University of Pittsburgh

Department of Veterans Affairs

Assistive Technology for Cognition for Traumatic Brain Injury

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"Many say technologies make things easier, for people with disabilities technologies make things possible."

- *Knut Ellingsen*

What is AT for Cognition (ATC)?

- Subclass of AT designed to increase, maintain, or improve functional capabilities for individuals whose cognitive changes limit their effective participation in daily activities.
  - Focus on real-life, functional task performance
  - Technology oriented (simple to complex)

- ‘Cognitive orthoses’ or ‘Cognitive prosthetics’

ATC Use among Veterans with TBI

- A survey study at the 2012 Winter Sports Clinic
- 29 veterans with TBI participated

Variables		n (%) mean ±SD
Age		42.7±11.4
Gender	Male	20(69)
	Female	9(31)
Racial	Caucasian	22(75.9)
	African American	2(6.9)
	Hispanic	2(6.9)
	Two or more races	3(10.3)
Education (years)	<12	18 (62.1)
	12	4 (13.8)
	>12	7(24.1)

ATC Use among Veterans with TBI

- Eight ADL areas (keeping track of appointments and events, performing multi-step tasks, keeping track of medication, staying focus, remembering names/faces, locating items, managing emotions, way finding)
  - Difficulties in each area
  - Impact on quality of life
  - Type and amount of ATC use

ADL areas	No. of participants who had difficulties (N=29)	No. of participants who were significantly affected[1*]	Total number of ATC used	Types of ATC devices used in each area[2*]
Perform multi-step tasks	19	15 (78.9%)	5	Smart phone (3) Computer (1) Alarm/Timer (1)
Keep track of appointments & events	22	17 (77.3%)	29	Smart phone (16) Computer (4) Smart pad (2) Paper tools (5) Alarm/Timer (2)
Stay focused on a task	27	18 (66.7%)	4	Smart phone (1) Computer (1) Paper tools (1) Alarm/Timer (1)
Keep track of taking medications	17	11 (64.7%)	5	Smart phone (2) Alarm/Timer (1) Pillbox(2)
Remember names and faces	28	17 (60.7%)	5	Smart phone (1) Computer (2) Paper tools (2)
Manage emotion	22	13 (59.1%)	1	Smart phone (1)
Navigate ways	17	9 (52.9%)	3	Smart phone (1) GPS (2)
Locate items	26	9 (34.6%)	0	N/A

User Feedback

- For both paper-based and electronic tools, lack of built-in reminders and limited feedback were reported as major barriers.
- About 2/3 users purchased the ATC and apps, and learn to use them on their own.
- About 1/3 users went through the prescription process with VA clinicians.
- Formal training was considered very/extremely helpful.

Types of ATC

Memory and executive functioning

- Scheduling ATC
  - Remind users to perform a task
    - Paper-based tools
    - Alarms and timers
    - Computer-based tools
    - Paging systems/services
    - Smartphones & PDAs
- Sequencing ATC
  - Guide users in performance multi-step tasks

