

## PART 2: TECHNOLOGY-DRIVEN INTERVENTIONS

# *Mechanisms in Dementia Caregiver Intervention Research*

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## PURPOSE

This guidance document is designed for researchers developing and evaluating technology-driven interventions for family caregivers of persons living with dementia. Technology-driven interventions may include but are not limited to: mobile apps, wearables, web-based platforms, telehealth, AI-enabled tools, and smart-home technologies. It provides a practical framework for specifying, measuring, and testing mechanisms of action that are uniquely enabled—or constrained—by digital delivery.

This guide complements the companion documents on general mechanisms of action and tailoring by focusing specifically on the unique considerations for digital interventions.

## WHY IS MECHANISM TESTING CRITICAL FOR DIGITAL INTERVENTIONS?

Technology-driven interventions differ from traditional behavioral programs in ways that fundamentally affect how mechanisms operate:

- Effects are often **indirect**, operating through engagement, usability, and learning processes
  - An individual must first engage with technology before mechanism(s) can be activated
  - Poor usability blocks mechanism activation regardless of content quality
- Exposure is **self-paced and variable**,
  - Not session-based and may not have standardized delivery formats
  - Wide variation in when, how often, and which features can be and are used
- Intervention “dose” is **behavioral and dynamic**
  - Measured by logins, time spent, features used, tasks completed
  - Traditional concept of dose as the number of sessions does not capture actual engagement
- Rapid iteration and scaling are possible with technology
  - Enables quick updates and modifications
  - Requires clarity about which features are active ingredients
- Look and feel and options may become outdated rapidly with evolution of technology
- Need to distinguish why a digital tool works vs. how often it is used
  - High usage does not mean the intervention is effective (can indicate poor usability or inefficiency)
  - Low usage does not mean the intervention is ineffective (may deliver benefit efficiently)

## FRAMEWORK FOR UNDERSTANDING MECHANISMS OF TECHNOLOGY-BASED CAREGIVER INTERVENTIONS

Technology-based caregiver interventions operate across three layers with each having distinct mechanisms.

**TABLE 1. Three-Layer Framework for Technology-Based Caregiver Interventions\***

LAYER	EXEMPLAR THEORIES	MECHANISM PATHWAY → OUTCOME
LAYER 1: Technology Layer	<b>Technology Acceptance Model (TAM)</b> Perceived usefulness and ease of use predict adoption	Perceived usefulness → Intention to use → Adoption Perceived ease of use → Reduced cognitive load → Sustained use
	<b>Human-Centered Design</b> User needs drive design decisions	User needs assessment → Relevant features → User satisfaction Iterative refinement → <b>Contextual tailoring</b> → Continued engagement
LAYER 2: Engagement Layer	<b>Self-Determination Theory</b> Autonomy, competence, relatedness drive, intrinsic motivation	Autonomy support (choice) → Sense of autonomy → Intrinsic motivation Competence support (feedback) → Sense of confidence → Continued use Relatedness & support → <b>Social connection</b> → Sustained engagement

*continued*

LAYER	EXEMPLAR THEORIES	MECHANISM PATHWAY → OUTCOME
	<b>Behavioral Economics</b> Defaults, framing, and nudges shape behavior	Defaults (pre-selected) → Reduced decision burden → Higher uptake Framing (positive/negative) → Changed perception → Behavior change Nudges (choice architecture) → Guided behavior → Desired action
	<b>Habit Formation</b> Cues, routines, and rewards create sustained use	Cue (notification) → Attention → Routine initiation Reward/feedback → <b>Skill Building</b> → Habit strength
<b>LAYER 3: Behavioral &amp; Psychosocial Layer</b>	<b>Stress Process Model</b> Digital resources buffer stress effects	Stressors (care demands) → Resources (digital coping tools) → <b>Perceived control</b> → Reduced burden Primary appraisal → Secondary appraisal → Coping response → Adaptation
	<b>Cognitive Behavioral Theory</b> Thoughts, behaviors, emotions interact	Identify thoughts (digital tracking) → Challenge distortions → <b>Emotional regulation</b> → Reduced distress Behavioral activation (app-guided) → Pleasant activities → <b>Emotional regulation</b> → Well-being
	<b>Social Cognitive Theory</b> Self-efficacy drives behavior change	Modeling/instruction (video) → <b>Knowledge acquisition</b> → <b>Self-efficacy</b> → Behavior change



**\*CRITICAL INSIGHT:** All three layers must function for digital interventions to produce outcomes. Each link must be present. A break at any point prevents benefit.

**TABLE 2. Core Mechanisms of Action in Technology-Driven Caregiver Interventions**

MECHANISM OF ACTION	DEFINITION	TARGET	DIGITAL FEATURES	PROXIMAL OUTCOME	DISTAL OUTCOMES
<b>Knowledge Acquisition</b>	Tailored, accessible, and on-demand information improves knowledge.	Dementia knowledge, anticipatory guidance	Microlearning, searchable libraries, adaptive content	Accurate appraisal	Knowledge
<b>Skill Building</b>	Interactive tools support translation of knowledge into action.	Care skills, problem-solving, task mastery	Step-by-step guides, simulations, action plans, gamification, reminders	Task mastery	Lower burden
<b>Self Efficacy &amp; Perceived Control</b>	Successful use of digital tools reinforces caregivers' confidence and mastery.	Confidence, perceived competence	Feedback loops, progress tracking, goal completion	Confidence	Sustained use of skills
<b>Cognitive &amp; Emotional Regulation</b>	Digital strategies help caregivers manage stress and emotional responses in real time.	Distress, coping, emotional reactivity	Mindfulness modules, cognitive reframing prompts, mood tracking	Reduced stress	Better mental health
<b>Social Connection &amp; Validation</b>	Technology facilitates social support and normalization of the caregiving experience.	Isolation, perceived support	Peer forums, moderated groups, messaging	Connectedness	Sustained caregiving over time
<b>Environmental Fix/ Contextual Tailoring</b>	Personalization aligns strategies with caregiver context and care recipient needs.	Person-environment fit, relevance	Algorithms, tailoring rules, adaptive recommendations	Goal attainment	Effectiveness at scale, e.g., quality of life

