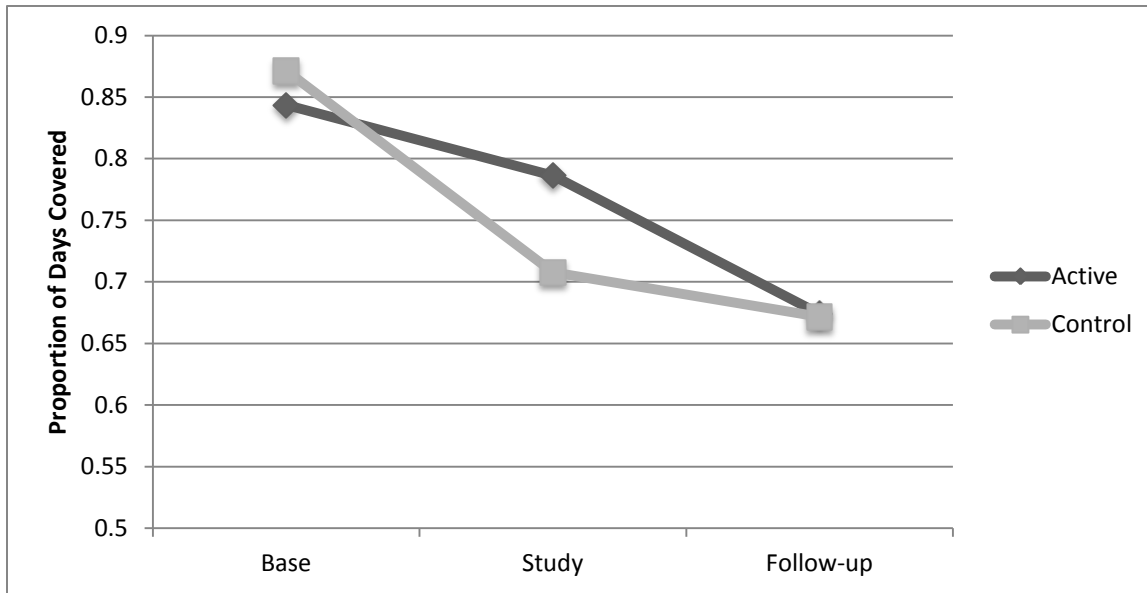


Figure 4.2. Intervention Impact on Medication Adherence



Values represent mean PDC for each time period

20 subjects with complete pharmacy records for all time periods were analyzed

## **CHAPTER V. DISCUSSION**

As one of the first studies focused on adult patients with diabetes to combine tailoring with text messaging, this pilot study sought to create, deliver, and then test the effectiveness of tailored text messages to improve medication adherence. Additionally, this investigation aimed to assess the extent to which these messages altered subjects' condition and treatment-related beliefs by focusing message creation on theory-driven and medication-specific concepts. Finally, we collected personal responses from participants on their mobile phone use and acceptance as well as impressions from intervention subjects on their experiences with receiving a daily, tailored text message.

### **Summary of Study Aims**

#### **Aim 1**

Using theory, medication-specific information, and insight from adults with diabetes, a library of 296 messages was created and formatted for delivery by mobile phone messaging. In combination with self-reported characteristics (age, gender, medication, etc.), all messages were individually tailored and prepared for use in the intervention using baseline responses to a survey instrument. This method allowed us to create deeply tailored messages that corresponded to each subject's level of health beliefs, motivation, competence, and regulation, and deliver subsequent

messages aimed at directing individuals toward a target attitudinal level. Such an approach was in accordance with what previous research has shown in terms of a gradual change in health beliefs or behavior change over time rather than trying to create an abrupt alteration.<sup>1</sup> Additionally, this approach may be easily replicated for similar, future studies and is perhaps the first investigation to provide such transparency on how tailoring may be wed with mobile phone delivery in an attempt to improve medication taking in adults. Earlier studies using individualized texting have provided some details on either their approach (instruments, message derivation, etc.) or listed example messages, but not to the extent given herein.<sup>2,3</sup>

This study also demonstrated how established survey instruments could be leveraged to design message content. While many tailoring studies opt to create original instruments, the use of tested questions, when appropriate items are available and reliable, improves the efficiency by which an investigation may be conducted. For our purposes, items based on two well-established theories were used in order to further test their applicability to medication adherence and to introduce to the literature example messages based on the Health Belief Model and Self-Determination Theory. Such an approach proved to ease the manner by which question items could be used to develop message stems and responses translated into scaled messages. Considering the myriad reasons for nonadherence, the use of these theories limited the concepts that were addressed but participants' reception of the messages is important for researchers interested in conducting theory- and communication-based interventions.<sup>4</sup> To this end, interview responses indicated that the theory-based messages were motivational and could be of added value for recently diagnosed patients with diabetes. Additionally, while not formally tested, personal responses from intervention subjects indicated that education on medications being

taken for diabetes was helpful and could even be increased in the future, particularly for different types of insulin in order to better connect patients with their individual treatment regimen.

Similar to the dearth of guidance in tailoring text messages, the literature is similarly lacking insight to how an intervention using mobile phones as a communication channel may be successfully delivered and managed. Over the course of this intervention, a total of 2,230 messages were relayed to mobile phones by an automated server, 94.3% of which were received as planned; when interruptions occurred they were generally brief (received later in the same day or on the next day) and most often due to message coding interfering with the server's automated process. Such a demonstration is indicative of the ease by which automated messages, even when individualized, can be introduced to the care process in order to reach and engage patients. While this study developed its own engine to produce tailored materials, it is likely that the introduction of tools specifically designed to tailor electronic messages will ease this process and improve the means by which patients may be reached. Furthermore, a standard algorithm for message delivery was used where all subjects received the same order and number of messages based on survey responses from one period in time. This approach provides a blueprint for interventions seeking to have a defined treatment period with a static dose; however, post-intervention interviews, suggested that alterations in this algorithm might be more appropriate. Specifically, it was suggested that additional messages be sent per day to correlate more closely with each treatment regimen, and changes in the mix and types of messages could be made to more closely match the needs of patients based on their baseline beliefs and needs. Furthermore, changes to the mix of messages over time could be made to parallel changes in need over time. Overall, this study was successful in delivering the intervention as planned and defined, adding valuable

methods to the scant literature on the conducting of a tailored text message program primarily focused on changing medication adherence.

## Aim 2

In terms of concrete outcomes, this study sought to understand the extent to which tailored messages could impact treatment and condition-related health beliefs and attitudes, specifically some of those previously observed to be related to the medication-taking process. Results indicated that minimal changes in the included concepts were realized; however, some differences should be highlighted irrespective of statistical significance. Of note, the receipt of messages focused on perceived competence and benefits as well as those with specific medication information translated into some differences in mean values from baseline in the intervention group. These results are promising considering the focus of a majority of the messages, the relatively brief period over which the intervention was run, and the adult population recruited. While more evident improvements in particular diabetes-specific attitudes were observed in a younger population by an earlier study, our results provide some guidance on what may be accomplished in older patients over a shorter period of time.<sup>5</sup> Moreover, our results should be of particular interest to researchers focusing on populations with a specific need to improve perceived competence in adults with diabetes and may be considered for those with a low perceived benefit of treatment. For these purposes, the use of messages with a focus on competence and benefits may show significant effects over a longer treatment period and may be most appropriate for those having been recently diagnosed with diabetes. While complete support for the application of concepts related to the Health Belief Model and Self-Determination Theory was not provided by this study, value was still realized by subjects in the

intervention as the conceptual messages were well received. Such insight is useful to investigators wishing to apply other theories of health behavior to the tailored text messaging process when specifically targeting medication nonadherence.

