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External Support for Collaborative Problem Solving in a Simulated Provider/Patient Medication Scheduling Task

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Taking medication requires developing plans to accomplish the activity. This planning challenges older adults because of age-related cognitive limits and inadequate collaboration with health providers. The authors investigated whether an external aid (*medtable*) supports collaborative planning in the context of a simulated patient/provider task in which pairs of older adults worked together to create medication schedules. Experiment 1 compared pairs who used the medtable, blank paper (unstructured aid), or no aid to create schedules varying in complexity of medication constraints (number of medications and medication co-occurrence restrictions) and patient constraints (available times during the day to take medication). Both aids increased problem-solving accuracy and efficiency (time per unit accuracy) compared to the no-aid condition, primarily for more complex schedules. However, benefits were similar for the two aids. In Experiment 2, a redesigned medtable increased problem-solving accuracy and efficiency compared to blank paper. Both aids presumably supported problem solving by providing a jointly visible workspace for developing schedules. The medtable may be more effective because it externalizes constraints (relationships between medication and patient information), so that participants can more easily organize information.

Keywords: distributed cognition, external aids, health communication, problem solving, medication adherence

Older adults' self-care is a crucial health care issue because our society is aging at a time of increasing patient responsibility for self-care. Self-care activities such as taking medication challenge older adults, leading to errors that threaten safety and undermine treatment efficacy. A recent study found that almost 25% of older adults took 5 or more and 12% took 10 or more prescribed medications (Kaufman, Kelly, Rosenberg, Anderson, & Mitchell, 2002). On average, 50% of older adults do not take their medications as prescribed (Haynes, McKibbon, & Kanani, 1996). Moreover, over one third of older adults' hospital admissions are due to adverse drug events, often reflecting medication misuse (Budnitz, Pollock, Weidenbach, Mendelsohn, Schroeder, & Annest, 2006). Among other factors, nonadherence has been linked to age-related differences in cognitive function and health literacy combined with inadequate collaboration between patients and providers, leading to calls to improve self-care by supporting patient/provider collaboration and planning (for review see Aspden, Wolcott, Bootman, & Croenwett, 2007).

Cognitive and Collaborative Determinants of Medication Planning

Creating and implementing self-care plans can tax cognitive abilities, such as working memory and processing speed. Developing medication plans requires understanding and integrating information (e.g., when to take medication; warnings to keep in mind), and implementing these plans requires prospective memory (Park & Jones, 1997). Indeed, performance on measures of cognitive ability predict errors in taking medication (Insel, Morrow, Brewer, & Figuerosa, 2006) and loading pill organizers (Carlson, Xue, Fried, Tekwe, & Brandt, 2005) among older adults.

Ideally, health care providers mitigate these cognitive demands by collaborating with patients, as suggested by patient-centered approaches to communication (Bodenheimer, Lorig, Holman, & Graumbach, 2002) and conceptions of adherence that focus on patient/provider concordance about adherence goals (Vermeire, Hearnshaw, Van Royen, & Denekens, 2001). Unfortunately, patient/provider collaboration can be inadequate because of system barriers, such as limited patient contact time and inadequate communication training (Aspden et al., 2007). Providers omit information, present dense, disorganized information, and rarely check

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Partial results (the problem-solving accuracy and efficiency analyses in Experiment 2) were presented at the 51st Annual Meeting of the Human Factors Society (Morrow, Raquel, Schriver, Redenbo, & Rozovski, 2007).

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patients' comprehension (Ley, 1997; Schillinger et al., 2003). As a result, patients leave consultations without a clear plan and either end up calling back to clarify confusion or taking medication incorrectly.

Improving Patient/Provider Collaborative Planning

We investigated the role of external aids as environmental support for collaborative problem solving relevant to self-care. According to distributed cognition theories, complex task performance depends on the interaction of internal and external resources (Hutchins, 1995). Older adults may reduce reliance on retrieval, computation, or other mental operations that become less reliable with age by using environmental support (e.g., memory retrieval cues), which decreases need for self-initiated mental processing (Craik & Jennings, 1992; Morrow & Rogers, 2008). While age differences occur for instrumental problem solving domains, such as medication management, as they do for other complex domains, the role of environmental support for this important everyday ability is rarely investigated (for review see Thornton & Dumke, 2005). Collaboration can sometimes provide environmental support for older adults' problem-solving because partners provide retrieval cues or suggest problem-solving strategies (e.g., Gould, Dixon, & Kurzman, 1994), but collaboration may itself impair problem-solving because of the cognitive demands of joint performance (Schwartz, 1995). We investigated whether external aids support collaborative problem solving relevant to medication use.

External aids are ubiquitous in health care settings, with providers relying on white boards and other "cognitive artifacts" to support routine tasks such as ordering tests or scheduling patients (Nemeth, Cook, O'Connor, & Klock, 2004). Yet their potential for supporting patient/provider collaboration has been under investigated (Aspden et al., 2007). We investigated the impact of the medtable (see Figure 1) on collaboration involved in creating multimedication schedules typical of chronically ill older adults. This aid may support collaborative processes, such as sharing information about medications (e.g., how much and often to take, drug interactions) and patients (daily routine, constraints on when patients can take medication) and integrating this information into a schedule.

