Enhancing Clinical Decision Support Applications for Community Pharmacist-Delivered Medication Therapy Management

Final Report

Principal Investigator: Margie E. Snyder, PharmD, MPH, FCCP

Organization: Purdue University College of Pharmacy

Project Period: 9/13/16-8/31/19

Project Officer: Steve Bernstein

Acknowledgement and Grant number: This study was funded by the Agency for Healthcare Research and Quality grant number R21HS025005. The content is solely the responsibility of the authors and does not necessarily represent the official views of the Agency for Healthcare Research and Quality.

Structured Abstract

Purpose: To evaluate the usability and usefulness of MTM alerts and make recommendations for improving the design of MTM alerts

Scope: This was a mixed-methods investigation of MTM alerts, with data collected in collaboration with two regional practice-based research networks.

Methods: In Aim 1, investigators conducted a heuristic evaluation of MTM alert screenshots submitted by community pharmacists. In Aim 2, triangulated data from three sources (MTM alert data submitted by pharmacists, naturalistic usability testing, semi-structured interviews) were reviewed to identify key challenges in MTM alert design from an end-user perspective. Both Aims informed recommendations for improving MTM alert design.

Results: A total of 10 pharmacists representing 8 pharmacy locations were recruited and participated in data collection for one or more parts of the study. A total of 77 MTM alerts were submitted. In Aim 1, across all alert categories, 4 recommendations were identified; 4 additional recommendations were identified for all alert categories except adherence (which were stronger overall); 3 final recommendations were made for specific alert categories. In Aim 2, 15 recommendations were identified.

Key Words: medication therapy management, Medicare, policy, clinical decision support

Purpose
The purpose of this study was to evaluate the usability and usefulness of MTM alerts and make recommendations for improving the design of MTM alerts. The specific aims of the study were to:

- **Aim 1:** Evaluate the extent to which computerized clinical decision support for community pharmacist-delivered medication therapy management aligns with established human factors principles.

- **Aim 2:** Assess the *usability* of medication therapy management computerized clinical decision support for community pharmacists, as well as pharmacists' *perspectives* on the *usefulness* and *usability* of these technologies for patient care.

Scope

Background[1]
Medication therapy management (MTM) is a service, most commonly provided by pharmacists, intended to identify and resolve medication therapy problems (MTPs) to enhance patient care. MTM is typically documented by the community pharmacist in an MTM vendor's web-based platform. These platforms often include integrated alerts to assist the pharmacist with assessing MTPs. In order to maximize the usability and usefulness of alerts to the end users (e.g., community pharmacists), MTM alert design should follow principles from human factors science.

Methods—Aim1[1]

Conceptual Frameworks
This study was informed by the Systems Engineering Initiative for Patient Safety (SEIPS) v. 2.0.[22] As described in SEIPS 2.0, six work system components influence work processes, which thereby influence outcomes.[22] One component is "tools and technology," such as alerts for MTM. In addition, we used the MTP taxonomy described by Cipolle *et al*.[23] to organize our findings. According to this taxonomy, MTPs can be categorized as related to a medication's: 1) indication (e.g., to assess whether a medication is medically indicated for the patient), 2) effectiveness (e.g., a higher dose of medication is recommended), 3) safety (e.g., a drug-drug interaction is present that increases the risk of toxicity for the patient), or 4) medication adherence (e.g., the patient has difficulty remembering to take their medication.)[23] For this study, we added a MTP category: 5) payer-driven alerts for *cost-containment* purposes (e.g., the alert recommends a brand to generic switch) to align with alerts that are available in MTM vendor platforms. Thus, as described below, we used these five categories to examine how the extent of alert alignment with human factors principles varies by category of MTP targeted by the MTM alert.

Setting, Participants, and MTM Alert Systems
MTM vendors contract with pharmacies and payers on MTM program delivery. These vendors have developed web-based commercial documentation platforms in which pharmacists document MTM services. These platforms often include integrated alerts to assist the pharmacist in the assessment of MTPs. This study was conducted in collaboration with regional pharmacist/pharmacy practice-based research networks located in two different states: the Medication Safety Research Network of Indiana (Rx-SafeNet) and the Minnesota Pharmacy Practice-based Research Network (MPPBRN).[24-25] Community pharmacists from these networks were eligible to participate if they reported that they routinely provided CMRs for at least one of two national MTM vendors that require documentation in a web-based platform with

integrated alerts. Eligibility criteria focused on these particular MTM vendors because the researchers were aware of their long-standing use by pharmacists in the collaborating networks. All MTM vendors with alerts evaluated as part of this study have been contracting on MTM program delivery for more than 10 years.

Study Design & Modification of I-MeDeSA

A heuristic evaluation is "one method for measuring usability…through which experts identify potential usability problems by comparing designs against established principles (i.e., heuristics)."[26] We followed established techniques to conduct a heuristic evaluation of MTM alerts.[27-30] A heuristic evaluation was chosen to understand how well MTM alerts align with established human factors principles and to maximize our ability to identify opportunities to enhance MTM alert design. The heuristic evaluation was guided by a modified version of the *Instrument for Evaluating Human-Factors Principles in Medication-Related Decision Support Alerts* (I-MeDeSA).[31] The original I-MeDeSA contains 26 heuristics pertaining to human factors principles and was designed to evaluate drug-drug interaction alerts associated with EHRs .[21,31-32] Because the original I-MeDeSA focused solely on drug-drug interactions, we modified it to encompass the broader alerts generated during MTM. Our modified version of the I-MeDeSA removed one heuristic and added 7 additional heuristics for a total of 32 heuristics pertaining to eight human factors principles: *alarm philosophy*, *placement*, *visibility*, *prioritization*, *color*, *text-based information*, *proximity of task components being displayed*, and *corrective actions* (Additional file 1). The additional heuristics incorporate usability design heuristics and human factors recommendations related to warning design.[33] The scoring procedures for the I-MeDeSA were also modified to enable indication of heuristics that were "unable to be assessed" from screenshots, to avoid forcing analysts into an inaccurate response and provide insights on areas for future research. Prior to data analysis, the modified I-MeDeSA was piloted by two investigators (a research pharmacist and a human factors professional) with two rounds of review with example MTM alert screenshots.

