Intelligent Prompting Systems for People with Cognitive Disabilities

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Background

Age-specific cognitive disabilities
- Among the population of the elderly
- Dementia (or Alzheimer’s)

Other forms of cognitive Disabilities
- Traumatic Brain Injury (TBI)
- Developmental disabilities, mental retardation, etc.

<table>
<thead>
<tr>
<th>Region</th>
<th>Population (millions), aged ≥60 years (2001)</th>
<th>Number of people (millions) with dementia, aged ≥60 years</th>
<th>Proportionate increase (%) in number of people with dementia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Western Europe (EURO A)</td>
<td>89.6</td>
<td>4.9</td>
<td>43</td>
</tr>
<tr>
<td>Eastern Europe low adult mortality (EURO B)</td>
<td>27.4</td>
<td>1.0</td>
<td>51</td>
</tr>
<tr>
<td>Eastern Europe high adult mortality (EURO C)</td>
<td>44.6</td>
<td>1.8</td>
<td>31</td>
</tr>
<tr>
<td>North America (AMRO A)</td>
<td>53.1</td>
<td>3.4</td>
<td>49</td>
</tr>
<tr>
<td>Latin America (AMRO B/D)</td>
<td>40.1</td>
<td>1.8</td>
<td>120</td>
</tr>
<tr>
<td>North Africa and Middle Eastern Crescent (EMRO B/D)</td>
<td>27.5</td>
<td>1.0</td>
<td>95</td>
</tr>
<tr>
<td>Developed western Pacific (WPRO A)</td>
<td>34.5</td>
<td>1.5</td>
<td>99</td>
</tr>
<tr>
<td>China and developing western Pacific (WPRO B)</td>
<td>151.1</td>
<td>6.0</td>
<td>96</td>
</tr>
<tr>
<td>Indonesia, Thailand, and Sri Lanka (SEARO B)</td>
<td>23.7</td>
<td>0.6</td>
<td>100</td>
</tr>
<tr>
<td>India and south Asia (SEARO D)</td>
<td>93.1</td>
<td>1.8</td>
<td>98</td>
</tr>
<tr>
<td>Africa (AFRO D/E)</td>
<td>31.5</td>
<td>0.5</td>
<td>82</td>
</tr>
<tr>
<td>TOTAL</td>
<td>616.2</td>
<td>24.3</td>
<td>74</td>
</tr>
</tbody>
</table>

Table 2: Number of people with dementia, 2001, 2020, 2040, and percentage increase

Figure 1: Number of people with dementia world-wide (Ferri et al., 2005)
Challenges with Cognitive Disabilities

✧ Executive function deficiency
  ✧ prospective memory; planning and problem solving; task sequencing and switching; self-monitoring, and self-initiation
  ✧ failing to initiate, sustain, or terminate an action, forgetting an unfinished task after interruptions, performing task incorrectly, and so on

✧ Cognitive Support
  ✧ People: cost, burden
  ✧ Technology
    ✧ Timers, electronic calendars
    ✧ Assisted Cognition (Kautz 2002)
      ✧ Artificial Intelligence
      ✧ Ubiquitous computing
      ✧ Sense aspects of the context
Intelligent Prompting

✦ Context-Aware: take context into account and adapt accordingly

✦ State estimator
  ✦ interpret behaviors

✦ Controller
  ✦ integrate heterogeneous sources of information
  ✦ autonomous decision making

✦ User interface
  ✦ Various forms of prompts

Sensor data (RFID, motion sensor, GPS, etc)

Other sources of information

State estimator

Controller

User Interface

Prompts, reminders, or questions

Figure 2. Typical Structure of Prompting System
Prompting Systems for Cognitive Disabilities

COACH automated hand-washing assistance (Mihailidis, 2008)

Autominder: introduce unified framework of a context-aware prompting system (Pollack, 2002)

PEAT planning and execution assistant (Levinson, 1997)

Others: way-finding (Liu, 2009)
Outline

✦ **Challenges**
  ✦ Avoiding unnecessary prompts (e.g., *system of least prompts (SLS)*)
  ✦ Decision making under uncertainty
  ✦ Adapting and customizing prompts
  ✦ Identifying the state reliably

*Solution: Partially observable Markov Decision Process (POMDP) →* Computational Cost (*Intractable*)