continued

## TESTING MECHANISMS ACROSS THE NIH STAGE MODEL (DIGITAL CONTEXT)

### Stage 0-I: Discovery and Design

- Identify which digital features are hypothesized to activate mechanisms
- Test usability, acceptability, and engagement as necessary precursors
- Use qualitative feedback and analytics to refine mechanisms and technology features
- Test relationships between intervention and measures of mechanism

### Stage II-III: Efficacy

- Establish temporal ordering: engagement mechanism outcome
- Test mediation using both self-report and trace data
- Compare mechanism activation across features or modules

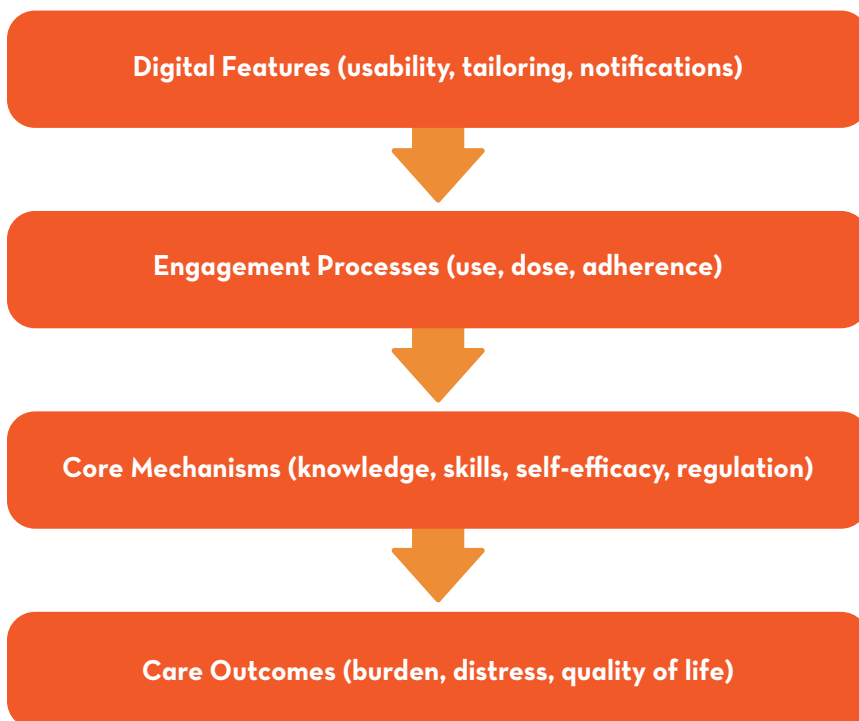
### Stage IV: Effectiveness and Pragmatic Trials

- Test robustness of mechanisms under variable, real-world use
- Identify minimal engagement thresholds needed for benefit
- Examine subgroup differences in mechanism activation

### Stage V: Implementation and Sustainment

- Shift focus to *implementation mechanisms* (training, support, integration) to increase spread and use of the technology intervention
- Test whether caregiver-level mechanisms remain activated during scale-up

## MECHANISM PATHWAYS IN DIGITAL CAREGIVER INTERVENTIONS



**KEY INSIGHT:** Digital features increase engagement which supports activation of core mechanisms leading to proximal and distal outcomes. Engagement is typically a **mediator or moderator**, not the ultimate mechanism.

**INCORRECT:** “Our mechanism is app engagement”

**CORRECT:** “Our mechanism is increased self-efficacy through skill-building. App engagement is necessary to deliver the skill content that builds efficacy.”

## DESIGN AND REPORTING TIPS

- Specify *which digital features* are intended to activate *which mechanisms*
- Report engagement data alongside mechanism outcomes
- Avoid equating usage metrics with effectiveness
- Test alternative pathways (e.g., low use but high impact)
- Report null or inactive mechanisms to inform optimization



### COMMON PITFALLS TO AVOID

- 1. Equating Usage with Effectiveness:** More logins  $\neq$  better outcomes (may indicate confusion or inefficiency); some users may benefit from brief, focused use
- 2. Ignoring Non-Users in Analysis:** Intent-to-treat (ITT) analysis includes non-users (conservative) per-protocol or Complier Average Causal Effect (CACE) analysis among engagers (optimistic, efficacy estimate). Report both analyses for full picture
- 3. Assuming Technology Acceptance:** Not all caregivers find technology acceptable or usable; remember that technology layer mechanisms must be tested, not assumed
- 4. Overlooking Context:** When/where/why caregivers use app affects mechanisms (e.g., 3 am stress vs. planned daily check-in may activate different processes)
- 5. Conflating Engagement with Mechanisms:** Engagement enables mechanisms; 'engagement' is not the mechanism itself, so focus on what engagement enables (learning, practice, support)

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