Data Collection: Screenshots of MTM Alerts

Following recruitment and training, community pharmacists submitted screenshots of MTM alerts that were generated by the MTM vendor platform as part of community pharmacists' routine provision of CMRs. Pharmacists used HyperSnap software (Hyperionics, vs. 7 and 8, Boswell, PA)[34] to take screen shots associated with MTM alerts. Specifically, pharmacists were instructed to take screenshots representing their routine workflow for opening and responding to MTM alerts, including the initial screen from which the alert is accessed to the final screen where the alert is resolved or requires later action. They were instructed to redact any protected health information. Pharmacists were asked to submit alert screen shots for five MTP alert categories: 1) *indication,* 2) *effectiveness*; 3) *safety*; 4) *adherence*; and 5) payer-driven alerts for *cost-containment* purposes.[23] Pharmacists submitted screenshots to our team using REDCap, a secure, web-based application developed to support the collection of research data.[35] We asked pharmacists to start by submitting alerts for three patients, preferably with MTM alerts representing varying categories. Submitted MTM screenshots were first reviewed by two investigators (a research pharmacist and nurse.) The purpose of this review was to 1) ensure completeness of the submission (e.g., screenshots for each step in the pharmacist's workflow) and request clarifying information from pharmacists when needed, and 2) to purposefully sample 1-2 alerts per category per vendor, with a goal of collecting a total of 24 alerts for our evaluation. As data collection proceeded, we provided guidance to pharmacists on categories of alerts that were still needed for data collection goals.

Data Analysis: Heuristic Evaluation
Prior to analysis, a second pharmacist on the research team verified the categorization of MTM alerts made during the initial review. Four analysts conducted the heuristic evaluation. The analyst team was comprised of three human factors professionals and one pharmacist/MTM domain expert.[27,30] This mix of analysts is supported by literature on heuristic evaluation, which demonstrates that at least 3 expert reviewers are needed, 3-5 reviewers can identify up to 75% of usability problems, and including domain experts (i.e., MTM, community pharmacy) can further strengthen the rigor and quality of results.[27,30] Analysts completed a total of three hours of training which included further pilot testing of the modified I-MeDeSA and minor revisions of the instrument to ensure clarity of heuristics for all analysts. This level of training aligns with recommendations from the literature.[30]

Each analyst independently rated each alert on the modified I-MeDeSA. To maintain the same sentiment as scoring for the original I-MeDeSA (i.e., alerts scored a "1" for each heuristic met) but to enable investigators to distinguish between definite alignment and uncertainty, heuristics were scored as "0" when the alert "did not align" with the heuristic, "1" when the analyst was "unable to assess" whether the alert aligned with the heuristic (e.g., if the alert was appropriately timed but no specific timing information was available), and "2" when the "alert aligned" with the heuristic so that increasing scores reflected increased certainty in alert alignment. Therefore, for each evaluated MTM alert, the total possible scores on the modified I-MeDeSA ranged from 0 to 64 (32 heuristics each given a score of 2 would indicate alignment across all heuristics.) Analysts were required to enter explanatory comments when indicating "unable to assess" a heuristic or "not aligned" with the heuristic.

Some heuristics on the modified I-MeDeSA are applicable to individual alerts (alert-level) and others refer to the MTM vendor system as a whole (vendor system-level) (Additional file 1.) For vendor system-level heuristics on the modified I-MeDeSA, analysts scored each heuristic one time for each vendor by considering the body of all alerts evaluated for the vendor. Scores on vendor system-level heuristics were then used in computing scores for all alerts from that vendor. Analysts completed all scoring in REDCap.[35] For each MTM alert, analysts' individual ratings were summed and a mean score on the modified I-MeDeSA computed. For each heuristic, we also computed the percent of analyst ratings indicating alignment with the heuristic. We did this for all alerts evaluated to produce an "overall" summary of analysts' ratings for a given heuristic, and we also computed this separately for each alert category to determine whether specific heuristic alignment differed by alert category. All computations were performed using SPSS (IBM, v. 24, Armonk, NY).[36] Focus was made on heuristics where ≤ 50% of analysts' ratings indicated alerts aligned with the heuristic. Analysts' explanatory comments were also considered when summarizing findings and recommendations for future alert design for MTM. In an effort to provide comprehensive reporting of this evaluation, we consulted the STAR-HI statement in the preparation of this paper.[37] This evaluation was approved by the Purdue University Institutional Review Board (IRB; study number 1608018057.) Pharmacists provided written informed consent; patient consent was waived by the IRB.

Methods—Aim 2[2]

Conceptual frameworks
This study was informed by three complementary frameworks: 1) the Systems Engineering Initiative for Patient Safety (SEIPS) v. 2.0.,[21] 2) the MTP taxonomy framework described by Cipolle *et al*,[22] and 3) Russ et al.'s prescriber-alert interaction model, adapted for pharmacist-MTM alert interactions.[23] In the SEIPs 2.0 model, the work system includes "tools and technology," which along with other factors, shape work processes and desired and undesirable

patient outcomes.[21] For the purposes of the current study, MTM alerts were the "tools and technology" of interest. The Cipolle framework was applied to organize MTM alerts into the following 4 categories: 1) indication (e.g., medication is not medically warranted), 2) effectiveness (e.g., suboptimal dose), 3) safety (e.g., drug-drug interaction), or 4) adherence (e.g., the patient forgets the medication.)[22] Alert categorization is described in detail below. Finally, Russ' model describes 9 factors that influence how prescribers perceive and respond to medication alerts. These factors are: 1) alert system logic, 2) alert system redundancy, 3) alert content, 4) alert display, 5) cognitive factors, 6) pharmaceutical knowledge, 7) medication management, 8) workflow, and 9) alert system reliability.[22] As described below, this framework was applied during the collection and analysis of interview and usability testing data, and triangulation of findings across data sources.

Setting and participants

This research was the second part of an overarching study that examined MTM alert design to identify recommendations for improvement. The first part conducted a heuristic evaluation of MTM alert screenshots to determine alert designs' alignment with human factors principles, and the findings from that evaluation were recently published.[24] The second part, described herein, explored the experiences of pharmacists as end-users. This part of the study analyzed data from three sources, described below. The article herein is the only article for this second part of the overarching study that presents data describing the experiences of pharmacists with the MTM alerts.

