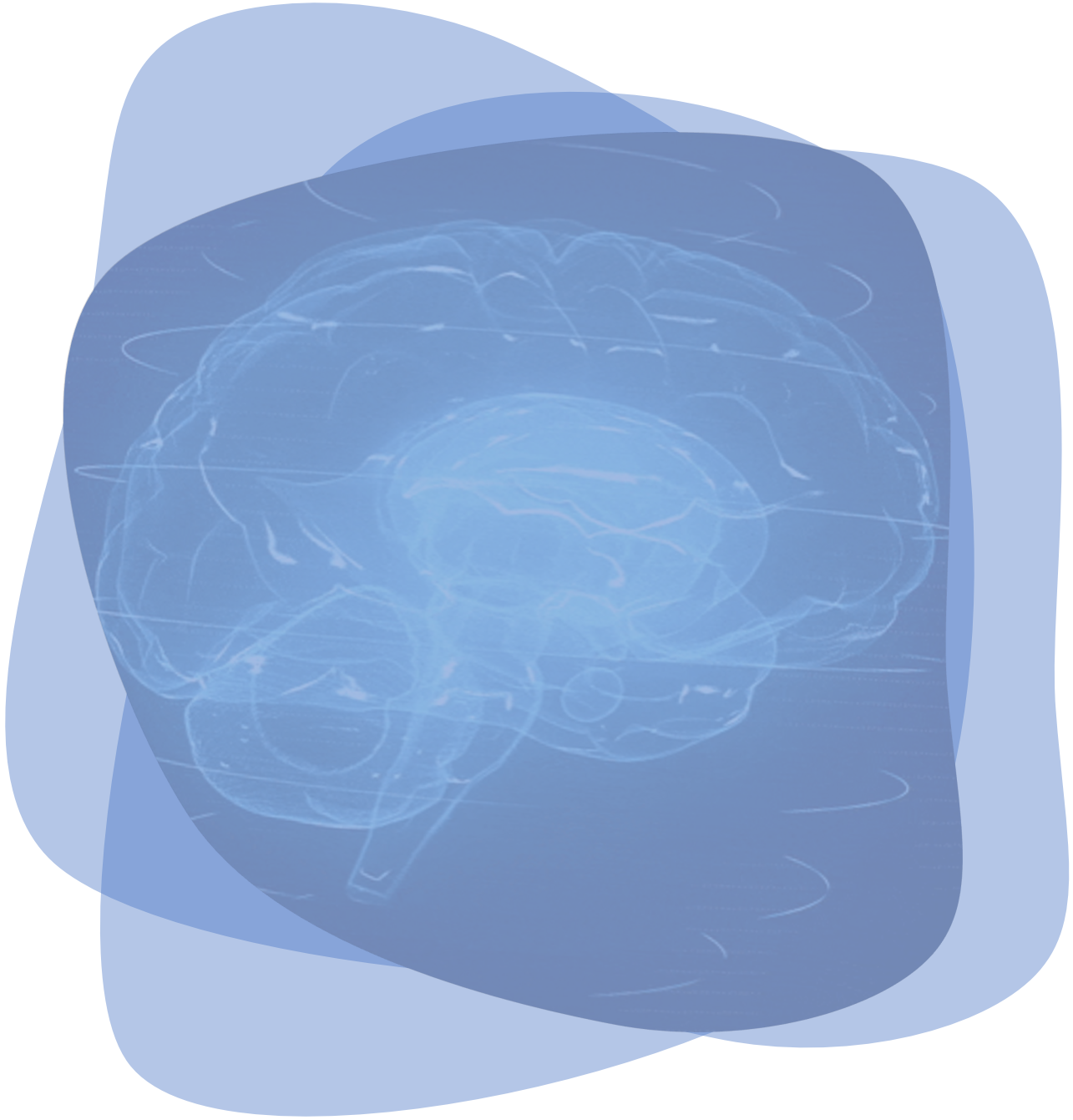


Investigating the Design of an Immersive Smart Home System for Supporting Seniors Living with Neurocognitive Disorders

Lorans Alabood
2022

The Computational Media Design program (CMD)

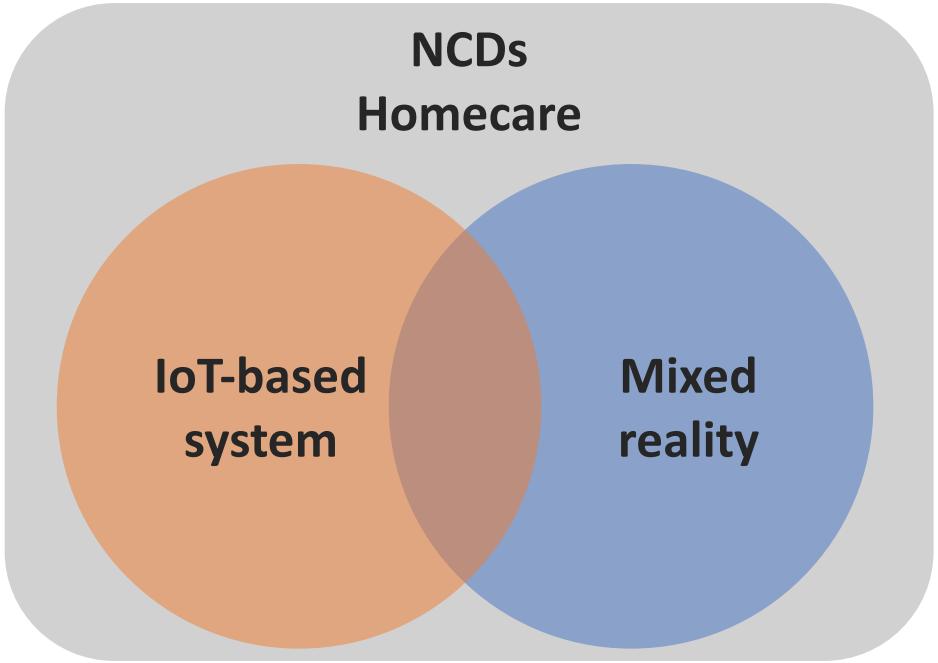
Supervisors:

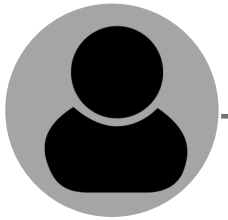
Dr. Frank Maurer
Dr. Fabian Neuhaus

Committee members

Dr. Linda Duffett-Leger
Dr. Richard Levy

Immersive Smart Home System





Accommodate the user's special requirements

Improve system usability by tailoring the design to their experience

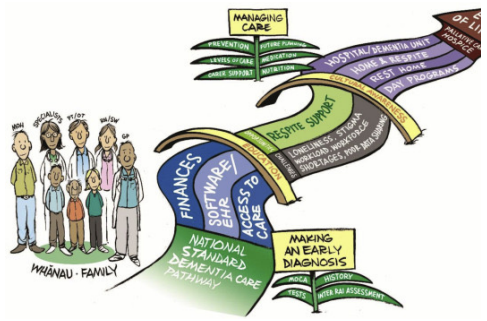
Use Internet of Things (IoT)

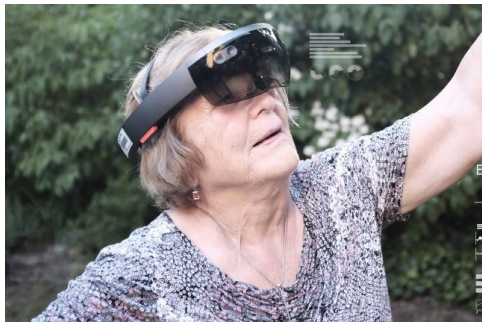
Customized, affordable, accessible

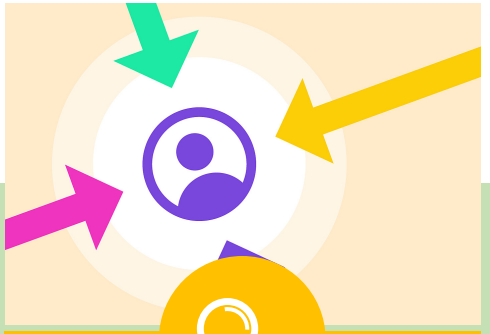
Mixed reality

Provide the user with an immersive, hands-free, seamless user experience

What Are The Problems?







