External tools for collaborative medication scheduling

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Abstract Medication adherence—taking medication as prescribed—is critical for successful self-care, especially among older adults. Adherence depends on developing and implementing plans for taking medications. Age-related cognitive declines that affect adherence may be mitigated using external tools that support patient-provider collaboration needed to develop these adherence plans. We tested the effectiveness of structured collaborative medication tools to support better medication planning and adherence practices. Evidence for benefits of collaborative tools has been mixed in terms of their usefulness for medication-scheduling tasks, perhaps because the tools have not been explicitly designed to support patient-provider collaboration. A total of 144 community-dwelling older adults participated in pairs and performed the role of a patient or provider in a simulated patient-provider medication-scheduling task. Each pair worked with a structured (MedTable™ and e-MedTable) or unstructured (Medcard) scheduling tool and completed four problems (2 simple and 2 complex). Performance was measured using the following: problem-solving (medication schedule) accuracy, problem-solving time, solution (schedule) optimality, tool usability, collaborative effectiveness, and subjective workload involved in creating the medication schedules. Participants using structured tools produced more accurate and optimal schedules. They also rated subjective workload as lower and thought that the structured tools were easier to use, reduced subjective workload associated with creating the schedules. There was also suggestive evidence that participants using the structured tools rated more highly the quality of their collaboration. Structured medication-scheduling tools have the potential to improve medication adherence among older adults because they support collaborative planning and reduce the cognitive load involved in creating these adherence plans.

Keywords Medication adherence · Patient-provider communication · Problem solving · Older adults

1 Introduction

Medication non-adherence, or the failure to follow medication regimens as prescribed (Osterberg and Blaschke 2005), is a significant self-care issue for older adults who take more medications than any other age cohort in the United States (Mitchell et al. 2007). Non-adherence often
arises from inadequate knowledge about the medications as well as poor planning on how to take them (Wolf et al. 2011). Non-adherence can also be traced, in part, to age-related declines in patients’ cognitive and perceptual-motor capacities (Park 2000) and to inadequate communication between patients and their care providers (Apsden et al. 2007).

Creating and implementing adherence plans requires cognitive effort. To create an effective plan, it is important for older adults to identify and integrate diverse information such as medication-taking times, constraints regarding the medicines (e.g., drug–drug interactions), and other personal or work-related constraints. Such activities require working memory and other cognitive resources (Park and Jones 1997). Implementing these plans also involves self-initiated active monitoring and other prospective memory processes that tend to decline with age (d’Ydewalle et al. 1999; Einstein and McDaniel 1990).

In light of the above, effective collaboration between patients and their healthcare providers should have the potential to improve older adults’ medication knowledge and planning. Unfortunately, there is increasing evidence that patient-provider collaboration is inadequate. Key information is often not presented, and patient comprehension of what is presented is not checked, resulting in patients not knowing up to 40% of the information they need to safely take their medications (e.g., duration of intake, frequency/timing, number of pills, possible adverse events (Tarn et al. 2006). This results in providers and patients not agreeing on how medications should be taken, consequently, undermining adherence (Machtlinger et al. 2007). To sum up, there is a recognized need for structured collaborative review of patients’ medications in order to support better medication knowledge and adherence (Apsden et al. 2007; Tarn et al. 2006).

2 External tools for patient-provider collaboration

External tools support several collaborative functions in distributed environments (Hutchins 1995; Klein et al. 2003) such as lowering cognitive demands, supporting easier indexing and information retrieval (Larkin and Simon 1987), off-loading task relevant information to an external resource (Zhang and Norman 1994), and acting as memory aids for cognition (Hutchins 1995). Additionally, external tools also provide a visual space that helps to anchor conversations, in part by supporting processes involved in establishing common ground (i.e., shared knowledge between conversational partners) (Clark and Brennan 1991).

