

Collaborative Tools in a Simulated Patient-Provider Medication Scheduling Task

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Medication adherence is an essential activity for successful self-care, particularly for older adults who take multiple medications. Adherence depends on understanding how to take medication, which in turn depends on effective communication with providers. Unfortunately, physician and patient communication is often substandard and ineffective. Furthermore, successful adherence is often tied to supporting the patient's prospective memory by integrating medication taking with a daily routine. We have developed a paper-based tool (MedTable) for supporting provider-patient collaborative planning about taking medication, which has improved performance in a simulated medication scheduling task. The tool is used as an external workspace that reduces cognitive demands while also facilitating collaboration in a planning task. In the current study, the MedTable was redesigned and an electronic version was also developed. Both tools were compared to a less structured paper tool similar to medication reconciliation cards used in many health care settings (Medcard). 144 community dwelling older adults (aged 60 and over) participated in pairs in a simulated patient-provider medication scheduling task. Each pair solved four medication scheduling problems (2 simple and 2 complex) using one of the three tools (MedTable, e-MedTable, Medcard). Although all three tools supported highly accurate solutions, the MedTable produced significantly more accurate schedules than the Medcard (there were no tool differences in solution time). Moreover, participants rated workload associated with problem solving as lower for the two structured tools compared to the Medcard. The MedTable was also rated more usable than the non-structured aid. Finally, there was no evidence that older adults had difficulty using the computer-based tool, which suggests that a computer-based tool could be an effective intervention for improving provider-patient collaboration.

INTRODUCTION

Background

The 1999 Institute of Medicine (IOM) report on medical errors shook the foundations of the US healthcare industry with the claim that 44,000 to 98,000 preventable deaths occur annually in US hospitals (Kohn, Corrigan, & Donaldson, 1999). Since then, numerous articles have appeared looking at the role of human error in contributing to adverse events in all facets of healthcare. Of particular interest is medication error, as this error is common and preventable; the IOM concludes that 1.5 million preventable adverse drug events (ADEs) occur each year in the US. Many ADEs occur in the home because patients do not always take medications as prescribed (Apsden, Wolcott, Bootman, & Croenewett, 2007).

Why is medication adherence so important? First, about half of all Americans take at least one prescription medication (Mitchell, Kaufman, & Rosenberg, 2006), and about half of the 3.5 billion annual prescriptions in the United States are not taken as prescribed (Osterberg & Blaschke, 2005). Poor medication adherence costs the healthcare system \$100 billion annually (McDonnell & Jacobs, 2002).

Communication is an important factor for adherence. When new medications are prescribed, on average, 40% of the information that should be shared with the patient is completely omitted (Tarn, Heritage, Paterniti, Hays, Kravitz, & Wenger, 2006). This often includes information about length of usage, frequency, and adverse side effects. Additionally, physicians often overestimate a patient's health

literacy and fail to check the patient's understanding (Bass, Wilson, Griffith, & Barnett, 2002); (Schillinger, et al., 2003). Unfortunately, successful self-care requires patients to synthesize this often fragmented medication information into a meaningful mental representation (Morrow & Wilson, 2010). Successful adherence places demands on cognitive resources, such as working memory, to integrate medication information into a comprehensible and feasible plan. Multi-medication plans can be more complex as medication constraints (e.g. drug interactions, differing times per day) must be maintained in working memory to develop an appropriate schedule. Compounding age-related declines in cognition and health literacy with poor communication between patient and provider is a recipe for poor at home self-care (Apsden et al., 2007).

Medication adherence is a serious issue for the entire population. For older adults the issue is compounded. More than half of men and women 65 years and older take at least 5 medications (Mitchell, Kaufman, & Rosenberg, 2006). Furthermore, older adults have more issues with comprehension, memory and adherence of physician instructions than older adults because of age related declines in the cognitive resources required for these tasks (Brown & Park, 2002).

Interventions for Adherence

Two of the major recommendations from the 2007 IOM study were (Apsden et al):

1. Patients should maintain an active list of medications for all providers.

2. All healthcare organizations should make available decision-support tools for prescribing medication.

Since 2008, the Agency for Healthcare Research and Quality (AHRQ) has been running a public service advertisement entitled: "Questions are the answer" - calling for patients to engage in asking questions of their provider during consultations (www.ahrq.gov/questionsaretheanswer/).