User-related

- NCDs special requirements
- Variety of needs
- Progressive illness

Technology-related

- Using mobile phones
- Homecare purposes
- User-system interaction

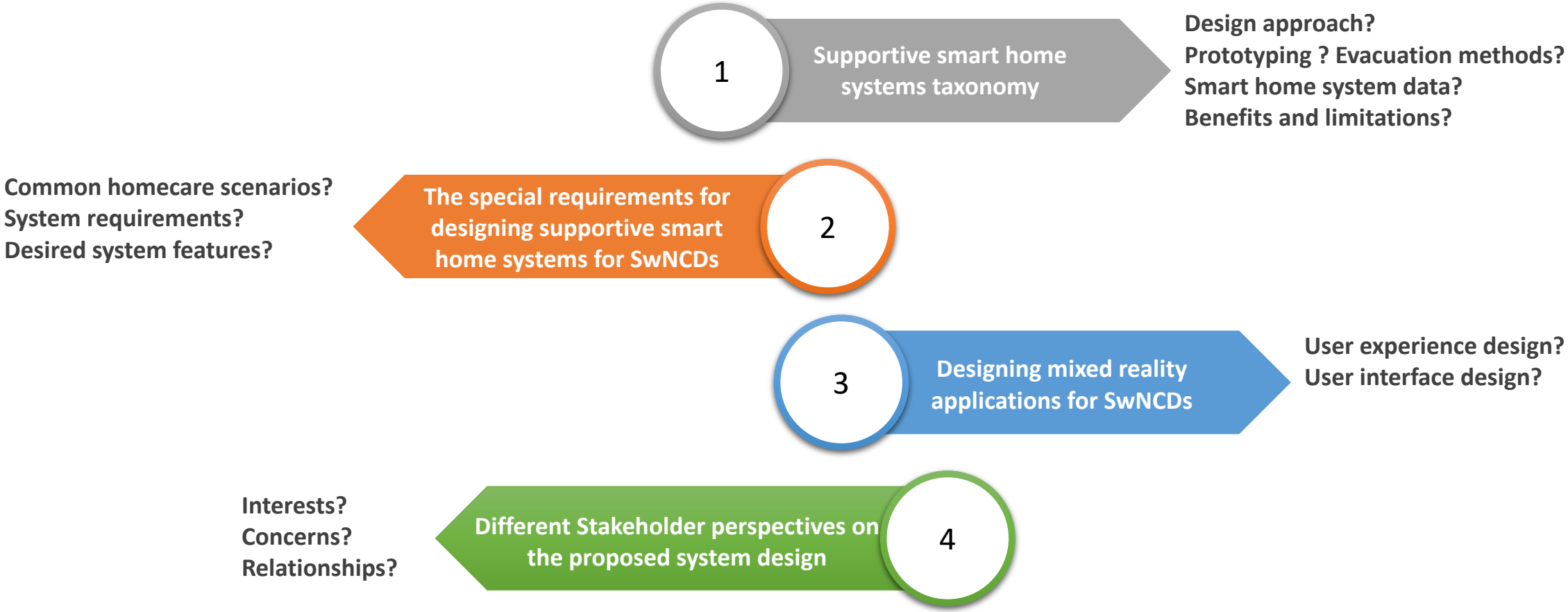
Design-related

- Lack of design guidelines
- Lack of studies
- New evaluation methods

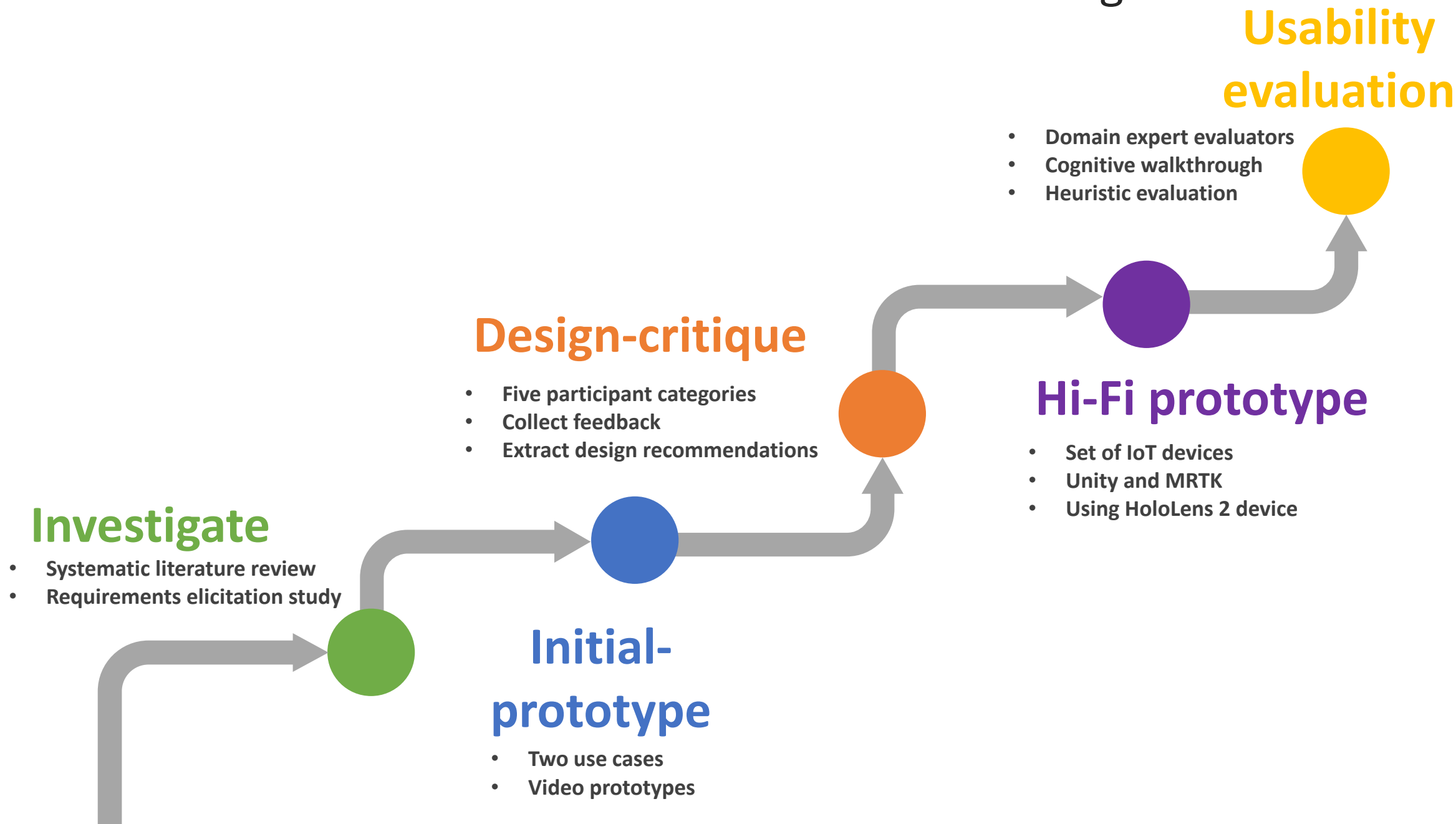
Research-related

- User-centered design
- User research
- Smart home taxonomy

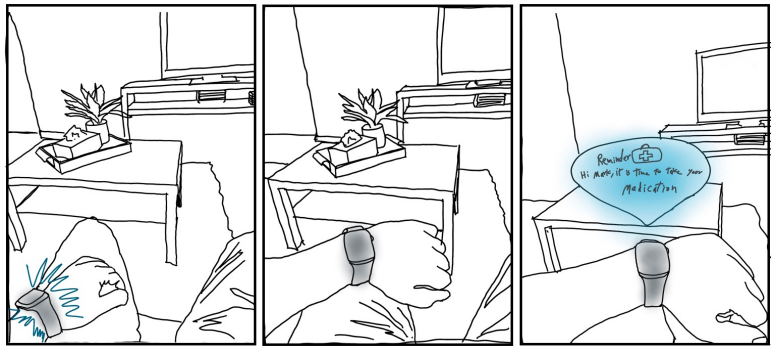
Research Questions

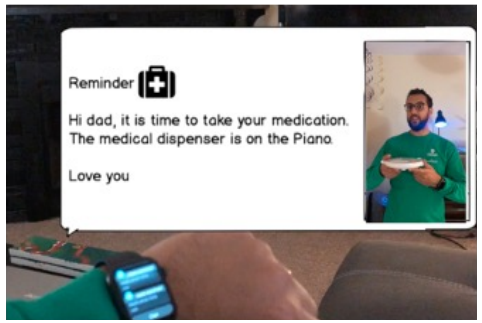


Research Activities and User-Centered Design



Initial System Prototype





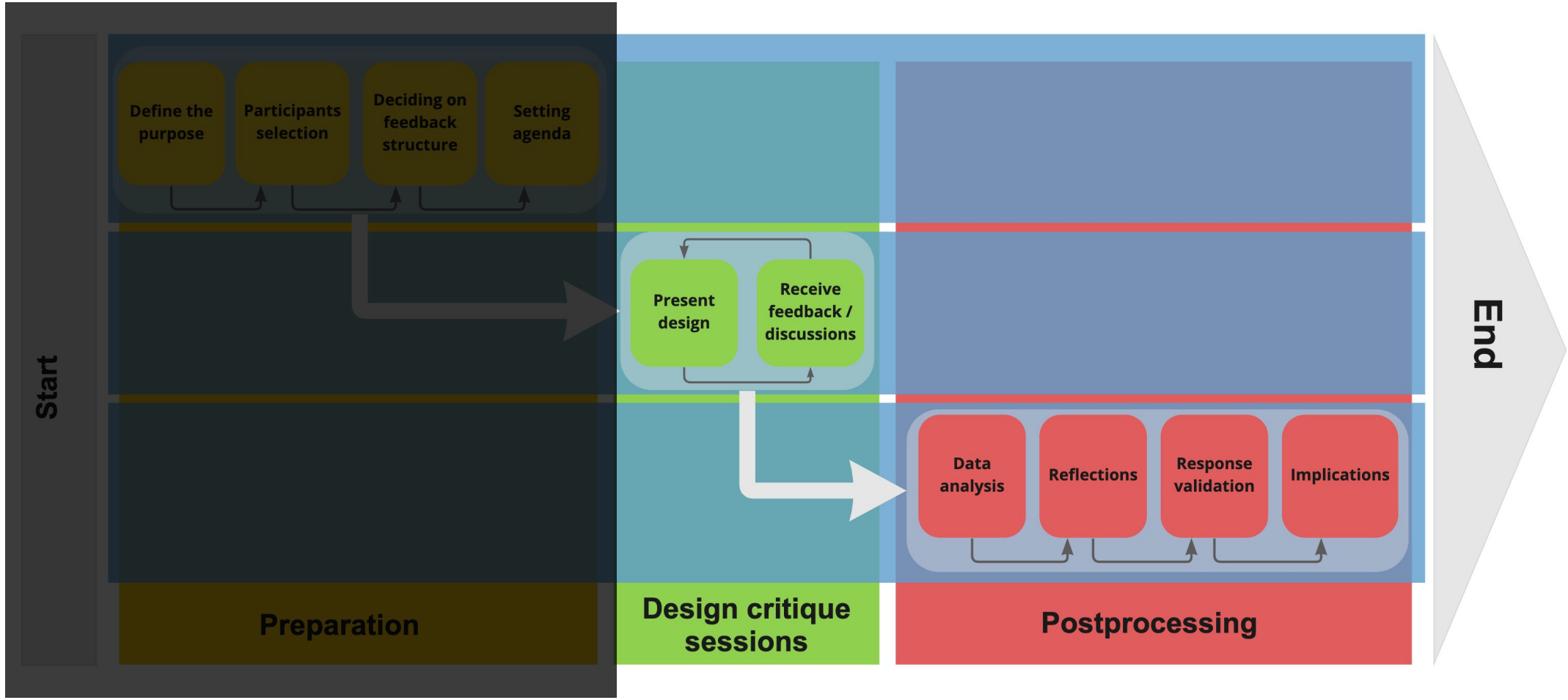
Activity monitoring

Reminder

Prompting

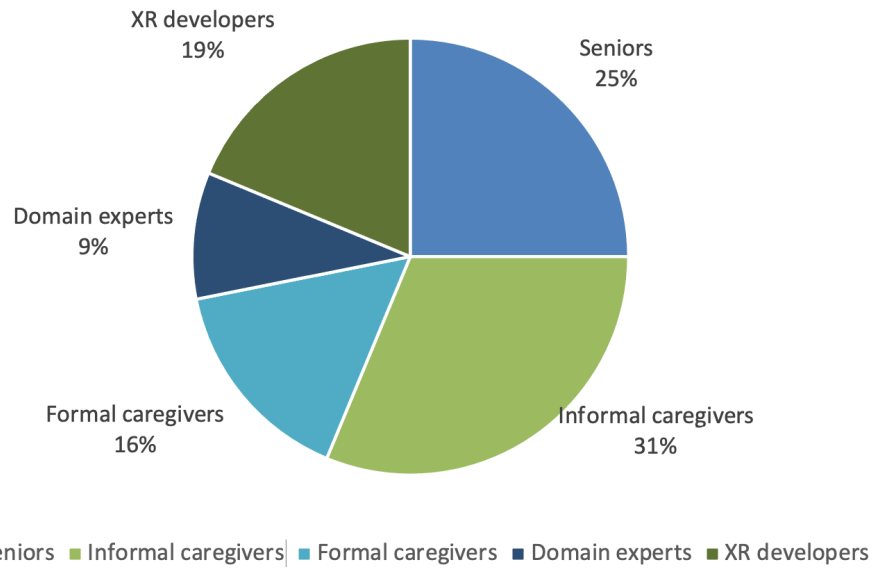
System functionality

Design Critique Process



Design Critique Study

Overview of study participants



Participant	Age	Sex	Location	Senior citizen	Informal caregiver	Formal caregiver	Domain expert	MR developer
P1	30-40	Female	Montreal			Yes	Yes	
P2	30-40	Female	Calgary				Yes	
P3	80-90	Male	Calgary	Yes			Yes	
P4	70-80	Female	Toronto	Yes	Yes	Yes		
P5	30-40	Female	Calgary		Yes			
P6	40-50	Male	Calgary		Yes			
P7	60-70	Female	Louisville	Yes				
P8	50-60	Female	Montreal		Yes			
P9	80-90	Female	Calgary	Yes	Yes			
P10	30-40	Female	Calgary			Yes		
P11	60-70	Female	Calgary	Yes		Yes		
P12	70-80	Female	Vancouver	Yes	Yes			
P13	40-50	Male	Edmonton		Yes			
P14	60-70	Female	Calgary	Yes	Yes			
P15	30-40	Female	Calgary		Yes			
P16	40-50	Female	Calgary		Yes			
P17	60-70	Female	Ottawa	Yes		Yes		
P18	40-50	Female	Calgary		Yes			
P19	20-30	Male	Calgary					Yes
P20	20-30	Male	Calgary					Yes
P21	20-30	Male	Calgary					Yes
P22	20-30	Female	Toronto					Yes
P23	20-30	Female	Edmonton					Yes
P24	20-30	Female	Calgary					Yes

Design Critique Study
Round one

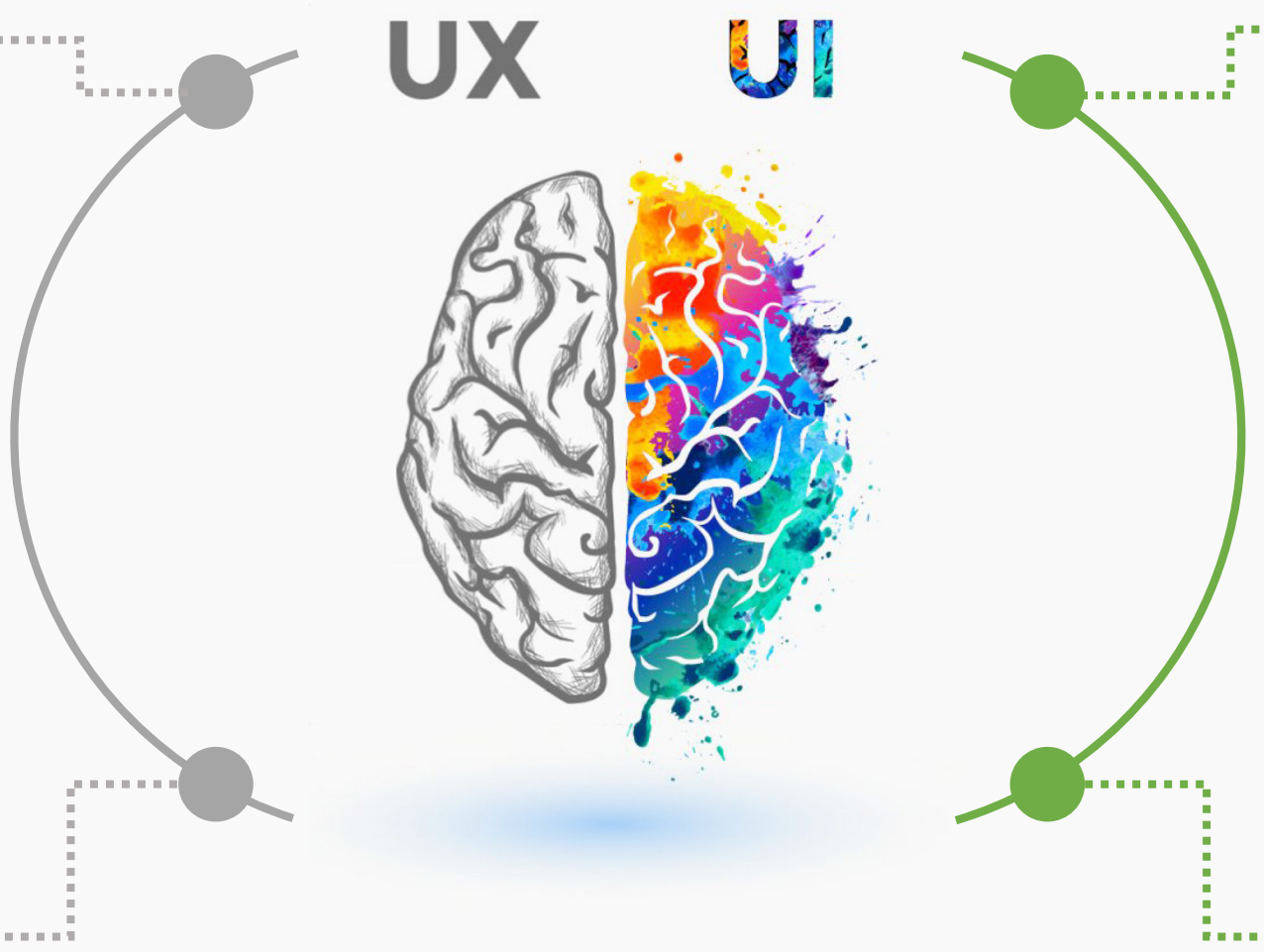
Main Theme	No. of References
Design recommendations for MR applications	205
Considerations for supportive smart home systems design	78
User scenarios	76
User support	62
Advantages of the proposed system	57
Concerns	54