✦ **Key contributions**
  ✦ Hierarchical Control
  ✦ Adaptive Prompting
  ✦ Selective-inquiry based dual control
    ✦ Robust state estimation
    ✦ Unified model

✦ **Focus group study**
Model Architecture
  : Hierarchical Control
System Overview

✧ Main Goal: support schedule adherence and time management

Sensor data (RFID, motion sensor, etc) → State estimator
User input → Temporal planner

State Assessment

Controller

State Assessment

System actions (prompts, inquiries)

Agent feedback

Decide the optimal action
Fully observable (MDP)
Partially observable (POMDP)

Breakfast:
start [0, 30]
scheduled start: 10
scheduled end: 30

TakeMedicine:
.......
Markov Decision Process

- state $s \in S$
- action $a \in A$
- policy $\pi(s) : S \rightarrow A$
- reward $r(s, a)$
- dynamics $p(s' | s, a)$

**Goal:**
find the optimal policy $\pi^*$ that will maximize
$$E[r_0 + \gamma r_1 + \cdots + \gamma^t r_t + \cdots]$$

$\gamma \in [0, 1]$: discount factor

Cumulative Discounted Reward
Solving MDPs

✦ Dynamic programming
✦ p(s'| s, a) & r(s, a) are known
✦ Solve Bellman equation - **Value Iteration**
  ✦ Value function \( V^*(s) \): expected cumulated reward starting from \( s \) by following \( \pi^* \)
  ✦ \( V^*(s) = \max_{a} E\left[ r_t + \gamma^t r_{t+1} + \cdot\cdot\cdot + \gamma^\tau r_{t+\tau} + \cdot\cdot\cdot \mid s, t, \pi^* \right] \)
  ✦ \( \pi^* = \argmax_{a} \sum_{s'} P(s' \mid s, a) V(s') \)

✓ Reinforcement learning
✦ p(s'| s, a) & r(s, a) are unknown
✦ Learn from actual experience \([s_1, a_1, r_1, s_2, a_2, r_2, ...]\)
✦ Q-learning
  ✦ Action value function \( Q(s, a) = r(s, a) + \sum_{s'} \gamma P(s' \mid s, a) \max_{a'} Q(s', a') \)
  ✦ Value update
  ✦ \( Q_{k+1}(s, a_t) = (1 - \alpha) Q_k(s, a_t) + \alpha (r_{t+1} + \gamma \max_{a} Q_k(s', a)) \)

Old Value  Learned Value

Saturday, October 26, 2013
Hierarchical Reinforcement Learning

Motivation
✦ “Flat” RL works well but on small problems.
✦ In the prompting domain:
  ✦ Multiple task
  ✦ Each task could be divided into sub-stages or subtasks.
  ✦ Complex prompting behavior
✦ Need to scale up? - curse of dimensionality

Solution - Temporal abstraction
✦ include temporal extended actions: persist over a variable period of time
✦ semi-MDP
✦ Q update $Q(s, a)$
  ✦ System executes $a$ in $s$, takes $T$ steps, and transits to $s'$
    • $Q_{t+1}(s_t, a_t) = (1 - \alpha)Q_t(s_t, a_t) + \alpha (r_{t+1} + \gamma r_{t+2} + \cdots + \gamma^{T-1}r_{t+T} + \gamma^T \max_a Q_t(s_{t+1}, a))$
    accumulated reward over temporal extended action $a$
Options

- An option is defined with:
  - A region of the initiated state space
  - An internal policy $\pi$
  - A termination condition

- Learning over options
  - Basic idea: treat each option as a primitive action
  - Fundamental Observations: MDP + options = semi-MDP (Sutton 1999)

- Q update $Q(s, o)$
  - $Q_{k+1}(s, o) = (1-\alpha)Q_k(s, o) + \alpha(r + \gamma \max_{o'} Q_k(S', o'))$
Control Hierarchy for Prompting

- Task domain \( \{T_1, T_2, ..., T_N\} \)
- Define an option-based \( MDP_i \) over each \( T_i \)
- Each \( MDP_i \) has its own set of options \( O_i \).

Options help progress a task through different **status**.

