Icons Improve Older and Younger Adults’ Comprehension of Medication Information

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We examined whether timeline icons improved older and younger adults’ comprehension of medication information. In Experiment 1, comprehension of instructions with the icon (icon/text format) and without the icon (text-only format) was assessed by questions about information that was (a) implicit in the text but depicted explicitly by the icon (total dose in a 24 hour period), (b) stated and depicted in the icon/text condition (medication dose and times), and (c) stated but not depicted by the icon (e.g., side effects). In a separate task, participants also recalled medication instructions (with or without the icon) after a study period. We found that questions about dose and time information were answered more quickly and accurately when the icon was present in the instructions. Notably, icon benefits were greater for information that was implicit rather than stated in the text. This finding suggests that icons can improve older and younger adults’ comprehension by reducing the need to draw some inferences. The icon also reduced effective study time (study time per item recalled). In Experiment 2, icon benefits did not occur for a less integrated version of the timeline icon that, like the text, required participants to integrate dose and time information in order to identify the total daily dose. The integrated version of the icon again improved comprehension, as in Experiment 1, as well as drawing inferences from memory. These findings show that integrated timeline icons improved comprehension primarily by aiding the integration of dose and time information. These findings are discussed in terms of a situation model approach to comprehension.
White Pills

Identifying your medicine
1. Name of doctor:
   Your doctor is Dr. Farley. You can call Dr. Farley at (603) 436-2200.

2. Name of medicine:
   The name of your medicine is White Pills.

3. Purpose of medicine:
   Your White Pills are for relief of symptoms from seasonal allergies.

How to take your medicine
4. Dose:
   Take two pills each time.

5. Time to take medicine:
   Take the White Pills four times each day. You should take your medicine
   at 8 a.m. in the morning, 12 noon, 4 p.m. in the afternoon, and 8 p.m. in
   the evening.

6. How long to take medicine:
   Take your White Pills for two weeks.

7. Warnings:
   Take with a full glass of water. If you miss a dose, take immediately upon
   remembering.

Possible side effects
8. Mild side effects:
   Continue to take your medicine even if you experience an increase in
   appetite or feel weak. Consult your doctor only if these symptoms persist.

9. Dangerous side effects:
   Stop taking the White Pills and call Dr. Farley if you experience heart
   palpitations or perspire excessively.

10. In case of emergency, use your telephone and dial 911.

Figure 1. Example of expanded instructions with integrated icon (Experiment 1).

depicted (conveyed by the icon) and stated (conveyed by text) whereas other information (e.g., side effects) is only
provided in the instructions. Note that the icon also depicts
the total daily dose (the number of pills taken in a 24-hour
period), whereas this information is implicit in the text and
must be inferred by combining dose (“take two pills”) and
time (“take four times a day”) information. Morrow, Leirer,
and Andrassy (1996) found that dose and time information
was interpreted more accurately when conveyed by this
timeline than when conveyed by two versions of a clock
icon. Moreover, the timeline was interpreted as accurately
as a text schedule, although the text was recalled better.
However, this study did not examine possible benefits of
combining text and icon formats or the influence of the
timeline on inferential processes. We investigated two pos-
sible explanations for why icons may improve comprehen-
sion of medication information.

**Situation models and instruction comprehension.**—First,
icons may help the reader create a situation model (or men-
tal model) of the described task (e.g., Glenberg & Langston,
1992). Situation models represent what the text is about and
can be distinguished from a representation of the text itself
(van Dijk & Kintsch, 1983). Thus, this type of representa-
tion is critical to linking instructions to the context of the
task. Creating a situation model involves integrating infor-
information from the instruction with knowledge about the task, which often requires drawing inferences. Icons may facilitate integration because, relative to text formats, they are more compatible with how people represent information such as quantity (e.g., medication dose) and time or sequence (e.g., medication-taking times; Glenberg & Langston, 1992). Icons may facilitate inferential processing in particular because they are often more explicit than text, reducing the need for making inferences (e.g., Larkin & Simon, 1987). Thus, icons may reduce the demands of instruction comprehension on working memory.

We examined whether the timeline improved inferences about the total daily dose. Such inferences are involved in loading a daily or weekly pill organizer, determining how many pills to take when away from home, and in other aspects of medication adherence. The timeline should facilitate such inferences because it conveys the total dose explicitly whereas this information is only implicit in the text. By directly or perceptually integrating dose and time information, the icon may aid the mental integration required by the inference (Wickens & Carswell, 1995). This prediction was tested in both experiments of this study.

If the timeline improves comprehension by integrating dose and time information, then these benefits should be reduced if the icon is changed so that, like the text, it does not integrate dose and time information. Experiment 2 compared the icon in Figure 1 (the integrated timeline) to a less integrated version of the same icon (the nonintegrated timeline, see Figure 2). The nonintegrated timeline indicated the dose separately from the medication times, so that participants would have to integrate dose and time information mentally in order to identify the total daily dose. The situation model account predicts that the integrated icon should be more effective than either the nonintegrated icon or the text-only conditions, because the model is easier to construct when the icon reduces the amount of integration required to identify dose and time information.

The situation model account predicts that icons will facilitate comprehension of depicted information that is stated in the text as well as depicted information that is implicit in the text because icons attract attention (e.g., Glenberg & Langston, 1992). Thus, dose and time information may be understood more quickly and accurately when it is both depicted and stated in the instructions compared to when it is only stated (text-only instructions). However, information in the instruction that is unrelated to the icon (e.g., side effects) should not be facilitated by the icon. Previous studies have found selective effects of pictures in illustrated text (Glenberg & Langston, 1992; Waddill & McDaniel, 1992).

Repetition and instruction comprehension.—Repetition provides a second explanation for icon benefits in instructions. The timeline may improve comprehension simply by repeating information already stated in the instructions. Repetition generally improves memory for verbal information (for a review, see Crowder, 1976). A related explanation is dual coding theory, which predicts better memory for combined format instructions because pictures and text are coded separately in memory, thereby benefitting retrieval (Paivio, 1971). The repetition and situation model explanations predict benefits for information that is both depicted and stated but not for information that is only stated in the icon/text instructions (compared to the text-only condition). However, unlike the situation model approach, the repetition account does not predict greater benefits of icons for implicit compared to stated information. The repetition explanation also predicts that the integrated and nonintegrated versions of the timeline icon will improve comprehension to the same extent because the dose and time information is repeated (presented pictorially as well as verbally) in both cases.

Aging and Icon Benefits

The timeline may reduce age differences in comprehension. In general, older adults should have more trouble understanding instructions because of age-related decrements in working memory capacity or speed of processing (Saltzhouse, 1991), particularly when comprehension requires them to draw inferences (e.g., Cohen, 1979). According to the environmental support hypothesis (Craik & Jennings, 1992), external supports that reduce comprehension demands on limited cognitive resources should reduce age differences in performance. The timeline may serve as an environmental support by simplifying the process of creating a situation model from medication instructions (e.g., by
facilitating inferences). There is some evidence that pictures provide such support: Age differences in recognition memory are reduced for meaningful pictures (Park, Smith, Morrell, Puglisi, & Dudley, 1990). Therefore, the timeline may reduce age differences in understanding or remembering medication information.