Older adults' adherence may be improved by reducing the cognitive demands involved in creating adherence plans, which would address age-related declines in working memory (Park D. C., 2000). Fortunately, external representations can be used to offload some of these demands by moving information to a medium where it can be perceived and used with minimal high-level interpretation, reducing the need for memory search, computation or other cognitively intensive operations (Zhang & Norman, 1994). Moreover, visual external aids support collaborative planning tasks since they encourage the conversational grounding between participants necessary for collaboration (Kraut, Fussell, & Siegel, 2003)

Also, use of a memory aid has been proven to improve older adults' prospective memory (Einstein & McDaniel, 1990), and recent work with aging and memory that has shown that adherence can be improved by targeting a patient's prospective memory (Park, Gutchess, Meade, & Stine-Morrow, 2007; Wilson & Park, 2007). Thus, structured collaborative tools that support prospective memory should improve adherence.

Tools that support collaborative adherence planning may be most effective if computer-based, so that they can be integrated with electronic medical records or other information technology systems.

METHODS

Collaborative Aids

Three tools were developed for use in this study.

a) The first tool, the Medcard, represents the usual care condition. It lists medication name, purpose, dose, frequency, and directions and replicates the medication reconciliation cards that are currently in use in many health care settings (all around the US). However, since the intention of a medication card is to help patients maintain a complete list of medication information, it is not structured to support communication and collaborative planning between patient and provider, as described above.

b) The MedTable (fig. 1) is a table where medications are listed on each row, with key medication information listed in the first column. Times corresponding to the patient's routine label the remaining columns, and the cells in between are used by the patient for scheduling. The left hand column carries the same information found on the medication card. The patient's routine is represented by sixteen hourly timeslots, and icons representing the three basic meals, wake-up, and bedtime. The MedTable is organized to support collaborative planning by making schedule constraints visible to patient and provider, so that the table serves as an external workspace.

c) The e-MedTable (fig. 2) is a computer-based version of the MedTable. It is a simple electronic interface created with Microsoft Access and Visual Basic for Applications, that imitates the redesigned MedTable with medication information stored on the left of the screen, the patient's routine and scheduling buttons across the middle-top, and the cells for scheduling in the center of the screen. The e-MedTable was designed to minimize mouse movement by keeping the medication selection buttons and medication scheduling buttons all in one area of the interface thereby minimizing visual search and need for fine motor control (Winkelholz & Schlick, 2007). Also, scheduling buttons were used instead of checkboxes as they provided a bigger target for participants to click; and no double clicks are necessary for interaction (Hawthorn, 2000). These features of the interface were intended to accommodate age-related slowing of mental processing that has been shown to impair older adults' use of a mouse when performing routine computer tasks (Mead, Lamson, & Rogers, 2002).

As mentioned previously, all three tools included information about the medication so that the participants were not responsible for inputting this information into the tool. This marks a departure from the previous study in which the MedTable was compared to scheduling with a blank paper (Morrow, Raquel, Schriver, Redenbo, Rozovski, & Weiss, 2008). However, only two of the aids in the present study were structured (the MedTable and the e-MedTable) because they included information about the patient's schedule and contained boxes for medication scheduling. The Medcard only had white space in which the participant was told they could use in any manner for medication scheduling.

Figure 1: MedTable

Figure 2: e-MedTable

Hypotheses

We predict that the two structured tools (MedTable and e-MedTable) will support cognition by reducing the cognitive demands of planning better than the unstructured aid. The structured aids should assist grounding quicker than the unstructured aid and so the structured aids should result in quicker and more accurate medication schedules. Also due to the arrangement of this organizational task, the structured aids should have higher usability and lower perceived workload (as measured by the NASA-TLX, see Design and Dependent Variables below). Furthermore, the MedTable is expected to perform better than the e-MedTable due to age-related usability and preference issues.

Scheduling Problems

Participant pairs were asked to complete medication problems that varied in complexity. Six problems were created by the research team, three simple and three complex. All medication problems consisted of four medications presented with name, purpose, size of dose, frequency, and special instructions (take at meals, on an empty stomach, etc.). The medication names were fictional but the instructions were similar to existing medications. Also, for each problem a patient routine was created with mealtimes, wake-up, bedtime, and the patient's work schedule including breaks. The difference between simple and complex problems was the size of the solution space. Complex problems had more constraints associated with the medication and patient routine information, and fewer feasible solutions that met these constraints. Therefore, the complex problems required more cognitive effort to search the problem domain to find a feasible solution (Newell & Simon, 1972).