Thematic framework

Design Recommendations for MR Applications

System-User interaction

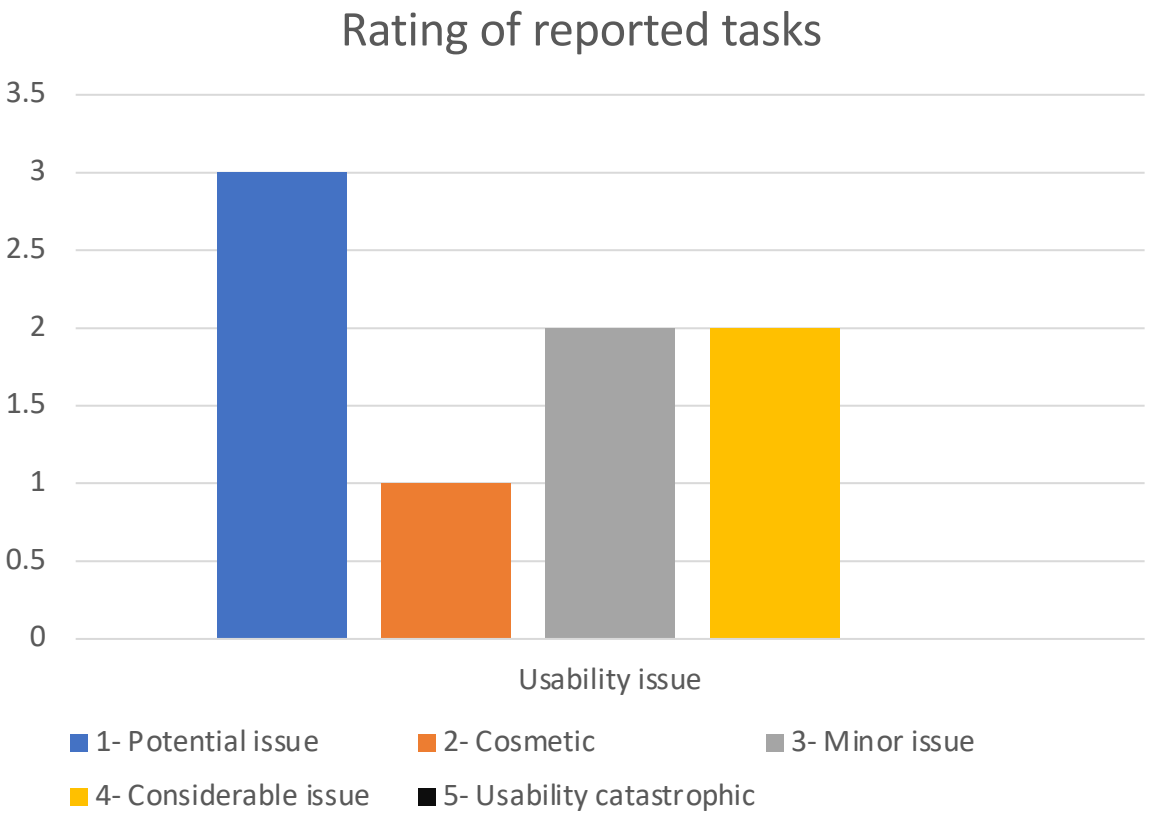
Visual components

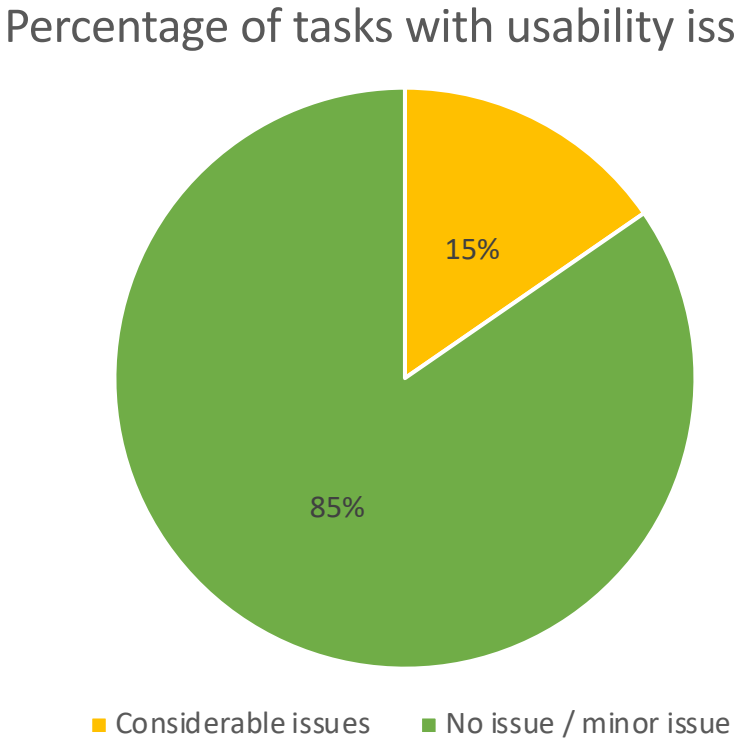


User-system interaction

System language

Fourth Study – Hi-Fi Usability Evaluation

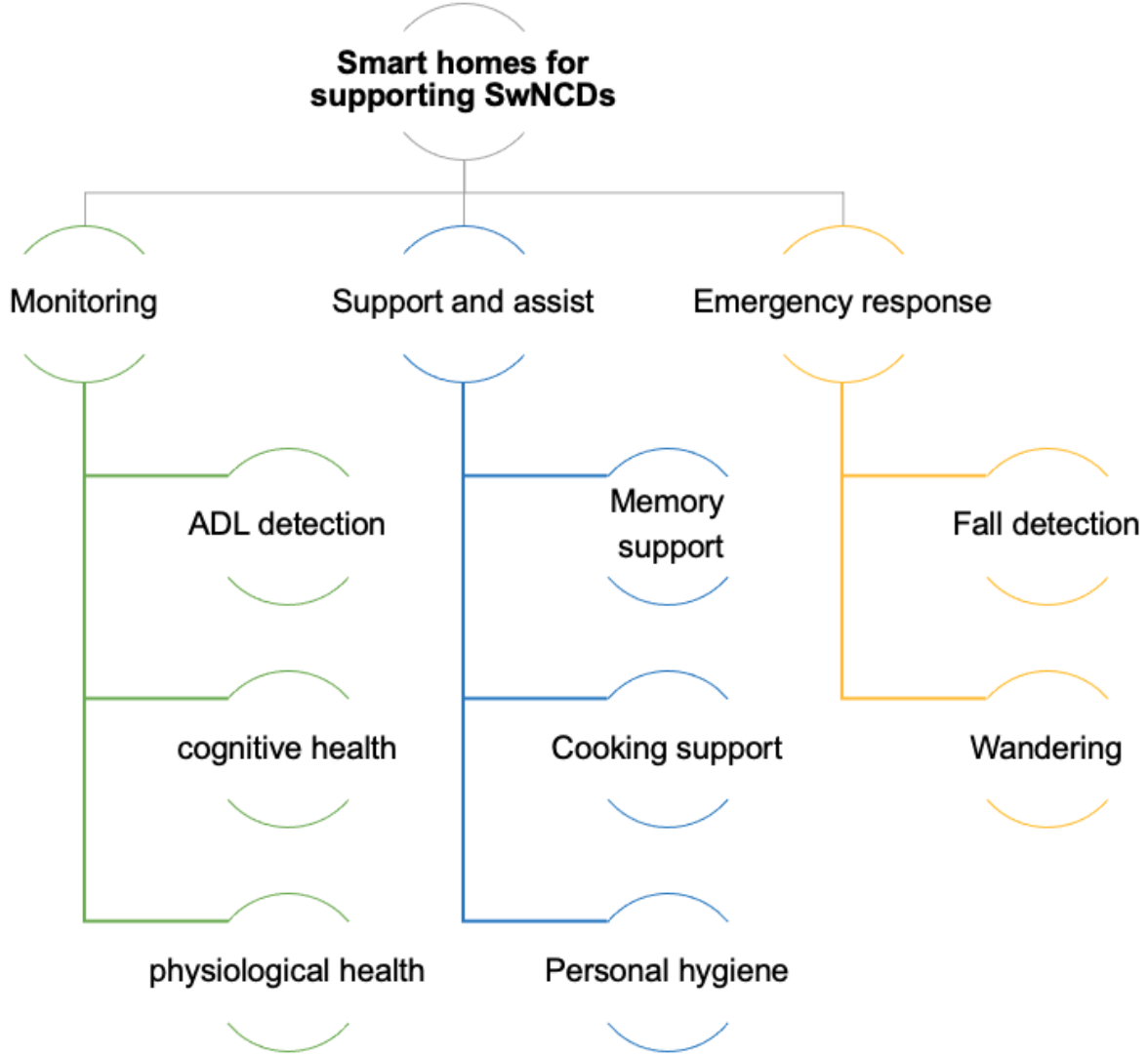




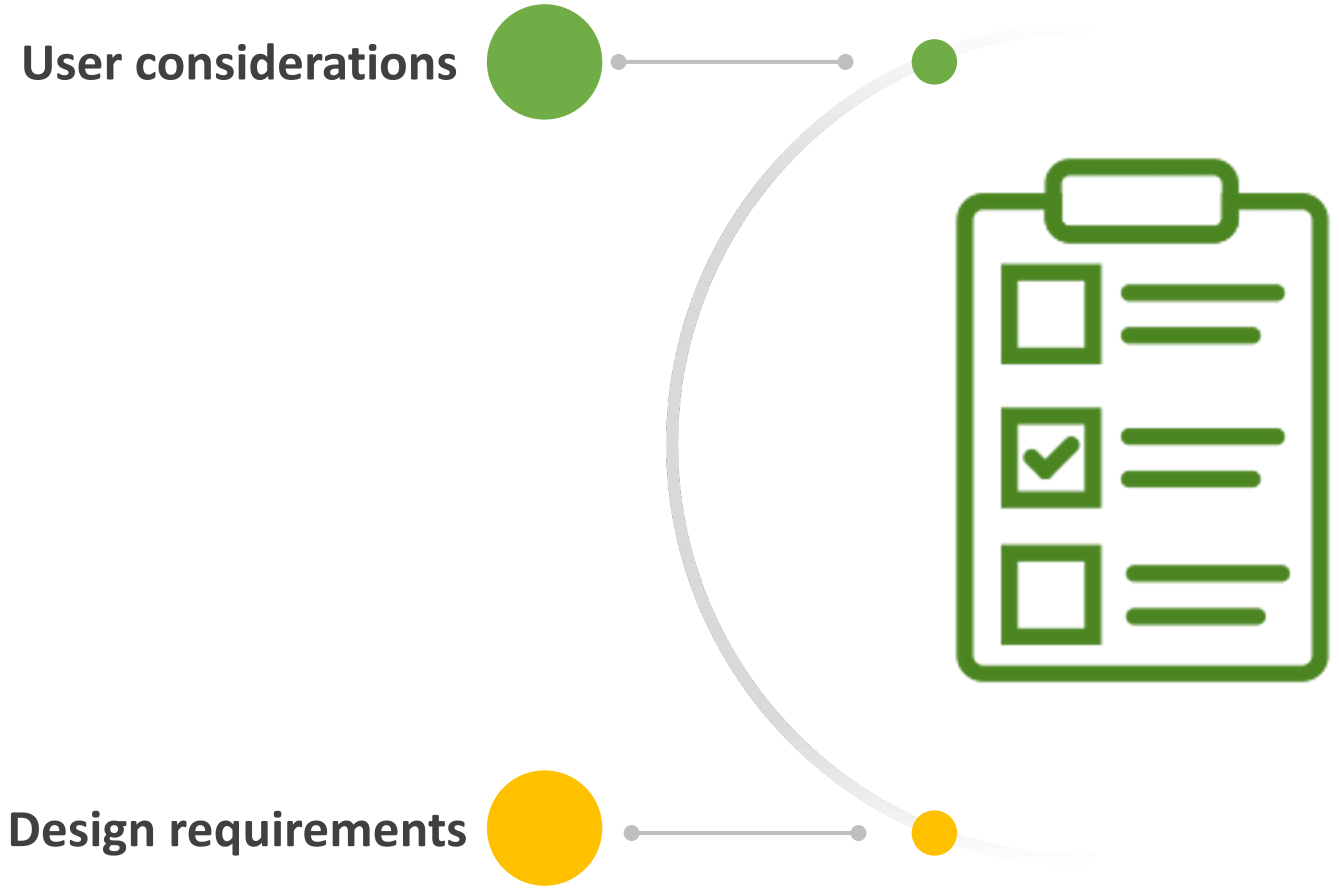
Overview of the Contributions and Research Questions

1- Taxonomy and comprehensive analysis of the literature

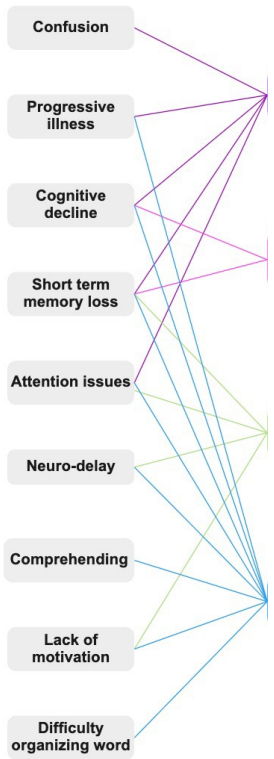
- Majority of studies fall under monitoring
- Ambient and hybrid sensing
- Lack of user research
- Lack of studies in supporting and assisting
- High-fidelity prototype
- Accuracy, usability, technology acceptance



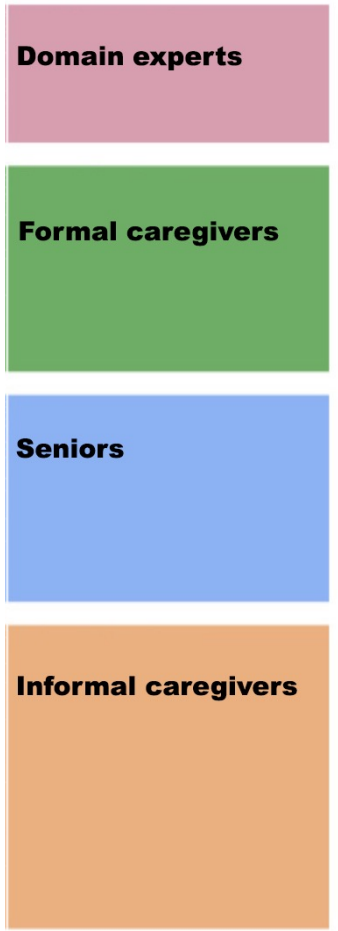
2 – Special requirements for supportive smart home systems for SwNCDs



3 – Immersive applications design recommendations for SwNCDs



4 – Relationships between stakeholders and design recommendations



Thank You!