On the other hand, adding icons to instructions may also penalize older adults if additional resources are required to identify referential links between the icon and text formats (Mayer & Sims, 1994). Morrell et al. (1990) found that adding icons to medication labels reduced older adults’ recall, perhaps because the older participants had greater difficulty than younger participants with integrating the verbal and nonverbal information, or translating from nonverbal to verbal formats during encoding or retrieval of the instructions. The nonintegrated timeline in Experiment 2 may penalize older adults to a greater extent than it does younger adults if it increases integration demands compared to the integrated icon.

To summarize, we investigated whether icons improved older and younger adults’ comprehension and recall of medication instructions. The situation model account predicts greater icon benefits for depicted information that is implicit rather than stated in the text and no facilitation of nondepicted information. Moreover, icon benefits are expected to be less likely to occur for the nonintegrated icon in Experiment 2, which requires participants to integrate information in order to identify the daily dose. The repetition explanation also predicts selective benefits (facilitation only for depicted information), but does not predict greater benefits for inferred information than for information stated in the text, or greater benefits for the integrated icon than for the nonintegrated icon. Also, the integrated timeline may provide environmental support that reduces age differences in comprehension, especially when participants are required to make inferences. This should not be the case for the nonintegrated timeline.

EXPERIMENT 1

Experiment 1 examined whether the timeline icon improved comprehension of and recall for depicted information that was either implicit or stated in the text. Comprehension was measured by a search task that has been used to investigate the influence of verbal formats on instruction comprehension (Morrow et al., in press). In this task, the participant is asked questions about the medication and the time he or she requires to find the answer in the instruction is measured. Instruction recall was measured in a separate task after unlimited study time. Recall was also analyzed as a function of study time by computing a measure of “effective study time,” or the amount of study time required per recalled item.

Experiment 1 also investigated more general issues related to aging and instruction recall. Age differences in recalling expanded instructions have been found when study time is restricted (e.g., Morrow, Leirer, Andrassy, Tanke, et al., 1996). In the present study, more time was allowed for studying the instructions. Age differences in recall should be reduced if older adults take advantage of the additional time in order to encode the information more elaborately.

However, Morrell, Park, and Poon (1989, 1990) have found that unlimited study time does not reduce age differences in recalling medication instructions, suggesting an age-related decline in the ability to monitor comprehension. We also examined the influence of both verbal abilities (measured by a vocabulary test) and spatial abilities (such as visualization or mental rotation) on age differences in recall of medication information because comprehension of instructions with both text and icon formats may draw upon both types of abilities (Baddeley, 1986; Morrell & Park, 1993). More specifically, spatial abilities may be involved in interpreting the timeline icon because medication information is spatially coded (e.g., medication times are coded by position of marks on the timeline).

Method

Participants

Thirty-six older adults (19 men and 17 women) and 36 younger adults (13 men and 23 women) participated. Older adults (mean age = 72.4, range 64–90 years) were recruited from local senior centers and community organizations. The younger adults (mean age = 22.3, range 20–30 years) were college students. Both the older (O) and younger (Y) groups rated themselves as moderately healthy (7-point scale with 1 = very poor health and 7 = excellent health; O = 5.4, Y = 5.5, t(70) < 1.0. Older participants had completed more years of education (O = 16.7, Y = 14.8), t(70) = 3.5, p < .05.

Verbal ability was measured by the Advanced Vocabulary Test from the Kit of Factor-Referenced Cognitive Tests (Ekstrom, French, Harman, & Dermen, 1976). This 8-minute test contains 36 items, each of which requires the participant to choose one of five words as most similar in meaning to a standard. Spatial abilities such as visualization were measured by the Object Rotation subscale from the Schae-Thurstone Adult Mental Abilities Test (Schae, 1985). This 5-minute test consists of 20 items; each item contains a drawing of a standard object and 6 rotated copies of the object, some of which are mirror images of the standard. Participants choose alternatives that are not mirror-reversed versions of the standard. Older participants scored higher on the Vocabulary (Voc) test (O = 26.8, Y = 16.4), t(68) = 8.6, p < .001, but lower on the Object Rotation (OR) test (O = 24.4, Y = 33.7), t(68) = 3.1, p < .01. This pattern of age differences is typical of research on aging and text processing.

Medication Instructions and Study Design

Eight instructions (with arbitrary names such as “White Pills”) were created, each describing how to take medications for infection, allergies, influenza, migraine, heart disease, cholesterol, depression, or blood pressure (two instructions were for the Search task and six for the Recall task described in the Procedure section that follows). The instructions were based on information selected from the Physician’s Desk Reference manual (1993; Medical Economics Data, Montvale, NJ). Each instruction was presented in two versions, one with the timeline (icon/text condition) and one without the icon (text-only condition). The
content and organization of the text was identical in both versions and was based on our previous research (Morrow, Leirer, Andrassy, Tanke, et al., 1996; Morrow et al., in press). Figure 1 shows that 10 types of medication information were grouped into 3 categories: "Identifying your medicine" (name and purpose), "How to take your medicine" (e.g., dose, time, warnings), and "Possible side effects" (outcomes).

In the icon/text condition, the instructions contained a timeline icon that depicted medication dose and time, as shown in Figure 1. The timeline was placed just below the corresponding text. Pretesting showed that older adults preferred this arrangement to a version in which the icon occurred below all of the text so that it would not disrupt text coherence. This embedded icon arrangement is consistent with research showing that illustrations should be placed next to relevant text (e.g., Mayer & Sims, 1994).

We also manipulated the complexity of the medication schedule in the instructions. Although complexity can be defined in different ways (see Park & Jones, 1997), in our study it was defined as the total number of pills per day for a single medication (i.e., the total dose). Complexity was examined because more complex schedules (either more medications or more complex schedules per medication) are sometimes associated with reduced memory for medication information (e.g., Morrell et al., 1989) and more adherence errors (see Park & Jones, 1997, for a review). Complexity was manipulated between participants: For half of the participants, the total dose in the icon/text condition was two (take one pill twice a day) while the total dose in the text-only condition was eight (take two pills four times a day). The combination of schedule complexity and instruction type was counterbalanced across participants in each age group.

Procedure
The study lasted about 2 hours and consisted of an instruction comprehension task, an instruction recall task, and several cognitive ability tasks. The experiment began with a 2-minute session that familiarized participants with the timeline. After the experimenter explained how to interpret the icon, participants were given a new timeline and were asked to paraphrase the depicted time and dose information. Next, they were each given two blank timelines and asked to fill in dose and time information as provided by the experimenter. All participants were able to use the timeline correctly. Next, participants performed the two medication instruction tasks.

Instruction comprehension.—Ease of understanding the instructions was measured by the search task (Morrow et al., in press). Participants performed this task for two expanded instructions, one with and one without the timeline icon (the order of the format conditions was counterbalanced across participants). For each instruction, participants had 15 seconds to look over the information and then, with the instructions still in front of them, they answered nine questions about information stated in the instruction (e.g., "What is the medicine used for?" and "At what times do you take the medicine?"). In addition, an inference question was asked about the total dose in a 24-hour period, which required participants to integrate dose and time information in the text-only condition. Question order was randomly determined with one exception: The inference question was presented before the direct questions about dose and time, so that answering the direct questions would not activate the information needed for the inference. Participants were told to answer the questions as quickly and accurately as possible, and their answers were taped for later analysis. Participants first practiced the search task procedure, but not the specific formats, by answering questions about a magazine's table of contents.