As described for the first part of the study,[24] community pharmacists were recruited from 2 regional practice-based research networks (PBRNs): the Medication Safety Research Network of Indiana (Rx-SafeNet) and the Minnesota Pharmacists PBRN (MPPBRN).[25-26] They were eligible to participate in this study if they reported routine (i.e., 2 or more each week) CMR provision through contracts with national MTM vendors which utilize web-based platforms with integrated MTM alerts. The goal was to recruit a total of 10-15 pharmacists. This number was expected, from investigators' experience, to be sufficient for the detection of usability errors during usability testing sessions[27] and in the identification of themes from semi-structured interviews, described below.

Data Collection

This was a mixed-methods evaluation of data collected from 3 sources, with individual pharmacists contributing data to one or more sources: 1) community pharmacist submission of observational data about MTM alerts encountered during routine MTM provision (all pharmacists were asked to participate), 2) naturalistic usability testing of MTM alerts (a sub-set of pharmacists were asked to participate), and 3) semi-structured interviews to elicit pharmacist perspectives on MTM alert usefulness and usability (all pharmacists were asked to participate). Study procedures were approved by the Purdue University Institutional Review Board.

MTM alert data submission

Pharmacists submitted MTM alert data to the study team as previously described for the first part of the study.[24] For this part of the study, data collected pertained to pharmacists' experiences with MTM alerts as part of the process of identifying and resolving MTPs during a CMR. Specifically, each pharmacist was asked to submit alert data for 3 patients, making an effort to include patients with alerts warning about different MTP categories from the Cipolle framework.[22] The primary sampling goal (as described previously[24]) sought to obtain a representative cross-section of MTM alerts for both national vendors across all MTP categories. As data collection proceeded, the study team provided guidance to the pharmacists on which

alert categories to prioritize for submission based upon what alerts had been received up to that point.

Data were submitted by pharmacists in REDCap, which is a secure web-based application designed for the collection of research data.[28] Investigators reviewed MTM alert data to ensure completeness of the pharmacists' submission and request clarifying information from pharmacists when needed. During this time, a pharmacist investigator categorized the submitted alerts using the Cipolle framework as a guide, specifically categorizing MTM alerts as warning about one of 7 MTPs within one of the framework's 4 MTP categories. Indication-related MTPs included the following: 1) unnecessary medication therapy and 2) needs additional medication therapy; effectiveness-related MTPs included 3) ineffective medication/needs different medication and 4) dose too low; safety-related MTPs included 5) dose too high and 6) adverse drug reaction; and adherence-related MTPs included 7) any adherence-related MTP.[22]

The following data elements were submitted by pharmacists: *pharmacist demographics* (age, sex, race/ethnicity, education/training, employment information, and MTM experience); *patient demographics* (age, sex, race/ethnicity, insurance); *information about the MTM encounter* (MTM vendor, initial/follow-up CMR, mode of delivery [e.g., face to face], status of CMR [e.g., scheduled], roles of other pharmacy staff in CMR provision, number of MTM alerts generated for patient); *information about each MTM alert submitted* (screenshot images of the alert, timing of alert's appearance, assessment of whether [yes/no and why] MTM alert appeared at the "ideal" timein MTM workflow); *pharmacist response to each MTM alert* (number and types of MTPs identified with the alert, actions taken with patients and prescribers in response to MTPs); *MTPs identified without the alert*; and ratings of pharmacists' satisfaction with the MTM vendor platforms, assessed via the *system usability scale* (SUS) which contains 10 Likert-type scale items with response options ranging from 1=strongly disagree to 5=strongly agree,[29] completed for each unique vendor for which alert data was submitted. Data were collected from April 2017 to March 2018.

Naturalistic usability testing

Naturalistic usability testing[30-32] was conducted, meaning that the usability evaluation was conducted in the natural work environment while pharmacists used MTM vendor software at their pharmacy for their own patients. Usability testing focused specifically on the pharmacist-MTM alert interactions, and was conducted with a subset of pharmacists who participated in the overall study. A purposeful subset of pharmacists was invited for usability testing, targeting a range of practice settings (e.g., geographic region covered by PBRN) and characteristics (e.g., gender, MTM experience). The sample size goal was to recruit 5 pharmacists for usability testing, because, based upon usability literature, five participants can uncover 55-99% of major usability problems[27] and our usability goals were more descriptive in nature, intended to be triangulated with the other data sources, rather than fully comprehensive of all possible MTM alert usability problems.

Usability testing sessions were conducted remotely[33] between October 2017 and April 2018 with pharmacists, using WebEX conferencing software[34] and were facilitated by a moderator experienced in user-centered design and usability testing. To maintain consistency, the moderator utilized a standardized script and refined this script via pilot testing prior to data collection (Appendix A [not shown]). As part of the script, pharmacists received brief instruction, including a standardized training video,[35] on how to think aloud[30] in order to verbalize their thought process as they interacted with the MTM alerts generated for CMR-eligible patients.

Since we conducted usability testing in the natural clinical environment, patients' protected health information was visible and inherently recorded as part of the usability videos. Thus, patients provided written consent and HIPAA authorization for their data to be used in this research. Patients were eligible if 1) they were 18 years of age or older and 2) were eligible for a CMR through one of the MTM vendors used by a participating study pharmacist. Patients' demographics were not collected because these sessions were conducted to examine MTM alert usability from a pharmacist perspective.

The moderator used Morae software [Techsmith, v 2.0, Okemos, MI][36] to record each usability session, specifically capturing participating pharmacists' computer screen actions, (shared over WebEx), pharmacists' facial expressions, and voice as they engaged in 'think aloud' and worked on MTM related activities and responded to alerts. These recordings were the data source for subsequent analysis.