Highlights of the Limitations

- Sample size and sampling bias
- Researcher bias
- Threats to validity
- Participants experience

First Study: Systematic Literature Review

First Study: Systematic Literature Review

Importance of the study:

- Smart homes for SwNCDs particularly
- Assistive technology vs supportive smart homes

Scope of the study:

- Papers that introduced supportive smart home system concepts for SwNCDs
- And, developed a system prototype
- And, conducted a form of evaluation on system prototypes

Objectives

- Taxonomy of the supportive smart home systems for SwNCDs literature
- Explore the different design approaches
- Smart home sensor data
- Prototype fidelity and evaluation methods
- Data privacy
- Benefits and limitations

First Study: Systematic Literature Review

Method

- Guidelines for Performing SLRs by Kitchenham and Stuart, 2007
- Inclusion and exclusion criteria for each stage

Search process:

- Develop search keywords and search strings
- Run primarily searches on Google Scholar
- Systematic documented searches on Google Scholar
- Supplementary searches: ACM Digital Library and IEEE Xplore

Screening process

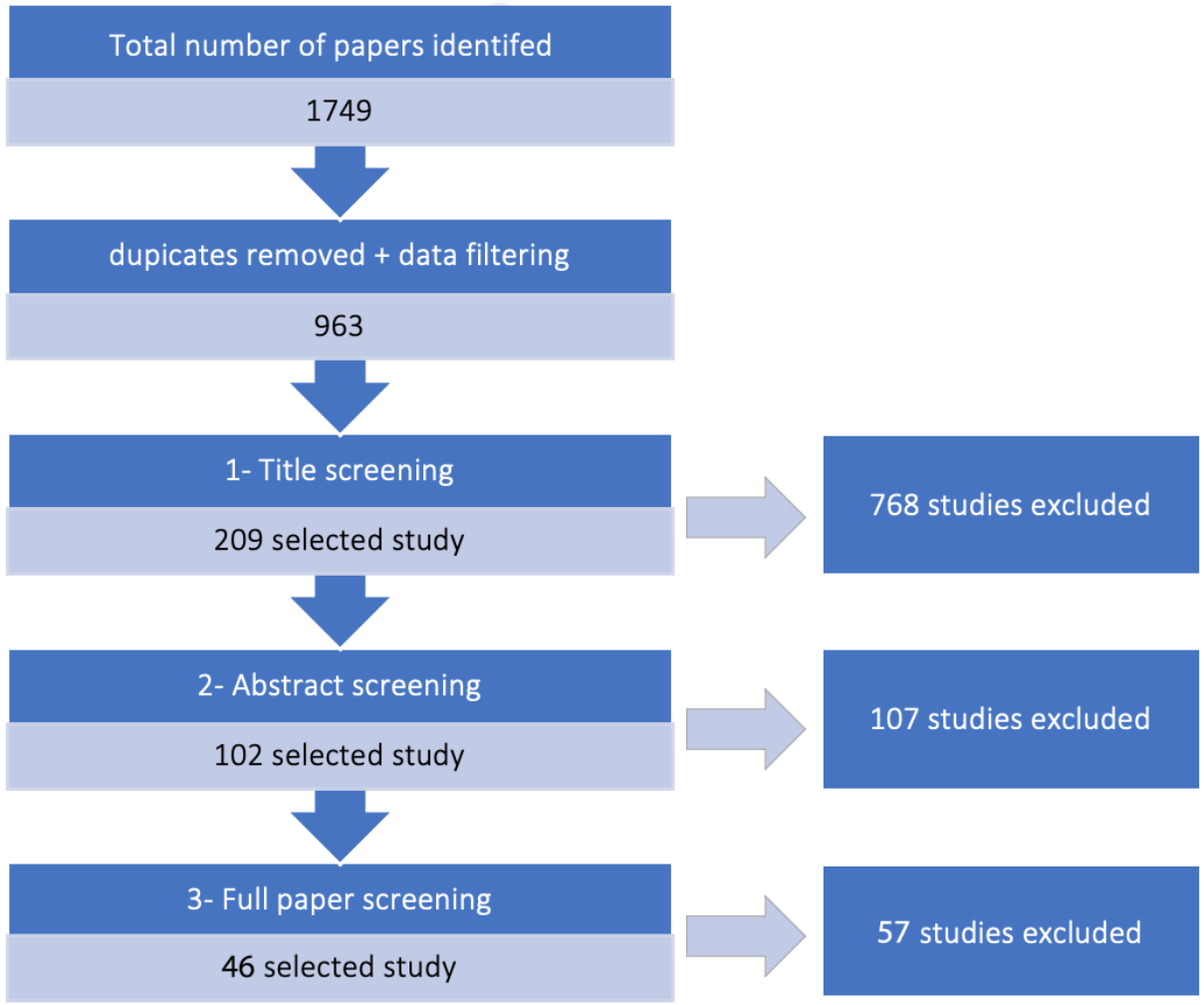
- Title screening
- Abstract screening
- Full script screening

First Study: Systematic Literature Review

Search terms

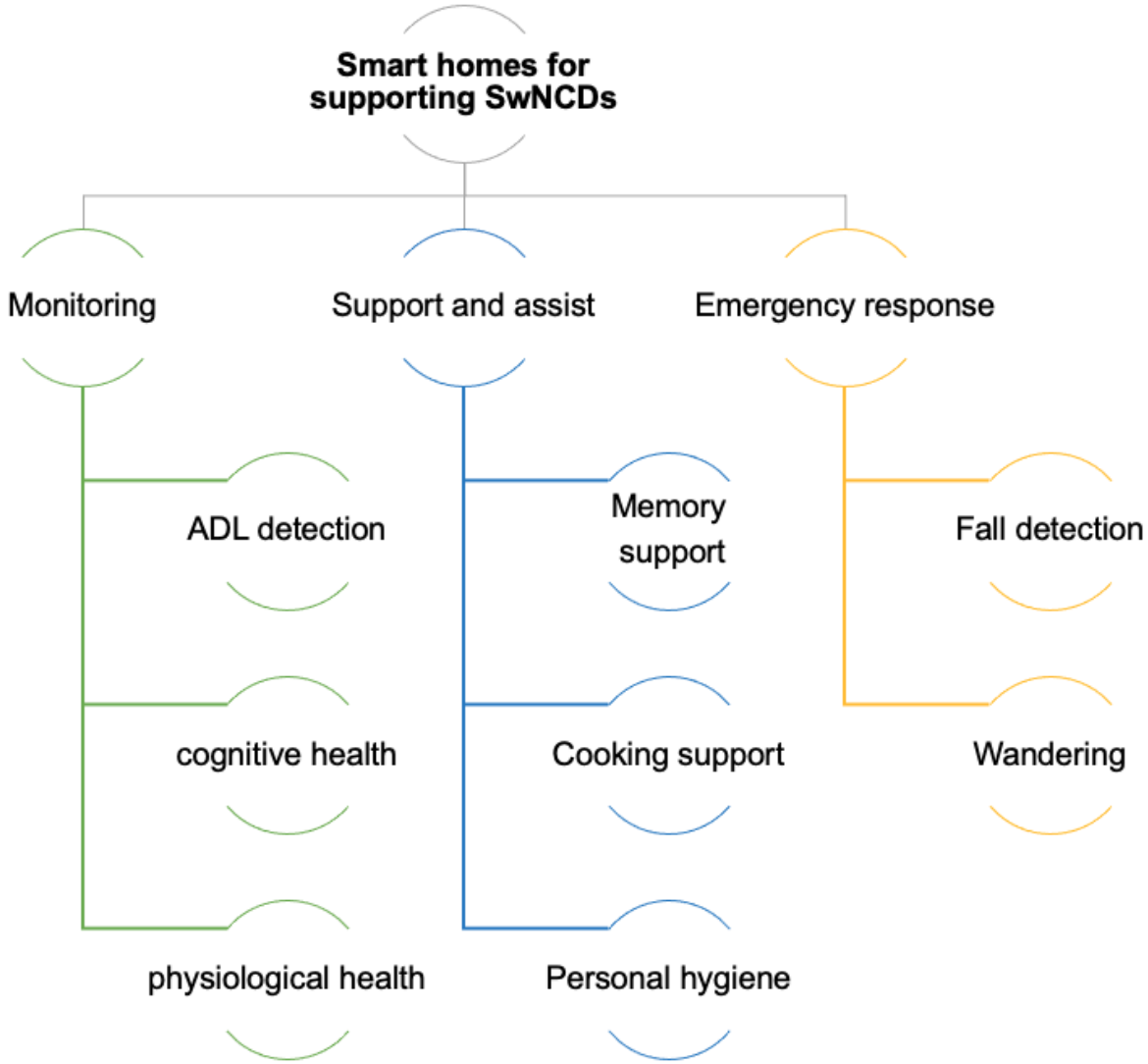
“smart home”, “aging in place”, “ambient intelligence”, “smart architecture”, “ambient assisted living”, “Alzheimer”, “Dementia”, “MCI”, “NCD”, “neurocognitive disorders”, “cognitive impairment”, “empirical”, “prototype”, “pilot”, “evaluation”, “testing”.