Instruction recall.—In this task, participants studied two sets of three expanded instructions each for later recall. All three instructions were from the same format condition (the order of format conditions was counterbalanced across participants). Participants were told to study the three instructions so that they could remember information about taking the medication in their own words. They were given a maximum of 10 minutes to study the instructions (42% of older and 39% of younger participants used the maximum time for the icon/text condition; 39% of participants in both groups used the maximum time for the text-only condition). After studying the three instructions, participants completed a 2-minute distractor task and then recalled the three instructions (each instruction was cued with the medication name).

Between the two study-recall trials, participants completed the Vocabulary test (Ekstrom et al., 1976), and the Object Rotation test (Schaie, 1985). Finally, preferences were measured by asking participants which version of the instruction (with or without the icon) was easier to understand, which did the better job of explaining how to take the medication, and which they would prefer to receive from their pharmacists.

Results
Inference Accuracy
To investigate icon effects on how participants drew inferences, data from the question about the total daily dose (which required an inference in the text-only condition) were compared to questions about dose and time information stated in the text. Thus, only depicted information was investigated in this analysis. Accuracy (percent of correctly answered questions) was analyzed by an Age (older or younger) × Format (icon/text or text-only) × Question type (total daily dose, which is implicit in the text condition, or stated dose and time information) analysis of variance (ANOVA), with the latter two factors repeated measures.

Table 1 shows that questions were answered more accurately when the icon was present, F(1,70) = 4.3, p < .05, MSe = .05. Accuracy was also higher for questions about directly stated rather than implicit information, F(1,70) = 7.7, p < .001, MSe = .08. Although the Format × Question type interaction did not reach significance, F(1,70) = 3.2, p < .08, MSe = .04, planned comparisons (p < .05) showed that the icon improved accuracy for inference but not for direct questions. This suggests that icon benefits were greater.
Table 1. Mean Accuracy (% Correct) and Answer Time (sec) for Questions About Stated* and Implicit Dose/Time Information (Experiment 1)

<table>
<thead>
<tr>
<th>Icon/Text Format</th>
<th>Text-Only Format</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Answer Accuracy</strong></td>
<td></td>
</tr>
<tr>
<td>Older</td>
<td>100.0 (0.0)</td>
</tr>
<tr>
<td>Younger</td>
<td>100.0 (0.0)</td>
</tr>
<tr>
<td>Mean</td>
<td>100.0</td>
</tr>
<tr>
<td><strong>Answer Time</strong></td>
<td></td>
</tr>
<tr>
<td>Older</td>
<td>1.1 (0.8)</td>
</tr>
<tr>
<td>Younger</td>
<td>1.0 (0.4)</td>
</tr>
<tr>
<td>Mean</td>
<td>1.1</td>
</tr>
</tbody>
</table>

*Mean of questions about medication dose and time stated in instructions.

Table 2. Mean Accuracy (% Correct) for Questions About Stated* and Implicit Dose/Time Information by Format and Schedule Complexity (Experiment 1)

<table>
<thead>
<tr>
<th>Format</th>
<th>Low Complexity</th>
<th>High Complexity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Direct</td>
<td>Inference</td>
</tr>
<tr>
<td>Icon/Text</td>
<td>100.0 (0.0)</td>
<td>89.8 (31.9)</td>
</tr>
<tr>
<td>Text-only</td>
<td>98.6 (8.3)</td>
<td>91.7 (28.0)</td>
</tr>
</tbody>
</table>

*Mean of questions about medication dose and time stated in instructions.

Accuracy and Answer Time for Directly Stated Information

The accuracy of identifying information that was stated in the instruction was analyzed by an Age \( \times \) Format (icon/text or text-only) \( \times \) Information type (depicted [dose/time] or other information [e.g., side effects] in the icon/text instructions) ANOVA, with the latter two factors repeated measures. These analyses excluded the inference question. An effect of Information type was not interesting in itself because the depicted and other information varied on several dimensions (e.g., sentence length, word frequency), but the Information type \( \times \) Format interaction tested whether icon benefits were selective. The timeline improved comprehension accuracy for information stated in the text; questions about icon/text instructions were answered more accurately than questions about text-only instructions (99.5% vs 98.5% items correct), \( F(1,70) = 4.7, p < .05, MSe = .002 \). The Format \( \times \) Information type interaction was not significant, probably because of ceiling effects on the accuracy measure (Depicted: icon/text = 100%, text-only = 98%; Other information: icon/text = 99%, text-only = 98%), \( F(1,70) < 1.0, MSe = .003 \). Age effects were not significant.

Answer time for information stated in the text was analyzed the same way as accuracy. Times greater than three standard deviations above the mean for each participant were replaced by the mean for that condition (1.9% of responses for older participants and 2.3% of responses for younger participants). Times for incorrect answers were excluded.

The icon reduced answer time for depicted information for questions requiring participants to integrate dose and time information than for questions that simply required identifying this information (but icon benefits on directly stated information may have been limited by ceiling effects). Age did not influence accuracy and did not interact with the instruction or question variables.

We also examined whether making inferences was more difficult for participants faced with more complex medication schedules (total dose = eight vs two pills per day) in the icon/text and text-only conditions. Accuracy and answer time were analyzed by an Age \( \times \) Complexity \( \times \) Format \( \times \) Question type ANOVA, with the latter two variables repeated measures. Only the accuracy results are presented in this article, because complexity did not influence answer time. Our most important finding is that more complex schedules increased inference errors for text-only but not for icon/text instructions, Format \( \times \) Inference \( \times \) Complexity interaction \( F(1,68) = 4.5, p < .05, MSe = .04 \); see Table 2.

Inference Answer Time

Answer time was defined as the interval between the offset of the question and the beginning of the answer, and was measured blind to condition. Times for incorrect answers were excluded. Table 1 shows that questions were answered more quickly when the icon was present in the instructions, \( F(1,53) = 11.9, p < .01, MSe = 11.2 \), and for questions about direct rather than implicit dose/time information, \( F(1,53) = 99.8, p < .001, MSe = 8.4 \) (see Appendix, Note 1). Most important, the time required to answer the implicit questions was reduced when the icon was present in the instruction, Format \( \times \) Question type interaction \( F(1,53) = 9.8, p < .01, MSe = 9.8 \), again suggesting that icon benefits were greater for questions requiring participants to integrate dose and time information.