- Type: start,
- Task id: breakfast
- Initiation: task is **ready**
- Termination: task is **failed, underway** or **completed**
- Strategy: first prompt at \( t_p \), ... 

Example **Start** option in the prompting domain
The Complete Observable Control Algorithm

Procedure: CO-Controller

Input
$S_t$: the state vector at time $t$

Return
$a$: the primitive action to be generated

At each time step, the controller

1. check the termination condition of the running option (if there is any) against the current state $S_t$, and terminate it when the condition is met

2. form the set of available options $O_t$ based on the policy of each MDP $\pi_{MDPi}$, and select the option with highest utility $o_{max}$ for execution

3. Run $o_{max}$ only when no other option is running, or interrupt the running option if $o_{max}$ is of higher priority

4. Decide an action $a$ (wait or prompt) based on the prompting strategy of the running option
Conclusion

✦ System structure: state estimator, temporal planner, and controller
✦ Controller: option-based MDPs
✦ Why options for prompting?
  ✦ support early deployment
  ✦ exploit problem structure
  ✦ specify complex prompting routine
  ✦ improve interpretability and facilitate design
✦ Completely observable control algorithm (CO-Controller)
✦ distribute control among individual MDPs
✦ Task independent assumption
Adaptive Prompting: a decision-theoretic approach
Learn Timing of Prompt

- Prompt too early - user being over reliant
- Prompt too late - jeopardize system performance
- User behaviors vary a lot
- How to adapt the timing to different needs?

Approach
- timing as one of the features of state
- RL (Rudary et al. 2004) -- exponentially increase state space
- timing as one of the parameters of prompting strategy of an option
- learn a set of different options with fixed timings -- exponentially increase state-option pair
- adaptive prompting strategy -- avoid long period policy exploration
- user modeling: initiative and responsiveness
- decision-theoretic analysis based on the expected utility
Adaptive Option

✦ Adaptive option adapts its strategy to different user models.

Example: expected utility of generating a prompt at time $t$, $EU(p, t)$

Considering three outcomes:
1. user initiates the action
2. user starts the action after a prompt
3. user failed to start the action

Objective: find the $t$ that maximizes $EU$

$P_1$, $P_2$ and $P_3$ are computed based on user model
• $F_1$ probability of initiating an action
• $F_2$ probability of responding to a prompt
• Reliability model (Weibull) and censored data analysis

States: $s_1$ (action is started), $s_2$ (action is failed)
**Experiment I: Simulation**

**Method:** compare the learning result of adaptive options with that of different *fixed* options

Consider the **start** options of four different prompt strategies

I. no prompt
II. earliest prompt \( t_p = ES \)
III. latest prompt \( t_p = LS - 5 \)
IV. adaptive prompt

**Simulated Users**

- **Type I:** high initiative, high responsiveness
- **Type II:** low initiative, high responsiveness
- **Type III:** low initiative, low responsiveness

**How well did the adaptive strategy adapt to different users?**

*How well did the adaptive strategy adapt to different users?*  

**User I**

*How well did the adaptive strategy adapt to different users?*

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*How well did the adaptive strategy adapt to different users?*
How well did the adaptive strategy adapt to different users?

Simulation Result

- User II
  - Optimal
  - Adaptive
  - Latest
  - Earliest
  - No prompt

- User III
  - Optimal
  - Adaptive
  - Earliest
  - Latest
  - No prompt

Diminished responsiveness
Simulation Result

How well did the adaptive strategy adapt to user preferences?

Scheduled (preferred) execution time $t_s$;
Penalized when later than $t_s$

$EU_d(p, t) = EU(p, t) - EDC(p, t)$

Expected Delay Cost

The number of iterations

User II

User III
Experiment II: Human Subjects

✦ **Experiment Design**
✦ Subjects: 9 (6 male, 3 female), ordinary unimpaired
✦ Primary Task: sequence of randomly ordered steps
✦ Dual Task: simulate cognitive impairment
   ✦ mental arithmetic, i.e., multiplication

Example Task Script

1. **pour** sugar and water into blue cup
2. pour pepper into yellow cup
3. pour water into green cup
4. **stir** yellow cup
5. pour salt into red cup
6. **mix** yellow into blue cup

Procedure (individual session)
✦ Memory practice
   ✦ listen to the script once
   ✦ go through all steps once
✦ Data collection
   ✦ four runs (same script)
Experimental Setup

✦ **Prompts**
remind of the next step
(text-to-speech API)

✦ **Sessions**
(Four different task scripts)
  I. earliest prompt
  II. latest prompt
  III. adaptive prompt
  IV. adaptive prompt (single task)

✦ **Experimenter**
  I. select a task script
  II. select a prompting strategy
  III. carefully mark the start and end of each step, record error
**Experiment Results**

How did the adaptive prompting perform compared with other strategies?