Of equal importance to the intervention's impact on health beliefs were the impressions of study participants on the acceptance of mobile phone messaging and the receipt of a tailored message during the treatment process. While mobile phone use and mHealth capabilities have grown exponentially in recent years, relatively little is understood about what patients want out of these devices and how they would prefer to use these tools as accessories to their medication regimen.<sup>6</sup> Results suggested that technology acceptance, in terms of ease of use and usefulness, was high in adults with diabetes when considering the receipt of a tailored text message. Importantly, acceptance remained high regardless of mobile phone type and texting frequency, suggesting that smartphones and regular texting were not barriers to accepting mobile messaging as a value-added service to patients. Additionally, subjects found a once-daily message to appropriately meet their needs but some could have benefited from a system that mimicked their treatment regimen; therefore, we may reasonably assume that a truly individualized system, and one that may lead to significant behavior change, may be one that matches the message dose with specific patient needs. This information will be useful to health systems, payers, and providers interested in developing and implementing a messaging service as an interactive feature for their patients. In terms of specific content, subjects found both medication-specific information and theory-based messages to be useful, in spite of still serving as a regular reminder to take medication. The majority of those interviewed indicated interest in continuing to receive tailored messages by mobile phone and would welcome even more interaction with a messaging system or providers in the future (e.g. relaying blood sugar or receiving ongoing medical advice).

These findings echo what previous studies have found, suggesting that patients have great interest in being more engaged in their therapy.<sup>5,7</sup> Moreover, such positive receipt is encouraging for the implementation of messaging systems that go beyond simply relaying reminder messages, particularly considering the adult population from which impressions were gathered.

### Aim 3

Primarily, this study aimed to evaluate the impact of tailored text messages on adherence to diabetes medications in adults. While the tailoring of text messages has been applied in other conditions and younger populations with diabetes, this is one of the first studies to investigate this approach in adults with diabetes. Over the course of the three-month intervention, results indicated that mean adherence levels (using proportion of days covered) declined from baseline in both those receiving a tailored text message and those having standard care only. Additionally, the proportion of those already adherent (PDC>80%) also declined from baseline levels, suggesting a lack of benefit from the intervention. While differences did not reach statistical significance, we originally hypothesized and anticipated that tailoring would lead to improvements in medication-taking by focusing messaging on factors previously observed to relate to adherence, or at the very least would result in levels of adherence higher than those in the control group. However, these results should be taken with caution as less than half of the subjects involved were able to have their medication use analyzed due to the methods employed to assess adherence; resultantly, the study was underpowered to determine reliable differences in mean values between groups.



It was also the aim of this study to assess the fit of the conceptual framework as outlined by the specific aims. Using individual-level data, we observed that the methods used to create our tailored messages led to minimal statistically significant changes in health beliefs; however, as the majority of changes for intervention subjects (except for perceived susceptibility) were in the intended direction we may infer that the messages used may be impactful in terms of altering patients' perceived health beliefs. Resultantly, it is reasonable to suggest that the outlined framework to construct and deliver tailored text messages may be appropriate for interventions seeking to alter patients' diabetes-related beliefs. Unfortunately, inferences beyond these conclusions cannot be made due to a lack of individual-level pharmacy claims data on study subjects. Therefore, conclusions related to the entire framework, specifically whether the messages employed led to changes in health beliefs and then, ultimately, whether these alterations led to changes in medication adherence, must be reserved for a future, larger investigation with sufficient data.

As a pilot study, this investigation sought to better understand the applicability of tailored text messages in affecting adherence to diabetes medications. Therefore, the findings, in spite of statistical inference, have value to the research community in terms of evaluating methods that may effectively address the myriad reasons for nonadherence. Elsewhere, tailored text messaging has shown benefit to some adults with diabetes;<sup>2</sup> presently, these messages may have proven beneficial to the medication-taking process to subjects in this study but were unobserved. It is important to note that, mean values for many health beliefs were at or near target levels prior to the intervention and the majority of adherence inference was made on claims for insulin. Therefore, this population may not have been ideally suited to benefit from the chosen concepts; other theoretical constructs or adherence barriers may have been more appropriate and resulted

in significant change. Moreover, the analytic methods employed may not have accurately captured actual medication possession considering the high prevalence of claims for insulin- due to the nature of dosing for these products medication use may have been dramatically different than what was determined. As research continues in this area and tailored text message libraries grow, studies may benefit from expanding the options of message concepts available for testing in order to more precisely target barriers to adherence. The approach taken is just one method by which tailoring may be applied to mHealth interventions in a theory-based manner and may be easily replicated by researchers interested in further evaluating potential impacts on adherence in particular populations.

Health systems and payers seeking to increase engagement with their patients may also easily duplicate the methods employed in a potentially cost-effective manner. While a formal cost analysis was not performed as part of this study, direct costs to reach all involved participants were approximately \$250 over the course of the entire investigation (including both reaching and interacting with the subjects in both arms)- roughly \$1.30 per active subject per month on average. Considering the relatively low cost per message charged to the patient, the relaying of individual information by text message might provide all entities a cost-effective communication channel and one that will continue to decrease in price. Policymakers, particularly those focused on reducing the high administrative costs of care, may be especially interested in the use of tailored messaging to improve the flow of information between patients, providers, and payers. Moreover, the tailoring of mobile-based messages may also be of value as adjunct services to reach newly diagnosed patients or those beginning new and unfamiliar treatment regimens as a means to improve patient engagement and knowledge at critical times of therapy and between encounters with providers. However, prior to implementation by payers or

suggestion being made by policymakers, a better understanding of related indirect costs, such as the time required to capture patient information and build original messages, must be better understood. Should these costs prove to be manageable and the exchange of tailored material demonstrate correlation with consistently and measurably improved health outcomes, the costs to the patient may be worthy of coverage by payers and included as regular services.

## **Limitations**

Similar to other studies involving mobile health interventions, the most prominent limitation of this study was the sample size enrolled. Over one-third of those recruited and consented were lost prior to the beginning of the study, severely limiting the analytic power to detect differences in adherence and health beliefs and attitudes as well as conduct sub-group analyses. Additionally, the loss of follow-up data due to unreturned surveys further limited our interpretability. Moreover, reliable and consistent pharmacy claims data were only available for less than half of all subjects, providing only a glimpse of what the intervention may have done to alter medication-taking in the study population. However, the intention of this study was to pilot a particular approach to tailored messaging and, in spite of a small sample, effect sizes and interpretations were determined and the results will serve to guide future, similar investigations.

Although comparable to other similar studies, the length of the intervention (three months) may not have been long enough to adequately address the target behavior or state of health beliefs in all subjects. As subjects were enrolled having diabetes for a variable length, the dose of the intervention may not have been appropriate to result in behavior change for those with advanced disease or having been diagnosed many years ago; conversely, if newly diagnosed

patients were involved then a noticeably higher change may have been realized. Determining an appropriate intervention length—in order to lead to long-standing change—is a challenge for all investigations and this study, while relatively brief, provided insight on what may be achieved over three months of daily messaging. Moving forward, studies may benefit from longer intervention periods and may even consider comparing across variable lengths of time used to encourage change.

The methods behind the messages employed also introduced some limiting factors. It is possible that the application of concepts beyond what was employed may have impacts on adherence and health beliefs in adults with diabetes beyond what was observed herein. As one of the few studies using a theory-based approach to tailored text messaging, the results will aid future studies but a deeper understanding of the most appropriate theoretical applications is needed.

Secondly, the recruitment process may have inadvertently removed those with an unfavorable view of text messaging, thus biasing the results related to technology acceptance. As well, the reception of certain messages may not have been appropriate for all subjects and the impact of the messages may have been limited by each subject's stage of treatment and disease severity.