Specific to patient-provider collaboration, external tools are likely to improve adherence behavior among older adults by facilitating two important cognitive support functions: first, they provide a medium for collaborative interaction, reducing the cognitive effort for developing comprehensive, efficient, and accurate plans for taking multiple medications (including development of optimal schedules). For example, a medication schedule tool can explicitly represent constraints for optimal schedules that the provider and patient can easily visualize. Second, they encourage older adults to take an active role in developing a medication plan, which may support their prospective memory (Park et al. 1992).

Prior research provides mixed results on the use of medication-scheduling tools by providers or patients. Several tools have been developed to support low-literacy patients’ management of complex medication regimens and to improve adherence. However, these tools have not been evaluated as collaborative tools (Kripalani et al. 2007), have shown limited effectiveness in improving adherence (Cordasco et al. 2009), or were developed to support adherence to individual medications but not complete regimens (Machtlinger et al. 2007).

Morrow et al. (2008) developed a paper-based medication-scheduling tool, MedTable™. Its design is based on the following key ideas: (a) support for collaboration between patient and provider in the form of a visual representation that encourages the sharing of information about medications (e.g., when to take a medication, possible drug–drug interactions) and the patient’s daily routine (e.g., work schedule, constraints on medication taking), and (b) a medium for externalizing the task, which reduces the cognitive load involved in integrating medication and the patient’s routine information into an adherence plan. Multimedia representation (pictures, explanatory text) of the plan may be especially appropriate for patients with lower literacy (Doak et al. 1996). Moreover, the MedTable™ also helps in monitoring and evaluating patient comprehension, as the provider is actively involved in the medication schedule creation process.

Using a simulated patient-provider collaborative planning task, Morrow et al. (2008) found evidence that, compared with an unstructured aid, the MedTable™ reduced the cognitive effort involved in creating adherence plans, potentially leading to better medication adherence. In the present paper, we further investigate the effect of structured tools on collaborative medication scheduling by comparing two structured tools, the paper-based MedTable™ (Morrow et al. 2008) and its electronic counterpart (e-MedTable), to a less structured tool similar to the pill cards used in many clinics (Medcard).

We compared paper-based and electronic versions of the MedTable™ because collaborative tools may be most effective and most likely to be adopted by clinicians, if they are computer-based and leverage information technology capabilities in health clinics (Paasche-OrlOWN et al. 2006). With the current federal incentives on the
computerization of health services, new health IT systems have to be developed and supported. Accordingly, we developed an electronic replica of the MedTable™ (e-Med Table), preserving its key functionalities, layout, and structure. Interaction with the e-MedTable requires selecting from menu items and using check boxes on an interface (e.g., to select and schedule medications). Visual components in the e-MedTable were designed at a scale large enough to address age-related perceptual and motor limitations (e.g., buttons, better spacing between elements, and feedback.).

Both structured tools were compared with a less structured medication card (Medcard) that is used in many healthcare practices to support medication reconciliation (keeping patients’ medication lists current and complete (Apsden et al. 2007). Unlike the MedTable™, Medcard does not support the process of developing an integrated medication schedule (e.g., it does not explicitly represent medication and patient routine constraints) and is not designed to support collaborative planning. Screenshots of the three tools are provided in Figs. 1, 2 and 3.

We investigated the effect of these tools on medication-scheduling performance in simulated medication-scheduling tasks designed to emulate routine encounters between a patient and provider during a clinic visit (Morrow et al. 2008). We also considered two levels of medication-scheduling problem complexity (Problem Complexity): simple and complex. Problem complexity was defined in terms of the constraints that were imposed on medication taking. Complex problems had more constraints associated with medications and patient routine, resulting in fewer feasible solutions that met all the constraints. Complex problems require more cognitive effort to search the problem space for reaching a feasible solution than simple medication problems (Newell and Simon 1972).