The medtable supports these processes in several ways. First, it reduces the cognitive demands of understanding and integrating problem-relevant information by externalizing this information (Larkin & Simon, 1987). As shown in Figure 1, the table's rows allowed participants to list each medication, and the columns corresponded to times to take these medications during the day. Familiar icons and verbal labels indicated daily events, such as meals, and the row below the icons allowed participants to write specific times corresponding to these events that were consistent with their routine (similar to the timeline previously shown to improve memory for medication schedules; Morrow, Hier, Menard, & Leirer, 1998). Columns also indicated intervals before and after meals that were consistent with restrictions about taking medications with or without food. Thus, the medtable should help participants develop schedules by explicitly representing relationships between medications and daily event times (Day, 1988). It may especially benefit older adults' problem solving by reducing the need for age-vulnerable working memory processes such as storing and accessing multiple sources of information (Bopp & Verhaeghen, 2007). Thus, the aid may provide environmental support for specific processes known to decline with age without itself taxing elders' cognitive processes (Morrow & Rogers, 2008).

Second, by providing a shared workspace, the medtable supports joint attention to critical information, reducing the need to describe information (e.g., proposed medication times), acknowledge

Medication Matrix

			Morning			Afternoon			Evening	
	Wake-up	Break-fast	2 hours after meal	1 hour before meal	Lunch	2 hours after meal	1 hour before meal	Dinner	2 hours after meal	Bed-time
Time / Medication										
1										
2										
3										
4										

Figure 1. Original medtable aid (Experiment 1).

partners' contributions, or other processes involved in sharing information (Gergle, Kraut, & Fussell, 2004). Finally, it reduces the "process loss" sometimes associated with collaboration (e.g., one partner's contribution interferes with another's retrieval; Schwartz, 1995). In short, the medtable may improve problem-solving by reducing the cognitive demands of collaboration, which ideally translates into better patient self-care. Similar aids have been included in education interventions designed to improve patient adherence (e.g., Murray et al., 2007). Kripalani et al. (2007) evaluated benefits of a medication schedule card similar to the medtable in a randomized trial and found many patients thought it was helpful. However, these studies have not directly investigated benefits of visual aids for patient/provider collaboration.

Overview of Experiments

The overall goal of our research program is to test whether the medtable improves the ability of patients and providers to develop medication schedules that support adherence. As a first step, the present study investigated medtable benefits for problem solving in a simulated patient/provider collaborative planning task. Pairs of older adults, randomly assigned to be provider or patient, worked together to create schedules that satisfied medication and patient constraints. The task was intended to simulate some aspects of planning between patients and those providers responsible for patient education (e.g., pharmacists and nurses), such as sharing information. However, the simulation likely has limited generalizability to actual clinical situations. For example, "providers" were not clinicians. In addition, older adults served as both patient and provider even though providers are often younger than chronically ill patients. However, we note that many nurses and pharmacists are middle-aged or older (Buerhaus, Donelan, Ulrich, Norman, & Dittus, 2006). Older adults served as patients in our study because this age group is most often prescribed complex medication regimens. Providers were of similar age to the patients to avoid potential intergenerational communication problems, such as younger adults using "elderspeak" (Ryan, Merideth, MacLean, & Orange, 1995).

Experiment 1 compared problem solving time and accuracy for pairs who used the medtable, blank paper (unstructured aid to control for general effects of external support), or no aid (talk only). Because the aids might reduce problem-solving effort without increasing accuracy, we also included the NASA-TLX instrument to measure the subjective workload associated with problem-solving (Hart & Staveland, 1988). Both aids provide environmental support in the form of a jointly visible workspace for sharing information and developing schedules, and therefore should increase problem-solving accuracy and reduce time, improving efficiency compared to the no-aid condition. The medtable should be more effective than paper because it externalizes constraints, allowing participants to easily organize information. Complexity of medication (number of medications and co-occurrence restrictions) and patient (flexible/inflexible schedule) constraints was also varied. We expected larger aid-related benefits for more complex problems, which would impose greater cognitive demands in the absence of the aid.

Experiment 1

Method

Participants. Ninety-six community-dwelling older adults participated (mean age = 69, 56–84 years; 52% female). They were screened to ensure they were native speakers of English with no physical or cognitive impairments that could limit participation (e.g., stroke in the last 3 years). They were randomly assigned to serve as patient or provider, with pairs randomly assigned to the three aid conditions. Speed of mental processing was measured by the Letter Comparison and Pattern Comparison tasks (Salthouse, 1991). In these paper-and-pencil tasks, participants decide as rapidly as possible whether pairs of letter sets or line patterns are the same or different.

Participants in the three groups differed in mean number of prescribed medications but not in terms of the other measured variables (see Table 1). Participants assigned as patient and provider did not differ on any of the variables. Because partner familiarity can influence collaborative performance (Andersson & Ronnberg, 1995), we controlled for this variable by selecting partners who did not know each other before the study.