Participants

144 community-dwelling older adults ($M = 71$, $SD = 7.3$; 64% females) participated in pairs. All participants were screened to ensure everyone used a computer at least weekly. Pairs were randomly assigned to one of the three tool groups (24 pairs per group). Demographics, vocabulary, and speed of processing were measured to ensure that groups did not differ in terms of cognitive abilities that might influence planning performance. Both vocabulary and speed of processing came from the Kit of Factor-Referenced Cognitive Tests (Ekstrom, French, & Harman, 1976). The three groups did not significantly differ in age, education, or vocabulary scores. However, the speed of processing was significantly higher ($p < .05$) for the group that used the e-MedTable than the other two groups.

Procedure

Each participant in a pair was randomly assigned a role: either patient or provider. Although patient and provider worked together to create each medication schedule, the patient was responsible for documenting the schedule on the tool, either by writing on the paper tool or inputting the

information on the e-MedTable with a mouse. All groups were given the same two practice problems, one easy and one complex. The practice problems were given to familiarize the pair to the tool, the task, and to minimize learning effects across the four experimental trials. The four problems were blocked by complexity (2 simple and 2 complex), and the order of problems within each block, as well as the order of the blocks, was counterbalanced across participants in each tool group.

Each trial was audio recorded and timed. Before the start of each trial, the patient was given a sheet of paper listing the patient routine, and the provider was given the list of four medications for the problem. They were given up to 90 seconds to study the information, without collaborating. After the study period, the tool was given to the patient or the computer program was opened, and the pair was told to begin planning. After every trial, the patient was prompted to read out the created schedule to the experimenter. Following that, both the patient and provider were asked to fill out a subjective workload measure. Upon completion of all four trials, the patient was given a tool usability survey (SUS) (Brooke, 1996).

Design and Dependent Variables

The dependent variables related to problem solving were problem solving accuracy, completion time, and subjective workload. Perceived ease of using each tool was measured by usability (Brooke, 1996). Problem solving performance was analyzed by a Tool Group (MedTable, e-MedTable, Medcard) x Problem Complexity (Simple vs. Complex) ANOVA, with Complexity a repeated measure. In addition, because subjective workload was measured for each partner, it was analyzed by Tool Group x Role (Provider vs. Patient) x Problem Complexity ANOVA, with Complexity as a repeated measure. Furthermore, since we made specific predictions about tool differences, pairwise comparisons of main effects were also performed using Least Significant Difference.

Accuracy for each problem was measured by the proportion of the number of problem constraints met by the solution. These constraints included: correct number of doses, appropriate medication taking times, patient routine restrictions, and medication co-occurrence restrictions. For the simple problems, there were 18 constraints. The number of constraints for the complex problems was 22 or 24, depending on the particular problem. Completion time was measured from when the tool was given to the pair to when the pair indicated to the experimenter that they had completed scheduling or until the time limit was reached.

Subjective workload was measured using the NASA Task Load Index (Hart & Staveland, 1988). The index consists of six subjective scales (0 to 100): mental demand, physical demand, temporal demand, performance, effort, and frustration. The measure asks the participant to mark along a segmented line to rate the degree of each factor from very low to very high (except perceived performance, which goes from perfect to failure). The scales are structured that small scores

represent minimal subjective workload and perceived performance as perfect.

The usability questionnaire was developed by taking seven questions from the System Usability Scale (Brooke, 1996). Three questions were omitted because they were irrelevant to using the paper tools. A composite of the seven remaining questions was created according to Brooke's methods (higher scores are better).

RESULTS

Accuracy

Accuracy was extremely high for all three tool groups: Medcard ($M = .965$, $SD = .005$); e-MedTable ($M = .974$, $SD = .005$); MedTable ($M = .980$, $SD = .005$). Even though speed of processing did not significantly correlate with accuracy, it was included as a covariate in the analysis because the groups differed on this measure. Although the effect of complexity was not significant with the covariate included, $F(1, 68) = 1.41$, $p = .24$, it was in a multivariate test on complexity, $F(1,68) = 20.49$, $p < .01$. While the tool effect was not significant $F(2,69) = 2.2$, $p = .126$, the pair-wise comparison between the MedTable and the Medcard was significant ($p < .05$), with no difference between the structured aids ($p = .56$).

Problem Completion Time

Speed of processing was included as a covariate because it negatively correlated with completion time and differed by Tool group. There was a significant effect of Complexity, with simple problems ($M = 233$ s, $SD = 8.6$) solved more quickly than complex problems ($M = 497$ s, $SD = 16.9$). However, there was no effect of tool on solution time (Medcard ($M = 356$ s, $SD = 20.1$); e-MedTable ($M = 371$ s, $SD = 19.7$); MedTable ($M = 366$ s, $SD = 19.7$)), $F(2,68) = .141$, $p = .869$, and the tool x complexity interaction was not significant, $F(2,68) = .618$, $p = .542$.