While we did not investigate whether structured tools improve medication adherence, there is reason to believe they may do so to the extent that they help patients and providers create and implement more accurate and optimal adherence plans because measures of patient-provider agreement about the goals of adherence have been found to predict adherence (Machttinger et al. 2007). Based on the Tool type (structured and unstructured) and Problem Complexity (simple and complex) levels, we evaluated the following hypotheses:

H1a The two structured tools would lead to quicker, more accurate, and more optimal (simpler) medication schedules than the less structured tool.

H1b The structured tools would support the collaborative processes leading to better schedules: Participants will perceive structured tools as easier to use, able to support collaboration, and having lower workload associated with creating the schedule.

H2a Problem-solving performance will be better (faster and more accurate) for simpler medication problems (with fewer constraints to meet)

H2b The benefits of structured tools would be greater for the more complex problems, which impose more demands on cognitive processes that can be offloaded to the tools (i.e., tool × complexity interaction)

While the e-MedTable was designed to be simple and easy to use, older adults may find it more difficult to use...
than the paper MedTable™ because of age-related perceptual-motor and cognitive limitations (Mead et al. 2002). Hence, we also investigated the following secondary hypothesis: among the well-structured tools, the paper-based MedTable™ would support better medication-scheduling performance (accuracy, optimality, and time taken to complete tasks) than its electronic version, the e-MedTable.

3 Method

3.1 Participants

One hundred and forty-four (144) community-dwelling older adults (60 years and older) participated in this study (age: $M = 71, SD = 7.3$; 64% females). Participants were paired randomly and assigned the role of a patient or provider and then assigned to one of the three tool conditions (Medcard, Medtable, and e-Medtable), totaling 24 pairs per tool condition. Participants were screened to ensure that they were native speakers of English, had no obvious physical or cognitive impairments that could restrict their participation (e.g., stroke in the last 3 years), and use a computer at least weekly. Medical professionals were excluded from the study. Participants in each pair were unfamiliar with one another and were not familiar with any of the medication-scheduling tools. Participants were paid for their time.

3.2 Experimental design

We used a mixed ANOVA design, with medication-scheduling Tool (MedTable™, e-Medtable, and Medcard) as a between-groups variable and level of Problem Complexity (simple and complex) as a repeated measure. Each pair of participants collaborated to complete four medication-scheduling problems (2 simple and 2 complex), with trials blocked by problem complexity. The presentation order of blocks (and order of problems within each block) was counterbalanced across participant pairs in each group.

3.3 Materials

We considered two types of medication problems: simple and complex. All medication problems consisted of four medications presented with name, purpose, size of dose, frequency, and special instructions (e.g., take at meals), and...
also a specific, fixed patient routine. The problems were adapted from First Data Bank and Cerner Multum, via rxlist.com. The patient routine contained details of their mealtimes, wake up, bedtime, and work schedule including breaks. The work schedule information was not documented on any of the tools. A patient’s day consisted of 16 h (from wake up to bedtime), but the times of key events varied for each problem. Detailed descriptions of the four medication problems are provided in Appendix in supplementary material.

3.4 Measures

We describe the individual and the task-based measures that were used for the analysis of data collected during the various medication-scheduling tasks.

3.4.1 Individual measures

In addition to the basic demographic survey, the participants also completed the Advanced Vocabulary test and the Letter and Pattern Comparison tests. Verbal ability was measured by the Advanced Vocabulary test from the Kit of Factor-Referenced cognitive tests, an 8-minute test with 36 multiple choice items (Ekstrom et al. 1976). This test was included to check whether the experimental groups varied on verbal ability, because verbal ability has been shown to relate to problem-solving performance. The participants also completed the Letter and Pattern Comparison tests (Salthouse 1991), which were used as a measure for the speed of processing. The speed of processing measure is frequently used as an index fluid mental ability, which declines with age. This measure has also been shown to predict performance on the medication schedule task (Morrow et al. 2008). Like the vocabulary measure, it was included to check whether the groups in the study were equivalent in terms of abilities relevant to the problem-solving task.