Materials and design. Complexity of the medication and the patient information given to provider and patient participants (respectively) was varied. In the complex medication condition, information about four medications commonly used by older adults was presented, including purpose, number of pills and times per day to take them, dose spacing, and special instructions or warnings (an example is presented in Appendix 1, adapted from www.drugs.com). In the simple condition, information about two medications was presented, with fewer co-occurrence constraints

Table 1
Mean (and Standard Deviation) Values for Continuous Demographic and Individual Difference Variables, by Condition (N = 32 per Group) in Experiment 1

Variable	Medtable	Paper	No aid	*p* value
Age (years)	70.1 (5.4)	69.5 (5.8)	68.8 (5.6)	>.10
Education (years)	14.3 (2.7)	15.3 (3.9)	15.0 (2.6)	>.10
Comparison task score	43.4 (7.7)	44.3 (11.2)	44.0 (9.0)	>.10
Self-rated health score	5.0 (1.4)	4.8 (1.5)	5.1 (1.4)	>.10
Mean number of medications	4.0 (3.3)	2.4 (1.6)	3.5 (2.2)	<.05

Note. Comparison task is a measure of processing speed (Salthouse, 1991). The mean of the Letter (Maximum score = 42) and Pattern Comparison (Maximum score = 30) tasks was used because performance on the two tasks were correlated (r = .79). Self-rated health is a 7-point scale from 1 (*very poor health*) to 7 (*very good health*).

on when these medications could be taken. In the complex patient information condition, patients had a strict daily work routine (e.g., afternoon/night shift) and they could only take medications at lunch or after work. In the simple condition, there were no daily restrictions and patients could adjust wake-up times and mealtimes. Complexity of daily routine was investigated because older adults' adherence is influenced by this factor (Park et al., 1999).

We also measured how many participants took the medications used in the study because patients may better remember information about medications they actually take (Morrow et al., 2005). The three groups did not differ in the percent who took one or more of these medications (44% of participants in no-aid group, 31% in the paper group, and 28% in the medtable group, $\chi^2 = 1.9$, $p > .10$). Problems were presented blocked by medication complexity with order of simple and complex medication problems, and the order of simple versus complex patient schedules within the simple and complex medication condition, counterbalanced across participant pairs in each group.

Participants in one group used the medtable (see Figure 1) to help create their schedules. Participants in the paper group received a blank 8" × 11" sheet of paper (same size as the medtable). Finally, participants in the no-aid group did not receive an external aid.

Procedure. Pairs of participants (one randomly assigned as provider and one as patient) completed four problems, one from each of the four conditions created by combining medication and patient complexity. They were given 1 min for each simple medication problem and 2 min for each complex medication problem to become familiar with their assigned information. They were told to share the information verbally, but not to look at each others' information sheets. Next, they worked together to create schedules consistent with the medication and patient constraints. After they agreed on the schedule, the patient described it to the experimenter (reported schedules were taped for later scoring). A maximum limit of 4 min for simple medication problems and 10 min for complex problems was imposed to be consistent with limited patient contact time in routine primary care visits (Braddock & Snyder, 2005).

After each schedule was reported, provider and patient separately completed the NASA-TLX measure (Hart & Staveland, 1988). This instrument, composed of 5-point Likert scales that measure mental demand, time pressure, mental effort required, assessed performance, and frustration, has been used to measure subjective workload associated with a wide range of tasks (including problem solving) and people (Tsang & Wilson, 1997). Participants practiced the task with sample medication and patient information of moderate complexity (3 medications).

Dependent variables and plan of analysis. Problem-solving accuracy, completion time, and efficiency were measured. Accuracy was measured by the total points (out of 24 or 29, depending on specific medications used) awarded for meeting medication requirements, which included medication name, number of pills, times per day, dose spacing, whether scheduled times met food and water restrictions, medication co-occurrence restrictions, and patient schedule restrictions. Problem-solving time was measured from when provider and patient began sharing medication and patient information until the patient indicated that he or she was ready to describe the schedule or until the time limit was reached **(**measured during the session by stopwatch**)**. An efficiency score was created by dividing solution time by accuracy, indicating time needed to achieve the same level of accuracy across participants.

Mean solution time (sec), accuracy (percent correct), and efficiency (time per unit accuracy) were analyzed by an Aid (medtable, paper, none) × Medication Complexity × Patient Complexity mixed design ANOVA with the latter two variables repeated measures. A composite mental workload measure was created based on a factor analysis (Principal Components extraction method; Varimax rotation; factors with Eignenvalues > 1.0 were considered) of the five NASA-TLX scales for each of the four medication x patient complexity conditions (total of 20 variables). Four factors accounted for 72% of the variance. Factor loadings showed that 4 of the 5 scales (mental demand, time pressure, mental effort required, and frustration) loaded on the same factor within each complexity condition (loadings = .35-.91). Composite variables created by averaging scores for these four variables within each complexity condition were analyzed by an Aid × Role (Provider vs. Patient) × Medication Complexity × Patient Complexity ANOVA, with the latter two variables repeated measures.