Older adults answered questions more slowly than younger participants did, \( F(1,53) = 12.3, p < .001, MSe = 9.7 \), and this age difference was greater for implicit than for direct questions, Age \( \times \) Question interaction \( F(1,53) = 10.3, p < .01, MSe = 8.4 \). However, the Age \( \times \) Question \( \times \) Format interaction was not significant, \( F(1,53) < 1.0 \), suggesting that the icon benefitted older as well as younger adults' abilities to draw inferences.
(icon/text format = 1.2 sec, text-only format = 1.6 sec) but not for other information (2.3 sec for both conditions), Format × Information type interaction \(F(1,70) = 4.7, p < .05, MSe = .48\). Selective icon benefits were similar for older and younger participants, Age × Format × Information type interaction \(F(1,70) < 1.0\). The main effects of Format, \(F(1,70) = 2.3, p > .10, MSe = .79\), and Age (O = 2.0 sec, Y = 1.7 sec), \(F(1,70) = 3.3, p < .08, MSe = 1.9\), were not significant. Depicted information was identified more quickly than other information in both format conditions, \(F(1,70) = 92.2, p < .001, MSe = .70\). This probably reflects the fact that dose and time information was easier to understand than the other information in the instruction (e.g., warnings, side effects) even when it was not depicted (in the text-only condition) because these items contained fewer (and higher frequency) words.

Instruction Study Time and Recall

Instruction study time was analyzed by an Age × Format ANOVA. Older and younger participants did not differ in overall study time (O = 7.8 min, Y = 8.0 min), \(F(1,70) < 1.0, MSe = 8.8\). However, older but not younger participants studied the instructions for a longer time when the icon was present (O: icon/text = 8.3 min, text = 7.2 min; Y = 8.0 min in both conditions), Age × Format interaction \(F(1,70) = 5.8, p < .05\).

To investigate recall after the study period, the mean proportion of items recalled from the three instructions for each participant was analyzed by an Age × Format × Information type ANOVA, with the latter two factors repeated measures. Younger participants recalled the instructions more accurately (Y = 59% vs O = 41% items recalled), \(F(1,70) = 21.1, p < .001, MSe = .11\). The effect of Format was only marginally significant (icon/text = 52% vs text-only = 48% items recalled), \(F(1,70) = 3.7, p < .06, MSe = .03\). The influence of Information Type was significant (Depicted = 68% vs Nondepicted = 32%), \(F(1,70) = 264.0, p < .001, MSe = .04\). However, unlike the comprehension time findings, the Format × Information type interaction was not significant for recall, \(F(1,70) = 2.0, p > .10\).

Because study time differed for the instruction format conditions, we analyzed recall as a function of study time. We examined the time participants required to encode information effectively from the instructions by dividing total study time by the amount of dose and time information that was recalled. Stine and Hindman (1994) used a similar "effective study time" measure to analyze age differences in reading time and recall. Consistent with the cognitive slowing hypothesis (Salthouse, 1991), older participants in our study needed more time than younger adults did to recall an equivalent amount of information (O = 2.3 min vs Y = 1.3 min per item recalled), \(F(1,70) = 12.2, p < .001, MSe = 26.2\). Notably, less study time was needed to recall information when the icon was present (icon/text = 1.5 vs text-only = 2.1 min per item), \(F(1,70) = 4.3, p < .05, MSe = 20.9\), suggesting that study time was more effective when the icon was present. The Age × Format interaction was not significant, \(F(1,70) < 1.0\). This finding suggests that by taking more time to study instructions with icons, both older and younger participants were better able to recall these instructions compared to text-only instructions. Converging evidence is provided by the finding that study time was correlated with icon instruction recall for older (\(r = .40, p < .05\)) but not younger participants (\(r = .18, p > .10\)). Study time did not predict text-only recall for either age group (O: \(r = .26, Y: r = .19\)).

Individual Differences in Instruction Recall

We examined whether cognitive ability and age predicted recall of icon/text and text-only instructions. In a hierarchical regression analysis, cognitive ability (OR and Voc) scores were entered as a block before age, because age differences occurred for these variables (see Table 3). Cognitive ability scores accounted for a significant amount of variability in icon/text instruction recall \(R^2 = .09\), \(F(2,65) = 3.3, p < .05\). Participants with higher OR scores recalled these instructions more accurately, \(r = 2.1, p < .05\), suggesting that adults with greater spatial abilities processed the instructions with the icon more effectively. Age also predicted recall \(R^2 = .07\), \(F(1,66) = 4.6, p < .05\), although age accounted for less variance than when it was entered first in the equation \(R^2 = .10\). This suggests that the influence of age was due at least in part to age differences in cognitive ability. The analysis of recall for the text-only instructions showed that no variable accounted for a significant amount of variability in the recall scores.

Preferences for Medication Instructions

Almost all of the participants preferred the instructions with the icon. They thought that this instruction was easier to understand (O = 97%, Y = 94%), that it did the best job of telling them how to take the pills (O = 100%, Y = 97%), and that they would most like to receive this type of instruction from their pharmacists (O = 97%, Y = 92%). Participants cited the following reasons for their preferences: The icon enables people to quickly understand key information (15%); it is best suited for visual learners (13%); and it is appropriate for people with lower verbal abilities (3%).

Discussion

Adding timeline icons to expanded instructions improved comprehension of medication information. These benefits were greater for information about the total daily dose, instructions compared to text-only instructions. Converging evidence is provided by the finding that study time was correlated with icon instruction recall for older (\(r = .40, p < .05\)) but not younger participants (\(r = .18, p > .10\)). Study time did not predict text-only recall for either age group (O: \(r = .26, Y: r = .19\)).

Table 3. First-Order Correlations Among Participant Age
(0 = Younger, 1 = Older), Vocabulary Test Scores (Voc), Object Rotation Test Scores (OR), and Recall and Study Time for Icon/Text and Text-Only Instructions (Experiment 1)

<table>
<thead>
<tr>
<th>Age</th>
<th>Voc</th>
<th>Voc OR</th>
<th>Voc Icon</th>
<th>Voc Text</th>
<th>Icon Study</th>
<th>Icon Text</th>
<th>Text Study</th>
<th>Text Icon</th>
</tr>
</thead>
<tbody>
<tr>
<td>.72***</td>
<td>-.35**</td>
<td>-.47***</td>
<td>.06</td>
<td>-.30**</td>
<td>-14</td>
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<td>.70***</td>
<td>.26*</td>
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<td></td>
</tr>
</tbody>
</table>

*\(p < .05\); **\(p < .01\); ***\(p < .001\).
which was conveyed explicitly by the icons but only implied by the text instructions, than for information that was stated as well as depicted. Moreover, increasing the complexity of the medication schedule increased inference errors for text-only instructions but not for instructions with icons. Participants also identified information more quickly and accurately from instructions with icons, and this benefit occurred primarily for depicted information in the icon/text instructions. The icons also improved effective study time, reducing the study time needed to recall dose and time information. However, the influence of the icons was less clear cut for the memory than for the comprehension measures.

Although older adults in Experiment 1 answered questions more slowly and recalled the instructions less accurately, they benefited as much as younger adults from the timeline icons. They did not, however, take advantage of study time in order to recall the instructions as accurately as younger participants did. They spent about the same amount of time as younger participants studying the text-only instructions, yet recalled less information. These results, as well as similar findings by Morrell, Park, and Poon (1989, 1990), suggest that older adults do not monitor their comprehension processes accurately enough to adjust study time when given the opportunity. They may benefit from more explicit guidelines about what information to study and how much time to devote to it (Park, 1992). Indeed, the finding that older participants in our study spent more time studying instructions when the icon was present provides some evidence that older adults can adjust study strategies in response to external support.