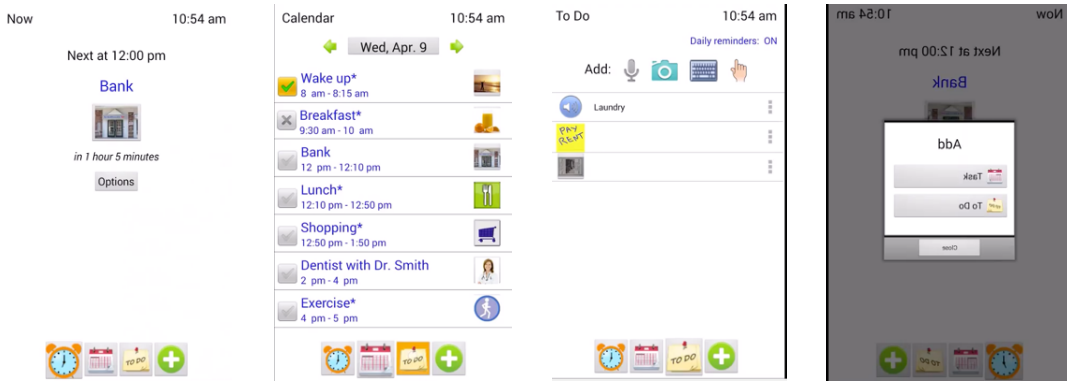
Invisible clock

Watch Minder

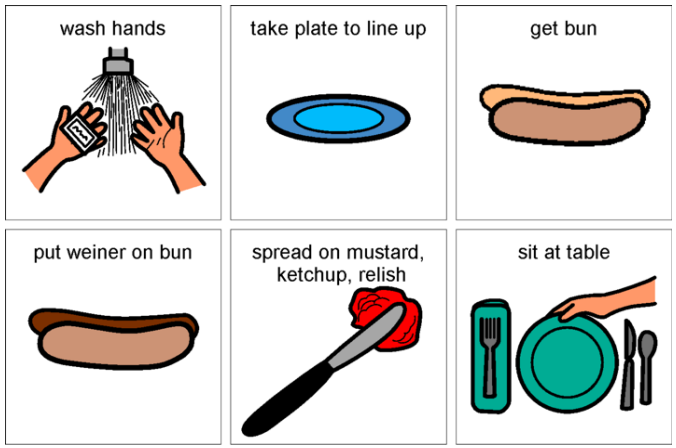
VoiceCue

VideoBrix

Smartphone apps



BrainAid PEAT



Picture Book

Visual Assistant

Memory Aid Prompting System

Effectiveness of ATC

- More case studies than clinical trials
- Limited work on comparing electronic ATC to other strategies

Stapleton et al., 2007

- To investigate the use of a “reminders’ function on a mobile phone as a memory aid for 5 individuals with TBI
- ABAB design.
- Two improved target behavior completion rate (P1: 51% to 95% and P5: 58% to 88%), while three did not change.
- People with severe memory and executive functioning difficulties did not benefit.

Effectiveness of ATC

Svobada et al., 2012

- To investigate PDA/smartphone use by 10 individuals with moderate-to-severe memory impairments.
- ABAB design, 10 one-hour training sessions with errorless fading-of-cues protocol
- All 10 individuals showed robust improvement in day-to-day functioning post-intervention

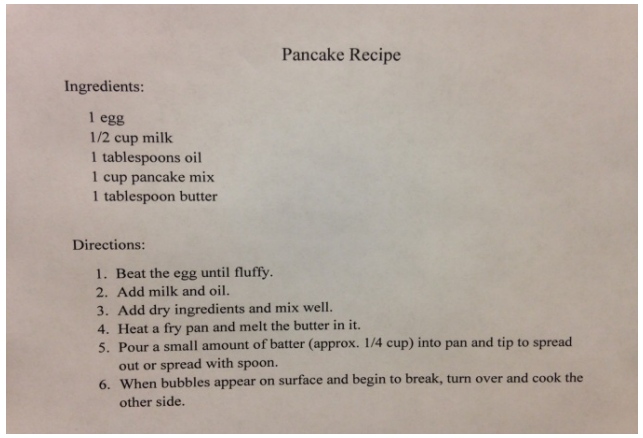
Charter et al. 2015

- Efficacy of electronic portable assistive devices for people with acquired brain injury: a systematic review
- 23 reports – 0 in level 1, 4 in level 2, 10 in level 3.
- Insufficient evidence to recommend any practice standards, but sufficient evidence to recommend the use of electronic reminder systems in supporting the everyday functioning

Effectiveness of ATC

Wang et al., 2014

- To investigate the effectiveness of Visual Assistant for assisting meal preparation tasks among 10 individuals with TBI
- Randomized cross-over design, paper-based recipe vs Visual assistant on an iPad.
- All needed external prompts. 6 needs more prompts with paper-based method and 4 needs more prompts with Visual Assistant.
- Visual assistant received better subjective ratings.