Results

Problem solving accuracy. Participants created more accurate schedules for problems with simpler medication information, $F(1, 45) = 77.7$, $p < .001$, $\text{eta}^2 = .63$, and with simpler patient information, $F(1, 45) = 6.5$, $p < .05$, $\text{eta}^2 = .13$, (see Table 2). They were also more accurate when using the aids, $F(2, 45) = 14.8$, $p < .001$, $\text{eta}^2 = .40$. Planned comparisons showed that participants were more accurate with either aid compared to no aid, with no difference between aid conditions. Aid-related benefits depended on medication complexity, $F(2, 45) = 16.9$, $p < .001$, $\text{eta}^2 = .43$. This interaction was analyzed by comparing the aid conditions for problems with simple and complex medication information. An aid effect in the simple medication condition, $F(2, 45) = 4.2$, $p < .05$, $\text{eta}^2 = .16$, showed that participants were more accurate when using paper rather than no aid ($p < .01$), with no difference between the paper and medtable or no-aid and medtable conditions (ps $>.10$). An aid effect in the complex medication condition, $F(2, 45) = 15.6$, $p < .001$, $\text{eta}^2 = .41$, showed that participants were more accurate with either aid than no aid ($p < .001$), with no difference between aids.

Problem solving time. Solution time results paralleled accuracy (see Table 2). Participants were faster for problems with

Table 2
Mean (and Standard Deviation) Values for Medication Schedule Solution Measures in Experiment 1

		Performance measure		
Medication complexity	Aid	Accuracy % correct *M* (*SD*)	Time sec *M* (*SD*)	Efficiency sec/acc *M* (*SD*)
Simple	None	93 (8.7)	132 (57.7)	1.6 (1.0)
	Paper	99 (1.8)	117 (45.7)	1.2 (0.5)
	Medtable	96 (5.1)	159 (42.2)	1.7 (0.5)
Complex	None	52 (25.3)	563 (60.4)	17.8 (21.1)
	Paper	84 (17.1)	510 (80.3)	6.8 (3.9)
	Medtable	88 (10.9)	527 (70.5)	6.3 (2.6)

simpler medication, $F(1, 45) = 1851.0$, $p < .001$, eta$^2 = .98$, and simpler patient information, $F(1, 45) = 11.0$, $p < .001$, eta$^2 = .20$. While there was no overall effect of aid, $F(2, 45) = 1.9$, $p > .10$, eta$^2 = .08$, the Aid × Medication complexity interaction was significant, $F(1, 45) = 4.1$, $p < .05$, eta$^2 = .15$. In the simple medication condition, an aid effect, $F(2, 45) = 6.1$, $p < .01$, showed that participants created schedules more slowly when using the medtable ($p < .05$), with no difference between paper and no aid ($p > .10$). In the complex medication condition, an aid effect, $F(2, 45) = 4.7$, $p < .05$, showed that participants created schedules more slowly when they did not have an aid ($p < .05$), with no difference between the aid conditions.

Problem solving efficiency. Problem solving was more efficient for problems with simpler medication information, $F(1, 45) = 98.0$, $p < .001$, eta$^2 = .70$, but not for those with simpler patient information ($p > .10$). Problem solving was more efficient when participants used either aid rather than no aid, $F(2, 45) = 4.9$, $p < .05$, eta$^2 = .19$, with no difference between the aids (planned comparisons $p > .10$). An Aid × Medication Complexity interaction, $F(2, 45) = 5.4$, $p < .01$, eta$^2 = .20$, showed that the aids increased efficiency for problems with complex medication information, $F(2, 45) = 4.2$, $p < .05$ (no difference between aid conditions), but not for those with simple medication information, $F(2, 45) = 2.1$, $p > .10$.

Subjective mental workload. Problem-solving was associated with lower workload for problems with simple versus complex medication information, $F(1, 90) = 288.9$, $p < .001$, eta$^2 = .76$, and in the no-aid than in either aid condition, $F(2, 90) = 11.6$, $p < .001$, eta$^2 = .21$ (see Figure 2). The cost of not having an aid for perceived workload was greater for complex than for simple medication problems, $F(2, 90) = 8.1$, $p < .001$, eta$^2 = .15$. Workload ratings were greater for patients than for providers, $F(1, 90) = 7.2$, $p < .01$, eta$^2 = .07$.

Analyses of external aid strategies. We analyzed how participants used the aids to support problem solving. They used the paper in similar ways, usually creating verbal lists by organizing information in terms of medication name rather than times to take the medications (66% of pairs, $p < .06$, binomial test, $N = 32$). Then, for each medication they wrote down times to take it. Those few who created time-based schedules were as likely to embed notes (e.g., about warnings) in the schedule as to segregate them (64% embedded notes, $p > .10$, $N = 11$).

Participants also used the medtable in similar ways. Most wrote down medication names for each row of the table under the medication column (81%, $p < .01$), and special instructions for each medication next to the name (69%, $p = .05$). They tended to use the timeline that organized the table columns by writing daily event times below corresponding icons (81%, $p < .01$). The majority wrote medication names or times in the table body (72%, $p < .05$), suggesting difficulty with using the medtable. For example, participants who correctly filled in the time row often wrote additional times in the body. Other strategies also suggested difficulty. For example, they did not always fill in the time row of the table exactly as the column headers indicated they should: For the column "1 hour before meal" next to the column "dinner," they often filled in a time 30 min before dinner because one medication had to be taken 30 min before a meal.