Search and selection results



First Study: Systematic Literature Review

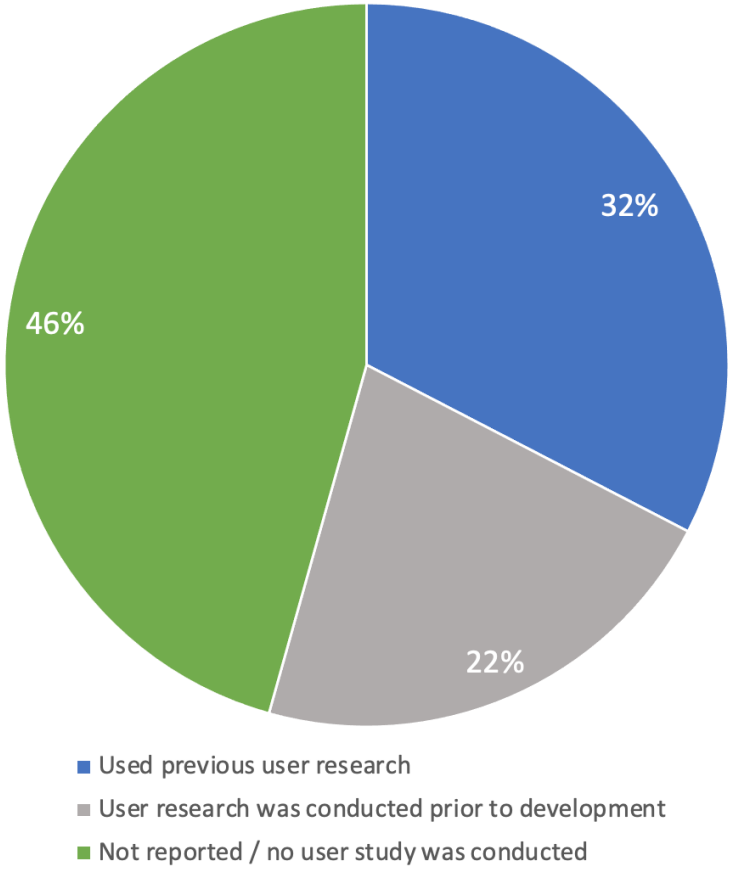
Findings



Breakdown of the three main SSHS categories and their subcategories

First Study: Systematic Literature Review

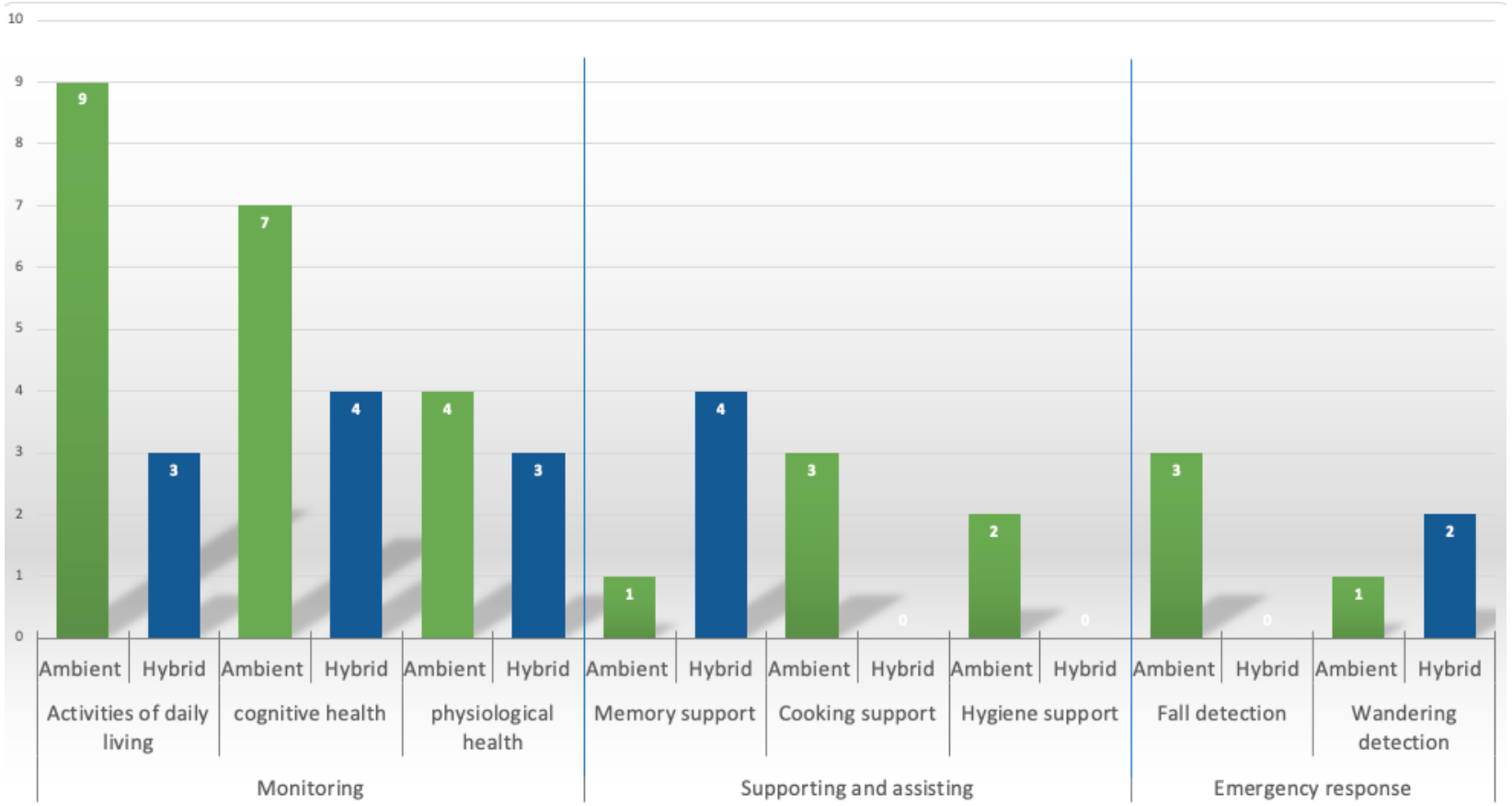
Discussions



Analysis of the design approach bases

First Study: Systematic Literature Review

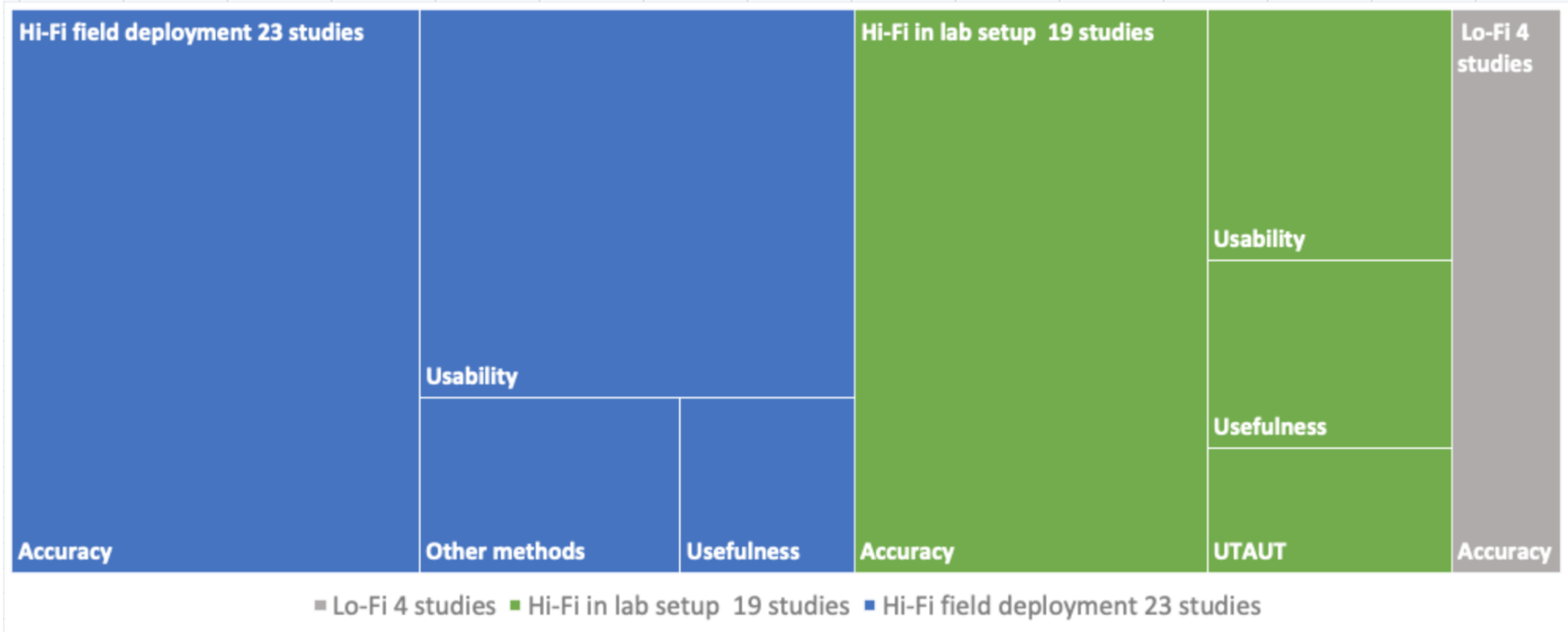
Discussions



Analysis of the sensing approach

First Study: Systematic Literature Review

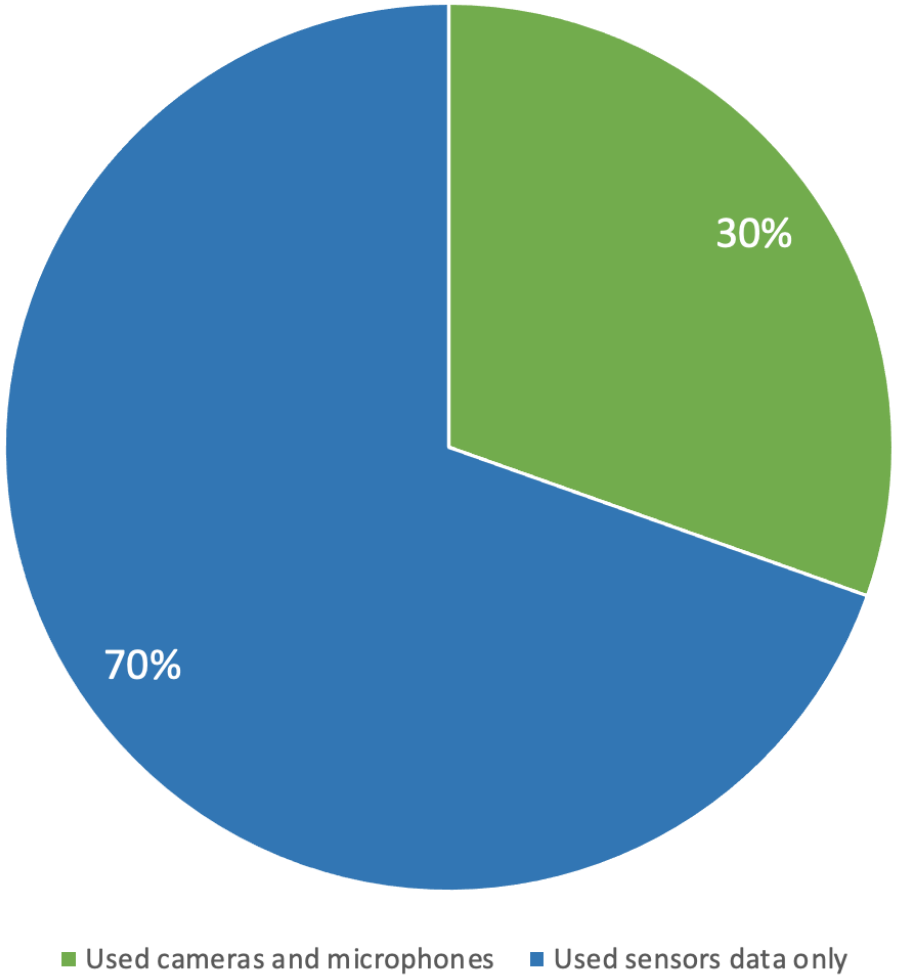
Discussions



Prototype evaluation methods analysis

First Study: Systematic Literature Review

Discussions



First Study: Systematic Literature Review

Takeaways:

- Lack of concepts that directly support senior users
- The importance of tailored memory prompts
- Humble attempts to use different user-system interaction methods
- Capturing the user's attention and assuring successful delivery remains a challenge
- A better user-system interaction method is still required
- Studies that followed User-Centered Design showed better results

First Study: Systematic Literature Review

Limitations:

- Sample size
- Inclusion and exclusion criteria
- Search strategy
- Search engine
- Selection bias

Second Study: Requirements Elicitation

Second Study: Requirements Elicitation

Purpose of the Study

- Gather design requirements
- Understand the user needs
- Homecare scenarios

Method

- Semi-structured interviews
- Site visits
- Fly on the wall observations

Participants

Participant	Category	Age	Condition
P1	Senior	Early 70s	MCI
P2		Early 70s	Early dementia
P3	Formal caregiver	Late 20s	NA
P4		Late 50s	NA
P5	Informal caregiver	Mid 20s	Early dementia
P6		Early 60s	Dementia

Data Analysis Method

- Transcribed interviews
- Using NVivo software
- Reflexive thematic analysis
- Buran and Clarke guidelines

Second Study: Requirements Elicitation

Themes development

Main Theme	No. of References
Common homecare issues	37
Desired system features	34
System requirements	35
Caregiver worries and coping mechanisms	30

Thematic framework

Second Study: Requirements Elicitation

Daily living

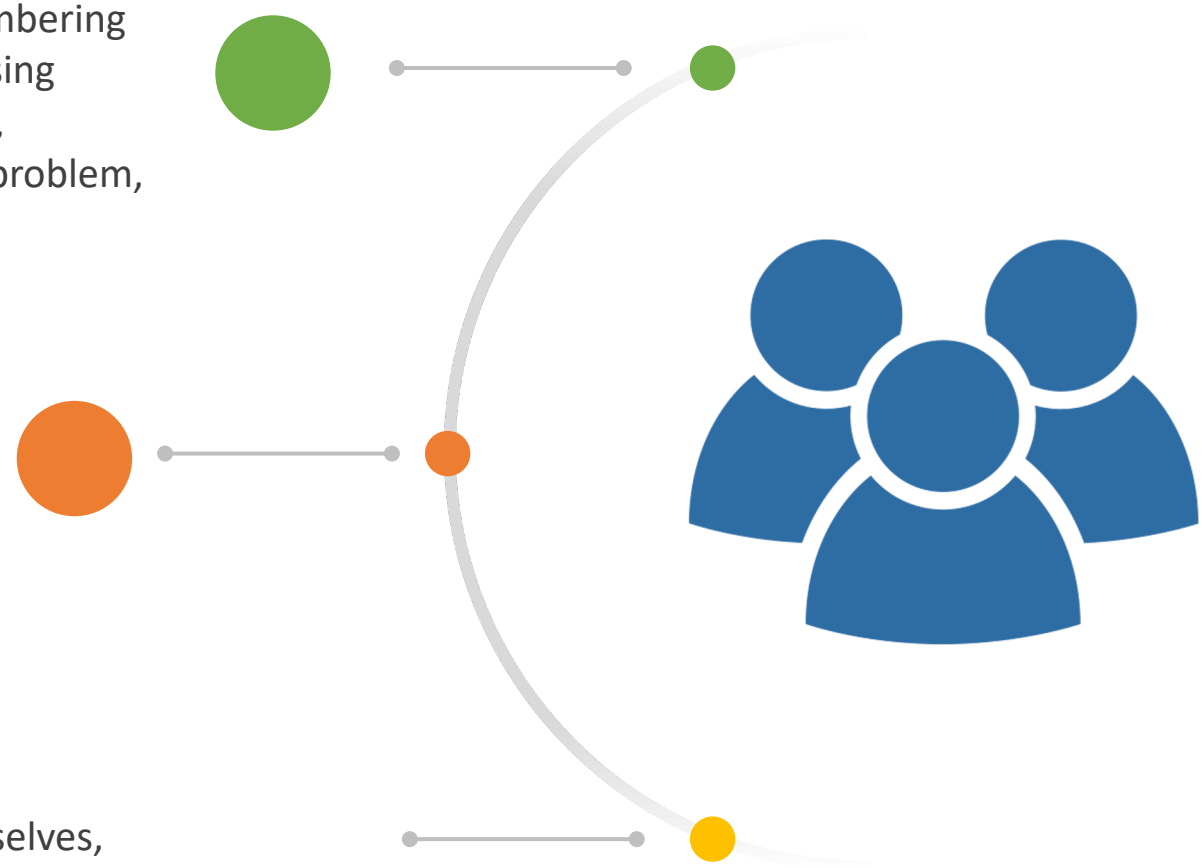
Leaving home appliances on, difficulty remembering names, difficulty recognizing new objects, losing personal items at home, losing sense of time, difficulty completing daily tasks, orientation problem, risk of not comprehending

Health related

Missing important medication, losing appetite, sleeping issues, lack of drinking water, potential hygiene issues, risk of falling

Personality changes

Safety paranoia, difficulty expressing themselves, hide personal items, higher levels of frustration, irritation



First theme: Common Issues theme and all three sub-themes

Second Study: Requirements Elicitation

Activity monitoring

Monitor stove usage, importance of real-time activity monitoring, sleeping, medication monitoring, eating, physical activities, hydration

Prompting

Cooking safety support, task completion prompts, support communications, physical activities

Second theme: Desired System Features theme and its two sub-themes

Second Study: Requirements Elicitation

User considerations

Safety is the number one priority, maintain a sense of agency, account for user feelings, support senior and caregiver users, self introduction technology, account for neurodelay, user consent is required, culture and religious factors, family decision