<table>
<thead>
<tr>
<th></th>
<th>p</th>
<th>result</th>
<th>confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adaptive - Latest</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Means Diff</td>
<td>$\leq 0.05$</td>
<td>reject $H_0$</td>
<td>[7.4-2.4, 7.4+2.4]</td>
</tr>
<tr>
<td>Paired Means Diff</td>
<td>$0.003 &lt; 0.05$</td>
<td>reject $H_0$</td>
<td>[7.6-3.7, 7.6+3.7]</td>
</tr>
<tr>
<td>Adaptive - Earliest</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Means Diff</td>
<td>$\leq 0.05$</td>
<td>reject $H_0$</td>
<td>[4.7-1.2, 4.7+1.2]</td>
</tr>
<tr>
<td>Paired Means Diff</td>
<td>$\leq 0.05$</td>
<td>reject $H_0$</td>
<td>[4.9-0.9, 4.9+0.9]</td>
</tr>
</tbody>
</table>

Did the multitasking successfully induce cognitive overload? **Yes**

Significantly better

![Bar plot showing the scores averaged rewards over 4 trials per subject obtained with the adaptive prompting strategy, compared with the other two prompting strategies.](image)

![Graph showing the number of multiplications done per trial for different prompting strategies.](image)
Experiment Results

Averaged time per trial

Averaged number of prompts per trial

Averaged number of arithmetic questions

The learned initiative function

Was the system able to correctly learn user behavior? Yes
Experiment Results

Did the participants find the prompts useful?

- dislike
- like
- indifferent
- particularly like

Immediate prompt

Later prompt

Get some time to think, but don’t want to want too long

All agree “learning is the worst”

“annoying”
“overwhelmed”
“no chance using the memory”
“no time recalling the order of steps”

Illustration of Participants’ Preferences
Summary

Simulation
✦ Adaptive prompting adapts to different user needs
✦ Adaptive prompting scores best
✦ User modeling is done correctly

Human Subjects
✦ Adaptive prompting scores best across all subjects
✦ User modeling is done correctly
✦ Overall, participants responded positively to the use of prompts
  ✦ Immediate prompts compromise learning, and could be annoying
  ✦ People are easily driven by prompts
✦ A relatively “later” prompt is most desirable: key to improve usability
Partial Observability

: Dual control approach and unified model
Partially Observable Markov Decision Process

System state can not always be determined ➔ Partial Observability

✦ Action outcomes are not fully observable
✦ Add a set of observations $O$ to the MDP model
✦ Add an observation distribution $O(s, o)$ to the model
✦ Add an initial state distribution $I$

Key notion: belief state $b$, a distribution over all possible system states

“where I think I am”

Belief update: $b'(s') = \alpha O(s', o) \sum_s P(s, a, s') b(s)$

normalizing constant

⇒ optimal action depends on $b$, $a = \pi^*(b)$
Solving POMDP

✧ Equivalent Belief-State MDP
  ▸ Each MDP state is continuous belief state $b$
  ▸ Hugely intractable to solve optimally!
  ▸ Approximately solved offline ⇒ computationally expensive
  ▸ Learning is difficult ⇒ require extensive training instances

✧ Heuristic (Greedy) Approaches
  ▸ Solve underlying MDP
    ▸ $\pi_{MDP}: S \rightarrow A$, $Q_{MDP}$
    ▸ Choose action based on current belief state
      ▸ “most likely” $\pi_{MDP}(\text{argmax}_s b(s))$
      ▸ “Q-MDP” $\text{argmax}_a(\sum_{s \in S} b(s) Q_{MDP}(s, a))$
    ▸ Act optimally as if the world were to become observable after the next action
Dual-Mode Control