Discussion

Both aids increased collaborative problem-solving accuracy and efficiency while reducing subjective workload compared to the no-aid condition, primarily for the complex medication problems. The time measure may have been hampered by the imposed time limit. This limit was reached for 72% of the complex medication problems in the no-aid condition and for 34% in each aid condition, so that aid-related effects would more likely occur for problem solving accuracy than for time. However, we note that problem-solving was slower as well as less accurate when not supported by an aid in the complex medication problem condition.

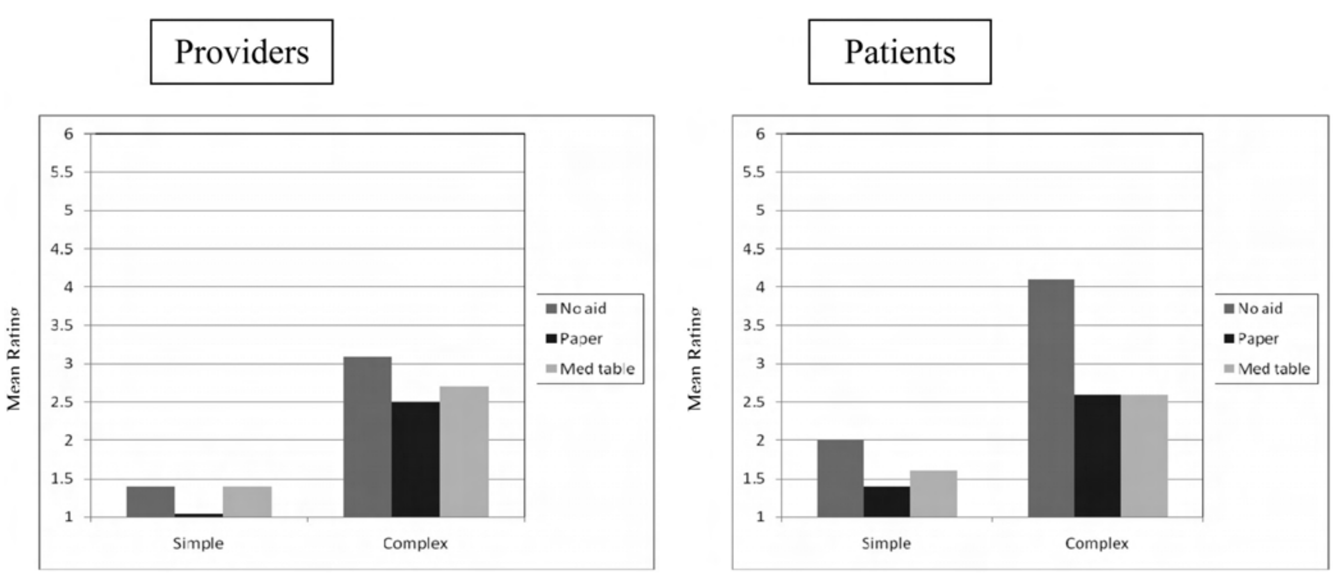

Figure 2. Mean subjective workload ratings (NASA-TLX, Hart & Staveland, 1988), by participant role, aid, and medication complexity (Experiment 1).

Creating the complex schedules required integrating information about four medications in terms of the patient's daily routine, which likely imposed heavy demands on cognitive resources. Participants using either aid could offload these demands to an external representation. Yet, the medtable was no more effective than the unstructured aid in supporting problem-solving. Analysis of how participants used the aids suggested difficulty using the medtable's timeline to map medication times onto daily events, perhaps because before/after meal time columns were too specific to support flexible use.

Therefore, the aid was revised to more clearly represent task constraints (see Figure 3). First, the primary function of mapping medication onto patient constraints was highlighted by using color to distinguish and relate these two types of information: the medication column was outlined in red while the time row was outlined in blue. In addition, the "Medications" and "Times" headings were separated to clarify that the top row was for time information only. Second, the time row was separated from the table body to clarify that it represented daily event times rather than times for only the first medication. Third, colons were added to the time row to clarify where medication-taking times should be written. Fourth, the titles "2 hours after meal" and "1 hour before meal" were eliminated because they were too specific. Finally, more space was provided next to the medication names on the rows along with the labels "Name" and "Instructions" so patients could write special instructions. If the revised medtable is easier to use as a joint workspace, it may encourage partners to access information from the aid rather than memory (Fu & Gray, 2000), so that problem solving is less limited by working memory. The medtable, revised to better reflect constraints relevant to creating medication schedules, was compared to the unstructured aid in Experiment 2.

Experiment 2

Method

Participants. Sixty-four community-dwelling older adults participated (mean age = 69, 60–86 years; 55% female). As before, they were randomly assigned to be provider or patient, with pairs randomly assigned to the two aid conditions. Participants in these conditions did not differ on any variable except processing speed scores (see Table 3), so this variable was included as a covariate (mean processing speed score per pair) for the analyses.