Semi-structured interviews with pharmacists

All recruited community pharmacists were invited to participate in a one-on-one, audio-recorded, semi-structured telephone interview to elicit their perspectives on MTM alert usability and usefulness. Interviews were conducted between November 2017 and January 2018. An interview guide (Appendix B [not shown]) was developed with questions encompassing each factor of the modified Russ prescriber-alert interaction model.[23] The guide was pilot tested with 2 pharmacists, audio-recordings of these pilot tests were reviewed and discussed by 3 investigators, and minor revisions for clarity were made prior to commencing study interviews. One investigator, a pharmacy fellow with formal training in qualitative data collection and experience in MTM delivery, conducted all interviews. Interview audio-recordings were transcribed verbatim by a professional transcriptionist and transcriptions were reviewed by the pharmacy fellow for accuracy prior to qualitative analysis.

Data Analysis

MTM alert data submission

Prior to analysis, the pharmacy fellow verified the MTM alert categorization (i.e., specific MTP warned about[22]) made by another pharmacist investigator during the initial review. The MTM alert data (pharmacist/patient demographics, alerts submitted, MTPs identified, actions taken in response to MTPs, SUS scores) were then summarized using descriptive statistics, computed in SPSS [IBM SPSS v 24.0, Cary, NC.][37] SUS scores were computed by scaling, in a standardized fashion, all response values from 0 to 4. These values were then summed and multiplied by 2.5 to create a possible score range of 0 to 100.[29] An overall total mean score was computed from SUS ratings across all pharmacists' responses.

In addition, "congruency" between the MTM alerts that the pharmacist submitted vs. any MTPs identified by the pharmacists in response to the MTM alert was assessed. MTM alerts were defined as congruent if the actual MTP identified by the pharmacist with the alert was the same as the MTP warned about (i.e., one of seven specific MTPs) by the MTM alert. Congruency was evaluated in order to identify false alarms (i.e., alerts firing with no MTPs identified in response) and situations where a different MTP was identified from that warned about by the MTM alert.

Naturalistic usability testing

In order to note the time that pharmacists spent on each MTM alert, the "start time" was defined as the time when the pharmacists first selected the link to access the MTM alert and "stop time" was defined as the time when the pharmacist resolved the alert, and selects "OK" to

acknowledge as such, OR when the participant was unable to resolve the alert and intentionally or unintentionally closed the window so that the MTM alert disappeared. Time data were recorded in Microsoft Excel [2016, Redmond, WA].[38] Usability sessions were then analyzed using descriptive statistics to summarize the number of MTM alerts encountered by pharmacists, alerts' resolution status (not reviewed or addressed; reviewed but not addressed; left pending; resolved), time spent on MTM alerts, and the number and type of negative usability incidents encountered (e.g., alert did not support or adequately integrate with the pharmacist's preferred workflow). Usability incident data were analyzed by 2 usability specialists and their analyses were informed by comments from 2 pharmacist investigators who also reviewed and commented on all of the usability recordings. Usability incidents were categorized according to factors described in the Russ prescriber-alert interaction model.[23]

Semi-structured interviews with pharmacists

Interviews were analyzed by 2 pharmacist researchers with formal MTM and qualitative analysis training using a hybrid deductive and inductive approach to code development.[39] Specifically, a starting list of broad, conceptual codes was developed to sort text into the 9 factors of the modified Russ prescriber-alert interaction model.[23] Sub-codes were then developed inductively in order to identify intra- and inter-factor themes. Each investigator independently reviewed each transcript line-by-line to complete coding in the qualitative data analysis software, MAXQDA (VERBI, v. 12, Berlin, Germany).[40] Coding discrepancies were then compared and resolved through consensus, with a codebook and audit trail maintained throughout the process to track coding decisions.[41] A third pharmacist investigator trained in MTM and qualitative analysis participated in codebook development, independently reviewed half of the transcripts during coding, and discussed impressions with the 2 analysts. Final themes were identified through discussion.

Data Triangulation

Final results from each of the 3 sources of data were discussed by 6 investigators with expertise spanning MTM, nursing, health services research, human factors engineering, and alert design. The investigators met for approximately 12 hours to collectively review and discuss all analyses, identify areas of convergence/divergence across data sources, identify overarching findings pertaining to MTM alert challenges, and develop recommendations for MTM alerts from an end-user perspective.

Results

Aim 1—Heuristic Evaluation[1]

From April 2017 to March 2018, nine pharmacists, representing eight pharmacies, submitted data for a total of 77 MTM alerts and we selected a purposeful sample of 24 MTM alerts for inclusion in our heuristic evaluation (Table 1.) Screenshots are not provided here given the commercial, proprietary nature of MTM vendor systems.

Table 1. Summary of MTM alert screenshots evaluated.

Alert Category	N[a]	MTPs Targeted by Alert (number of alerts evaluated)
Indication	5	Need for ACE/ARB[b] therapy (2) Need for statin therapy (1) Duplicate/unnecessary beta blocker drug therapy (2)
Effectiveness	5	Drug-drug interaction to reduce plasma concentration of immunosuppressant drug (1) Sub-optimal statin dosage (1) Sub-optimal choice of cholesterol-lowering drug (2) Sub-optimal asthma drug (1)
Safety	6	Unsafe drug (anti-hypertensives; benzodiazepine; hypnotic; antidepressant) for patient due to patient age (5) Drug-drug (anti-hypertensives) interaction (1)
Adherence	6	Medication (sleep agent; antidepressants, cholesterol-lowering drug, anti-hypertensive, anti-diabetic) non-adherence (6)
Cost	2	Cost-savings opportunity through switch to alternative drug (statin; anti-hypertensive) (2)

[a] n = number of alerts evaluated for each category. (Total N = 24)
[b]ACE: angiotensin-converting enzyme inhibitor; ARB: angiotensin II receptor blocker

Overall findings across MTM alert categories

Overall, alert categories were rated similarly to one another (Table 2.) Heuristics pertaining to *visibility* and *color* were generally met. The primary opportunities for improvement were found for heuristics related to five human factors principles (Table 3; *prioritization*; *text-based information*; *alarm philosophy*; *proximity of task components being displayed*; *corrective actions*) resulting in recommendations applicable to all, or most, MTM alert categories. One *placement* heuristic (Table 3) was noted as an improvement opportunity for many alert categories. Some heuristics related to *placement* and *corrective actions* could not be consistently assessed from MTM alert screenshots and, therefore, potential areas for improvement could not be fully elucidated.

Table 2. Modified I-MeDeSA scores by alert category.