Also, input from potential subjects to the content of the proposed set of messages was relatively limited. No pre-testing of the message set was conducted in a representative group of potential subjects that may have benefited the construction process by identifying areas of the diabetic treatment process that could have been the focus of some messages (e.g. lifestyle modification, checking sugars). Moreover, this final study population was not assessed for literacy or numeracy levels which may have varied dramatically between subjects.

The manner by which medication taking was assessed in this study also has its limitations. The use of claims data only allows for the tracking of medication refills once a claim is generated; therefore, any medications filled through a discount generic medication program—those that would not be reported to the patient’s payer—were not able to be accounted for and analyzed. In this study, the distinct discrepancy between the lists of subject-reported medications and those for which a claim existed suggests that such a phenomenon may impact studies involving conditions for which a large number of generic medications are available and regularly used. Specific to this study, adherence could only be calculated among medications for which a claim was generated, limiting our interpretability of the intervention’s impact on overall medication use in some subjects. Additionally, the proportion of days covered, as an adherence metric, is an indirect measure of medication taking. While the refilling of medications implies use, there is no guarantee that a medication filled led to it being taken as directed. Similarly, the days supply field is used to generate the numerator to calculate adherence during a defined period, and this assumes that the amount supplied was intended to be taken for the number of corresponding days. However, certain products, such as insulin, may be dosed on a variable scale and the number of days provided might not equate to the number of days over which the medication was taken. In such cases, the level of adherence would be biased in either direction depending on how the insulin was dosed on a daily basis.

Finally, the reading of each message could not be confirmed. Therefore, it is difficult to assess whether a message sent resulted in a message read and understood by each subject.

## **Future Directions**

This investigation was one of the first to analyze the feasibility, implementation, and impact of tailored messages delivered by mobile phone aimed at improving medication adherence in adults with diabetes. While several key findings were taken from this study, much remains to be understood about how such an approach can impact the ongoing taking of medications. Considering the expected growth in mHealth applications in the coming years, such improved understanding has great potential to leverage mobile health into playing a pivotal role in the improving of health outcomes.

Moving forward it will be imperative to construct studies that enroll a larger number of subjects from diverse backgrounds, including adolescent and adult patients of varying socioeconomic levels, races, and ages. This should also include expanding the focus to subjects with other chronic conditions that require regular, ongoing medication use; hypertension, hypercholesterolemia, and asthma are diseases that may benefit from the combination of tailoring and text messaging- an expanded investigation involving diabetes should also be planned. In so doing, direct health outcomes related to these conditions should also be included, such as blood pressure, hemoglobin A1c, and hospitalizations, to corroborate the need for and impact of improving adherence to medication. Resultantly, investigations will need to expand well beyond three months in order to capture sufficient outcomes and properly assess how a messaging system can be more fully integrated into the ongoing care process. Furthermore, longer interventions will provide needed information surrounding the adequate length of a messaging program that most successfully leads to longstanding behavior change and positive outcomes.

Comments made by participants of this study provided significant direction for expanding the capacity and capabilities of a future messaging system. While this study targeted

several established factors influencing medication-taking behavior and disease management, other important health behaviors such as testing sugars, proper diet, and adequate exercise were only minimally included or absent. Moving forward, tailoring on the complete treatment regimen, rather than simply focusing on medication, should be included, and such an approach could easily be replicated in other conditions requiring treatment beyond medicinal therapy. Such improved tailoring should also include the expansion of medication-specific messages to all medications being taken rather than limiting them to the class or condition of interest. More individualized tailoring should also accommodate how often each subject would like to interact with the system. While several studies, including this one, have investigated the dose by which messages should be relayed, perhaps the most appropriate approach is one that is set by each subject rather than the investigators. Additionally, consideration for the stage of disease (i.e. time since diagnosis) should also be included in the content of each message and adjust over time, as patient's needs change. This could be accomplished by incorporating feedback mechanisms into the messaging program either by the surveying of subjects at multiple points or by direct interaction with subjects through the messaging system. To accomplish the latter, exchanges could include asking subjects to respond to quality of life items, supply clinical markers (e.g. blood pressure readings and blood glucose), send updates on diet and exercise, and provide any changes to medications being taken that could be relayed to physicians or pharmacists to better understand their patients' condition. Effectively, this will increase the patient's involvement over time and bring them closer to their care and providers. Furthermore, this will contribute to the constructing of a self-sustaining, robust messaging system that could be integrated to electronic health records and, eventually, be used for more direct interaction with patients. Such level of

communication could contribute to more efficient care and would certainly improve the ease by which health-related information is shared among interested parties.

As a pilot study, this investigation sought to establish the effect that tailored text messages have on medication adherence and health beliefs in adults with diabetes, and did so by comparing a tailored approach to standard care alone. However, since the majority of studies to date have investigated the impact of reminder messages on adherence, there is a need to understand how tailored messages may compare to the effect that simple reminder messages have on medication-taking behavior. As larger and longer studies are constructed, they should be developed to include multiple comparison groups, which at a minimum, should include tailored and reminder cohorts.

Finally, the sending and receiving of text messages involves some costs. If any mobile messaging system, particularly one that involves tailoring, is going to be fully integrated to the care process then its cost-effectiveness must be established. Future studies utilizing a tailored technique to relay text messages should capture the costs of creating and delivering these messages and model these against the health-related impact they are associated with throughout the study period.

## **Conclusions**

Nonadherence, particularly in patients with diabetes, remains a prevalent public health issue, and improved means to curb this problem are needed. The tailoring of messages delivered by a nearly universally owned device affords researchers the opportunity to further engage patients and encourage the following of prescribed treatments. While results of this study



indicated that adherence was not improved by delivering theory-based and medication-specific tailored messages to adults with uncontrolled diabetes, the methods employed were well-accepted by the population and showed promise in altering condition and treatment-related health beliefs. An effect size for detecting an impact on health beliefs ranged from 0.0 to 0.047 and was 0.035 for adherence to diabetes medications.

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## APPENDICES

### APPENDIX A

#### A. Tailoring Survey Instrument

The following questions are about your current medications and how you take them. Please list all of the prescription medications (including any samples) you are currently taking for diabetes. If you are not sure the medication is for your diabetes, please add it to the list. For each medication, please list the name, number of pills taken each time, number of times you take them each day, and check when you take them. For your reference, please see the attached list of medications to help fill out this form.

<u>Medication</u>	<u># of Pills</u>	<u>Times/Day</u>	<u>Time of Day (check all that apply)</u>
_____	___	_____	<input type="radio"/> morning <input type="radio"/> midday <input type="radio"/> afternoon <input type="radio"/> evening <input type="radio"/> night
_____	___	_____	<input type="radio"/> morning <input type="radio"/> midday <input type="radio"/> afternoon <input type="radio"/> evening <input type="radio"/> night
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_____	___	_____	<input type="radio"/> morning <input type="radio"/> midday <input type="radio"/> afternoon <input type="radio"/> evening <input type="radio"/> night

The following 15 questions are about your diabetes and the medications you take for it. Please CIRCLE the **ONE** answer that best describes how you think or feel about your diabetes or your prescription diabetes medications.