Procedure. The procedure was the same as before except for the following. First, the no-aid condition was eliminated because Experiment 1 clearly documented the cost of no aid for this task. Second, participants were given more practice using the two aids. In the paper condition, they were given sample medication and patient information and asked to consider how they would use the aid to develop a schedule. In the medtable condition, they were given a completed table and asked to describe the schedule. Next, the simple medication problems from Experiment 1 were used to practice the specific task. Thus, they were presented before the complex medication problems rather than counterbalancing the order of simple and complex problems as in Experiment 1, and data collection was restricted to the latter. This was done because

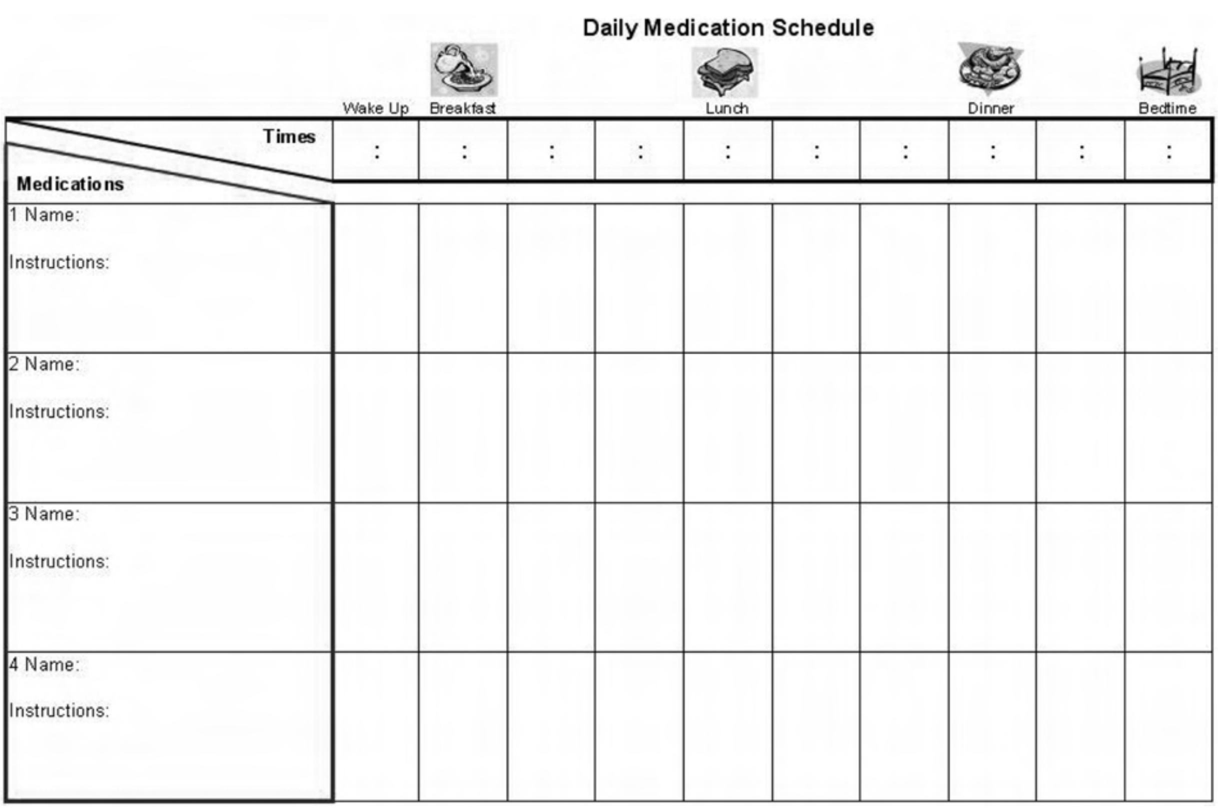

Figure 3. Revised medtable aid (Experiment 2).

Table 3
*Mean (and Standard Deviation) Values for Continuous Demographic and Individual Difference Variables, by Condition (*N *= 32 per Group) in Experiment 2*

Variable	Medtable	Paper	*p* value
Age (years)	68.6 (5.4)	68.6 (6.7)	>.10
Education (years)	15.4 (2.9)	15.0 (2.7)	>.10
Comparison task score	45.8 (4.6)	41.6 (3.6)	<.05
Self-rated health score	5.1 (1.4)	5.0 (1.4)	>.10
Number of prescribed medications	3.3 (2.8)	3.2 (2.9)	>.10

Note. Comparison task is a measure of processing speed (Salthouse, 1991). The mean of the Letter (Maximum score = 42) and Pattern Comparison (Maximum score = 30) tasks was used because performance on the two tasks were correlated ($r = .79$). Self-rated health is a 7-point scale from 1 (*very poor health*) to 7 (*very good health*).

accuracy for the simple conditions had been near ceiling in Experiment 1 so the problems were unlikely to discriminate effects of the two aids.

Third, maximum time limit was increased from 10 to 15 min in order to address the problem in Experiment 1 that many participants timed out before completing their schedule. Fourth, fictional medication names were used to avoid potential problems of some participants having taken medications used in the study. Fifth, a delayed cued recall task was included to explore whether the medtable would improve memory for schedules once they were created. This finding would have implications for improving patients' ability to remember medication information after consulting with providers. However, the measure had limited sensitivity because it occurred after participants had created two complex schedules (with 8 medications), so the potential for memory interference was high. The delayed test was given after participants completed the medication schedule problems and the individual difference measures (approximate delay 10 min). They were asked to write down any information they could remember about the medications and schedules they had created from the two complex problems. They were cued with the medication names and the patient schedule information from each problem.