Score by Alert Category[a] Mean ± SD; (Total N = 24)					
Indication (n=5)[b]	**Effectiveness (n=5)**	**Safety (n=6)**	**Adherence (n=6)**	**Cost (n=2)**	**Overall (N=24)**
36.2 ± 4.8	35.7 ± 5.4	37.2 ± 6.4	39.3 ± 6.6	37.8 ± 5.3	37.3 ± 5.9

[a] Possible range of scores from 0-64 with higher scores indicating greater alignment with human factors heuristics, as rated by analysts.
[b]each "n" refers to the number of alerts evaluated per category. Screenshots of each alert were independently rated by each of the four analysts.

Table 3. Summary of main findings for each of the eight overarching human factors principles assessed by modified I-MeDeSA[21,31-32]

Human Factors Principle (number of associated heuristics on modified I-MeDeSA)	Main Findings [a]
Principles generally met	
Visibility (3)	Across alert categories, all visibility heuristics (3i,3ii,3iii) were consistently assessed affirmatively (i.e., alerts were rated as distinguishable from the background, having appropriate color contrast, and font.)
Color (4)	All heuristics (5i-5iv), except the use of color coding (5i) to indicate specific MTP categories (e.g., minimal use of colors with clear meanings for each color), were consistently assessed affirmatively.
Principles with Improvement opportunities and/or unable to be assessed	
Alarm philosophy (1)	MTM vendor platforms did not appear to consistently have a catalog of MTPs indicating associated alerts' priority level and expected consequences if not followed (1i.)
Prioritization (5)	Across alert categories, colors, shapes, icons, and signal words were sometimes used, but these did not clearly indicate priority (4i-4iv.) For most alert categories, color, when used, was not a redundant cue (4ii.) For patients with multiple alerts, the order of alerts was found to not clearly indicate priority (4v.)
Text-based information (10)	Heuristics pertaining to the inclusion of text to explain why the alert was shown (6ii) and the appropriateness of language for the end user (6vii) were consistently rated affirmatively. Across all alert categories, however, signal words, if used, were rated as insufficient for indicating priority (6ia.) The need for a clear consequence statement (6iv) and minimization of text (6v) were noted as enhancement opportunities for most alert categories.
Proximity of task components being displayed (1)	For most alert categories, alerts did not consistently include the information needed to support decision-making within or in close proximity to the alert. (7i)
Corrective actions (4)	Alerts did not consistently include "intelligent" corrective actions (8ia.) Alert examples could not be consistently assessed on whether the systems monitored and alerted the user to follow through with corrective actions (8ii.) For most alert categories, improvements would be needed to help prevent usability-related errors (8iii.)
Placement (4)	For many alert categories, the layout of the alert was rated as insufficient for facilitating quick information uptake by the user (2iv.) For most alert categories, alert examples could not be consistently assessed on whether the alerts appeared at appropriate times (2iii.)

[a]Roman numerals refer to specific heuristics on the modified I-MeDeSA (Additional file 1)

Findings for specific alert categories

Medication Adherence
Adherence alerts were assessed the most favorably overall on the modified I-MeDeSA (Table 2) and adherence was the only alert category where five specific heuristics (Table 3; Additional file 1) were favorably assessed; these pertained to the following: color as a redundant cue for alert *prioritization*, *proximity of information components* on the alert, *placement*, where an alert is linked with the medication of concern by appropriate timing, minimizing *text-based information*, and *corrective actions* to prevent usability-related errors. No improvement opportunities unique to adherence alerts were identified.

Medication Indication and Safety
Analysts' assessments of heuristics for alerts targeting medication 1) indication and 2) safety followed the same pattern as each other, and that of alerts overall, with two exceptions. First, for indication alerts, our finding suggests that the *text-based information* provided in existing designs may place unnecessary memory load on the end-user. Specifically, existing designs require pharmacists to memorize information from other parts of the MTM vendor platform to respond to the alerts. For example, when alerts advised the pharmacist to recommend the addition of a new medication, the pharmacist would need to navigate to another screen to review pertinent information such as other medications and diagnoses in order to decide whether the recommendation was appropriate. Second, also with regards to *text-based information*, safety alerts were rated more favorably than other alerts with regards to having a clear consequence statement. Indication and safety alerts also scored the most favorably on the heuristic pertaining to *placement* of information to facilitate quick uptake.

Medication Effectiveness and Cost
Analysts' assessment of heuristics for alerts targeting 1) effectiveness and 2) cost MTPs followed the same pattern as each other, and that of alerts overall, with no improvement opportunities unique to either category.

Aim 2—End-User Perspectives[2]

Participants
A total of 10 pharmacists were successfully recruited and consented to participate, representing 8 community pharmacies. Of these, 9 pharmacists submitted demographic and MTM alert data in REDCap, 5 participated in usability testing, and 8 completed a semi-structured interview. All participating pharmacists were non-Hispanic Caucasians holding a PharmD, and 66% were female. About half (4, 44.4%) reported completion of a post-graduate year one residency program; 8 (88.9%) had completed at least one certificate program. Six participants practiced in an independent community pharmacy and 3 practiced in a chain pharmacy (4 or more locations.) They reported a mean (SD) of 4.2 (3.4) years of experience providing CMRs for patients and completing 8.2 (7.4) CMRs per month. For all results below reporting a mean, data are reported as mean (SD).

MTM Alert Data
Pharmacists submitted data for a total of 77 MTM alerts generated by 2 MTM vendors' software platforms, representing 28 patients eligible for a CMR. On average, each pharmacist submitted 2.8 (1.4) MTM alerts to the study team per patient. Patients for whom alert data were submitted were 67 (17.7) years old on average with varying types of MTM payers: 17 (60.7%) Medicare Part D, 8 (28.6%) Medicaid, and 3 (10.7%) commercial insurance. Pharmacists indicated that most (89.3%) patients were receiving their first CMR. Pharmacists reported that 69 alerts

(89.6%) appeared at the ideal time in their MTM workflow. SUS scores across all pharmacists' and MTM vendors was 70.8 (9.8) out of a maximum possible score of 100. According to Bangor et al., this result indicates an overall "OK to good" assessment[42] by the pharmacists regarding their satisfaction with the usability of the MTM vendor systems.