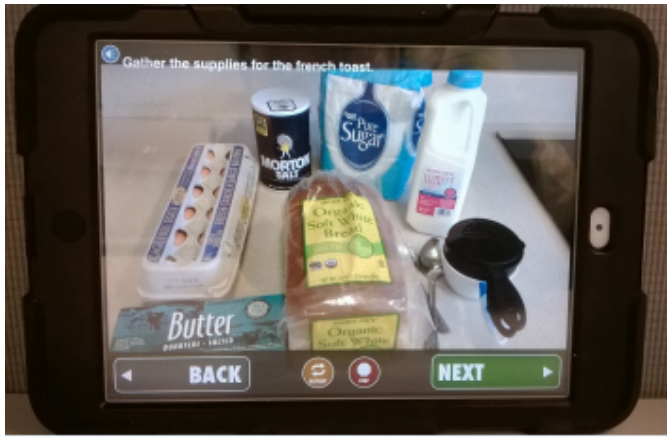
Pancake Recipe

Ingredients:

1 egg
1/2 cup milk
1 tablespoons oil
1 cup pancake mix
1 tablespoon butter

Directions:

1. Beat the egg until fluffy.
2. Add milk and oil.
3. Add dry ingredients and mix well.
4. Heat a fry pan and melt the butter in it.
5. Pour a small amount of batter (approx. 1/4 cup) into pan and tip to spread out or spread with spoon.
6. When bubbles appear on surface and begin to break, turn over and cook the other side.



Limitations of ATC

- Open-loop operation
  - Require input from users
  - Users to check their own progress
  - Users to determine when to proceed
- Prompts may be out of sync
  - Self-initiation
  - Dependency
- Fixed level of detail in the steps

Context-Awareness

- What is the context?
  - Any information that can be used to characterize the situation of an entity (e.g., person, place, object) that is considered relevant to the interaction between a user and an application.
- What is a context-aware application?
  - It uses context to provide relevant information and/or services to the users
- How to determine the context?
  - Sensors can tell us a lot!
  - Internet of things

Context-Awareness

- Potential benefits
  - Make technology ‘invisible’
  - Reduce user interaction with technology
  - Deliver maximum information under minimum cognitive effort

- Challenges
  - Instrumentation invasiveness
  - Technology reliability

COACH (Mihalidis et al. 2008)

COACH Evaluation

- Six participants with moderate-to-severe dementia from a long-term care facility in Toronto
- ABAB design, 10 trials per phase
- Subjects completed an average of 11% more steps independently and required 60% fewer interactions with a human caregiver with COACH
- COACH not responding to 10.9% of the errors made by participants and making an error in 26% of the cases where the participant was completing the step correctly.

N-CAPS (Mihalidis et al. 2016)

N-CAPS Evaluation

- Four participants with developmental disabilities around the University of Colorado.
- Participants completed 53% of the required steps without assistance from the human job coach and 86% with the prompts from N-CAPS.
- N-CAPS overall accuracy 83% with 86% sensitivity and 82% specificity.

Vocation Job Coaches

Automated vocational coach for food preparation (McCue et al.)

- Four IMUs to detect specific actions in a hamburger-making task (placing, salting, pressing, flipping, and removing)
- Tested 7 able-bodied and 3 TBI. Overall accuracy of 91.3%-100% based on individually trained models.

Locompt system (Chang et al. 2011)

- Nine task steps which fulfilled an order with desserts, beverages, and cookies
- Two participants (one with brain injury and one IDD)
- ABAB design
- Participant 1: 48%-98%-49%-99% correct task steps; Participant 2: 54%-99%-55%-100% correct task step.

VA SmartHome Project

- Deployed first at the VA Polytrauma Transitional Rehab Program in Tempa
- Expanded recently to include individual homes in the community
- Electronic caregiver
  - Track resident locations
  - Sensors to monitor the use of appliances
  - Context-aware prompts
  - Deliver customized prompts via interactive screens

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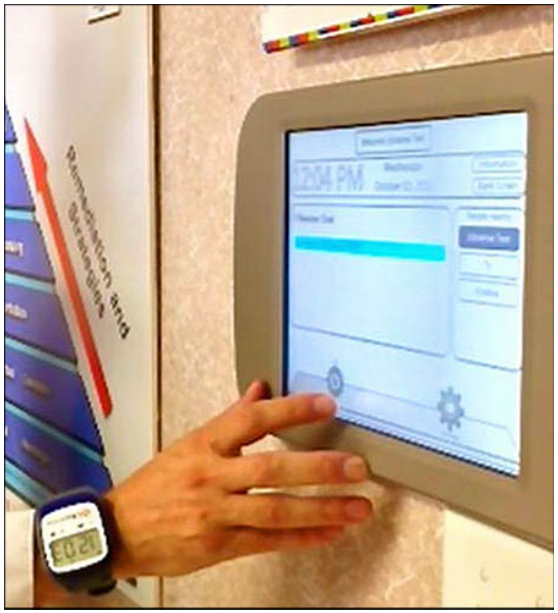