Design requirements

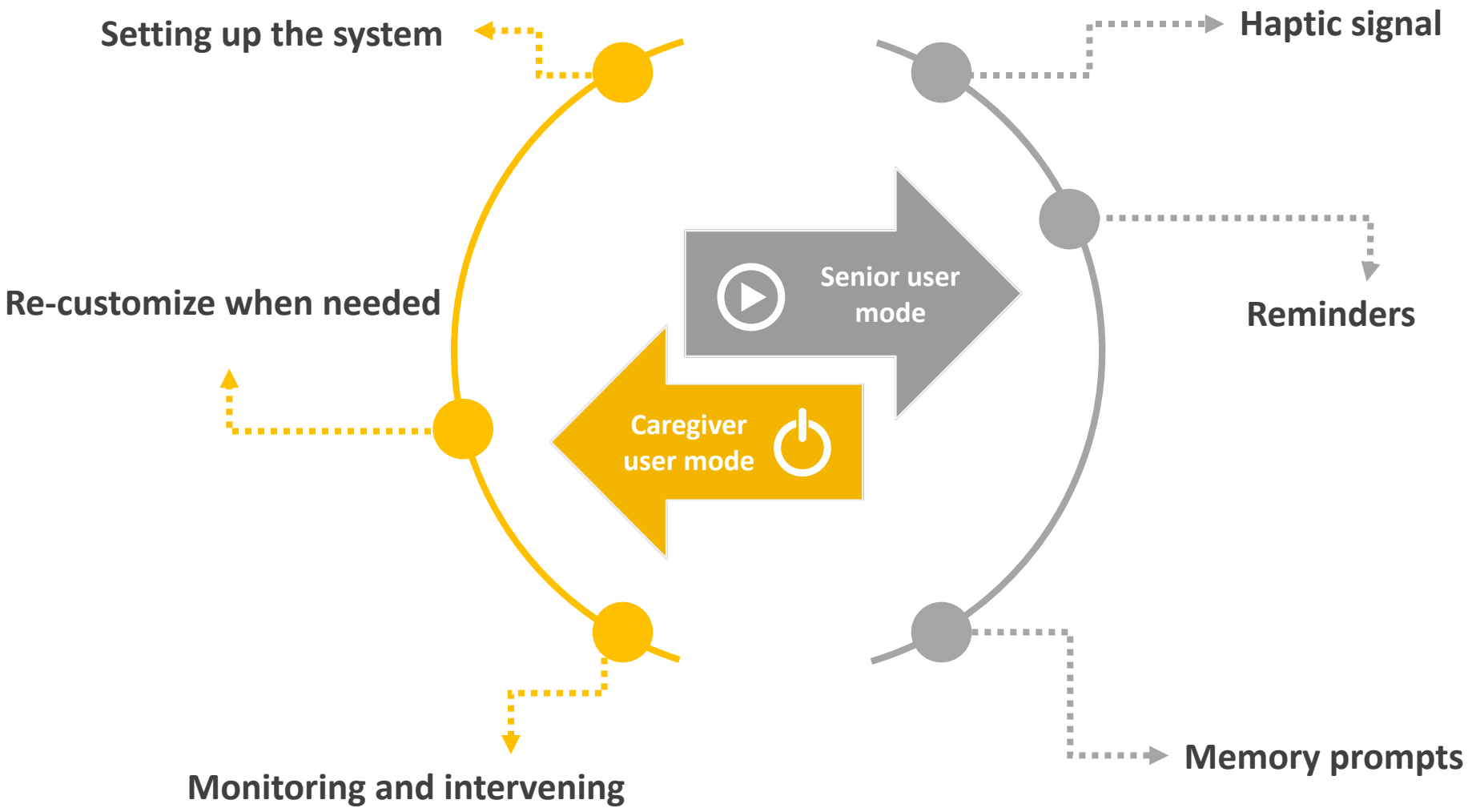
Repetition, simplicity is required for all users, different levels of interventions, using audio messages, the power of visuals

Third theme: System Requirements theme and its two sub-themes

Second Study: Requirements Elicitation

Discussions

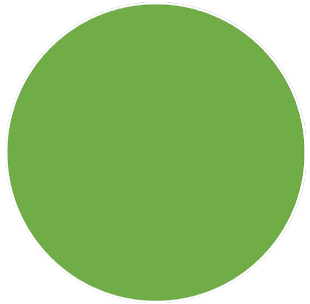
User's Interaction



Second Study: Requirements Elicitation

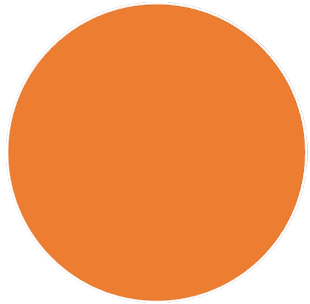
Discussions

Use cases



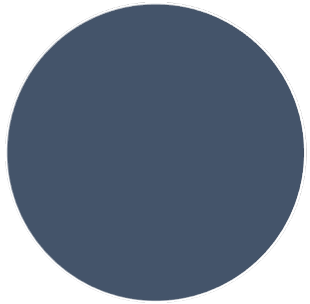
Can be addressed

- Medication
- Home appliances
- Sleeping, hydration
- Eating
- Wandering
- Falling



Considered

- Frustration
- Difficulty recognizing objects
- Risk of not comprehending
- Irritation



Currently cannot be addressed

- Difficulty expressing thoughts
- Preventing falling
- General forgetfulness

Second Study: Requirements Elicitation

Takeaways:

- Taking medication and cooking safety are two important scenarios
- User’s safety is a top priority
- Remote monitoring and interventions
- Simplicity and repetition
- Customization
- How to design user interface and user experience for this population?

First Study: Systematic Literature Review

Limitations:

- Sample size
- Selection bias
- Threats to validity
- Researcher bias

Initial System Prototype

Initial System Prototype

Use cases:

Medication and

Cooking support

- The first two problems to appear among SwNCDs
- All participant categories raised these issues
- There is a lack of SSHS that supports the senior user directly
- Directly affects the quality of life
- Apply learned lessons to other cases