- Extension to greedy approaches to allow information seeking actions
  - Compute entropy $H(b)$ of belief state
  - If entropy is below a threshold, use a heuristic for choosing action
  - If entropy is above a threshold, choose the action that reduces the uncertainty most
    - In our case, choose to inquiry the user
    - User reply is used to help reset the internal state model

- Selective-inquiry based dual mode control
  - Ask only when necessary
    - Different states lead to different actions (at least one is “prompt”)
    - The value of inquiry action is highest among all possible actions
  - Adaptive option supports selective-inquiry
    - Time of prompt action is optimal ➞ critical decision point
Selective-Inquiry based Dual Control Algorithm

Run on top of the completely observable control algorithm (Controller-CO)

Recall Controller-CO (S) returns action a

Input
b, the belief state of internal state model

Return
a’: the system action

At each time step, the controller

1. If get confirmed reply after an inquiry, reset internal state model and set \( H(b) \) to 0.
2. If \( H(b) \) is less than threshold, select \( s \leftarrow \text{argmax}_sb(s) \), update system state vector S, and return \( a' \leftarrow \text{Controller-CO}(S) \).
3. Otherwise, iterate through n most likely states \( S_n \), and for each \( s \in S_n \)
   - construct the pseudo state vector \( S' \) based on \( s \)
   - add \( \text{action} \leftarrow \text{Controller-CO}(S') \) into the set of permissible actions A
4. If A contains different actions, return \( a' \leftarrow \text{inquiry} \), otherwise return \( a' \leftarrow \text{any } a \in A \).
Robust State Estimation

✦ Key to dual control: estimate the belief state of the world, $b$
✦ State model to recognize the user activity
✦ Hidden Markov model ($HMM$)
✦ Filtering
   ♦ Compute the belief state of current state given all evidence to date
   ♦ Estimate the current activity given a sequence of sensor readings, e.g., cup, cup, cup, none, spoon, ...

✦ Key to selective-inquiry: implementation of adaptive option
✦ know when an activity starts, ends, suspends, and resumes
✦ Extend the model to recover the exact timing of events
✦ The current state $s_t$ is unambiguous ($H(b)$ is low)
✦ Viterbi (Most Likely State Sequence)
   ♦ Retrieve the state sequence that ends at $s_t$
   ♦ Determine the time point when activity status changes,$t$

Example state sequence

B1: start of B, A1: start of A
B suspends
B2: end of B, A1: start of A
B ends
Evaluation

✦ Proposed unified model (I)
  ✓ Selective-inquiry based dual control with adaptive option and robust state estimation
✦ Experiment Method
  ✦ Simulate partially observable environment (uncertainty 61%)
✦ Compare with alternative models
  ✦ II never inquiry
  ✦ III always inquiry
  ✦ IV only estimate the current state
  ✦ V run with a set of fixed options
✦ Evaluation Metrics
  ✦ System action: minimize interruptions
  ✦ Execution of schedule: improve adherence
  ✦ Inference: accurately log events
The smaller number is better!
Demonstrative Experiments

✧ Test the system’s performance in identifying states, generating prompts, asking questions and handling interruptions

✧ Two volunteer actors walk through three scenarios.
  ✧ Breakfast is sequenced by taking medicine
  ✧ Breakfast is interleaved with taking medicine
  ✧ Breakfast is interleaved with watching TV

<table>
<thead>
<tr>
<th>task</th>
<th>start window</th>
<th>scheduled start</th>
<th>scheduled end</th>
</tr>
</thead>
<tbody>
<tr>
<td>BF</td>
<td>[0, 30]</td>
<td>15</td>
<td>115</td>
</tr>
<tr>
<td>TM</td>
<td>[120, 150]</td>
<td>135</td>
<td>175</td>
</tr>
</tbody>
</table>

BF : BF_B (preparing), BF_M (eating), BF_E (cleaning up)  
TM : TM_B (getting), TM_M (taking medicine), TM_E (putting away)
### Example