The finding that the timeline especially improved the ability to identify information that was implied rather than stated in the text supports the situation model rather than the repetition explanation of icon benefits in instructions. However, the critical inference effects occurred primarily for comprehension time rather than for comprehension accuracy or for recall. This experiment also did not directly investigate which aspects of the timeline improved comprehension. Experiment 2 addressed both issues.

**EXPERIMENT 2**

In this experiment, we focused to a greater extent on the process of making inferences by including more inference questions and by including them in both the memory and comprehension tasks. Thus, the recall and comprehension measures should both provide clearer evidence for the benefit of a well-designed timeline icon in the processing of medication information.

We also wanted to provide more direct evidence that the timeline icon facilitates the inference process by reducing the need for mental integration of dose and time information. To do this, the timeline from Experiment 1 (the integrated timeline) was compared to a similar timeline that conveyed the dose and time information in a less integrated manner; that is, the dose information was indicated by a box separate from the timeline (for the nonintegrated timeline, see Figure 2). Comparing the two timelines allowed us to address several issues. First, the comparison helped pinpoint which aspects of the icon improve comprehension. If the timeline in Experiment 1 improved participants’ performances by directly integrating time and dose information, then the nonintegrated timeline in Experiment 2 should be less effective because, like the text-only instructions, this version of the icon requires mental integration to identify the total daily dose. Indeed, the nonintegrated timeline may be no better than the text-only condition. Older adults may find the nonintegrated timeline especially problematic if it increases overall comprehension demands on working memory compared to the other conditions. For example, they may have to integrate dose and time information mentally in order to interpret the nonintegrated timeline, and then combine this information with other information provided only by the text.

Second, comparing the two timeline icons provides an additional test of the possible explanations for icon benefits. The repetition hypothesis predicts that the two timelines should improve comprehension to the same extent because they both repeat the dose and time information stated in the text. The situation model account, on the other hand, predicts that the integrated icon should be more effective because it reduces the mental integration required to create a mental representation of the medication-taking task.

Third, the nonintegrated timeline addresses the possibility that the icon benefits in Experiment 1 were due to pretraining on the icon, which might provide an advantage over the text-only condition. If pretraining, rather than the icon itself, improved comprehension, then the two icons should improve comprehension to the same extent in Experiment 2, because participants were familiarized with both timelines before the study.

Finally, Experiment 2 expanded the individual difference measures of cognitive ability. Experiment 1 found that OR scores predicted memory for icon/text instructions. This relationship may reflect differences in processing speed, working memory capacity, or spatial ability because the OR task was timed. We therefore included a sentence span task, which measures the ability to simultaneously store and manipulate verbal information in working memory (Stine & Hindman, 1994). If differences in working memory capacity as well as spatial ability are involved in processing the icon/text instructions, then sentence span scores may be as important as OR scores (or more so) for predicting recall. An earlier study found that older and younger adults’ performances on a map learning task were better predicted by this sentence span task than by a measure of visualization (Morrow, Stine-Morrow, Leirer, Andrassy, & Kahn, 1997).

**Method**

**Participants**

Forty-five older adults (15 men and 30 women) and 36 younger adults (16 men and 19 women) participated. Older participants (mean age = 71.2, range 59–92 years) were recruited from local senior centers and community organizations. The younger participants (mean age = 18.6, range 18–21 years) were college students. Older and younger participants did not differ in self-reported health (O = 5.5, Y = 5.6), t(79) < 1.0. Older participants had completed more years of education (O = 16.1, Y = 12.4), t(79) = 9.1,
Experiment 1, except that participants answered five inference questions in addition to the nine questions about information (all ps > .10). Table 4 shows that the instruction that did the better job of explaining how to take the pills, and which they would prefer to receive from their pharmacists.

Results

Inference Accuracy

We investigated the influence of instruction format on the process of making inferences by comparing mean accuracy for the five questions about implicit dose and time information with accuracy for the two questions about stated dose and time information. Accuracy (percent correct answers) was analyzed by an Age × Format (integrated icon/text, nonintegrated icon/text, text-only) × Question type (questions about implicit or stated information) ANOVA, with the latter two factors repeated measures.

Instruction format influenced question accuracy, \( F(2,158) = 10.9, p < .001, MSE = .01 \). Table 4 shows that, as in Experiment 1, the integrated icon was more effective than the text-only condition, \( r(80) = 4.3, p < .001 \). It was also more effective than the nonintegrated icon, \( r(80) = 3.2, p < .001 \). The difference between the nonintegrated icon and the text-only conditions did not reach significance, \( r(80) = 1.8, p < .10 \). The Age × Format interaction approached significance, \( F(2,158) = 2.7, p < .10 \), but Table 4 shows that the integrated icon improved accuracy for both older and younger participants.

Icon benefits were greater for questions about implicit information than for questions about stated information, Format × Question type interaction \( F(2,158) = 8.6, p < .001, MSE = .02 \). The integrated icon improved inference accuracy compared to both the text-only condition, \( r(80) = 4.3, p < .001 \), and the nonintegrated icon condition, \( r(80) = 3.0, p < .001 \). However, differences between instruction conditions were not significant for questions about stated information (all ps > .10), reflecting ceiling effects on this measure. Questions about stated information were answered more accurately than implicit questions, \( F(1,79) = 77.4, p < .001, MSE = .02 \). Age did not influence accuracy and did not interact with the inference variable.
To examine if making inferences was more difficult for participants when faced with more complex medication schedules, the mean accuracy for questions about implicit information was analyzed by an Age × Complexity (2,6,8 pills per day) × Format (integrated icon, nonintegrated icon, and text-only) ANOVA, with the latter two variables as repeated measures (see Table 5). A Complexity × Format interaction, *F*(2,158) = 6.7, *p* < .01, *MSe* = .001, was analyzed by examining the influence of complexity for each instruction type. As in Experiment 1, errors tended to increase with complexity for text-only instructions, *F*(2,158) = 2.7, *p* < .10, *MSe* = .01, with more errors for high rather than low complexity schedules (*p* < .05). A similar pattern occurred for the nonintegrated icon instructions, *F*(2,158) = 4.2, *p* < .05, with more errors for high than for low complexity schedules (*p* < .05). On the other hand, comprehension of the integrated icon was not influenced by complexity, *F*(2,158) = 2.3, *p* > .10, *MSe* = .01. Errors did not differ for high and low complexity schedules for this type of instruction (*p* > .10).

**Inference Answer Time**

Answer times greater than three standard deviations above the mean for each subject were replaced by the mean for that condition (0.4% of responses for older participants and 0.6% of responses for younger participants). Incorrect answers were excluded from the answer time analysis. The results for the answer time measure were similar to the accuracy measure. Answer time was influenced by instruction format, *F*(1,156) = 6.7, *p* < .01, *MSe* = 1.5 (see Table 6). Answer time was faster for integrated icon instructions than for text-only instructions, *t*(80) = 3.7, *p* < .01. There was also a nonsignificant trend for answer time to be faster for the integrated icon instructions than for nonintegrated icon instructions, *t*(80) = 1.9, *p* < .07.