A summary of the demographic and cognitive test scores (verbal, letter, and Pattern Comparison tests) for the participants in the three tool conditions is given in Table 1. The three groups did not significantly differ in age, education, health, or vocabulary scores. However, the speed of processing was significantly higher (i.e., slower processing; \( p < 0.05 \)) for the group that used the e-MedTable than the other two groups.

3.4.2 Medication-scheduling task measures

We considered four medication-scheduling task-based measures based on the hypotheses that were presented: (a) medication problem-solving performance, (b) collaborative processes during problem solving, (c) tool usability, and (d) subjective workload during medication problem solving.

3.4.2.1 Medication problem-solving performance

Problem-solving performance was measured using solution accuracy, solution time, and solution optimality.

We developed a solution accuracy measure for each problem using the proportion of the problem constraints met by the solution. These constraints included correct number of doses, appropriate medication-taking times, patient routine restrictions (e.g., night-shift at work), and medication co-occurrence restrictions (18 points for simple; 22 or 24 for the complex). Two graders independently scored 6 different pairs (24 scheduling problems) with 99% inter-grader agreement. Solution time was measured from when the problem was given to the pair to when the pair indicated that they had completed their schedule or until the 15-min limit was reached.

Solution Optimality was measured using two parameters: (a) dosage spacing, the spacing between doses when a medication had to be taken multiple times in a day (e.g., 8 h between medicines), where more equal intervals between doses is considered more optimal and (b) number of medication-taking times during a day, where fewer instances were more optimal (provided other constraints were not violated). There is some evidence that without guidance, older adults tend to create overly complex medication schedules [i.e., medication times were not consolidated to fewest possible; (Wolf et al. 2011)]. An optimal schedule solution was created for each problem, considering all the problem constraints and the two optimality measures (i.e., dosage spacing, number of medication-taking times).

In order to develop an Optimal Score, the research team created an optimal solution for each problem. The optimal solution met all of the problem constraints and focused on meeting the two optimal factors as best as possible. For example, for one of our medication problems, the participants were given the following instruction: “Take 3 pills of Amelorine twice a day with a meal.” The optimal dosage spacing for Amelorine would be to put dose 1 (D1) with breakfast and dose 2 (D2) with dinner. Therefore, the optimal dose spacing for that problem would be the number of hours between those two meals. If there were more than two doses, an optimal spacing was found for each time period between the doses (i.e., between D1 and D2, between D2 and D3, etc.). For single dosage medications, optimal spacing was not considered.

The optimal (minimal) number of medication times for a schedule was found by grouping medications as much as possible. For example, the medication problem with Amelorine also contained Stezepine to be taken three times a day with meals. An optimal solution would be to take
Amelorine and Stezapine at breakfast and dinner, and at Stepazine at lunch. Therefore, considering these two medications, the optimal number of medication times would be 3. In all of our conditions, the optimal number was either 5 or 7.

The actual number of medication-taking times was analyzed from the participants’ problem solutions and compared with the optimal number for that problem. We computed the $OptimalScore$ for dosage spacing and number of medication-taking times using the following formula:

$$OptimalScore = 1 - \left[ \frac{ActualNum - OptimalNum}{OptimalNum} \right]$$

$ActualNum$ refers to the value that was observed in the solution created by the participants (for both dosage spacing and grouping of medications). $OptimalNum$ for each problem was computed a priori based on the optimal solution for each problem. The $Optimal Score$, in effect, measures the deviation from an optimum value.

The formula equally penalized dosages that were too close or too far apart (than the optimal). Additionally, pairs who had less than the requisite number of medication-taking instances were also penalized. Solutions with incorrect dosages were removed from the analysis (13% of the problems). There were no significant trade-offs between the two factors of optimality (where one type of optimality is achieved at the expense of the other, as reflected in a significant negative correlation), Simple, $r(72) = 0.256$, $p < 0.05$; Complex, $r(69) = -0.041$, $p > 0.10$. All optimality scores were between 0 and 1 and were considered as a proportion of optimality.