1. My diabetes is well controlled.

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
-------------------	-------	-----------	----------	----------------------

2. My diabetes would be worse if I did nothing about it.

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
-------------------	-------	-----------	----------	----------------------

3. I believe that my medications will help prevent complications related to diabetes.

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
-------------------	-------	-----------	----------	----------------------

4. Diabetes can be a serious disease if you don't control it.

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
-------------------	-------	-----------	----------	----------------------

5. My diabetes is no problem to me as long as I feel alright.

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
-------------------	-------	-----------	----------	----------------------

6. My diabetes will have a bad effect on my future health.

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
-------------------	-------	-----------	----------	----------------------

7. My diabetes will cause me to be sick a lot.

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
-------------------	-------	-----------	----------	----------------------

8. I believe I will always need my diabetes medications.

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
-------------------	-------	-----------	----------	----------------------

9. I believe I can control my diabetes.

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
-------------------	-------	-----------	----------	----------------------

10. I believe that my medications will control my diabetes.

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
-------------------	-------	-----------	----------	----------------------

11. My medicine makes me feel better.

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
-------------------	-------	-----------	----------	----------------------

12. I would have to change too many habits to follow my medications.

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
-------------------	-------	-----------	----------	----------------------

13. It has been difficult following the medications prescribed for me.

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
-------------------	-------	-----------	----------	----------------------

14. I cannot understand what the doctor told me about my medications.

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
-------------------	-------	-----------	----------	----------------------

15. Taking my medications interferes with my normal daily activities.

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
-------------------	-------	-----------	----------	----------------------

For the next 12 questions, please check how true you feel each statement is. For each item, 1 means not at all true and 7 means very true.

16. I am confident that I can take care of my diabetes.

1	2	3	4	5	6	7
Not at all True						Very True

17. I can handle my diabetes now.

1	2	3	4	5	6	7
Not at all True						Very True

18. I can do my own routine diabetes care now.

1	2	3	4	5	6	7
Not at all True						Very True

19. I can meet the challenge of controlling my diabetes.

1	2	3	4	5	6	7
Not at all True						Very True

20. Taking my diabetes medication is very important for being as healthy as possible.

1	2	3	4	5	6	7
Not at all True						Very True

21. I personally believe that taking my diabetes medications is the best thing for my health.

1	2	3	4	5	6	7
Not at all True						Very True

22. I feel that I want to take responsibility for my own health.

1	2	3	4	5	6	7
Not at all True						Very True



31. What race best describes you?
- African American
  - Asian-Pacific Islander
  - Hispanic
  - Multiple Races
  - Native American
  - White
  - Other
32. Total household income:
- \$0-25,000
  - \$25,001-50,000
  - \$50,001-75,000
  - \$75,001-100,000
  - More than \$100,000
33. With how many people do you currently live: \_\_\_\_\_

Response Scoring:

Items 1 through 15 constituted questions related to the Health Belief Model while items 16 through 27 measured responses to concepts of Self-Determination Theory. Each HBM item was scored from 1 to 5 in the pre-determined target direction as some items were reverse scored based on the phrasing of these items. The distribution of HBM questions by scoring was as follows:

- Scored 1 (Strongly Disagree) to 5 (Strongly Agree): items 1-4 and 6-11
- Scored 1 (Strongly Agree) to 5 (Strongly Disagree): items 5 and 12-15

Similarly, SDT items were scored from 1 to 7 in the pre-determined target direction to accommodate reverse scoring. The distribution of SDT questions by scoring was as follows:

- Scored 1 (Not at all True) to 7 (Very True): items 16-23
- Scored 1 (Very True) to 7 (Not at all True): items 24-27

Mean values were produced for each item and were then averaged across items for each corresponding theoretical construct. For purposes of message construction, break points were created for each item based on their scoring. For HBM items, responses corresponding to scores of '1', '2', or '3' were categorized as 'low' while responses corresponding to '4' or '5' were considered 'high'. For SDT items three categories were created: responses scored '1' or '2' were considered 'low'; responses corresponding to '3', '4', or '5' were considered 'medium'; and scores of '6' or '7' were deemed 'high'.



## APPENDIX B

### B. Endpoint Survey Technology Acceptance Model Items

The next 4 questions are about your phone and text messaging over the past 3 months. Please consider the messages that you received from the study when answering these questions. **CIRCLE** how much you agree or disagree with the following statements.

1. Using text messaging as part of my diabetes treatment increases my chances of achieving things that are important to me.

Strongly Agree	Moderately Agree	Somewhat Agree	Uncertain	Somewhat Disagree	Moderately Disagree	Strongly Disagree
-------------------	---------------------	-------------------	-----------	----------------------	------------------------	----------------------

2. Using text messaging as part of my diabetes treatment helps me accomplish things more quickly.

Strongly Agree	Moderately Agree	Somewhat Agree	Uncertain	Somewhat Disagree	Moderately Disagree	Strongly Disagree
-------------------	---------------------	-------------------	-----------	----------------------	------------------------	----------------------

3. I think learning how to use text messaging as part of my diabetes treatment is easy for me.

Strongly Agree	Moderately Agree	Somewhat Agree	Uncertain	Somewhat Disagree	Moderately Disagree	Strongly Disagree
-------------------	---------------------	-------------------	-----------	----------------------	------------------------	----------------------

4. I find text messaging as part of my diabetes treatment easy to use.

Strongly Agree	Moderately Agree	Somewhat Agree	Uncertain	Somewhat Disagree	Moderately Disagree	Strongly Disagree
-------------------	---------------------	-------------------	-----------	----------------------	------------------------	----------------------

Scoring:

Mean values for each item were produced by applying numeric values to each response. Values ranged from 1 (Strongly Disagree) to 7 (Strongly Agree). Items 1 and 2 were combined to produce a mean value for Perceived Usefulness; items 3 and 4 were combined to produce a mean value for Perceived Ease of Use.

## APPENDIX C

### C. Mobile Phone Use Survey Items

The following 4 questions relate to your use of mobile phone text messaging. If you own and operate more than one mobile phone, please answer them based on your primary phone only. If you do not know exact numbers, please estimate as best as possible. Place your answer in the space provided.

1. In a typical day, how many text messages do you send and receive?

\_\_\_\_ 1-10

\_\_\_\_ 11-20

\_\_\_\_ 21-30

\_\_\_\_ 31 or more

2. What best describes the type of phone you own?

\_\_\_\_ Smartphone

\_\_\_\_ Basic phone

3. To which of the following service providers do you subscribe?

\_\_\_\_ Verizon

\_\_\_\_ AT&T

\_\_\_\_ Sprint

\_\_\_\_ T Mobile

\_\_\_\_ Cricket

\_\_\_\_ MetroPCS

\_\_\_\_ Other

4. On average, what is your monthly bill for mobile phone services?

\$ \_\_\_\_\_

\_\_\_\_ Don't know

## APPENDIX D

### D. Focus Group Questions

1. Icebreaker
  - a. What feature of your cell phone do you like the most?
2. Mobile phone use questions
  - a. Could you please describe how you use your mobile phone on a daily basis in terms of talking, texting, app use, and/or browsing?
  - b. How many text messages would you estimate you send and receive on a typical day?
  - c. How often would you say you use your phone to access health-related material?
  - d. How comfortable would you be with receiving personalized diabetes-related information, such as details of your medication and tips on improving your condition, in a text message sent to your phone?
  - e. If so, how often would you prefer to receive these messages? (Provide ranges of options from which to choose)
3. Medication use questions
  - a. What challenges, if any, do you face in taking your diabetes medications as directed by your physician and/or pharmacist?
  - b. What have you done to help you take your medication more regularly?
  - c. How clearly did your physician and/or pharmacist describe the treatment you are on, in terms of how to take it and what to expect?
  - d. Is there anything that you wish your physician and/or pharmacist would have told you about your diabetes or treatment at your last visit that would have been helpful?
4. Wrap-up
  - a. Is there anything else about taking your diabetes medications that you would like to mention?