The Instruction × Question type interaction was significant, *F*(2,156) = 5.5, *p* < .01, showing that the integrated icon primarily reduced answer time for implicit rather than stated information. Finally, answer time was slower for inference questions than for direct questions, *F*(1,78) = 177.0, *p* < .001, *MSe* = 1.9, and this slowdown was greater for older participants, Age × Question type, *F*(2,156) = 27.6, *p* < .001.

| Table 4. Mean Accuracy (% Correct) for Questions About Implicit and Stated Dose/Time Information (Experiment 2) |
|--------------------------|--------------------|-----------------|-----------------|-----------------|
|                          | Integrated Icon   | Nonintegrated Icon | Text-Only | Row Mean |
| **Inference Accuracy**   |                   |                  |               |             |
| Older                    | 92.0 (12.4)       | 86.7 (17.6)      | 84.9 (21.4)   | 87.9        |
| Younger                  | 97.8 (6.4)        | 91.7 (15.4)      | 81.1 (24.4)   | 90.2        |
| Mean                     | 94.9              | 89.2             | 83.0          |             |
| **Direct Accuracy**      |                   |                  |               |             |
| Older                    | 100.0 (0.0)       | 99.3 (5.0)       | 100.0 (0.0)   | 99.8        |
| Younger                  | 100.0 (0.0)       | 100.0 (0.0)      | 98.6 (8.3)    | 99.5        |
| Mean                     | 100.0             | 99.7             | 99.3          |             |

*Note: Values are means with standard deviations given in parentheses.*

| Table 5. Mean Accuracy (% Correct) for Implicit Dose/Time Questions by Format and Schedule Complexity (Experiment 2) |
|--------------------------|-------------------|------------------|---------------|
|                          | Low Complexity*   | Medium Complexity* | High Complexity* |
| **Format**               |                   |                  |               |
| Integrated Icon          | 94.1              | 97.8             | 91.9          |
| Nonintegrated Icon       | 94.8              | 82.2             | 89.6          |
| Text-only                | 91.1              | 77.8             | 80.7          |

*Two pills per day.*

*Six pills per day.*

*Eight pills per day.*

| Table 6. Mean Answer Time (in sec) for Implicit and Stated Dose/Time Questions (Experiment 2) |
|--------------------------|-------------------|------------------|---------------|
|                          | Integrated Icon   | Nonintegrated Icon | Text-Only | Row Mean |
| **Inference**            |                   |                  |               |             |
| Older                    | 2.8 (1.5)         | 3.4 (1.9)        | 4.0 (2.6)    | 5.1        |
| Younger                  | 1.7 (0.8)         | 2.2 (1.8)        | 2.4 (1.5)    | 3.2        |
| Mean                     | 2.3               | 2.8              | 3.2          |            |
| **Stated**               |                   |                  |               |             |
| Older                    | 1.1 (0.6)         | 1.0 (0.4)        | 1.1 (0.6)    | 1.1        |
| Younger                  | 1.0 (0.4)         | 1.1 (0.5)        | 1.2 (0.5)    | 1.1        |
| Mean                     | 1.1               | 1.1              | 1.2          |            |

*Note: Values are means with standard deviations given in parentheses.*

*Mean of questions about medication dose and time stated in instructions.*

**Accuracy and Answer Time for Stated Information**

Accuracy of answering questions about information that was stated in the instructions was analyzed by an Age × Format × Information type (depicted or other information in the icon/text instructions) ANOVA, with the latter two factors repeated measures. These analyses excluded questions about implicit information. Unlike Experiment 1, icons did not influence comprehension of stated information (integrated icon 97%, nonintegrated icon = 97%, text-only = 98%), *F*(2,158) < 1.0, *MSe* = .003. The Format × Information type interaction was not significant, *F*(2,158) = 1.5, *MSe* = .003, again reflecting ceiling effects for the measure. An effect of Information type showed that questions about depicted information were answered more accurately than questions about other information in the instructions (depicted = 99.5%, other = 95.3%), *F*(1,78) = 21.9, *MSe* = .01.

Answer time was analyzed in the same way as accuracy. Times greater than three standard deviations above the mean for each subject were replaced by the mean for that condition (0.2% of responses for both older and younger participants). Times for incorrect answers were excluded. Instruction format did not influence answer time for stated information (integrated icon = 1.7 sec, nonintegrated icon = 1.8 sec, text-only = 1.9 sec), *F*(2,158) < 1.0, *MSe* = .77. The Format × Information type interaction was not significant, *F*(2,158) = 1.2, *MSe* = .60. Questions about depicted information were answered more quickly than questions about other information (depicted = 1.1 sec vs other = 2.5 sec).
sec), \(F(1,78) = 333.2, MSe = .79\). This depiction effect was greater for older adults (O: depicted = 1.1 vs other = 2.7 sec; Y: depicted = 1.1 vs other = 2.4 sec). Age × Information type interaction \(F(1,78) = 5.2, p < .05\).

### Memory for Implicit Information

Memory for the instructions was measured by the percent of correct answers to questions after each instruction was studied. Mean accuracy for implicit questions and for questions about stated dose and time information was analyzed by an Age × Format × Question type ANOVA, with the latter two factors as repeated measures.

Instruction format influenced memory question accuracy, \(F(2,158) = 4.6, p < .05, MSe = .04\). Table 7 shows that the integrated icon improved memory for dose and time information compared to the text-only condition, \(t(80) = 2.5, p < .05\), and to the nonintegrated icon condition, \(t(80) = 3.1, p < .001\). The text-only and nonintegrated icon conditions did not differ, \(t(80) < 1.0\).

The influence of icons on instruction memory also depended on participant age, Age × Format interaction \(F(2,158) = 3.3, p < .05\). For younger participants, the integrated icon improved memory compared to the text-only condition, \(t(35) = 2.4, p < .05\). This difference was not significant for older participants, \(t(44) < 1.0\) (although the means were in the expected direction; see Table 7). The nonintegrated icon appeared to pose particular problems for older participants. It was less effective than the integrated icon, \(t(44) = 2.7, p < .05\). There was also a nonsignificant difference in favor of text-only over the nonintegrated icon instructions, \(t(44) = 1.6, p > .10\).

Questions about stated information were answered more accurately than questions about implicit information, \(F(1,79) = 14.6, p < .001, MSe = .02\). Unlike the comprehension measures, the Format × Question type interaction was not significant for the memory measure, \(F(2,158) < 1.0\), suggesting that the integrated icon had similar effects on implicit and stated information. Finally, older participants generally remembered less than younger adults did, \(F(1,79) = 4.5, p < .05, MSe = .08\), although both age groups remembered the instructions very well.

### Memory for Stated Information

Accuracy of answering memory questions about stated information was analyzed by an Age × Format × Information type ANOVA, with the latter two factors as repeated measures. Instruction format influenced memory for stated information (integrated icon = 82%, nonintegrated icon = 78%, text-only = 78%), \(F(2,158) = 5.2, p < .01, MSe = .02\). The integrated icon improved memory relative to the text-only condition, \(t(80) = 2.7, p < .05\). As in Experiment 1, the Format × Information type interaction was not significant for instruction memory, \(F(2,158) < 1.0, MSe = .02\), suggesting that the icon helped participants remember both depicted and other information in the instruction. Memory was better for depicted than for other information (depicted = 93% vs other = 66%), \(F(1,79) = 316.1, p < .001, MSe = .03\), and this depiction effect was greater for older adults (O: depicted = 91% vs other = 58%; Y: depicted = 95% vs other = 73%), \(F(1,79) = 11.4, p < .01\). Overall memory was lower for older than for younger adults (O = 75% vs Y = 84%), \(F(1,79) = 15.2, p < .001, MSe = .07\).