Subjective Workload

In order to simplify the workload findings, we conducted two principal component analyses that included the six measures of the TLX, one for simple and one for complex problems. Both analyses returned a single factor that accounted for over half (Simple = 59.2%, Complex = 58.1%) of the variance within the data. Based off of the loadings (all greater than 0.5), a weighted composite was created for each level of complexity. An ANOVA on the weighted composite scores revealed a marginally significant effect of tool, $F(2, 138) = 3.008$, $p = .053$. Pair-wise comparisons showed that problem solving was perceived as more effortful when using the Medcard compared to either structured aid (p 's $< .05$).

Tool Usability

An ANOVA on the usability composite of all items showed a significant effect of tool, $F(2, 69) = 4.3$, $p < .05$. The pair-wise comparisons show that the Medcard ($M = 61.4$, $SD = 2.2$) was rated as more difficult to use than the MedTable ($M = 52.3$, $SD = 2.2$), $p < .01$, and a marginally significant difference suggested it was more difficult than the e-MedTable ($M = 57.6$, $SD = 2.2$), $p = .09$.

DISCUSSION

Structured Versus Unstructured Aids

Participants created more accurate medication schedules when using the paper MedTable rather than the unstructured Medcard (similar to Morrow et al., 2008). However, all three tool conditions supported very accurate problem solving (above 90% accuracy). The differences in accuracy account for one or two constraints being met in the MedTable condition that were not met with the unstructured Medcard. The high level of accuracy may reflect the fact that all three tools presented all of the necessary information to create feasible schedules, thus reducing the memory demands of planning in all conditions.

The workload measure suggests that problem solving was easier when using both structured aids compared to the less structured Medcard. One reason for this finding may be that the structured aids were easier to use, as suggested by the findings for the usability measure, and the fact that workload was inversely related to usability ratings ($r = -.26$; $p < .05$). This is most likely due to the fact that for the unstructured aid, there was no instruction on how to use the tool; participants were told they can use it any way they want. Thus, from the user's perspective little was done to make the tool "user-friendly". Finally the structured aids did not improve task completion time.

E-MedTable

We also explored differences in the impact of the two structured aids on collaborative planning. However, this can be seen as a benefit when discussing the comparison of the e-MedTable to the two paper tools. Very little research has been done with computers as a collaborative medium for co-located partners, especially involving older adults. The e-MedTable proved to be not just as effective as the two paper tools, but it supported the same level of accuracy as the other tools with lower perceived workload compared to the Medcard. Also, it was marginally deemed more usable than the unstructured aid.

Remember, there is currently no collaborative aid for medication scheduling in use in the average hospital or doctor's office. The Medcard is quite similar to medication reconciliation cards that exist in some clinical settings. The MedTable and e-MedTable are structured to directly support collaborative medication review and planning. This will likely improve patient-provider communication so that providers and patients can be mutually involved in the development and implementation of adherence plans. The advantage of the e-MedTable is that medication information can be extracted from existing electronic medical record (EMR) systems and so no time has to be wasted on writing the necessary medication

information onto a paper sheet. Furthermore, the e-MedTable could be designed to print out a usable stand-alone sheet that a patient can take home with him/her.

CONCLUSIONS

A simulation study of 72 pairs collaborating on a medication scheduling task suggested that structured aids were easier to use and improved the ability of patients and providers to work together to create accurate medication schedules with less effort, compared to a less structured aid. Furthermore, a computer interface can be a successful medium for co-located collaboration, even between older adults. As technology continues to pervade all areas of our lives, including healthcare, it may prove once again useful to introduce an electronic intervention to improve patient-provider collaboration concerning medication instructions.

Future Directions

The created e-MedTable could be to be more functional within the context of existing electronic medical records. A version of the e-MedTable should be tested in a clinical setting to see if the collaboration between actual patients and providers is improved as well as to evaluate the aid's effect on medication adherence.