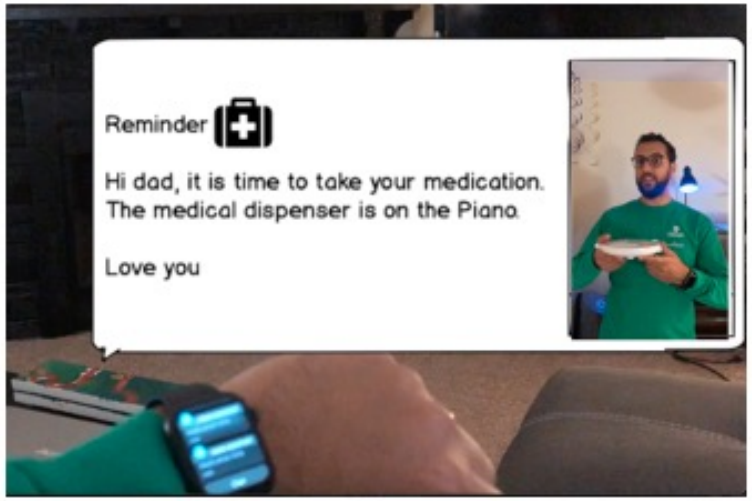
Initial System Prototype

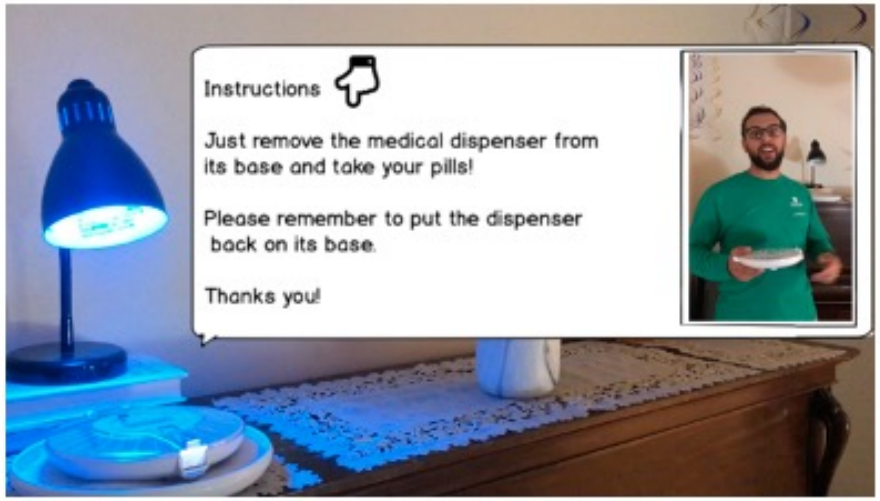
User persona

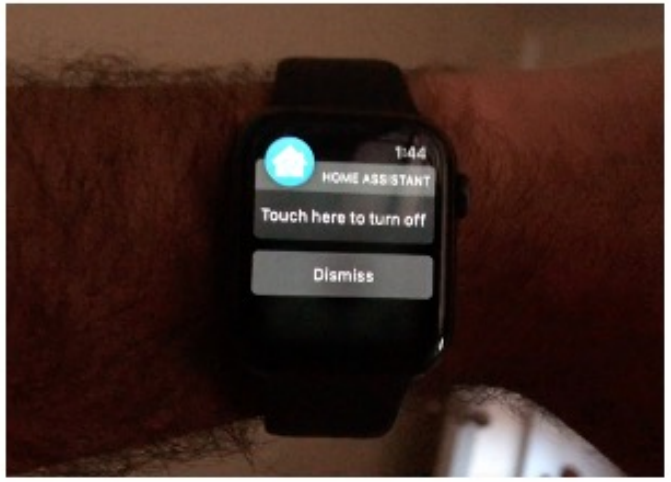
Initial System Prototype

Levels of Intervention

Initial System Prototype



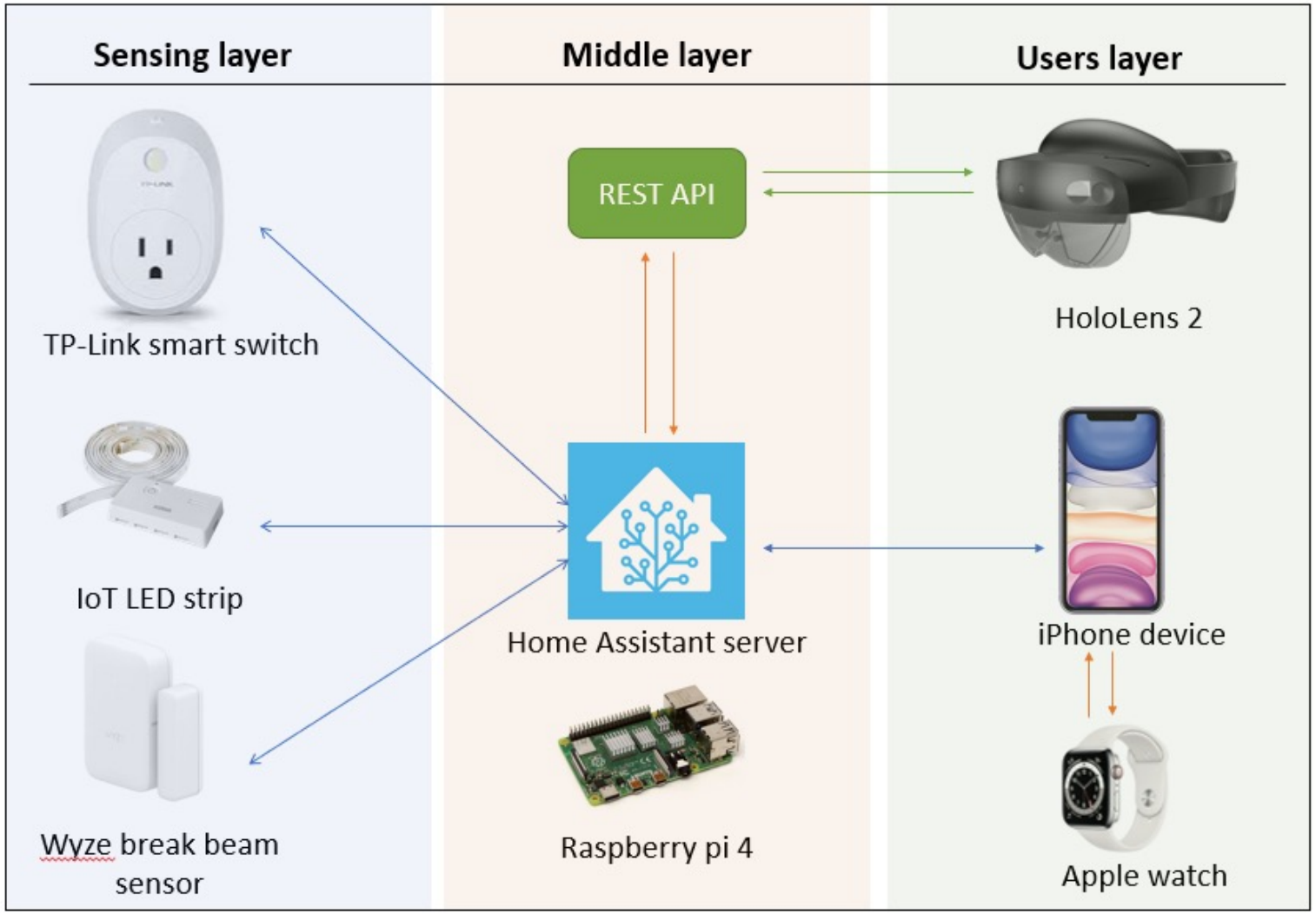




Video Prototype Screenshots

Initial System Prototype

Initial System Prototype

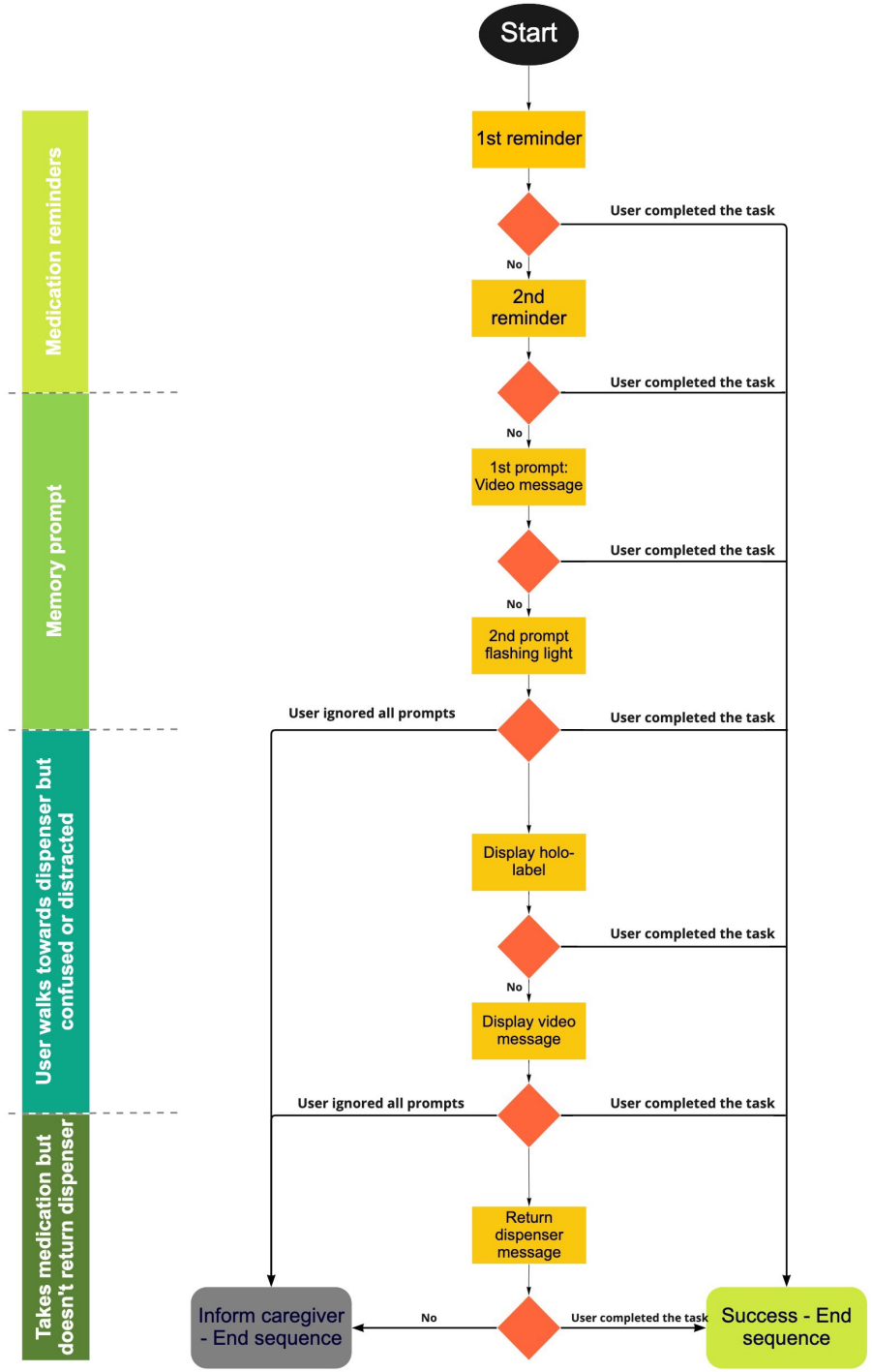


System Architecture

Initial System Prototype

User flow:

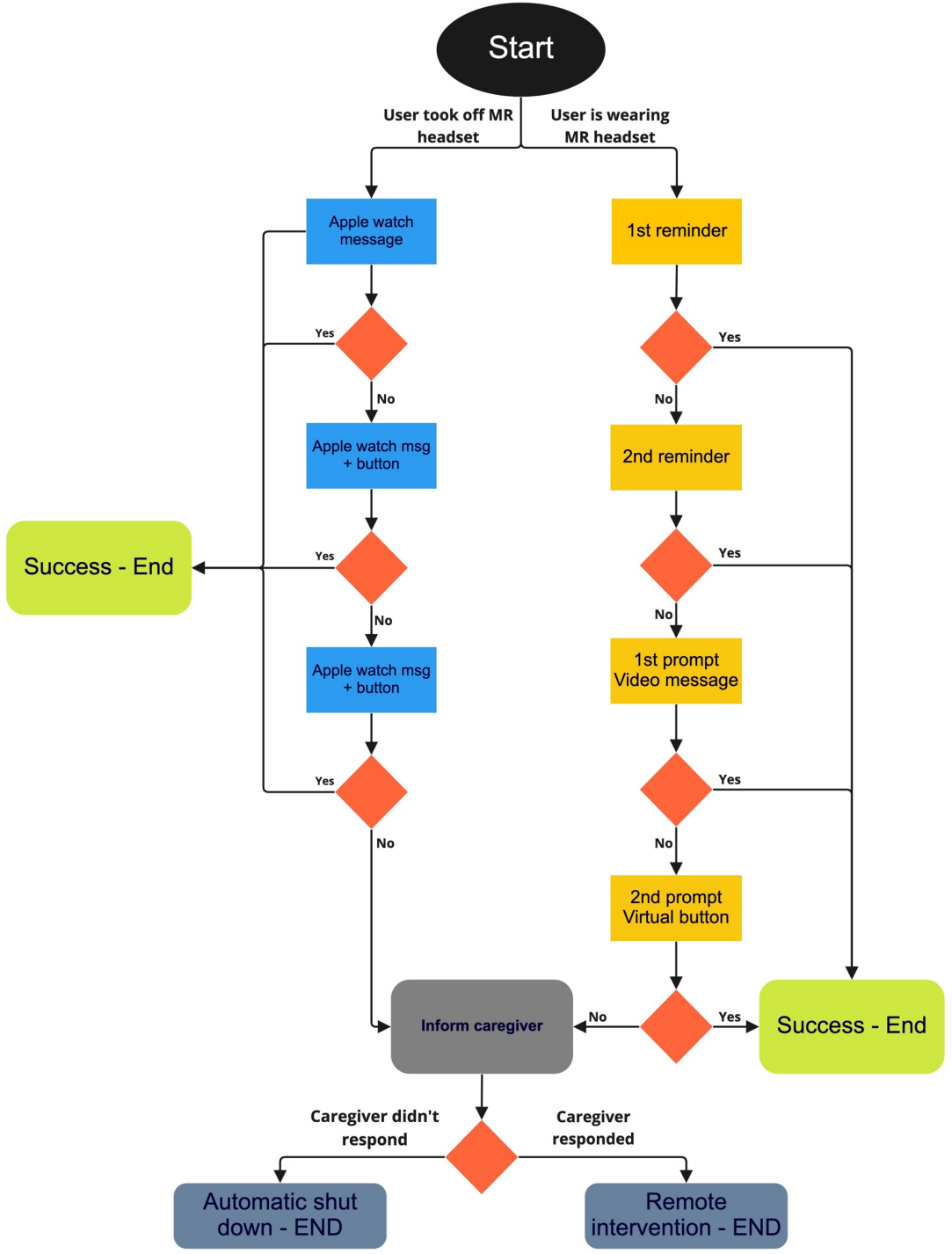
Medication support



Initial System Prototype

User flow:

Cooking support



Design Critique

Third study - Design Critique

Round one

Software Related Considerations

- Task completion verification
- Pre-set to start for risky tasks
- Escalate to the caregiver when system failure
- Inform caregiver if user didn’t use the wearables
- Send reminder if the user leaves the kitchen
- Verify that caregiver received and the read message

Hardware Related Considerations

- Use typical wearable devices such as a watch
- Longer triggers due to neuro-delay response
- Avoid using visible cameras

Second theme: considerations for supportive smart home systems design

Third study - Design Critique

Round one

Better Usability

- MR can provide effortless interactions
- Solve the problem of using smart phones
- More potential in managing emergencies

Better life quality

- Makes aging in place more accessible
- Improves the sense of independence and agency
- Less pressure on the caregiver
- Encourages users to stay active
- Allows for more aging options

Functional benefits

- Cooking support function could enable independence
- The medication reminder could improve user's health

Fifth theme: The advantages of the suggested system theme

Third study - Design Critique
Round one

Hardware concerns

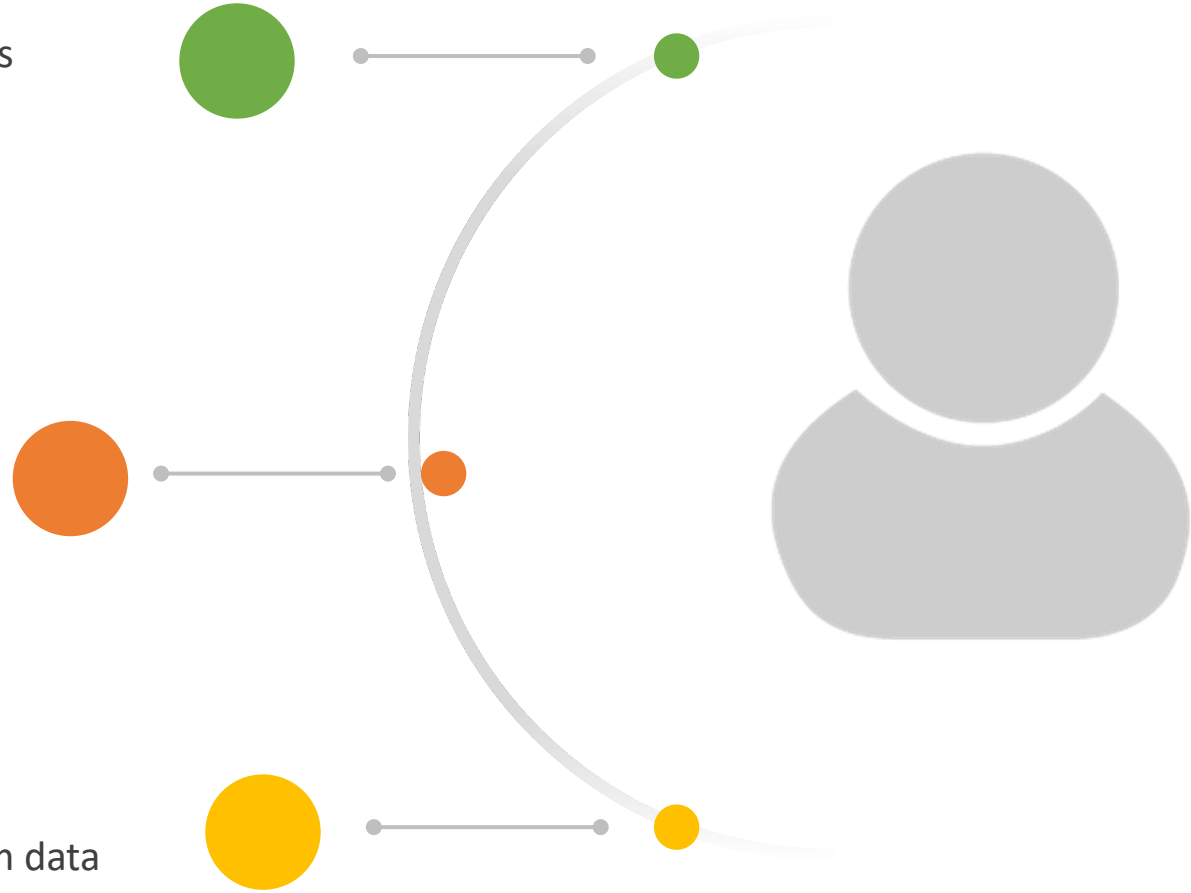
- Medication dispenser device-related concerns
- Charging wearable devices
- Hardware failure concerns
- MR glasses should match prescription

Senior user related concerns

- Cost-related concerns
- Reading capability is required
- Potential of not wearing wearable devices
- Possibility of stigmatization
- Medication often changes

Safety and privacy

- Safety and data privacy
- Concerns about storing system data
- Misusing MR glasses



Sixth theme: participant's concerns

Third study - Design Critique Round two

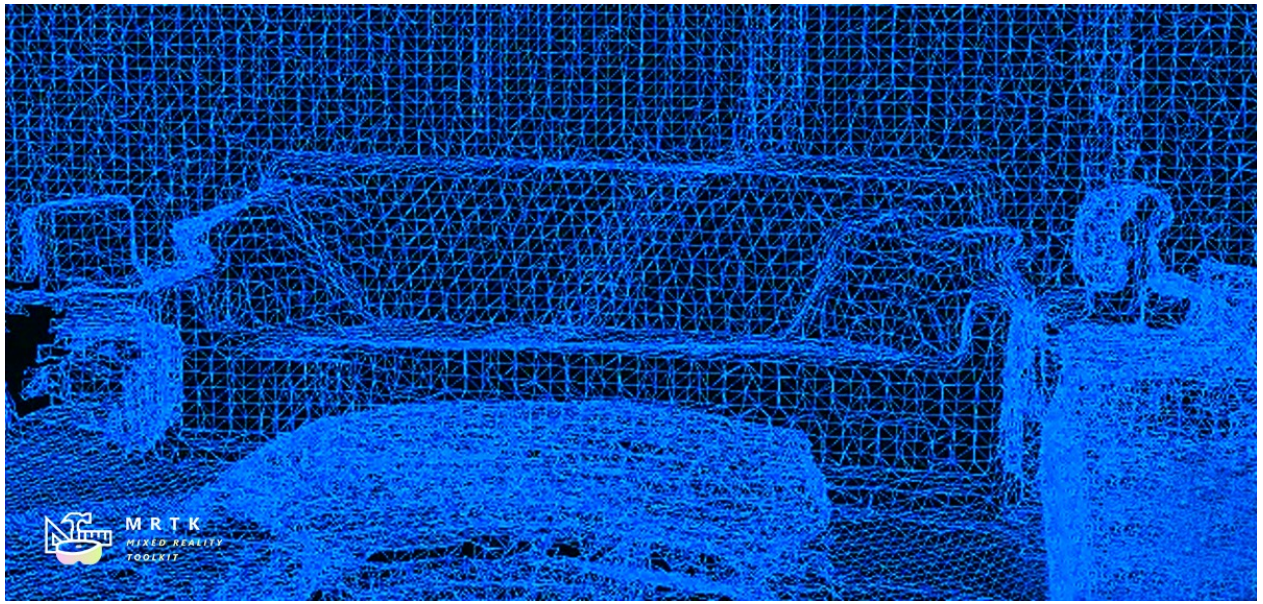
Thematic framework of the Mixed Reality developers DC sessions