Of the 77 submitted alerts, 69 could be categorized using the Cipolle framework,[22] resulting in the following categorizations: 24 (35%) targeted indication-related MTPs; 5 (7%) targeting effectiveness-related MTPs; 20 (29%) targeting safety-related MTPs; and 20 (29%) targeting adherence-related MTPs. Specific alerts targeting indication-related MTPs included 13 related to "unnecessary medication therapy" and 11 related to "needs additional medication therapy." Alerts targeting effectiveness-related MTPs were categorized specifically as "needs different drug product" (4 alerts) and "dose too low" (1 alert). Specific alerts targeting safety-related MTPs included 19 related to "adverse drug reaction" and 1 related to "dose too high." Finally, 20 alerts were categorized as targeting "non-adherence" as an MTP. The other 8 alerts submitted were categorized as targeting cost MTPs/disease state management (n=6) or did not include sufficient information for categorization (n=2).

About half (49.3%) of alerts resulted in the pharmacist identifying a MTP that the alert warned about. Pharmacists documented 3.2 (2.7) total MTPs per patient, with 1.7 (1.1) MTPs identified with the assistance of an MTM alert and 1.6 (2.1) MTPs identified without an alert. MTPs identified and actions taken are summarized in Table 1. All of the alerts warning about *effectiveness*-related MTPs resulted in the identification of an MTP, but this was not always an effectiveness MTP. Alerts warning about *adherence*-related MTPs was the only alert category without any incongruent MTPs (i.e., an MTP different than that warned about by the alert) identified. Most (51.7%) of the false alarm alerts were medication *indication*-related. A total of 46 MTPs were identified by pharmacists without an alert. Most (58.6%) of these MTPs related to a need for patient immunizations or problems with patients' medication adherence. With regards to actions taken for MTPs identified, similar patterns for actions were observed for MTPs identified both with or without an MTM alert. Overall, on average, MTPs resulted in more actions taken with patients than with prescribers.

Table 1. Summary of medication therapy problems (MTPs) Identified (total N=86)

MTP Variable[a]	**Result**
MTPs congruent with alert warning (n=34), n(%)	
Unnecessary medication therapy	2
Needs additional medication therapy	6
Needs different medication product	1
Dose too low	0
Adverse drug reaction	10
Dose too high	0
Non-adherence	15
MTPs different from alert warning (n=6)	
Unnecessary medication therapy	0 (0)
Needs additional medication therapy	2 (33.3)
Needs different medication product	2 (33.3)
Dose too low	1 (16.7)
Adverse drug reaction	0 (0)
Dose too high	1 (16.7)
Non-adherence	0 (0)

MTP Variable[a]	Result
Alert categories with no MTPs (false alarms) (n=29)[b], n (%)	
Unnecessary medication therapy	11 (37.9)
Needs additional medication therapy	4 (13.8)
Needs different medication product	0 (0)
Dose too low	0 (0)
Adverse drug reaction	10 (34.5)
Dose too high	0 (0)
Non-adherence	4 (13.8)
MTPs identified without an MTM alert (n=46), n (%)	
Unnecessary medication therapy	4 (8.7)
Needs additional medication therapy	16 (34.8)
Needs different medication product	3 (6.5)
Dose too low	4 (8.7)
Adverse drug reaction	2 (4.3)
Dose too high	4 (8.7)
Non-adherence	13 (28.3)
Mean ±SD actions taken with patients per MTPs identified with (without) alerts	
Unnecessary medication therapy	1.5 ± 1.9 (1.8 ± 1.0)
Needs additional medication therapy	1.3 ± 0.8 (2.6 ± 2.0)
Needs different medication product	0.5 ± 0.6 (0.7 ± 0.6)
Dose too low	0 (2.3 ± 1.3)
Adverse drug reaction	1.9 ± 0.7 (0)
Dose too high	0 (1.5 ± 0.6)
Non-adherence	2.1 ± 0.8 (1.4 ± 1.5)
Mean ±SD actions taken with prescribers per MTPs identified with (without) alerts	
Unnecessary medication therapy	0.8 ± 0.5 (0.8 ± 0.5)
Needs additional medication therapy	0.9 ± 0.4 (0.6 ± 0.6)
Needs different medication product	0 (1.3 ± 0.6)
Dose too low	0 (1.3 ± 0.5)
Adverse drug reaction	1.0 ± 0.6 (0.5 ± 0.7)
Dose too high	0 (1.3 ± 0.5)
Non-adherence	0.3 ± 0.4 (1.1 ± 0.6)

[a]Indication-related MTPs include: unnecessary medication therapy and needs additional medication therapy; Effectiveness-related MTPs include: needs different medication product and dose too low; Safety-related MTPs include: adverse drug reaction and dose too high; Adherence-related MTPs include: non-adherence

[b]number refers to the number of alerts submitted rather than MTPs identified

Naturalistic usability testing

After excluding usability sessions where no MTM alerts were generated for the CMR being completed, a total of 7 usability testing sessions, each lasting approximately 34 minutes on average, were completed with three pharmacists. Each pharmacist participated in 2 to 3 usability sessions. Two use cases for MTM alerts were observed: 1) pharmacists preparing for the patient's medication therapy review and 2) after the medication therapy review, when pharmacists were documenting/billing the CMR. Across the 7 sessions, a total of 13 MTM alerts were encountered by pharmacists with a median (range) of 2 (1-4) MTM alerts encountered per session. Six (46.1%) alerts were resolved by the pharmacist by the end of the session. The

remaining MTM alerts were either not addressed by the pharmacists or were unable to be fully resolved for various reasons. Pharmacists spent a median of 2 minutes and 22 seconds per alert.

A total of 39 negative usability incidents were identified. The most common incidents pertained to challenges associated with workflow (11 incidents across 6 sessions and 3 pharmacists), alert display (8 incidents across 4 sessions and 3 pharmacists), and alert system reliability (faulty guidance; 6 incidents across 5 sessions and 2 pharmacists.) With regards to workflow, challenges were noted wherein the alert did not support the pharmacists' preferred MTM workflow (e.g., the alert required clinical resolution on a screen different from which the pharmacist would have chosen to use.) During one session, a pharmacist stated, "I would like to…look at it [alert information] more closely, but it's not letting me do it from here." Display problems included challenges with drop-down menu options not matching the clinical circumstances of the CMR. As one pharmacist stated, "None of these [drop-down options on the MTM alert] is really appropriate." Challenges with alert system reliability were observed when the guidance provided by alerts was perceived by pharmacists as not aligned with actual patient care needs. For example, during one session a pharmacist stated, "I know she [the patient] has already tried both of the [MTM alert's] recommended medications, and they have not worked for her."