REFERENCES

- Apsden, P., Wolcott, J. A., Bootman, J. L., & Croenwett, L. R. (2007). *Preventing Medication Errors*. Washington, DC: The National Academies Press.
- Bass, P. F., Wilson, J. F., Griffith, C. H., & Barnett, D. R. (2002). Residents' Ability to Identify Patients with Poor Literacy Skills. *Academic Medicine*, 1039-1041.
- Brooke, J. (1996). SUS: a 'quick and dirty' usability scale. In P. W. Jordan, B. Thomas, I. L. McClelland, & W. B. (Eds.), *Usability Evaluation in Industry* (pp. 189-195). London: Taylor & Francis.
- Brown, S. C., & Park, D. C. (2002). Roles of age and familiarity in learning of health information. *Educational Gerontology*, 695-710.
- Einstein, G. O., & McDaniel, M. A. (1990). Normal Aging and Prospective Memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 717-726.
- Ekstrom, R. B., French, J. W., & Harman, H. H. (1976). *Manual for the kit of factor-referenced cognitive tests*. Princeton, NJ: Educational Testing Service.
- Hart, S. G., & Stavenland, L. E. (1988). Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research. In P. Hancock, & N. Meshkati (Eds.), *Human Mental Workload* (pp. 139-183). Elsevier.
- Hawthorn, D. (2000). Possible implications of aging for interface designers. *Interacting with Computers*, 507-528.
- Kohn, L. T., Corrigan, J. M., & Donaldson, M. S. (1999). *To err is human: building a safer health system*. Washington, DC: National Academy Press.
- Kraut, R. E., Fussell, S. R., & Siegel, J. (2003). Visual Information as a Collaborative Resource in Collaborative Physical Tasks. *Human Computer Interaction*, 13-49.
- McDonnell, P. J., & Jacobs, M. R. (2002). Hospital admissions resulting from preventable adverse drug reactions. *Annals of Pharmacotherapy*, 1331-1336.
- Mead, S., Lamson, N., & Rogers, W. A. (2002). Human Factors guidelines for web site usability: Health-oriented websites for older adults. In R. W. Morrell (Ed.), *Older Adults, Health Information and the World Wide Web* (pp. 89-107). Hillsdale, NJ: Erlbaum.
- Mitchell, A. A., Kaufman, D. W., & Rosenberg, L. (2006). *Patterns of Medication Use in the United States*. Retrieved February 14, 2010, from Slone Epidemiology Center at Boston University: <http://www.bu.edu/slone/SloneSurvey/SloneSurvey.htm>
- Morrow, D. G., & Wilson, E. A. (2010). Medication Adherence among Older Adults: A Systems Perspective. In J. C. Cavanaugh, & C. K. Cavanaugh (Eds.), *Aging in America*. Westport, CT: Greenwood Publishing Group.
- Morrow, D., Raquel, L., Schriver, A., Redenbo, S., Rozovski, D., & Weiss, G. (2008). External Support for Collaborative Problem Solving in a Simulated Provider/Patient Medication Scheduling Task. *Journal of Experimental Psychology: Applied*, 288-297.
- Newell, A., & Simon, H. A. (1972). *Human problem solving*. Englewood Cliffs, NJ: Prentice-Hall.
- Osterberg, L., & Blaschke, T. (2005). Adherence to medication. *New England Journal of Medicine* (353), 487-497.
- Park, D. C. (2000). The basic mechanisms accounting for age-related decline in cognitive function. In D. C. Park, & N. Schwarz (Eds.), *Cognitive Aging: A Primer* (pp. 3-21). Philadelphia: Psychology Press.
- Park, D. C., Gutches, A. H., Meade, M. L., & Stine-Morrow, E. A. (2007). Improving Cognitive Function in Older Adults: Nontraditional Approaches. *Journals of Gerontology*, 45-52.
- Schillinger, D., Piette, J., Grumbach, K., Wang, F., Wilson, C., Daher, C., et al. (2003). Closing the Loop: Physician Communication With Diabetic Patients Who Have Low Health Literacy. *Arch Intern Med*, 83-90.
- Tarn, D. M., Heritage, J., Paterniti, D. A., Hays, R. D., Kravitz, R. L., & Wenger, N. S. (2006). Physician Communication When Prescribing New Medications. *Arch Intern Med*, 1855-1862.
- Wilson, E. A., & Park, D. C. (2007). Prospective Memory and health behaviors: Context trumps cognition. In M. Kliegel, M. A. McDaniel, & G. O. Einstein (Eds.), *Prospective Memory: Cognitive, Neuroscience, Developmental, and Applied Perspectives*. Mahwah, NJ: Erlbaum.
- Winkelholz, C., & Schlick, C. M. (2007). Modeling Human Spatial Memory Within a Symbolic Architecture of Cognition. *Spatial Cognition V: Reasoning, Action, Interaction*, 229-248.
- Zhang, J., & Norman, D. A. (1994). Representations in distributed cognitive tasks. *Cognitive Science: A Multidisciplinary Journal*, 87-122.