#### Scenario III, Breakfast ➞ watch TV ➞ Breakfast ➞ Take medicine

<table>
<thead>
<tr>
<th>Step</th>
<th>Real Situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Start preparing BF;</td>
</tr>
<tr>
<td>57</td>
<td>Suspend eating BF;</td>
</tr>
<tr>
<td>59</td>
<td>Start watching TV</td>
</tr>
<tr>
<td>73</td>
<td>Watching TV; BF: suspended, TM: not ready;</td>
</tr>
<tr>
<td>80</td>
<td>Resume eating BF;</td>
</tr>
<tr>
<td>116</td>
<td>BF: resumed, TM: not ready</td>
</tr>
<tr>
<td>137</td>
<td>BF: completed, TM: ready</td>
</tr>
<tr>
<td>142</td>
<td>Start getting medicine; BF: completed, TM: started</td>
</tr>
<tr>
<td>162</td>
<td>BF: completed, TM: started</td>
</tr>
<tr>
<td>176</td>
<td>(same as above)</td>
</tr>
<tr>
<td>184</td>
<td>Finish putting away medicine; BF: completed, TM: completed</td>
</tr>
</tbody>
</table>

#### Activity Summary

- **Clean up Breakfast** from 3:20(100) to 3:52(16)
- **No Activity** from 3:54(117) to 4:42(141)
- **Oel Medication** from 4:44(142) to 5:16(158)
- **Take Medication** from 5:18(159) to 5:30(165)
- **Put back Medication** from 5:32(166) to 5:32(166)
- **No Activity** from 5:34(167) to 5:36(169)
- **Put back Medication** from 5:38(169) to 5:54(177) (now)

#### Estimated Activity: **Ambiguous**

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**Example Transcript**

Saturday, October 26, 2013
Summary

Simulation

✦ Selective inquiry based dual control (Unified model) shows consistently sound performance across all measures

Human Subjects

✦ System performs generally well in recognizing states, generating proper prompts, handling interruptions, and dealing with ambiguity
  ✦ 20 prompts from a total of 6 scenarios (one error)
  ✦ Avoid unnecessary prompts by being aware of contexts
  ✦ Selective-inquiry limited the number of questions
  ✦ 7 inquires out of 172 ambiguous steps
  ✦ Dual control works well in presence of partial observability (average uncertainty rate 27%)
Focus Group Study: Traumatic Brain Injury
Study Methods

Sample

<table>
<thead>
<tr>
<th>Group</th>
<th>TBI</th>
<th>Caregiver</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>II</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>

Data Collection

1. What types of support, if any, do you need to perform everyday tasks (including at home and work)?
2. What is it about a task you need help with?
3. How do you accomplish these tasks now? What works well, what doesn’t?
4. What additional types of support or accommodations would be helpful, if available?
5. Current use, comfort and familiarity with technology.
6. What technology was tried and failed and why?
7. What concerns do you have about the reliability of technology? What if software or services stop working?
8. Where do you fall on the spectrum of wanting technology for independence versus wanting assistance from a caregiver?

Analysis

- Standard qualitative methods
- Identify categories
- Identify themes across categories
Results

Psychosocial Support Needs
- Information overload
- Social miscues
- Distractibility
- Environmental stimuli
- Isolation

Task Support Needs
- Adhering to schedules
- Initiating activities
- Performing complex tasks
- Social interactions
- Learning new tasks
- Navigation & path finding
- Attention Control

Memory Support Needs
- Early reminders
- Immediate prompts

Users and Caregivers
- Users want technology for independence but do not want to do away with caregiver support
- Caregivers report that human support is integral; need for emotional support; people promote personal relationship

Interest in New Technology
Positive as long as:
- it is easy to use
- helps to connect user and caregiver
- includes training in use

Successful Strategies
- Active engagement
- Repetition

Challenges
- Reliability of technology
- Maintenance of technology
- Complexity of technology
- Accessibility

Technology as Support
- Cell phones
- Computers
- Cameras
- Textual reminder
- Assistive Technology
- Video games

People as Support
- Emotional support
- Memory support
- Organizational & scheduling support

Categories of Core Themes: Support Needs, Uses and Attitudes

Attention Control
- Navigation & path finding
- Learning new tasks
- Social interactions
- Initiating activities

Task Support Needs
- Adhering to schedules
- Initiating activities
- Performing complex tasks
- Social interactions
- Learning new tasks
- Navigation & path finding
- Attention Control