Cueing Kitchen

Smart environment that integrates sensing and cueing to

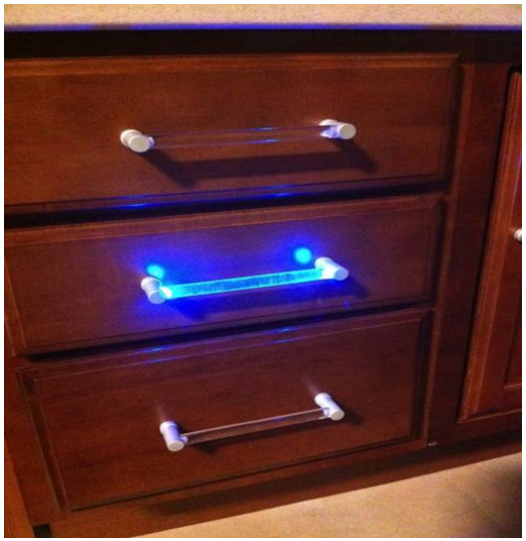
- Understand user actions
- Provide appropriate prompts
- Provide task guidance like a trained caregiver

Cueing Kitchen – Hardware

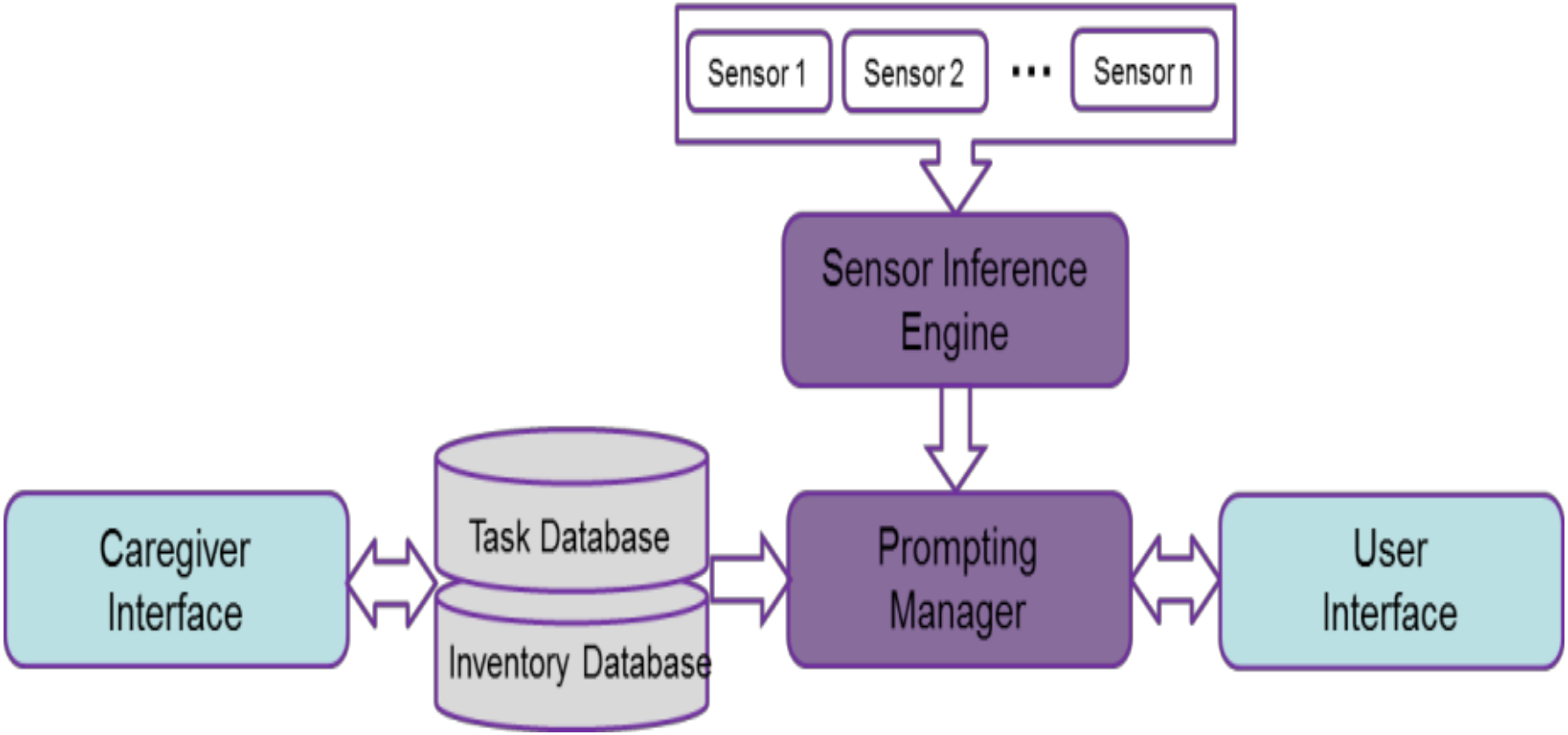
- Sensing components
  - Contact switches
  - Water flow meter and thermistors
  - Kinect sensors
  - Motion sensors
  - Power sensors