### 3.4.2.2 Collaborative processes during problem solving

A partner awareness survey (Convertino et al. 2008) was used to measure perceived collaboration efficiency during problem solving. The survey used a 5-point Likert scale (completed by both participants separately) to identify the nature of three important collaborative activities: effect of shared practices, quality of collaboration, and the grounding during communication.

### 3.4.2.3 Tool usability

The system usability survey (SUS) (Brooke 1996) was used for measuring the $tool usability$ (completed only by the patient). The survey was used for measuring the ease of using the tool to create the medication schedules. We used seven (out of 10) pertinent questions from the SUS questionnaire. A composite of the seven questions was created according to Brooke’s methods (with higher scores showing higher usability).

### 3.4.2.4 Subjective workload

Both participants separately completed the NASA Task Load Index (NASA-TLX) questionnaire (Hart and Staveland 1988) for measuring the subjective workload during the medication-scheduling tasks. The index consists of six subjective scales (0–100): mental demand, physical demand, temporal demand, performance, effort, and frustration. Participants rate the degree of each factor from very low to very high. The NASA-TLX was also used in the practice problems to help the participants anchor themselves on the scale.

The tool usability and partner awareness surveys can be found in Appendix in supplementary material.

### 3.5 Procedure

After obtaining consent, participants completed a short demographic survey and the Advanced Vocabulary test. Participants were next assigned their experimental roles (provider or patient) and given general instructions about the task, and then each was given introductory information about their role. The patient was given information about their daily routine, and the provider was primed with the patient’s detailed medication list. In addition to the medication information on their assigned tools (i.e., instructions on the medication regimen), the provider was given...
additional information regarding the medications and the need for taking them (e.g., diuretics are prescribed because they help reduce the build-up of fluids associated with onset of heart failure). This information was provided to encourage the provider to take a more active role in advising their “patient.”

The participants were given 1 min to read and become familiar with their presented information. After this, the patient and provider used their assigned tool to jointly create a medication schedule. While they were not instructed on how to create the schedule, they were provided examples of “good schedule practices” such as reducing the number of times at which medications were scheduled and trying to use equally spaced intervals between doses. They completed two practice problems (1 each of simple and complex) and then completed the four experimental problems (2 simple and 2 complex). A limit of 15 min was imposed for each problem (participants ran out of time in less than 2% of the trials; 5 complex problems).

After completing each scheduling task, the patient was prompted to read-aloud their schedule. If they identified an error during the read-back, they were allowed to change their schedule and additional time was added to the task completion time. After each problem, the participants completed the NASA-TLX questionnaire. At the end of the four trials, the participants filled out the SUS and partner awareness questionnaires (SUS was completed only by the patient). After this, both participants completed the Letter and Pattern Comparison tests. All sessions were audio-taped for further analysis. In the case of e-MedTable, all on-screen actions (mouse clicks and key strokes) were also captured using Morae (http://www.techsmith.com/morae.asp).

In all three conditions, the patient was responsible for filling out the medication schedule that was jointly developed. While both participants could view the scheduling artifact as additions or changes were being made, the task of making these additions or changes was solely performed by the patient. In the case of Medcard and MedTable™, the patient filled the schedule with a pen/pencil, while the keyboard and mouse was used in the case of the e-MedTable task.

4 Results

The results will be presented in terms of the previously described hypotheses. Because we predicted tool-related differences in performance, the planned comparisons were conducted even when main effects were not significant (Keppel and Wickens 2007). For clarity, we report those results that were consistent with our hypotheses and converge with other evidence in our study (unless otherwise stated, p < 0.05 was used for all comparisons).