Dependent variables and design. We investigated the impact of external aid and patient schedule complexity on problem solving. Participants either used the medtable or blank paper as they worked together to create medication schedules. Complexity of patient information was varied as in Experiment 1, but only investigated in the context of complex medication schedules. Thus, we used a mixed design with Aid as between-groups variable and Complexity of patient information as repeated measure to analyze problem solving performance, measured by accuracy (percent of points out of 24 or 29), time, and efficiency.

Results

Problem solving accuracy. Participants created more accurate schedules when using the medtable rather than blank paper, $F(1, 29) = 7.3$, $p < .05$, eta$^2 = .20$ (see Table 4). Complexity of patient information did not influence accuracy, nor interact with Aid, *p*s >.10. Participants presumably created more accurate schedules because they effectively used the medtable as an external workspace. To explore this possibility, we scored each pair's medtable or paper for accuracy of information written on the aid, using the same scoring scheme as for the verbally reported schedules. Findings were similar to those from the reported schedules: Accuracy was higher for medtable versus paper, $F(1, 29) = 5.8$, $p < .05$, eta$^2 = .16$, and for simpler patient information, $F(1, 29) = 4.6$, $p < .05$, eta$^2 = .13$.

Problem solving time and efficiency. Few pairs reached the time limit before finishing their schedules (M = 9%, P = 18%, $\chi^2 = 1.4$, $p > .10$). A nonsignificant trend suggested faster solutions when participants used the medtable, $F(1, 29) = 3.1$, $p < .10$, eta$^2 = .10$ (see Table 4). Complexity of patient information did not influence time nor interact with Aid (*p*s >.10). Problem-solving was more efficient when supported by the medtable, $F(1, 29) = 5.1$, $p < .05$, eta$^2 = .15$.

Subjective workload. As in Experiment 1, a composite workload measure was created from a factor analysis of the five NASA-TLX scales for the simple and complex patient schedule conditions (total of 10 variables). Two factors explained 69% of the variance. Factor loadings (.62 −.90) showed that mental demand, time pressure, mental effort expended, and frustration loaded on the same factor within each complexity condition. Composite variables were analyzed by an Aid × Role × Patient Complexity ANOVA, with the latter variable a repeated measure. While the pattern across conditions was similar to the two aid conditions in Experiment 1, only the complexity variable was significant (Simple = 2.3, Complex Patient Information = 2.9; $F(1, 60) = 17.3$, $p < .001$, eta$^2 = .22$). Ratings did not differ for patients and providers (2.6 vs. 2.5), nor for medtable and paper groups (2.5 vs. 2.6). Absence of significant effects for the role and

Table 4
Mean (and Standard Deviation) Values for Medication Schedule Solution Measures in Experiment 2

		Performance measure			
Patient complexity	Aid	Reported accuracy % correct *M* (*SD*)	Aid accuracy % correct *M* (*SD*)	Time sec *M* (*SD*)	Efficiency sec/acc *M* (*SD*)
Simple	Paper	90 (7.0)	89 (7.0)	702 (192.1)	7.8 (2.2)
	Medtable	96 (4.7)	95 (4.7)	553 (160.5)	5.8 (1.8)
Complex	Paper	84 (16.8)	85 (16.8)	734 (154.5)	10.0 (6.5)
	Medtable	92 (7.0)	91 (7.0)	694 (187.4)	7.6 (2.2)

aid variables may reflect the fact that the more discriminating conditions (no-aid vs. aid; simple vs. complex medication information) were excluded in Experiment 2. In addition, power to detect effects was limited by the small sample size (Costello & Osborne, 2005).

Delayed cued recall task. Accuracy of delayed recall, scored the same as accuracy in the problem-solving task, was low, reflecting the difficulty of this task. A nonsignificant trend suggested that patients recalled more information than providers (Patient = 28%, Providers = 22%, $F(1, 60) = 3.6$, $p < .10$, $\text{eta}^2 = .06$). There was no difference between the two aid conditions (Medtable = 24%, Paper = 26%, $F(1, 60) < 1.0$). This measure may have been insensitive because of the potential for interference among different medications. It is also possible that using the external aid reduced elaborate encoding of, and thus later memory for, information because cognitive effort was offloaded to the environment. Future studies should explore cognitive costs as well as benefits of external aids by including the no-aid condition and eliminating possible interference from multiple schedules.

Analyses of external aid strategies. Participants again consistently used paper to support problem solving. They organized information into lists by medication name rather than by times (69% of pairs, $p < .05$, $N = 32$), and for each medication they wrote times to take it. Those who created time-based schedules were as likely to embed notes in the schedule as to segregate them (64% embedded notes, $p > .10$, $N = 11$).