## APPENDIX E

### E. Post-Intervention Interview Guide

1. Did you enjoy receiving messages on your phone specific to your condition and treatment?
  - a. Yes: What specifically did you enjoy?
  - b. No: Why were these messages not enjoyable to receive?
    - i. Potential follow-up: Was this due to the content of the message?
    - ii. Potential follow-up: Was this because it was received on your phone?
2. Did you find the information in these messages helpful in your ongoing treatment?
  - a. Yes: What did you find most helpful?
  - b. No: Why do you feel these messages were not helpful?
3. You received several types of messages over the course of these 3 months. Could you describe the ones that you found to be the most helpful, interesting, or educational?
4. Similarly, could you also describe the types of messages you found to be the most distracting, unhelpful, or bothersome?
5. If you were to continue to receive messages on your phone about your treatment and/or condition, what topics or material should these messages focus on?
6. You received one message each day for 90 days. Was this too much, too little, or about right?
  - a. Potential follow-up: How often and how many messages would you prefer to receive?
7. Was it convenient for you to receive these messages on your phone?
  - a. Yes: Is this your preferred method of receiving health-related information?
  - b. No: How else would you prefer to receive health-related information? (Suggested sources: online, e-mail, mail.)
8. The messages you received were created specifically for you, meaning they were tailored to your treatment and current condition. Did this make you more or less likely to read, consider, and act on each message?
9. After receiving these messages for 90 days, do you feel more confident about managing your diabetes than you did before the study began?
10. When you received these messages did it make you more or less likely to take your prescribed medication for the day?
  - a. Yes: What made you more likely to do so?
  - b. No: What aspect of the messages made you less likely to do so?
11. In the future, how could we make a message-based system, similar to this one, more effective in terms of providing individual information and support? (Suggested topics: types of messages, interaction, timing.)
12. In the future, would you consider receiving tailored messages on your phone throughout the course of your treatment, similar to what you have for the past 3 months?
13. After receiving health-related information on your phone for 90 days, how likely are you to use your mobile phone for other health-related activities, such as tracking your condition, interacting with a healthcare provider, or looking up information?

## APPENDIX F

### F. Focus Group Demographic Survey

#### Participant Information

Age: \_\_\_\_\_

Gender: \_\_\_\_\_

Race: Caucasian \_\_\_\_\_

Asian \_\_\_\_\_

Native American \_\_\_\_\_

African American \_\_\_\_\_

Hispanic \_\_\_\_\_

Other \_\_\_\_\_

Diagnosis: Type 1 Diabetes (insulin-dependent) \_\_\_\_\_

Type 2 Diabetes \_\_\_\_\_

Years since being diagnosed with diabetes:

Less than 1 year \_\_\_\_\_

1-3 years \_\_\_\_\_

3-5 years \_\_\_\_\_

5-10 years \_\_\_\_\_

More than 10 years \_\_\_\_\_

Number of diabetes medications you currently take:

1 \_\_\_\_\_

2 \_\_\_\_\_

3 \_\_\_\_\_

4 \_\_\_\_\_

5 or more \_\_\_\_\_

## APPENDIX G

### G. Focus Group Guide

- Introduction
  - Study overview
  - Focus group logistics and format
- Icebreaker question
  - What feature of your cell phone do you like the most?
- Mobile phone use questions
  - Could you please describe how you use your mobile phone on a daily basis in terms of talking, texting, app use, and/or browsing?
  - How many text messages would you estimate you send and receive on a typical day?
  - How often would you say you use your phone to access health-related material?
  - How comfortable would you be with receiving personalized diabetes-related information, such as details of your medication and tips on improving your condition, in a text message sent to your phone?
  - If so, how often would you prefer to receive these messages? (Provide ranges of options from which to choose)
- Medication use questions
  - What challenges, if any, do you face in taking your diabetes medications as directed by your physician and/or pharmacist?
  - What have you done to help you take your medication more regularly?
  - How clearly did your physician and/or pharmacist describe the treatment you are on, in terms of how to take it and what to expect?
  - Is there anything that you wish your physician and/or pharmacist would have told you about your diabetes or treatment at your last visit that would have been helpful?
- Wrap-up
  - Is there anything else about taking your diabetes medications that you would like to mention?

## APPENDIX H

### H. Theory-Driven Message Library

Concept	Level	Message Stem
Perceived Severity	High	sounds like you are making progress with controlling your diabetes. Keep up the good work
		great to know your diabetes is well controlled. You must have a good plan so stick with it and keep it controlled
		even if your diabetes is controlled be sure to keep taking your INSERT MEDS as directed so you can keep making progress
		knowing that diabetes takes work goes a long way to improving your health. Every step matters, even at AGE, keep it up
		recognizing that you have to work to control your diabetes is a winning attitude. Keep making strides every day
		INSERT MEDS are powerful ways to help treat your diabetes, taking them as directed is a big step you're taking every day
		seems like you know how helpful your medications can be in helping avoid complications with diabetes. Eating well and exercising help them do more
		your medications certainly go a long way to preventing complications at AGE but be sure to eat well and exercise to further improve your diabetes
		your INSERT MEDS are doing their part to help you avoid complications. Be sure to also eat well and exercise to help them do more
		it seems like you know how serious diabetes can be even when you're AGE. Following the plan your doctor and you agreed upon is key to your health
		you know how serious diabetes can be. Taking your medications as directed will help you control this condition and improve your health
		even though uncontrolled diabetes can lead to serious problems, taking INSERT MEDS as directed will help you stay healthy and avoid issues
	Low	even if your diabetes isn't controlled today, taking your medications, exercising, and eating right will help you reach your goal
		controlling diabetes can be tough but your doctor has given you a great plan. Stick to it and you will see results
		taking INSERT MEDS is one of the easiest ways to control your diabetes. Be sure to keep taking them as directed by your doctor
		having diabetes can be challenging but a lot of it is in your control.

		Even small efforts each day, even when you're only AGE, can be helpful
		every day matters when trying to control diabetes. Even a small step can have a big impact. Make today count
		it may not seem like much but taking your INSERT MEDS does a lot to improve your diabetes. Every dose makes a big difference
		diabetes can lead to many complications but taking the medications your doctor suggests can help you avoid additional problems at AGE
		not taking your diabetes medications as directed by your doctor can double your risk of ending up in the hospital
		taking your INSERT MEDS is a simple way to avoid diabetes complications, both at age and in the future. Be sure to take them as directed
		diabetes requires careful attention in order to avoid future problems. Controlling it now, at AGE, can lead to better tomorrows
		it may not seem like a big deal now but problems due to diabetes can develop over time. Work on controlling your diabetes now to avoid future issues
		INSERT MEDS have been prescribed for you to help avoid long-term serious issues. Taking them is key to controlling your diabetes
Perceived Susceptibility	High	recognizing that there is more to treating your diabetes than just feeling ok is a great way to approach your health. Keep it up
		you know that diabetes can be an issue even at AGE. Even if you are feeling well, be sure to keep checking your blood sugar and seeing your doctor
		you know that diabetes can cause problems even if you feel ok. Taking your INSERT MEDS is key to staying healthy and feeling well
		it's true that diabetes can lead to complications but you have the tools and ability to manage your treatment and stay healthy
		you're right, having diabetes can lead to poorer health, but it is up to you to do things every day to stay healthy, like taking your meds
		taking your INSERT MEDS as directed will go a long way to improving your health, today, at AGE, and every day in the future
		having diabetes may mean you'll be sick a lot, but remember it is up to you to manage your treatment every day to avoid this
		with diabetes, how you feel each day is up to you. Do something today to help avoid feeling sick later, like taking your meds and eating well
		one of the best ways to make sure you don't feel sick due to diabetes is to take your INSERT MEDS as directed. Keep it up
		even at AGE recognizing that diabetes needs to be treated for a lifetime is important. It may be tough but every day matters, so make today count
		sounds like you know you need to take your diabetes medications for a long time. That may sound tough, but you can do it and you'll see results, too
		you may need to take INSERT MEDS for a lifetime but doing so will lead to better health today, at AGE, tomorrow, and years to come
	Low	even when you start to feel better, be sure to stick with the diabetes plan your doctor and you agreed upon. It'll pay off in the long-run
even if you feel alright at AGE, diabetes can be difficult. Taking your		