4.1 Effect of structured tools on problem-solving performance (H1a)

We evaluated the effect of problem-solving performance (i.e., solution accuracy, completion time, and solution optimality) using a Tool (Medcard, MedTable™, and e-MedTable) × Problem Complexity (Simple and Complex) mixed design ANOVA, with complexity as a repeated measure. Participants created very accurate schedules in all tool conditions (see Table 2). While the main effect of tool, F(2, 69) = 2.14, p > 0.10, ηp² = 0.058 was not significant, the comparisons showed that accuracy was greater in the MedTable™ (M = 0.980) than in the Medcard condition (M = 0.965) (p < 0.05).

The mean speed of processing score for each pair was used as a covariate in the Tool x Problem Complexity ANOVA for problem-solving time because the tool groups differed in speed of processing (p < 0.05), and completion time was inversely related to speed of processing (r(72) = −0.40, p < 0.01). The main effect of the tool, F(2, 68) = 0.14, p > 0.10, ηp² = 0.004 and planned comparisons was non-significant.

Solution optimality was based on two parameters: dosage spacing and number of medication-taking times. While the main effect of tool, F(2, 66) = 2.09, p = 0.131, ηp² = 0.060 was not significant, comparisons suggested that dosage spacing was more optimal for the MedTable™ (M = 0.87) than for the Medcard (M = 0.82) group, although there was only marginal significance (p = 0.052). The main effect of the tool for the number of medication-taking times was also not significant F(2, 66) = 1.77, p > 0.10, ηp² = 0.051. This pattern of the results suggested that schedules were potentially simpler (fewer medication times) when created using the MedTable™ (M = 0.95) than for the Medcard (M = 0.92), with marginal significance (p = 0.094).

An optimal schedule would be one in which medications were both evenly spaced and taken as few times per day as possible. Therefore, a secondary analysis was performed using the average of the two optimality factors, which did not trade-off with each other. Participants created more optimal schedules when using the structured tools compared with Medcard, F(2, 66) = 3.63, p < 0.05, ηp² = 0.099. The planned comparisons showed that the MedTable™ (M = 0.91) yielded significantly more optimal schedules than the Medcard (M = 0.87), (p < 0.05). The e-MedTable (M = 0.90) was numerically more optimal than the Medcard, but the difference was only marginally significant (p = 0.051).

In summary, we found that participants who used the structured medication tools created more accurate and
optimal schedules. In other words, we had partial support for H1a (accuracy and limited evidence for optimality, with no differences with respect to the completion time).

4.2 Effect of structured tools on collaboration and workload (H1b)

The ten questions for the partner awareness survey fell into a number of different analysis clusters: shared practices (Q1 and Q2), quality of collaboration (Q4 and Q5), and communication and common ground (Q8 and Q9) (classification based on (Convertino et al. 2008)). The remaining four questions were independent of these clusters and each other and were analyzed as separate items. The seven items were analyzed using a Role (Patient and Provider) x Tool (Medcard, MedTable™, and e-MedTable) ANOVA.

There were no significant tool- or role-related effects for the seven items (p’s > 0.05). However, the effect of tool had marginal significance (p = 0.07) for quality of the collaboration. Planned comparisons showed a significant difference between e-MedTable and Medcard conditions (p < 0.05). Participants who used the e-MedTable believed that they collaborated better than those who used the Medcard. The effect of the participant’s role was marginally significant (p = 0.07) for communication and common ground. Compared with providers, patients believed that they achieved better common ground than their partners (p < 0.05).

Principal component analysis (PCA) was conducted on the six NASA-TLX survey items. For both the simple and complex problems, the six items loaded on one factor that accounted for more than half the variance (simple (59.2%) and complex (58.1%)). The factor loadings were used to create a separate TLX composite for both simple and complex problems (higher values indicated higher workload). These composites were analyzed by a Tool x Role x Problem Complexity ANOVA with problem complexity as a repeated measure. The effect of tool was not significant, F(2, 138) = 3.01, p = 0.053, η² = 0.042. Planned comparisons suggested that participants created the schedules more easily when using the structured tools: subjective workload was lower for the MedTable™ (M = 93.0) and e-MedTable (M = 92.7) groups compared with the Medcard (M = 114.8) [p’s < 0.05]. The effect of role was not significant, F(1, 138) = 0.44, p > 0.10, η² = 0.000, suggesting providers and patients experienced similar levels of workload when creating the medication schedules.