### Individual Differences

As in Experiment 1, we examined whether cognitive ability and age predicted memory for dose and time information that was presented by instructions with and without icons. Cognitive ability measures included the sentence span, object rotation, and vocabulary tasks. The cognitive ability scores were entered as a block before age in a hierarchical regression analysis because age differences occurred for these variables (see Table 8).

### Table 7. Mean Accuracy (% Correct) for Memory Questions About Implicit and Stated Dose/Time Information (Experiment 2)

<table>
<thead>
<tr>
<th>Information Type by Age Group</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Integrated Icon</td>
</tr>
<tr>
<td>Implicit</td>
<td></td>
</tr>
<tr>
<td>Older</td>
<td>88.0 (18.8)</td>
</tr>
<tr>
<td>Younger</td>
<td>97.2 (88.5)</td>
</tr>
<tr>
<td>Mean</td>
<td>92.6</td>
</tr>
<tr>
<td>Stated</td>
<td></td>
</tr>
<tr>
<td>Older</td>
<td>93.7 (15.2)</td>
</tr>
<tr>
<td>Younger</td>
<td>97.7 (80.1)</td>
</tr>
<tr>
<td>Mean</td>
<td>95.5</td>
</tr>
</tbody>
</table>

*Note: Values are means with standard deviations given in parentheses.*

### Table 8. First-Order Correlations Among Participant Age (0 = Younger, 1 = Older), Vocabulary Test Scores (Voc), Sentence Span Scores (Span), Object Rotation Test Scores (OR), and Recall for Inferred Information From Integrated Icon, Nonintegrated Icon, and Text-Only Instructions (Experiment 2)

<table>
<thead>
<tr>
<th></th>
<th>Voc</th>
<th>Span</th>
<th>OR</th>
<th>Integrated Icon</th>
<th>Nonintegrated Icon</th>
<th>Text Recall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>.83***</td>
<td>-.36***</td>
<td>-.51***</td>
<td>-.29**</td>
<td>-.27*</td>
<td>-.03</td>
</tr>
<tr>
<td>Voc</td>
<td>-.23*</td>
<td>-.46***</td>
<td>.18</td>
<td>.27*</td>
<td>.40***</td>
<td>.21</td>
</tr>
<tr>
<td>Span</td>
<td></td>
<td>.34**</td>
<td>.43***</td>
<td>.29**</td>
<td>.28*</td>
<td>.12</td>
</tr>
</tbody>
</table>

*Note: Values are Pearson correlations. p < 0.05; **p < 0.01; ***p < 0.001.*
The cognitive ability scores accounted for a significant amount of variability in memory for the integrated icon instructions ($R^2 = .16$), $F(3,77) = 5.0, p < .01$. Participants with higher OR scores, $t = 2.5, p < .05$, and higher span scores, $t = 2.0, p < .05$, recalled these instructions more accurately. Age did not predict memory when cognitive ability was controlled ($R^2 = .003$), $F(1,79) < 1.0$. A similar pattern occurred for memory for the nonintegrated icon instructions. Cognitive ability scores accounted for a significant amount of the variance ($R^2 = .31$), $F(3,77) = 11.3, p < .001$, and participants with higher OR scores, $t = 4.0, p < .001$, and higher span scores, $t = 3.6, p < .001$, recalled these instructions more accurately. Age did not predict recall with cognitive ability controlled ($R^2 = .002$). Cognitive ability also predicted memory for the text-only instructions ($R^2 = .09$), $F(3,77) = 2.4, p < .10$. However, only participants with higher span scores, $t = 2.1, p < .05$, remembered these instructions more accurately. Age did not predict recall when cognitive ability was controlled ($R^2 = .0003$).

Preferences

Most participants preferred the instruction with the integrated icon over the other two types of instructions. They thought this instruction was easiest to understand (integrated icon = 82% vs nonintegrated icon = 12% and text-only = 6%) and that it did the best job of explaining how to take the pills (integrated icon = 79% vs nonintegrated icon = 12% and text-only = 9%). They would prefer to receive this kind of instruction from their pharmacists (integrated icon = 78% vs nonintegrated icon = 14% and text-only = 8%).

Discussion

Experiment 2 extends the findings of the first experiment in several ways. First, it provides more evidence that the integrated icon improves comprehension and memory accuracy as well as comprehension time. It also replicated the finding that the integrated icon primarily improved comprehension of implied information rather than dose and time information stated in the text. Inference errors in both experiments also tended to increase with schedule complexity for the text-only instruction but not for the integrated icon condition. This supports the idea that the icon improved comprehension by reducing the mental integration required to identify the total daily dose.

Second, Experiment 2 helps identify the aspects of the timeline icon that facilitate comprehension and memory. The finding that the integrated icon was more effective than the nonintegrated icon, which was usually no more effective than text alone, suggests that the timeline improved comprehension by directly integrating dose and time information. It is also interesting to note that the integrated icon was more effective than the nonintegrated version even though it contained more icon elements and thus could have been perceived as more cluttered, particularly by older participants.

Third, Experiment 2 suggests that the icon benefits were not due solely to prior exposure to the icons, because the integrated timeline icon was more effective than the nonintegrated timeline icon even though participants were allowed the same amount of prestudy familiarization time with both icons. Nonetheless, it is still possible that this familiarization contributed to the icon advantage because a no-training condition was not included in the study.

Fourth, the findings from the sentence span task expand our earlier findings about the relationships between cognitive ability and instruction memory. As in Experiment 1, the fact that OR scores predicted memory for instructions with icons but not for text-only instructions provides some support for the prediction that participants with higher spatial abilities are better able to take advantage of icons (also see Mayer & Sims, 1994; Morrell & Park, 1993). In addition, the finding that both sentence span and OR scores predicted memory for icon instructions suggests that these instructions also required verbal or general working memory capacity. This is not surprising considering that much of the information in the icon/text instructions was conveyed by text alone. Both experiments also showed that age differences in instruction memory were due in large part to age differences in cognitive abilities.

Finally, some findings in Experiment 2 were unexpected. The integrated icon did not facilitate comprehension of stated information as it did in Experiment 1, although it did facilitate memory for this information. Also, the integrated icon did not improve older adults’ memory for dose and time information, although it improved their comprehension of this information. This issue is addressed in the general discussion.

General Discussion

Benefits of Icons in Instructions

Adding a timeline icon to expanded medication instructions improved older and younger adults’ comprehension. Several findings suggest that the timeline improved comprehension by directly integrating dose and time information. First, icon benefits in both experiments occurred primarily for total daily dose information, which was implied by the text but conveyed directly by the timeline. Second, icon benefits did not occur for the nonintegrated version of the timeline in Experiment 2. Similar to the text-only instructions, this icon required readers to integrate dose and time information in order to identify the daily dose. Third, inference errors tended to increase with medication schedule complexity (number of pills per day) for the text-only and nonintegrated icon instructions, but not for the integrated icon instructions.