		<p>medications is a great way to treat your condition and feel better</p> <p>taking your INSERT MEDS may be helping you feel better but be certain to stick to your entire treatment plan to avoid problems</p> <p>it's tough to realize but diabetes can have bad effects on your future health, like vision problems. Taking your meds helps you avoid them</p> <p>at AGE it may be tough to see how diabetes can lead to more issues but taking your medications, eating right, and exercising can do a lot to help</p> <p>one of the best ways to make sure your diabetes doesn't affect your future health: take your INSERT MEDS as directed</p> <p>it may be hard to see, but uncontrolled diabetes, even when you're only AGE, can make you feel sick. Following your treatment will help</p> <p>even if you feel well now, diabetes can make you feel sick in the future if you don't work at controlling it. Taking your meds can help</p> <p>you may not realize it but diabetes can make you feel sick but your INSERT MEDS were prescribed to help. So take them as directed</p> <p>treating diabetes takes time, even at AGE, but every day matters. Make today count by taking your medications as directed and keep it going tomorrow</p> <p>today, tomorrow, and beyond, every dose matters. So, be sure to take your medications as directed so you can be in control of your diabetes</p> <p>every dose matters when treating diabetes. So, take your INSERT MEDS according to the plan your doctor and you discussed</p>	
Perceived Benefits	High	<p>thinking you have the tools and ability to control your diabetes is a great attitude that will help you see results. Keep it up</p> <p>believing in your ability to control your diabetes will go a long way in improving your health. Turn that attitude into action every day</p> <p>as you know, your medications are designed to help control your diabetes, and taking them as directed is the only way to know that</p> <p>believing in the power of your medications is great, taking them as directed will show you how much you can control your condition</p> <p>it's great that your medicine makes you feel better today. Keep taking them as directed and this will be just the start of even better health to come</p> <p>your medicine should help you feel better. Happy to hear that that they do. Keep taking them and it can lead to even better health</p>	
		Low	<p>there is a lot you can do to get control of your diabetes. It starts with a healthy diet and exercising regularly</p> <p>controlling your diabetes is within reach. Your doctor and you have devised a great plan but it is up to you to follow it. You can do it</p> <p>your medications can go a long way in controlling your diabetes. The plan your doctor outlined is tailored to meet your needs and improve your health</p> <p>you may not feel the effects but your medications are working hard to improve how your body controls your diabetes. Keep taking them, results will come</p> <p>even though you may not feel it, your diabetes medications are working hard to help improve your health. Keep taking them and you'll see results</p> <p>your diabetes medications may not make you feel much better today</p>

		but your body is thankful. It runs much better when you take them
Perceived Barriers	High	way to go. You're proof that taking your diabetes medications can be an easy habit to adopt and follow. Keep it up
		sounds like you have found a way to add taking your diabetes medications to your everyday rituals. It's a habit worth keeping
		you've made taking your INSERT MEDS a regular ritual. Make taking them, eating well, and exercising habits you can't break
		sounds like you have found a way to closely follow your treatment plan. Keep up the good work and keep taking your medications
		we know following your treatment plan isn't always easy, but you seem to be handling it well. Way to go, keep it up
		seems like you are having no problem taking your INSERT MEDS. Be proud of being able to make them a part of your everyday life
		sounds like your doctor gave you great direction on your diabetes medications. Be sure to put that plan in action every day
		understanding how to follow your treatment is a key step toward improving your health but it is up to you to execute your plan every day
		sounds like your doctor or pharmacist made it easy to understand how to take your INSERT MEDS. Turn that understanding into action each day
		sounds like you have found a way to make taking your diabetes medications a regular routine. Way to be committed to your treatment
		seems like taking your diabetes medications has been easy to fit into your schedule. Don't forget about that even when you travel
		nice job fitting your INSERT MEDS into your daily activities. Doing that every day will bring you closer to better health
		Low
	we all have habits and some of them are tough to break. Try to make taking your diabetes medications one of those rituals you can't shake	
	taking your INSERT MEDS can be your newest habit. Start with making them a part of today and you'll see how easily it can be done	
	taking medications regularly isn't always easy. Take a few minutes today and think about how you can easily follow your diabetes treatment plan	
	adding medications to your daily life can be hard. But it doesn't have to be. If you are having trouble, give your doctor or pharmacist a call	
	sounds like you may be having trouble taking your INSERT MEDS. It may be time to talk to your doctor about how to make this easier	
	knowing how to take your medications is important. Sounds like you may need to have a chat with your doctor or pharmacist to know exactly what to do	
	not knowing enough about your medications can be tough. Talk with your doctor or pharmacist to get a better understanding	
understanding how to take you INSERT MEDS is vital to your treatment. Talk with your doctor or pharmacist, they can help		
taking your diabetes medications doesn't have to be a burden. Think about today and how you can find a minute or two to easily take them		
your normal activities don't have to be affected by your treatment. Pair		

		a daily activity with taking your medications to easily fit them in think about today and how you can most easily fit in taking your INSERT MEDS. Then try and make it a daily routine
Perceived Competency	High	you should be confident, you can take care of your diabetes. It starts with taking your medications as directed and includes eating well each day
		keep that confidence going strong. You can definitely take care of your diabetes. Following your treatment plan as directed is strong proof
		being confident is one thing but showing you can take care of your diabetes by taking your INSERT MEDS is even better
		thinking you can handle your diabetes is a great attitude. Turn that into action every day and stick to your treatment plan to see results
		you're right, you can handle your diabetes. But remember there's more to it than just believing, you have to take action, too
		believing you can handle your diabetes and taking your INSERT MEDS is a powerful combination. Keep it up, and remember to eat well, too
		managing your routine care is tough, but you found a way. Way to go. Just be sure that includes taking your diabetes medications as directed
		being able to handle your routine diabetes care is essential to improving your health. Never forget: that includes your medications, too
		being able to handle your routine diabetes care puts you closer to improved health. Taking your INSERT MEDS will help even more
		thinking you can meet the challenges of your diabetes head on is a powerful attitude. Stay strong and keep up with your treatment
		sounds like you are meeting the challenge of controlling your diabetes. Prove it by taking your medications and eating well every day
		remember that controlling your diabetes includes eating well, exercising, and taking your INSERT MEDS as directed every day
	Medium	building confidence in being able to take care of your diabetes takes time. But you make progress every day by following your treatment plan
		taking your INSERT MEDS may not seem like much but it should give you confidence in being able to take care of your diabetes
		you should be confident, you can take care of your diabetes. It starts with taking your medications as directed and includes eating well each day
		you're on the way to being able to better handle your diabetes. You may not be there yet, but every day you follow your treatment, you get closer
		you may still be a bit unsure about being able to handle your diabetes, but taking your INSERT MEDS is proof that you can
		thinking you can handle your diabetes is a great attitude. Turn that into action every day and stick to your treatment plan to see results
it can take time to figure out your own diabetes care, but each day you take your medications you are making progress. Keep it up		
each day you take your INSERT MEDS you make progress in managing your own care, controlling your diabetes, and improving		