Cueing Kitchen – Hardware

- Prompting components
  - Computer (visual/audio cues)
  - Handles with LED
  - Smart glasses
  - Projected images
  - Interactive Island



Cueing Kitchen – System Structure



Cueing Kitchen Video

Feasibility Study

To evaluate the automatic prompting system vs. a commercially available user-controlled method (Visual Assistant)

Hypothesis a: Subjects will require less amount of external assistance, and complete the tasks with higher scores in adequacy and safety as measured by PASS when using automatic method versus user-controlled method.

Hypothesis b: Subjects will report less amount of cognitive load as measured by the NASA Task Load Index and greater usability ratings as measured by a custom questionnaire when using automatic method versus user-controlled method.

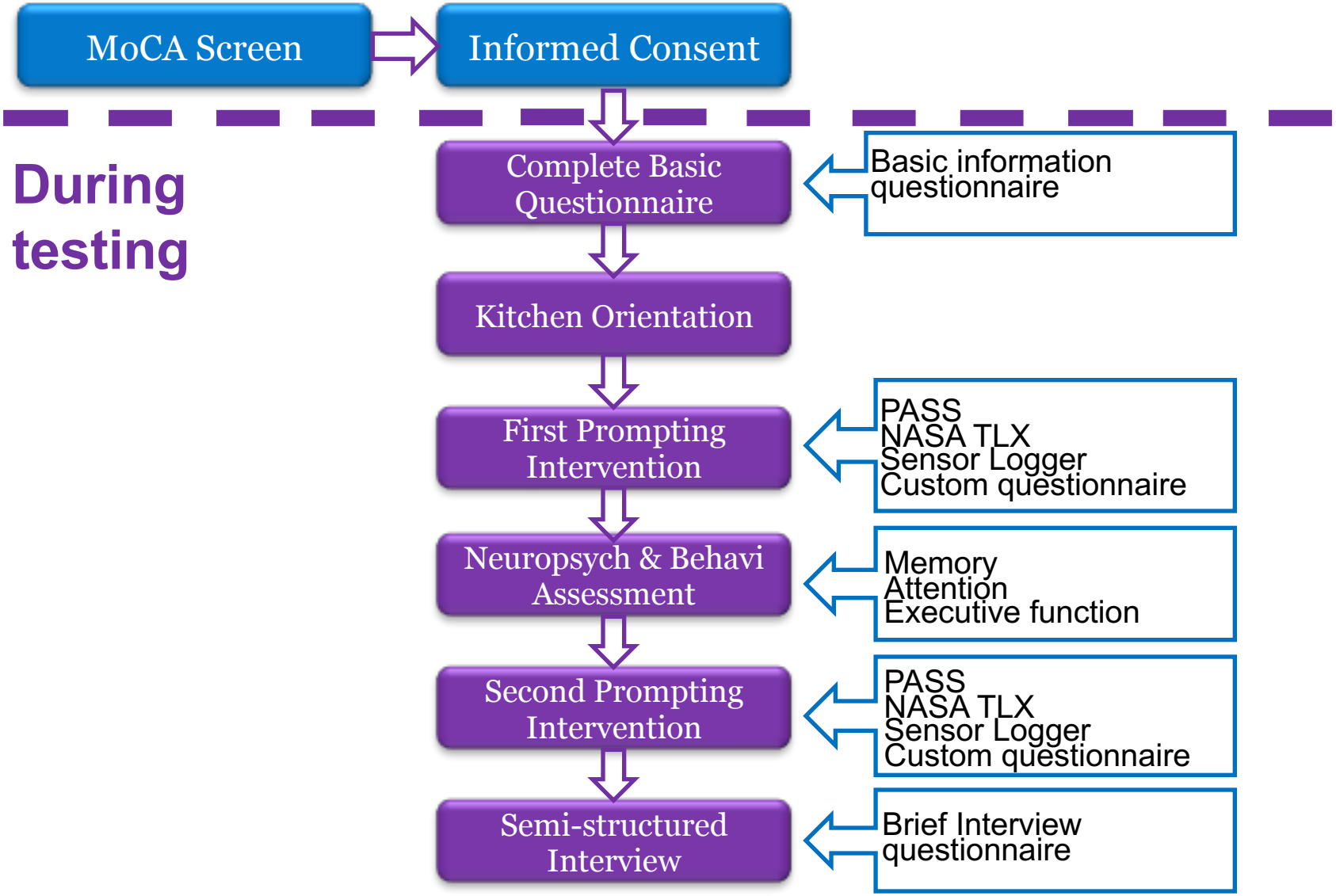
Feasibility Study

- Participants: 16 individuals with TBI Montreal Cognitive Assessment score between 11 and 25
- Automatic method (AU) and user-controlled method (UC)

	Automatic method	User-controlled method
Media	Computer	iPad mini
Step-by-step instruction	Yes	Yes
Prompting modalities	Text, image, verbal, light handles	Text, image, verbal
Required user interactions?	None	Press buttons
User activities	Sensor-monitoring	Self-monitoring

- Two cognitive equivalent cooking tasks

Feasibility Study



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Feasibility Study

- AU significantly decreased total amount of required assistance
- No significant difference in safety and adequacy

Outcomes	Automatic Method	User-controlled Method	Paired-T test (two tail)	
	Mean (SD)	Mean (SD)	t	P
Objective outcomes				
PASS- Safety summary score	2.88 (0.34)	2.75(0.48)	1.00	0.333
PASS- Adequacy summary score	2.75 (0.45)	2.38 (0.50)	2.09	0.054