A one-way ANOVA was used to test the usability differences among the tools. The SUS composite based on Brooke’s method (Brooke 1996) revealed a significant effect of tool on usability, F(2, 69) = 4.34, p = 0.017, η² = 0.112. Planned comparisons showed that the participants found the MedTable™ (M = 61.4) significantly easier to use than the Medcard (M = 52.3, p = 0.005). The same pattern occurred for the e-MedTable (M = 57.6), although the difference was only marginally significant (p = 0.09).

In summary, there was limited evidence of better participant collaboration using structured tools. Nevertheless, participants found the structured tools easier to use and experienced lesser workload (partial support for H1b).

4.3 Effect of problem complexity on medication scheduling (H2a and H2b)

We evaluated the effect of problem complexity using a Tool (Medcard, MedTable™ and e-MedTable) x Problem Complexity (Simple and Complex) ANOVA with complexity as a repeated measure. A significant effect of problem complexity showed that simple problems were scheduled more accurately than complex problems, F(1, 69) = 20.8, p < 0.001, η² = 0.231. Problem complexity did not influence solution time, F(1, 68) = 2.5, p > 0.10, η² = 0.036. The complexity x tool interaction was not significant for either solution accuracy or time.

The optimality of dosage spacing was influenced by problem complexity, with more optimal spacing for the simpler problems, F(1, 66) = 4.50, p < 0.001, η² = 0.249. Similarly, the number of medication-taking times was also influenced by problem complexity, with fewer scheduled times for the simpler problems, F(1, 66) = 18.83, p < 0.001, η² = 0.222. The analysis of the composite measure showed that schedules for complex problems were less optimal, F(1, 66) = 60.96, p < 0.001, η² = 0.480. The tool x complexity interaction was not significant.

The workload measures were analyzed by a tool x role x Problem Complexity ANOVA (see previous section on the PCA) with problem complexity as a repeated measure. The effect of complexity on workload was significant, with perceived workload higher for more complex problems, F(1, 138) = 162.3, p < 0.001, η² = 0.540.

In summary, partial support was found for H2a (simpler problems associated with more effective problem solving),...
but not for H2b, as any structured tool-related benefits were similar for solving simple and complex problems.

5 Discussion

We investigated the impact of tools on collaborative medication scheduling. Two structured tools (MedTable™ and e-MedTable) were compared with a less structured tool (Medcard), using a simulated medication-scheduling task. We found that older adults who used structured medication tools created more accurate and optimal schedules (partial support for H1a: limited evidence for optimality and no differences with respect to the completion time). Structured tools may also have improved collaborative planning as they were easier to use and reduced subjective workload associated with creating the schedules. There was also limited evidence that these tools improved the quality of collaboration between the participant pairs (partial support for H1b). While participants created more accurate and optimal schedules for the simple problems (support for H2a), they did not derive greater benefit from the structured tools when solving complex rather than simple problems (i.e., H2b was not supported). Perhaps, even the simpler problems also imposed heavy demands on participants’ cognitive abilities, which were partly offloaded to the structured tool.

One of the more important results, perhaps, is regarding the collaborative processes in the use of e-MedTable. We found few differences between the electronic and paper-based structured tool on performance, collaboration, usability, or workload measures (evidence against our secondary hypothesis). While null results must be interpreted with caution, this pattern suggests that contrary to our expectations older adults could use the electronic tool as well as the paper-based MedTable™. Moreover, e-MedTable use led to improved communication, quality of collaboration, and lower perceived workload when compared to the less structured Medcard. We note, however, that our sample of older adults were primarily well educated and had previous experience using computers.