Participants also consistently used the medtable and were more likely to take advantage of its organization than in Experiment 1. All patients wrote down medication names for each row of the table, under the Medication column, and included special instructions in the notes section next to the name (this strategy was more frequent than in Experiment 1: $\chi^2 = 4.6$, $p < .05$). All patients used the timeline that organized the table columns by writing times of daily events such as meals in the available space (again, this strategy was more frequent than in Experiment 1: $\chi^2 = 4.6$, $p < .05$). Finally, most patients wrote the number of pills (dose) in the table cells (84%, $p < .01$), rather than writing medication names or times as they did in Experiment 1, suggesting they better understood how to use the medtable.

General Discussion

Older adults who used external aids created more accurate medication schedules in a simulated provider/patient collaborative problem-solving task. While problem solving in Experiment 1 was more accurate and efficient when partners used an aid compared to when they only shared information verbally, there was no evidence that the medtable was more effective than an unstructured aid (blank paper). In Experiment 2, a redesigned medtable that more clearly represented task-relevant constraints (relationships between medication and patients' daily routine information) supported more accurate and efficient collaborative problem-solving compared to the unstructured aid.

External Aids and Collaborative Problem Solving

The external aids may have reduced problem-solving demands on working memory. They were used as a notepad to write down information such as medication names and times and then referenced while developing the schedules, so that problem solving was limited more by perceptual access (from the aid) than by memory retrieval. Similar benefits of external aids for problem-solving have been found for younger and older adults (Morrow & Rogers, 2008).

Our findings can be explained by distributed cognition theories that view performance as emerging from interacting internal and external task components, with people managing demands on limited cognitive resources by using external representations (Hutchins, 1995; Zhang & Norman, 1994). A key insight of this approach is that successful performance hinges on how easily internal and external components are coordinated to accomplish task goals. External aids should be more effective to the extent they clearly represent task-relevant constraints. The medtable's organization (explicitly mapping medications in rows onto daily event times in columns) externalized relationships between multiple information sources, reducing the need to store, manipulate, and access this information from working memory. Because these processes are age-sensitive (Bopp & Verhaeghen, 2007), the medtable may have provided environmental support for older adults' problem solving.

The medtable may have supported collaborative as well as individual problem-solving processes. External aid benefits have been found for collaborative as well as individual problem solving (Heiser, Tversky, & Siverman, 2004) and learning (Fischer & Mandl, 2005), although these studies did not investigate the health care domain. By providing a shared workspace, the aids in our study may have supported processes such as jointly attending to information as well as proposing and critiquing schedules. The medtable may have been most effective because it represented task-relevant constraints that support management of joint attention critical to collaboration (Schwartz, 1995).

Implications for Health Care Practice: Study Limitations and Future Research

There are some constraints on our ability to generalize these findings to clinical practice. First, participants were not actual patients and providers. Nurses or pharmacists might make better use of the aids because of medication knowledge. However, while practitioners often rely on external aids such as white boards to support many tasks (Nemeth et al., 2004), there is little evidence that they systematically use such aids to foster the patient/provider partnership essential for patient self-care and safety (Schwartzberg, Cowett, VanGeest, & Wolf, 2007). Because the medtable is designed to integrate information given by both providers (e.g., about medications) and by patients (e.g., about daily routine), it may help bridge the gulf between divergent conceptions providers and patients bring to clinical encounters (Patel, Arocha, & Kushniruk, 2002).

Second, communication barriers in the current health system, such as limited time with patients, may also preclude routine use of the medtable. Such tools may be most suitable for pharmacists or nurses who help chronically ill older adults manage complex medication regimens. This suggestion is consistent with our finding that aid-related benefits primarily occurred for the complex schedule problems. The medtable may also be appropriate for other situations where time is less of a barrier, such as nurses or caretakers working with older patients at home.

Finally, the medtable may be most effective if implemented electronically, which would be more flexible (e.g., tailoring to diverse patients) and expedite processes such as updating comprehensive medication lists. Electronic collaborative aids might also help mitigate problems associated with using electronic medical records during office visits, such as one-sided communication (Patel et al., 2002). However, it would be important for patients to take home a copy of their medtable schedule to guide adherence. We are now investigating the use of the medtable by pharmacy and nurse providers working with patients with low health literacy in clinical settings. Eventually, we will test whether collaborative use of the medtable improves older adults' health behaviors and outcomes.

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Appendix

Example of Medication Information Given to Provider Participants for Complex Medication Problems

1. Quinoxin (lowers cholesterol):
   - Special instructions:
     - Take medication on an empty stomach (at least 1 hour before or 2 hours after a meal).
     - Do NOT take any other medication within 1 hour.
   - Dose:
     - Take 1 pill twice a day. Space doses by at least 8 hours.
2. Fosavin (prevents osteoporosis):
   - Special instructions:
     - Do NOT eat for 30 minutes afterwards.
     - Do NOT lie down up to 1 hour afterwards.
   - Dose:
     - Take 1 pill twice a day. Space doses by at least 8 hours.
3. Spirotar (reduces water retention):
   - Special instructions:
     - Take with food.
     - Do not take medication within 4 hours of bedtime.
   - Dose:
     - Take 1 pill twice a day. Space doses by at least 8 hours.
4. Zanoxin (antibiotic):
   - Special instructions:
     - Take medication with a full (8 oz.) glass of water.
   - Dose:
     - Take 2 pill twice a day. Space doses by at least 8 hours.

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