PASS- Total amount of required assistance	1.19 (1.60)	2.94 (3.23)	-2.33	0.034*
PASS- Highest level of required assistance	1.75 (2.05)	2.50 (1.15)	-1.11	0.283

Feasibility Study

- AU received significantly higher ratings in ease-of-use
- Participants were less stressful with AU
- No significant difference in usefulness and workload

Outcomes	Automatic Method	User-controlled Method	Paired-T test (two tail)	
	Mean (SD)	Mean (SD)	t	P
Subjective outcomes				
NASA-TLX[1]	23.83 (13.62)	29.78 (14.51)	-2.04	0.060
Usefulness	0.89 (0.01)	0.87 (0.14)	1.39	0.186
Ease-of-use	0.92 (0.08)	0.85 (0.14)	2.71	0.016*
Stress	10.44 (3.16)	12.50 (4.51)	-2.17	0.047*

1: One participant failed to complete the NASA-TLX questionnaire. There were only 15 data points for NASA-TLX results.

Feasibility Study

User Feedback

- 9 participants: AU more useful and want it at home
  - Hands-free feature
  - System confirmations for safety concerns

    P13 "The automatic method, especially for newly injured people. The details (confirmations) told you whether you did it. The detail feature and it moves automatically are great in the whole process."

- 6 participants: UC more useful
  - Greater control on the pace/timing
  - Easy to maintain

    P7 "The user-controlled one was more useful, because it's my rate of speed."

Summary

Off-the-shelf electronic ATC and applications

- Can be useful for mild cognitive impairment
- Systematic training is recommended
- Lack of prescription guidelines and how to match ATC to individuals

Intelligent ATC and applications

- Not commercially available yet
- More case studies than clinical trials
- Technology robustness
- Deployment challenges

Pips Buttons

Amazon Echo Family

NOTIFYOU + iBeacon

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