		<p>your health</p> <p>managing your routine care is tough, but you found a way. Way to go. Just be sure that includes taking your diabetes medications as directed</p> <p>meeting the challenges of controlling your diabetes takes time, but taking your medications as directed moves you closer every day</p> <p>one of the ways to make controlling your diabetes easier is by taking your INSERT MEDS as directed. It goes a long way</p> <p>thinking you can meet the challenges of your diabetes head on is a powerful attitude. Stay strong and keep up with your treatment</p>
	Low	<p>you may not believe it yet, but you can take care of your diabetes. One of the things you can do every day to prove it: take your medications</p> <p>gaining confidence in your ability to take care of your diabetes starts with taking your INSERT MEDS as directed. You can do it</p> <p>building confidence in being able to take care of your diabetes takes time. But you make progress every day by following your treatment plan</p> <p>handling your diabetes doesn't always happen overnight. Hang in there and follow your plan, you'll be able to handle it better soon</p> <p>taking your INSERT MEDS will go a long way in helping you handle your diabetes even if it seems tough right now</p> <p>you're on the way to being able to better handle your diabetes. You may not be there yet, but every day you follow your treatment, you get closer</p> <p>taking care of your diabetes can be tough, but you can do it. Talk to your doctor about educational resources that may help you learn what to do</p> <p>not everything about diabetes is easy but taking your INSERT MEDS as directed is a good first step in managing your care</p> <p>it can take time to figure out your own diabetes care, but each day you take your medications you are making progress. Keep it up</p> <p>controlling diabetes can be challenging but there's a lot in your control, like following your medication schedule and eating well</p> <p>controlling your diabetes is a challenge but your INSERT MEDS are powerful and can help you meet your goals</p> <p>meeting the challenges of controlling your diabetes takes time, but taking your medications as directed moves you closer every day</p>
Autonomous Motivation	High	<p>you're right. Your diabetes medications are important to improving your health. Taking them every day is key to being as health as possible</p> <p>sounds like you have realized the importance of your medications. Keep taking them and even better health will be in your future</p> <p>you know the importance of your INSERT MEDS in reaching better health. But remember: they only work if you take them as directed</p> <p>believing in the power of your medications is a winning attitude when you have diabetes. Turn that attitude into action and take them every day</p> <p>you're right. Taking your diabetes medications is one of the best things for your health. So, keep taking them as directed to reach even better health</p> <p>seems like you know that taking your INSERT MEDS is one of the</p>

		<p>best things for your health. Show that every day by taking them</p> <p>wanting to take responsibility for your own health at AGE is a great attitude. Put that to work by following your treatment plan</p> <p>taking responsibility for your own health will go a long way in helping you improve your condition. Keep that attitude going strong every day</p> <p>taking your INSERT MEDS as directed is a great way to show that you are taking responsibility for your own health. Show that every day you're right, taking your medications is important to a lot of things in your life. Be sure to turn that belief into action every day</p> <p>knowing that taking your medications can affect your life is important and that will go a long way to helping you reach better health</p> <p>seems you know that taking INSERT MEDS is important for a lot of things in life, things you can better focus on with your diabetes under control</p>
	Medium	<p>sounds like you are starting to see how important your medications can be to your health. Stick with your plan and it will become more clear</p> <p>one of the best ways to see the importance of your INSERT MEDS is to take them as directed. Then, you can see results in your health</p> <p>you're right. Your diabetes medications are important to improving your health. Taking them every day is key to being as health as possible</p> <p>many things are important for your health when you have diabetes. Taking your medications as directed is one of them. See for yourself every day you take your INSERT MEDS you get closer to better health, better control, and to seeing why taking them is so important</p> <p>believing in the power of your medications is a winning attitude when you have diabetes. Turn that attitude into action and take them every day</p> <p>taking responsibility for your health takes time but you can do it. Part of that is taking your medications as directed, so start there</p> <p>the plan your doctor and you outlined, including taking your INSERT MEDS, is one way to start taking responsibility for your health</p> <p>wanting to take responsibility for your own health at AGE is a great attitude. Put that to work by following your treatment plan</p> <p>it may be tough to see but feeling better from taking your medications can allow you to focus more on the things you love in life</p> <p>taking INSERT MEDS can lead to better health and that allow you to spend more time on enjoying other aspects of your life</p> <p>you're right, taking your medications is important to a lot of things in your life. Be sure to turn that belief into action every day</p>
	Low	<p>it may not seem like much, but taking your medications goes a long way in you being as healthy as possible, even when you're only AGE</p> <p>it may be hard to realize their effect but your INSERT MEDS play an important role. Take them today for better health tomorrow</p> <p>sounds like you are starting to see how important your medications can be to your health. Stick with your plan and it will become more clear</p> <p>it may be tough to see but taking your diabetes medications is vital to your health. Taking them as directed may help you see their value</p> <p>your INSERT MEDS is/are a crucial part of reaching good health. Taking them will lead to results you can feel and see and then believe</p>

		<p>in</p> <p>many things are important for your health when you have diabetes. Taking your medications as directed is one of them. See for yourself</p> <p>it may seem hard to have to take responsibility for your health, especially at AGE, but tools are out there to help you, like your diabetes medications</p> <p>it can be hard to be in charge of your health. Take small steps. Start with taking your INSERT MEDS. The rest of your care, take one day at a time</p> <p>taking responsibility for your health takes time but you can do it. Part of that is taking your medications as directed, so start there</p> <p>your diabetes medications can have many benefits, some you may not even think of, but the only way to find out is by taking them as directed</p> <p>even though they are designed to help control your diabetes, taking your INSERT MEDS can improve many aspects of your life</p> <p>it may be tough to see but feeling better from taking your medications can allow you to focus more on the things you love in life</p>
External Regulation	High	<p>being able to handle your treatment without pressure must be helpful, that way you can focus on taking your medications because you believe in them</p> <p>without pressure from others you are in complete control of your treatment. Take that responsibility seriously, every day, and every dose</p> <p>without pressure from others, taking your INSERT MEDS is solely your responsibility. Control your treatment plan every day</p> <p>seems the only one that would be upset if you didn't take your medications is you. So keep taking them to avoid upsetting your health</p> <p>sounds like the only person to satisfy by taking your medications is you. Your health will feel satisfied, too. Keep it up</p> <p>taking your INSERT MEDS will help avoid stress among others who might be upset if you miss your meds</p> <p>you're right. You are the only person that needs to know you can stick to taking your diabetes medications every day. Keep it up</p> <p>sounds like you get it. You only need to prove to yourself that you can take your diabetes medications as directed. Great attitude</p> <p>stay focused on proving to you and only you that you can take your INSERT MEDS. Your opinion is the only one that matters</p> <p>you definitely have a great attitude, the only approval you need is the feeling of good health by meeting the goals of your treatment. Keep it up</p> <p>you're right, the only approval you need is your own and that of the benefit of the good health you'll see from sticking to your treatment plan</p> <p>sounds like you are focused on your health for your own approval. Good thinking. Taking your INSERT MEDS will help keep you on track</p>
	Medium	<p>feeling pressure from others about your diabetes can be distracting. Just try to focus on taking your medications for your own benefit and health</p>