Memory Support Needs
- Early reminders
- Immediate prompts

Users and Caregivers
- Users want technology for independence but do not want to do away with caregiver support
- Caregivers report that human support is integral; need for emotional support; people promote personal relationship

Interest in New Technology
Positive as long as:
- it is easy to use
- helps to connect user and caregiver
- includes training in use

Successful Strategies
- Active engagement
- Repetition

Challenges
- Reliability of technology
- Maintenance of technology
- Complexity of technology
- Accessibility

Technology as Support
- Cell phones
- Computers
- Cameras
- Textual reminder
- Assistive Technology
- Video games

People as Support
- Emotional support
- Memory support
- Organizational & scheduling support

Categories of Core Themes: Support Needs, Uses and Attitudes
Needs of Support

Psychosocial Support Needs
- Information overload
- Social miscues
- Distractibility
- Environmental stimuli
- Isolation

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Use of Support

Attitudes Toward Support
Results

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Figure 2.1: Categories of Core Themes: Support Needs, Uses and Attitudes
Participants. The most commonly used strategy is to keep notes of what needs to be done for the afternoon pill today is Tuesday. And if that Tuesday little thing is already open, then I've taken it; if not, then I take it.

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Categories of Core Themes: Support Needs, Uses and Attitudes

Results
Attitudes Towards Support

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Saturday, October 26, 2013
Implications for Technology Design

✧ Verbal prompts are more effective than written ones.
✧ Textual reminder fails
✧ Difficulty in initiation
✧ **Immediate** prompt helps with short-term memory

“Because, when I give him cues, everybody says he does so well with cues. He’s hearing my voice. Not only that I’m his wife, and I’m pretty strong. But I think the cues are really important. The cues of “You need to do this.”’

“I think people with brain injuries need verbal commands, verbal memory, verbal whatever it is. You speak into it.” -- caregiver

Earlier, repeated prompting helps to avoid surprises and allow for preparation time.

I “I said don’t put the seats down in the car. He’s going to pack the car. ....But the first thing he did is put the seats down....... So it’s those kinds of things that the short term memory is oh, she said not to put the seats down. It’s something that could come back at you right away and say okay, I was supposed to this. Now don’t put the seats down...... Talks back at you right away, that it could be you know that’s more interactive.” -- caregiver.

I don’t like to find out today that I have to go to a doctor today. It has to be two or three days so that I can prepare myself, ....... Now tomorrow I have to go to the doctor, but to wake up and then have my phone say ‘doctor at 12:00,’ I’m panicked. I’m really disturbed with that. So if everything comes to me slowly, then I’m prepared for it”
Implications for Technology Design

- Technology is not only designed for patients.
- People are an important part of the broader support network.
- Emotion feedback
- Promote personal relations

“I Because I think a telephone can't go and say, yay, you did it! You need that positive input I think every once in a while. And phones can't give a hug, so you got to have that. You got to have it.” -- caregiver

“But interaction with -- having another individual is more in promotion of developing -- than using a piece of technology. That's different. The technology is in promotion of relying upon it, where the person, it ends up being in promotion of, you know, that's -- developing further or, you know -- Personal relations.” -- caregiver.

But isolate, you isolate or you spend too much time farming on Facebook or you know, these virtual I caught myself ...... It's usually but it's very isolating.” -- patient
Conclusion

“Sometimes people are there and sometimes they’re not. So if I was able to have something with me all the time, I would -- it would be more reliable, and then I would be more independent…” -- patient

- Technology
  - increase independence
  - Availability of training
  - Design challenge

- Human
  - Essential role
  - Not always available
  - Expensive, time intense

...diminished quality of life, increased level of anxiety, poor self-esteem, and social isolation (Burns and Rabins, 2000)

Technology should be viewed as an opportunity to increase independence while providing a way to communicate support needs on an as-needed basis
Conclusions
A unified model that integrates the sensing, planning, prompting and user
Scale to large of set of tasks that are divided into subtasks
Explored the following issues:
- Hierarchical control
- Set of option-based MDPs, on-line learning and planning
- Adaptive prompting
- Adaptive option implements decision-theoretic analysis
- Partial Observability
- Selective-inquiry based dual control algorithm
- Robust state estimation
- Unified model

Focus group study
- broader support network that includes people as essential element

Future work
- Test wit clinical populations
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