Structured collaborative tools have the potential to improve adherence among older adults. First, external tools reduce the cognitive load encountered during medication scheduling, offsetting some of the challenges posed by age-related cognitive declines among older adults. While we do not have direct evidence of this, we believe that the lower perceived workload shows the effectiveness of structured tools in potentially “dividing” the effort of scheduling problem between the patient and the provider. The external representation may have provided explicit visual mechanisms for representing the medication and routine constraints on the structured tools that helped participants integrate diverse information critical to solving the problem. The structured representation may also have afforded an easy visual representation for dosage spacing and provided cues for the participants for aggregating doses where possible.

The division of work was also evident in the higher quality of collaboration in the use of structured tools, where the participants reported better conversational “grounding” of information needed to develop adherence plans. Thus, the offloading of the cognitive effort between collaborative partners and the structured external tool may help patients offset age-related cognitive declines that affect their medication adherence. Because older adults may create overly complex and unwieldy schedules when left to their own devices (Wolf et al. 2011), structured tools may improve adherence by supporting development of adherence plans with more optimal schedules.

Second, collaborative tools increase the likelihood of providing support for active monitoring of medication schedules and better prospective memory among participants, a key factor that affects adherence. In other words, collaborative tools provide a mechanism for active support in implementing the medication plans developed collaboratively with the provider. We found that the use of structured tools led to (a) simpler and more organized (i.e., possibly more optimal) schedules that were aligned with patient-routines and medication constraints (b) and more accurate schedules. The active collaboration between the patient and provider is likely to increase the patient’s knowledge about medications. The active role of the patient would potentially lead to better integration and understanding of medication-related information increasing the chances of adherence.

Finally, our study suggests the potential of electronic collaborative tools for supporting medication adherence. This is especially important given the current focus on the use of Electronic Medical Record (EMR) systems in primary care settings (Apsden et al. 2007). In addition to providing efficient mechanisms to manage medication schedules, electronic tools provide low-cost (in terms of effort and time) mechanisms to update or modify created schedules and to integrate information about medication regimens with other patient information. This results in opportunities for developing online collaborative tool for supporting older adults’ medication-scheduling practices, which could be a part of their personal health record (Tang et al. 2006).

6 Limitations

As with our previous experiments (Morrow et al. 2008), the current experiment was intended to simulate aspects of...
medication planning between patients and those providers responsible for patient education and support (e.g., pharmacists, nurses). However, the current experimental design has limited generalizability to actual clinical settings, as the providers were not actual clinicians. Additionally, older adults took on the role of both patients and providers, though in actual settings, providers are often younger than chronically ill patients. But there is research evidence suggesting that many nurses and pharmacists are middle-aged or older (Buerhaus et al. 2006) and often take the role of educating the patient about their medication regimens. We used providers of similar age to patients to avoid intergenerational communication problems, such as younger adults using “elderspeak” (Ryan et al. 1995).

As there was limited prior work on the use of tools for medication scheduling, we used a simulated task with older adults taking the roles of patients and providers. The simulation studies that mirror real-world scenarios helped in identifying promising tools that can be tested with actual patients. While the participants in our study who took the role of a provider were not experts on medication or healthcare practices, they were “trained” in their role by providing detailed descriptions about the medications that would be necessary for completing the tasks.

7 Key points

- The use of structured collaborative tools for medication scheduling improves the accuracy and optimality (simplicity) of created medication schedules.
- Structured tools are also easier to use, reduce the subjective workload associated with creating the schedules, and improve the quality of collaboration between the patient and provider.
- The electronic tool was as effective as the paper-based tool for supporting collaborative planning.
- In effect, structured collaborative tools can reduce the cognitive load associated with planning how to take medication and may support patient’s prospective memory for taking medication, potentially improving adherence.

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