	<p>just remember that taking your INSERT MEDS is in your hands, focus on the benefit to you, not the pressure from others</p> <p>being able to handle your treatment without pressure must be helpful, that way you can focus on taking your medications because you believe in them</p> <p>upsetting someone even a little is never fun but not taking your medications will upset your body even more. Stick to your plan for your health</p> <p>missing your INSERT MEDS is not supposed to upset others. Focus on yourself, take your meds, and satisfy your health needs</p> <p>seems the only one that would be upset if you didn't take your medications is you. So keep taking them to avoid upsetting your health</p> <p>it may be tempting to want to show others that you can take your diabetes medications but remember you only need to prove it to yourself</p> <p>wanting to show others you can take your INSERT MEDS may be tempting but stick to proving that to yourself, because that's what matters</p> <p>you're right. You are the only person that needs to know you can stick to taking your diabetes medications every day. Keep it up</p> <p>by focusing on your treatment plan you are gaining the only approval you need: that of your body. Your medications are designed to help with this</p> <p>the benefit of taking your INSERT MEDS will lead you to better health, better control, and the only approval you need: your body's</p> <p>you definitely have a great attitude, the only approval you need is the feeling of good health by meeting the goals of your treatment. Keep it up</p>
Low	<p>it can be tough to focus on your own care when others are pressuring you. Take control of your own care and they'll realize you don't need the pressure</p> <p>sounds like you may be feeling pressure to take your INSERT MEDS. Stick to your plan today and others will see you can handle it</p> <p>feeling pressure from others about your diabetes can be distracting. Just try to focus on taking your medications for your own benefit and health</p> <p>it's understandable that you wouldn't want to upset others. More importantly, by taking your medications you satisfy your own needs</p> <p>others may be upset if you don't take your INSERT MEDS but your health will suffer even more. Do it for your own good</p> <p>upsetting someone even a little is never fun but not taking your medications will upset your body even more. Stick to your plan for your health</p> <p>showing others you can handle your treatment might be helpful but remember you only need to prove to yourself that you can do it</p> <p>you may want to show others you can take your INSERT MEDS but you only need to prove it to yourself. Prove it today</p> <p>it may be tempting to want to show others that you can take your diabetes medications but remember you only need to prove it to</p>

		yourself
		when it comes to health the only approval you need is that of your body when it gets the benefit it needs from medications to treat your diabetes
		for your diabetes, nothing compares to the approval it will give you when you see the benefits from taking your INSERT MEDS as directed
		by focusing on your treatment plan you are gaining the only approval you need: that of your body. Your medications are designed to help with this

Notes:

AGE: indicates placement of subject age into the message

INSERT MEDS: indicates replacement of subject's medications into the message

A rotating greeting and the subject's name were placed before each message stem used



## APPENDIX I

### I. IRB Documentation



MERCY HEALTH PARTNERS

October 9, 2012

Dear Jason Barnum, PharmD, CDE,

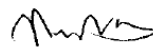
The MHP IRB has reviewed and hereby approves the project entitled, Targeting Medication Non-adherence Using Mobile Phone-based Tailored Messaging (otherwise known as, Mobile Text Messaging Medication Adherence Project or MTM MAP). This approval includes the associated Informed Consent Form dated 9/17/12.

This approval is by full board review. Based on a risk assessment of no greater than minimal, this project has been approved for one year. This approval expires on October 8, 2012 at 11:59 PM. An annual progress report to the IRB is required 6 weeks prior to expiration to avoid a lapse in approval. A final report is required when the project is complete.

All proposed changes to the study (such as study procedures or key personnel) must be approved in advance. Additionally, any unexpected adverse events must be reported.

Thank you for your submission.

Sincerely,



Harrison W. Johnson, MD  
MHP IRB Chairperson



MERCY HEALTH PARTNERS

April 4, 2013

Dear Jason Barnum, PharmD, CDE,

On behalf of the MHP IRB, this is to correct a date error listed in the approval letter (dated October 9, 2012) for the project entitled, Targeting Medication Non-adherence Using Mobile Phone-based Tailored Messaging (otherwise known as, Mobile Text Messaging Medication Adherence Project or MTM MAP), including the associated Informed Consent Form dated 9/17/12.

The approval expires on October 8, **2013** at 11:59 PM. The expiration year was incorrectly entered as **2012** in the approval letter, and this was a typographical error. Thank you for the opportunity to make this correction.

Sincerely,

Kathleen Thomas, RN, MSN  
MHP IRB Representative

**To:** Justin Gatwood

**From:**

Richard Redman

**Cc:**

Rajesh Balkrishnan  
Steven Erickson  
Lawrence An  
Karen Farris  
Justin Gatwood  
John Piette

**Subject:** Initial Study Approval for [HUM00061321]

**SUBMISSION INFORMATION:**

Study Title: Targeting medication nonadherence using mobile phone-based tailored messaging  
Full Study Title (if applicable):  
Study eResearch ID: HUM00061321  
Date of this Notification from IRB: 9/18/2012  
Review: Expedited

Initial IRB Approval Date: 9/17/2012

**Current IRB Approval Period:** 9/17/2012 - 9/16/2013

**Expiration Date:** Approval for this expires at 11:59 p.m. on 9/16/2013

**UM Federalwide Assurance (FWA):** FWA00004969 expiring on 6/13/2014

**OHRP IRB Registration Number(s):** IRB00000245

**Approved Risk Level(s):**

Name	Risk Level
Control group	No more than minimal risk
Experimental group	No more than minimal risk

**NOTICE OF IRB APPROVAL AND CONDITIONS:**

The IRB HSBS has reviewed and approved the study referenced above. The IRB determined that the proposed research conforms with applicable guidelines, State and federal regulations, and the University of Michigan's Federalwide Assurance (FWA) with the Department of Health and Human Services (HHS). You must conduct this study in accordance with the description and information provided in the approved application and associated documents.

**APPROVAL PERIOD AND EXPIRATION:**

The approval period for this study is listed above. Please note the expiration date. If the approval lapses, you may not conduct work on this study until appropriate approval has been re-established, except as necessary to eliminate apparent immediate hazards to research subjects. Should the latter occur, you must notify the IRB Office as soon as possible.

**IMPORTANT REMINDERS AND ADDITIONAL INFORMATION FOR INVESTIGATORS**

**APPROVED STUDY DOCUMENTS:**

You must use any date-stamped versions of recruitment materials and informed consent documents available in the eResearch workspace (referenced above). Date-stamped materials are available in the "Currently Approved Documents" section on the "Documents" tab.

**RENEWAL/TERMINATION:**

At least two months prior to the expiration date, you should submit a continuing review application either to renew or terminate the study. Failure to allow sufficient time for IRB review may result in a lapse of approval that may also affect any funding associated with the study.

**AMENDMENTS:**

All proposed changes to the study (e.g., personnel, procedures, or documents), must be approved in advance by the IRB through the amendment process, except as necessary to eliminate apparent immediate hazards to research subjects. Should the latter occur, you must notify the IRB Office as soon as possible.

**AEs/ORIOs:**

You must inform the IRB of all unanticipated events, adverse events (AEs), and other reportable information and occurrences (ORIOs). These include but are not limited to events and/or information that may have physical, psychological, social, legal, or economic impact on the research subjects or other.

Investigators and research staff are responsible for reporting information concerning the approved research to the IRB in a timely fashion, understanding and adhering to the reporting guidance ([http://www.med.umich.edu/irbmed/ae\\_orio/index.htm](http://www.med.umich.edu/irbmed/ae_orio/index.htm)), and not implementing any changes to the research without IRB approval of the change via an amendment submission. When changes are necessary to eliminate apparent immediate hazards to the subject, implement the change and report via an ORIO and/or amendment submission within 7 days after the action is taken. This includes all information with the potential to impact the risk or benefit assessments of the research.

**SUBMITTING VIA eRESEARCH:**

You can access the online forms for continuing review, amendments, and AEs/ORIOs in the eResearch workspace for this approved study (referenced above).

**MORE INFORMATION:**

You can find additional information about UM's Human Research Protection Program (HRPP) in the Operations Manual and other documents available at: [www.research.umich.edu/hrpp](http://www.research.umich.edu/hrpp).



Richard Redman  
Chair, IRB HSBS