Semi-structured interviews with pharmacists and triangulation across data sources
Pharmacist interviews each lasted approximately 30-60 minutes and provided rich end-user insights into MTM alert usability and usefulness. Main themes and representative quotations from interviews, and triangulation of findings across data sources, are summarized in Table 2 [data not shown; see manuscript]. Collectively, these triangulated findings revealed two overarching key challenges pertaining to MTM alert usability and four key challenges with MTM alert usefulness, informing a total of 15 actionable recommendations (Table 3) [see below] for improving the design of MTM alerts from a user-centered perspective.

Key Discussion Points[1,2]

- Both study Aims were achieved with recommendations identified in both the heuristic evaluation (Aim 1) and through triangulation of data from an end-user perspective (Aim 2)
- In Aim 1, across all alert categories, 4 recommendations were identified; 4 additional recommendations were identified for all alert categories except adherence (which were stronger overall); 3 final recommendations were made for specific alert categories
- For some heuristics, our Aim 1 findings align with Phansalkar et al.'s results for EHR drug-drug interaction alerts.[32] For example, *visibility* heuristics were rated favorably in both. In addition, both ours and Phansalkar's evaluations found improvement opportunities for *alarm philosophy* and *prioritization* heuristics.[32] In contrast, whereas *proximity of task components* was assessed favorably for EHR drug-drug interaction alerts,[32] we found improvement opportunities for this heuristic for most categories of MTM alerts. Moreover, while the *placement* of information was assessed favorably for EHR alerts,[32] we found improvement opportunities for some alert categories with regards to the alert layout needing to better facilitate quick uptake of information.
- In Aim 2, 15 recommendations were identified; many of which align with results from Marcilly et al.'s 2015 review of usability "flaws" associated with medication-related alerts used in hospitals and primary care[43]

Key Limitations[1,2]

- Static nature of screenshots prevented complete assessment of some heuristics

- Cost alerts and usability testing represented only 1 vendor system
- Limited sample of MTM alerts included in each Aim

References/List of Publications and Products (since last report):

1. Most text taken verbatim from published paper resulting from this work. Please see paper for list of specific citations: Snyder ME, et al. Alerts for community pharmacist-provided medication therapy management: recommendations from a heuristic evaluation. *BMC Med Inform Decis Mak*. 2019 Jul 16;19(1):135. doi: 10.1186/s12911-019-0866-0.
2. Most text taken verbatim from paper (in review) resulting from this work. Please see paper for list of specific citations: Snyder ME, et al. A User-Centered Evaluation of Medication Therapy Management Alerts for Community Pharmacists: Recommendations to Improve Usability and Usefulness. Under review at *Research in Social and Administrative Pharmacy.*
3. Modified I-MeDeSA (see below)

Additional File 1. Modified I-MeDeSA[a,b]

Alarm philosophy

1i *[**Vendor**] Does the system provide a general catalog of medication-related problems, correlating the priority level of the alert with the severity of the consequences?*

Placement

2i *[**Vendor**] Are different types of alerts meaningfully grouped? (i.e., by the severity of the alert, where all level 1 alerts are placed together, or by medication, where alerts related to a specific medication are grouped together)*

2ii Is the response to the alert (e.g., way to document actions taken to resolve problem) provided along with the alert, as opposed to being located in a different window or in a different area on the screen (e.g., external to the alert)?

2iii Is the alert linked with the medication by appropriate timing? (i.e., a drug-drug interaction alert appears as soon as a drug is chosen/entered and does not wait for the user to complete data entry and then alert him/her about a possible interaction)

2iv Does the layout of critical information contained within the alert facilitate quick uptake by the user? Critical information (see Text Based information below) should be placed on the first line of the alert or closest to the left side of the alert box. The most important information should appear in larger font and/or at the top of the alert.

Visibility

3i Is the area where the alert is located distinguishable from the rest of the screen? This might be achieved through the use of a different background color, a border color, highlighting, bold characters, occupying the majority of the screen, etc.

3ii Is the background contrast sufficient to allow the user to easily read the alert message? (i.e., dark text on a light background is easier to read than light text on a dark background)

3iii Is the font used to display the textual message appropriate for the user to read the alert easily? (i.e., a mixture of upper and lower case lettering is easier to read than upper case only)

Prioritization

4i *[**Vendor**] Is the prioritization of alerts indicated appropriately by color? (i.e., colors such as red and orange imply a high priority compared to colors such as green, blue, and white.*

4ii If color is used, is it used as a redundant cue? Due to color blindness, color should NOT be the only indicator of alert priority.)

4iii *[**Vendor**] Are signal words consistently and appropriately assigned to each existing level of alert to indicate clinical priority? (e.g., 'note,' 'warning,' or 'danger', 'high risk' or other terms) [A signal word is 1-3 words or so to capture attention]*

4iv Does the alert utilize shapes or icons in order to indicate the priority of the alert? (i.e., angular and unstable shapes such as inverted triangles indicate higher levels of priority than regular shapes such as circles)

4v *[**Vendor**] In the case of multiple alerts for the same patient, are the alerts placed on the screen in the order of their importance? The highest priority alerts should be visible to the user without having to scroll through the window.*

Color

5i *[**Vendor**] Does the alert utilize color-coding to indicate the type of medication-related problem? (i.e., drug–drug interaction vs. allergy alert vs. possible medication non-adherence)*

5ii Is color minimally used to focus the attention of the user? As excessive coloring used on the screen can create noise and distract the user, there should be less than 4 colors used in a given alert.

5iii ***[Vendor]*** *There should be no more than 7 colors total used by the vendor for alerts.*[b]

5iv Is the meaning of each color adequately conveyed?[b]

Text-based information: Does the alert possess the following information components?