The integrated icon also improved memory for medication instructions. It improved effective study time in Experiment 1, reducing the study time participants needed to recall dose and time information. In Experiment 2, the same icon improved participants’ memory for the dose and time information that was implied by the text, even when their study time was limited.

The integrated icon improved comprehension and memory for stated and implicit information in Experiment 1. Participants identified stated information more quickly and accurately from instructions with the integrated icon, and these benefits primarily occurred for depicted information rather than other information in the instructions. The timeline icon did not improve comprehension of stated information in Experiment 2, presumably because of ceiling effects.
on the accuracy measure. However, the integrated icon did improve memory for stated information.

**Situation Models and Icons**

These results are consistent with a situation model explanation of how icons improve instruction comprehension. According to this approach, the icon helped participants create mental representations of the medication dose and time information in part because the icon was more compatible than text with this type of representation (e.g., Glenberg & Langston, 1992; Glenberg & McDaniel, 1992). Creating a situation model from a set of instructions requires participants to identify information in the instruction and integrate this information in terms of prior knowledge. The timeline facilitated integration processes by directly (perceptually) integrating dose and time information, thereby aiding mental integration. Thus, benefits in the present study were greater for questions about implicit information than for questions about stated information, which did not require integration. Moreover, these benefits were eliminated when the timeline did not integrate dose and time information (the nonintegrated icon in Experiment 2).

The integrated icon improved participants’ inferences even for more complex medication schedules, whereas their inference errors increased with schedule complexity for text-only and nonintegrated icon instructions. However, even the integrated timeline may not be suitable for conveying very complex schedules that involve multiple medications. A matrix, which directly integrates dose and time information across multiple medications, may be more effective for such schedules (Day, 1988). Still, a similar principle holds: By directly conveying multimedication schedule information, the icon facilitates integrative processing involved in creating a situation model of the task. More generally, our experiments demonstrate the importance of designing displays that directly or explicitly specify information that would otherwise have to be integrated mentally or cognitively (e.g., Kirlik, Walker, Fisk, & Nagel, 1996).

The finding that the nonintegrated timeline was no more effective than text raises the possibility that the degree of explicitness of information is more important than the distinction between icon and text formats. The text-only condition might have been as effective as the integrated icon condition if the text had stated the total daily dose; for example, “Take two pills four times each day. You should take your pills at 8:00 in the morning, 12:00 noon, 4:00 in the afternoon, and 8:00 in the evening. Take a total of eight pills each day.” However, this example suggests that more explicit text also tends to be longer, which brings us back to the point that icons tend to have an advantage over text in terms of explicitness (Larkin & Simon, 1987).

The repetition approach is less successful in explaining the findings from this study. It does not predict greater icon benefits for information implied rather than stated in the instructions. It also does not explain the finding that the integrated icon was more effective than the nonintegrated icon in Experiment 2. Instead, this approach predicts that the two icons should improve comprehension equally because they both repeat the dose and time information stated in the text. Dual coding theory also predicts that both icons should improve comprehension because the dose and time information should be multiply encoded in either case.

Our findings are also difficult to reconcile with accounts based solely on the motivational effects of icons. For example, it is possible that icons may increase interest in the instructions as a whole, encouraging participants to devote more effort to understanding the information (e.g., Levin, 1981). This prediction is inconsistent with the finding that the integrated icon only facilitated comprehension of depicted (vs other) information in the icon/text instructions of Experiment 1 (although the finding that icon benefits for instruction memory in Experiment 2 were not selective is consistent with the motivation account). Other studies have also found selective benefits of pictures in text (e.g., Glenberg & Langston, 1992; Waddill & McDaniel, 1992). The motivation account also fails to explain the superiority of the integrated icon over the nonintegrated version of the timeline and the finding that icon benefits were greater for implicit than for stated information.

**Aging and Icon Benefits in Medication Instructions**

The integrated timeline icon facilitated both older and younger adults’ comprehension of medication instructions. This finding converges with more general studies of aging and discourse memory (e.g., Hess, 1990; Morrow et al., 1997) to reveal a qualitative similarity in the strategies that older and younger adults use to construct situation models from pictures and text. The fact that older adults benefitted as much as younger adults did from the integrated icon also suggests that icons provide environmental support for older adults, facilitating the process of creating a situation model of the medication-taking task. Like younger adults, older adults benefitted from the icon especially when they were asked to draw inferences, even though inferential processing was more difficult overall for the older adults. However, we did not find that the integrated timeline icon reduced age differences in comprehension or memory.

Icon benefits for older adults were more apparent for comprehension than for memory. However, in Experiment 1 the icon helped older adults devote more time to studying the instructions, which improved their recall of dose and time information. It is also possible that older adults studied the medication instructions longer when the icon was present because they had difficulty interpreting the icon or integrating the icon and the text. This explanation is unlikely for two reasons. First, Morrow, Leirer, and Andrassy (1996) found that the timeline icon was interpreted as accurately as text schedules by older and younger adults alike. Second, the effective study time analysis in the present study showed that older participants’ extra study time was useful—it improved their recall of dose and time information relative to the text-only condition. In Experiment 2, younger but not older adults’ memory for inferred information was improved by the integrated icon (vs the text-only condition). This may reflect the fact that study time was restricted in this experiment, so that older adults did not have enough time to make use of the icon as they did in Experiment 1.

Older participants experienced particular difficulties with the nonintegrated icon in Experiment 2. Similarly, Morrell, Park, and Poon (1990) found that adding an icon to medica-
Implications for Medication Instruction Design

Our findings should help improve expanded medication instructions. Similar instructions are now provided to many pharmacy customers with prescribed medications (FDA, 1995) and will likely be needed for over-the-counter (OTC) medications as more prescription medications are switched to OTC status. Our earlier research focused on text formats for instructions: We found that older and younger adults share preferences for organizing medication information, suggesting a general schema for taking medication. Instructions were better recalled when organized to match this schema (Morrow et al., 1991; Morrow, Leirer, Andrassy, Tanke, et al., 1996) and when schema organization was emphasized by a list (vs paragraph) format (Morrow et al., in press). Our present study shows that instructions can also be improved by augmenting the text with icons. In particular, the integrated timeline facilitated inferences about the medication dose. Such inferences may be important for taking medication correctly (e.g., determining how many pills to take out of a container in order to load a pill organizer).

We also examined potential costs and benefits associated with combining icon and text formats. It is possible that icons improved comprehension of depicted information at the expense of the nondepicted information; that is, participants payed less attention to nondepicted information when an icon was present. However, we found no evidence that comprehension of nondepicted information was reduced in the icon/text condition as compared to the text-only condition. Thus, at least in the present study, we did not find any costs associated with combining icon and text formats in medication instructions. However, we did find that icon benefits were eliminated by changing the icon to reduce the degree of integration of dose and time information. This finding highlights the importance of designing and validating icons and other aids carefully so that they support rather than undermine the cognitive abilities required to accomplish daily tasks. Our study also suggests that improving health information for older adults tends to yield benefits for people of all ages.

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APPENDIX

1. Excluding times for incorrect answers eliminated 8 older and 9 younger participants from the inference time analysis.