6i A signal word is present on the alert (e.g., 'note,' 'warning,' or 'danger', 'high risk' or other terms) [1 to 3 words to capture attention]

6ia If yes, does the signal word or text shown near/with signal word indicate clinical priority?[b]

6ii A statement of the nature of the medication-related problem describing why the alert is shown. This may be a generic statement in which, for example, interacting classes are listed, or an explicit explanation in which specific drug-drug interactions are clearly indicated.

6iia If yes, are the specific medication-related problem(s) (e.g., interacting drugs, possible medication non-adherence) explicitly indicated to explain why the alert is appearing?

6iii An instruction statement (telling the user about the desired action or how to avoid the undesired clinical/patient outcome.)

6iiia If yes, does the order of recommended tasks reflect the order of required actions?

6iv A consequence statement telling the user what might happen if the alert is ignored; (medical or patient care consequences, for example, the allergic reaction that may occur if the instruction information is ignored.)

6v Does the alert minimize the use of text? (e.g., short statements rather than long complex statements or complete sentences)

6vi. Does the alert minimize the memory load of the end-user? (Users should not have to memorize a lot of information from other parts of the system in order to respond to the alert. e.g., an alert for medication non-adherence should present prescription fill data, etc.)[b]

6vii. Is all of the language in the alert likely to be understandable to the intended end-users (pharmacists)? (e.g., avoids use of abbreviations, unfamiliar technical terms)[b]

Proximity of task components being displayed

7i Are the informational components needed for decision making on the alert present either within or in close spatial and temporal proximity to the alert? For example, is the user able to access relevant information directly from the alert, that is, a drug monograph, an 'infobutton,' or a link to a medical reference website providing additional information?

Corrective actions

8i	Does the system allow corrective actions that also serve as an acknowledgement of having seen the alert? (A corrective action is an intervention or response that the alert is not relevant.)
8ia	If yes, does the alert utilize intelligent corrective actions that allow the user to complete a task? For example, if warfarin and ketoconazole are co-prescribed, the alert may ask the user to 'Recommend warfarin dose be reduced by 33–50% and follow the patient closely.' An intelligent corrective action would be 'Monitor patient AND recommend warfarin dose be reduced by 33–50%.' Selecting this option would simultaneously over-ride the alert AND direct the user back to a screen where the user can prepare prescriber recommendations.
8ii	*[**Vendor**] Is the system able to monitor and alert the user to follow through with corrective actions? Referring to the previous example, if the user tells the system that he/she will recommend a reduced warfarin dose but fails to follow through on that promise, does the system alert the user?*
8iii	Does the alert design help prevent usability-related errors? (e.g., extra clicks, easy to enter wrong information; sources of confusion; too much scrolling, inappropriate use of 'check all' vs. 'check one'; inappropriate use of defaults. etc.)[b]

a: Heuristics in italics are at the vendor level
b: Heuristic was added by research team

Additional Aim 2 Results Table

Table 3. Summary of Key Challenges with MTM Alert Usability and Usefulness Identified Through Triangulation and Actionable Recommendations for Improving MTM Alert Design

Key Challenges with MTM Alerts[a]	Actionable Recommendations for MTM Vendor Systems
Usability Challenges	
1. Alert display does not always support pharmacists' preferred MTM workflow and sometimes requires redundant data entry.	1. Ensure MTM alerts are generated at times which support different use cases (e.g., for pharmacists first accessing the MTM vendor systems after the CMR is complete, because they primarily document services in another system) 2. Enable flexibility in how (e.g., from which screens) pharmacists can access alert information and initiate documentation 3. Remove duplicative data entry fields (e.g., the need to re-type "educated patient" in response to an alert) 4. Improve, reduce, and/or remove drop-down menus/options to better align data entry options with the full range of clinical contexts encountered during a CMR (e.g., a pharmacist's inability to provide medication synchronization for a patient who receives medications at another pharmacy.)
2. A lack of system integration between MTM vendors and other pharmacy systems interrupts pharmacist workflow	5. MTM systems should fully integrate with pharmacy dispensing systems and electronic medical records
Usefulness Challenges	
1. Redundant alerts are pervasive and reduce pharmacist efficiency	6. Enable systems to recognize pharmacists' prior actions taken on alerts and generate/suppress alerts accordingly 7. Ensure that MTM alerts are unique from alerts generated for the same patients during prescription fulfillment/drug utilization review

Key Challenges with MTM Alerts[a]	Actionable Recommendations for MTM Vendor Systems
Usefulness Challenges	
2. MTM alerts often falsely identify MTPs, many MTPs are identified without alerts, and usefulness of alerts varied with pharmacist experience	8. Examine alert sensitivity and specificity and make adjustments (e.g., re-word or remove alerts) accordingly to minimize false positives and negatives. 9. Consider the development of new MTM alerts, particularly for immunizations and a re-design of existing alerts (i.e., those targeting non-adherence) to improve alert usefulness 10. Except for safety alerts, enable users to suppress MTM alerts, by alert type, user group (e.g., a newly hired pharmacist vs. experienced pharmacist), and prevalence of MTP documentation without alerts (e.g., "turn on" alerts for MTPs currently found without alerts to support consistent and comprehensive MTP detection across users.) 11. Update alert logic to ensure alignment with contemporary clinical practices (e.g. remove alerts that warn about the use of multiple medications for hypertension)
3. Alerts are perceived as more highly influenced by payer goals, rather than patients' clinical and safety needs	12. Form advisory groups of patients, pharmacists, and prescribers to facilitate participatory design of MTM alerts that are informed by MTM stakeholders 13. For alerts targeting MTPs with lower clinical priority (i.e., not likely to pose an imminent safety concern), enable users to select which alerts are generated or suppressed for their patient population
4. MTM alerts contain too little patient-specific information, positioning pharmacists to rely on patients for information which can be problematic	14. Re-design MTM alerts to provide pharmacists with more patient-specific information to inform decision-making, such as recent laboratory data 15. Policies should be developed by CMS and other payers that incentivize and reward models for MTM delivery which utilize meaningful health information exchange for CMR completion with bidirectional data exchange between prescription dispensing systems, MTM vendor software systems, and electronic medical records

[a:]Identified through triangulation of all three data sources (MTM alert submission, semi-structured interviews, usability testing)