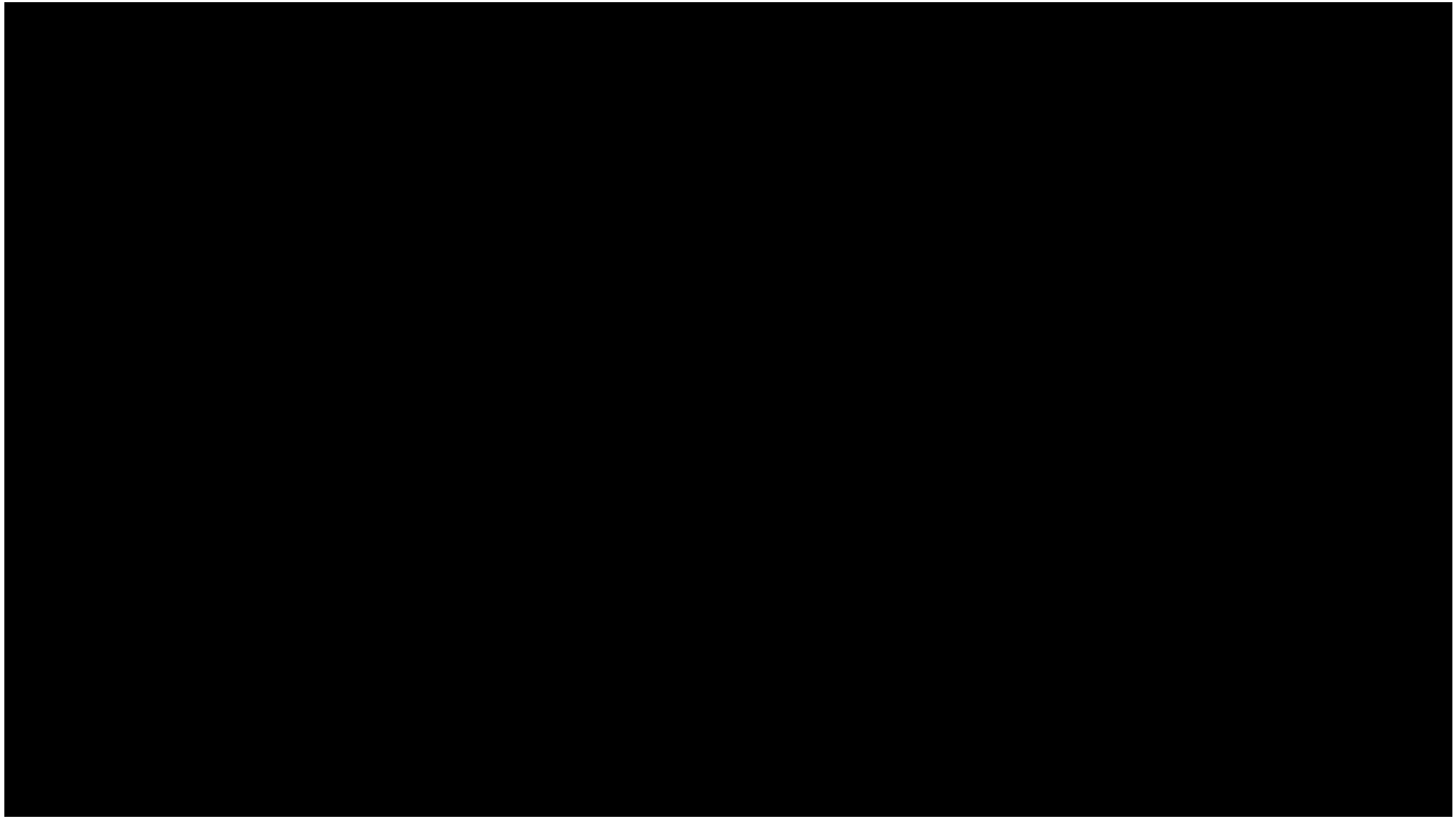
Theme	Codes	No. of Part.	No. of Ref.
User interaction	Billboarding to keep holograms facing user	3	5
	MRTK hand tracker feature	4	5
	Drag and drop for anchoring new virtual objects	3	5
	Use eye tracking script to verify user interaction	3	4
	QR codes to mark, detect, or place object	2	3
	Password protect the caregiver mode	2	3
	Gazing and tracing	2	3
	Left hand menu for setting up the system	2	2
	Follow me menu	2	2
	Use labels for verbal interaction	1	1
Prompting in MR	Directional solvers	3	6
	Use familiar avatars	2	4
	Animated holograms	3	3
	Use practical systems	3	3
	ToolTip feature	1	2
	Audio-visual prompts	1	1
Challenges	Use RFID tags to track the dispenser	4	5
	ML to detect medical dispenser in space	3	3
	Verify that user is watching the video	3	3
	Account for limited processing power	2	3
	Avoid seizure triggers	2	2
	Count for device latency	1	1
	External cameras to track dispenser	1	1
	Orienting the system after user takes off glasses	1	1
	Identify wearable devices in the environment	1	1
Using text in MR	Avoid using computer text	4	6
	Images instead of texts is an option	4	6
	Text Pro when text is needed	2	2
	3D texts is an option	1	1
Hologram design recommendations	Use canvases for images and videos	5	6
	Stabilization script to deal with shakiness	2	3
	Use MRTK materials not Unity materials	1	2
	Keep holograms messages transparent	1	1
	Use MRTK banner component	1	1
	Account for the user's distance from objects	1	1
Spatial awareness related	Configure the spatial awareness profile	3	4
	Use spatial sound feature	1	1
	Spatial mapping to add new virtual objects	1	1
	Disable rendering spatial awareness	1	1

Third study - Design Critique

Discussions: data privacy and user safety

- Using camera
- Using MR headset camera
- Using depth camera

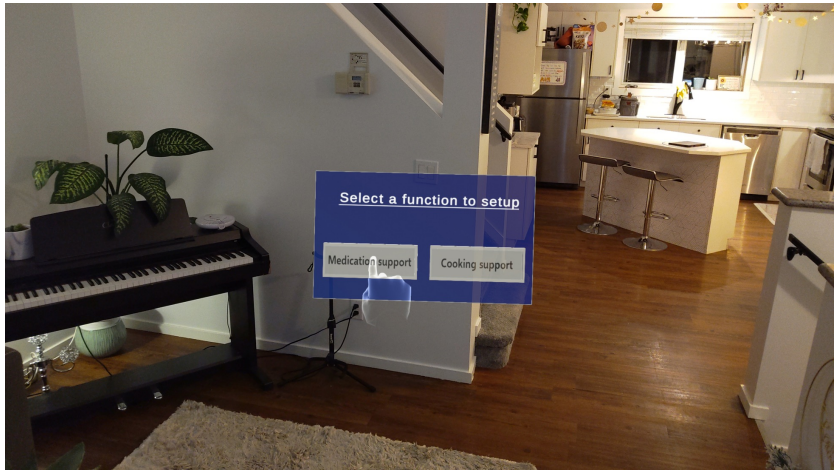


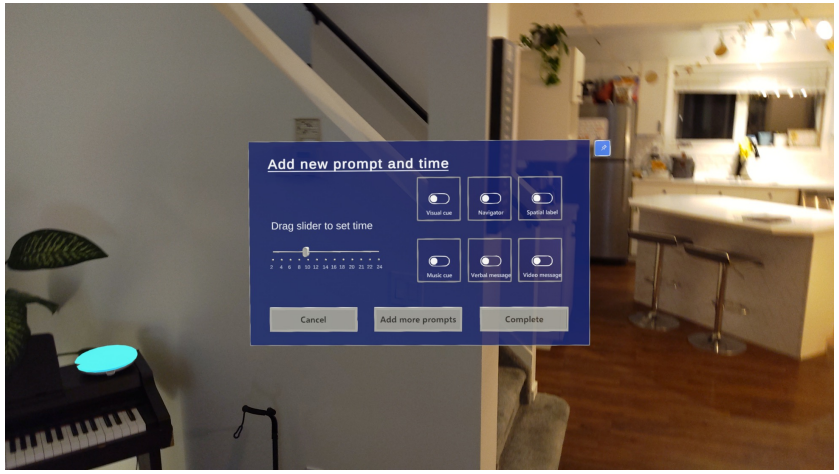


Demo of the built-in reminders and memory prompts

Usability Evaluation

Fourth Study – Hi-Fi Usability Evaluation





Selected screenshots of the caregiver mode

Fourth Study – Hi-Fi Usability Evaluation

Usability testing:

Cognitive walkthrough

Caregiver task questions

1. Can this step be completed by users from different technology experience levels? (new questions)
2. Will the user achieve the right results?
3. Will the user recover from an error in this step? (new questions)
4. Will users associate the correct action with the result they are trying to achieve?
5. After the action is performed, will users see that progress is made toward the goal?

Senior user task questions

1. Can this task be completed using gazing interaction only?
2. Will the user notice the system's action?
3. Is it believable that the user will understand this action?
4. Will the user associate the system's action with completing a daily task (take medication / watch stove)?

Fourth Study – Hi-Fi Usability Evaluation

Usability testing:

Cognitive walkthrough

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A) First time running: Medicine dispenser

1- Drag and drop virtual object

	Yes	Maybe	No
1- Can this step be completed by users from different technology experience levels?	○	○	○
2- Will the user achieve the right results?	○	○	○
3- Can the user recover from an error in this step?	○	○	○
4- Will users associate the correct action with the result they're trying to achieve?	○	○	○
5- After the action is performed, will users see that progress is made toward the goal?	○	○	○

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B) Default sequence: medicine dispenser

1- Dispenser first and second reminder

	Yes	Maybe	No
1- Is there any user-system interaction requirement beyond gazing?	○	○	○
2- Will the user notice the system's action?	○	○	○
3- Is it believable that that user will understand this action?	○	○	○
4- Will the user associate the system's action with a completing a daily task (take medication / watch stove)?	○	○	○

Fourth Study – Hi-Fi Usability Evaluation

Usability testing:

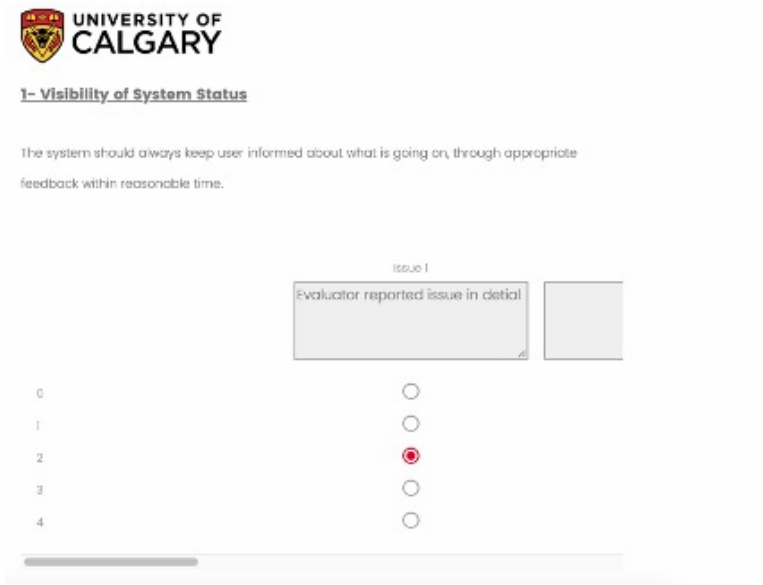
Heuristic evaluation

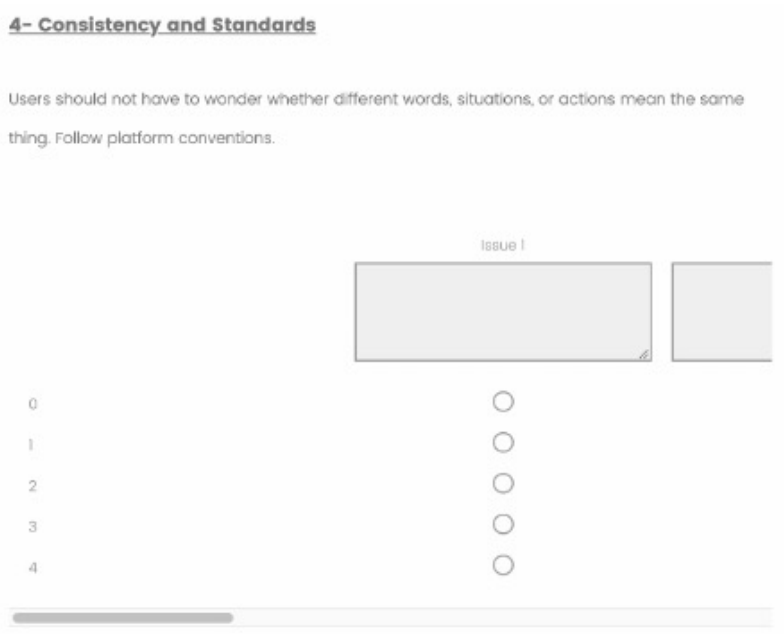
Jakob Nielsen and Rolf Molich 10 usability heuristics

Fourth Study – Hi-Fi Usability Evaluation

Usability testing:

Heuristic evaluation

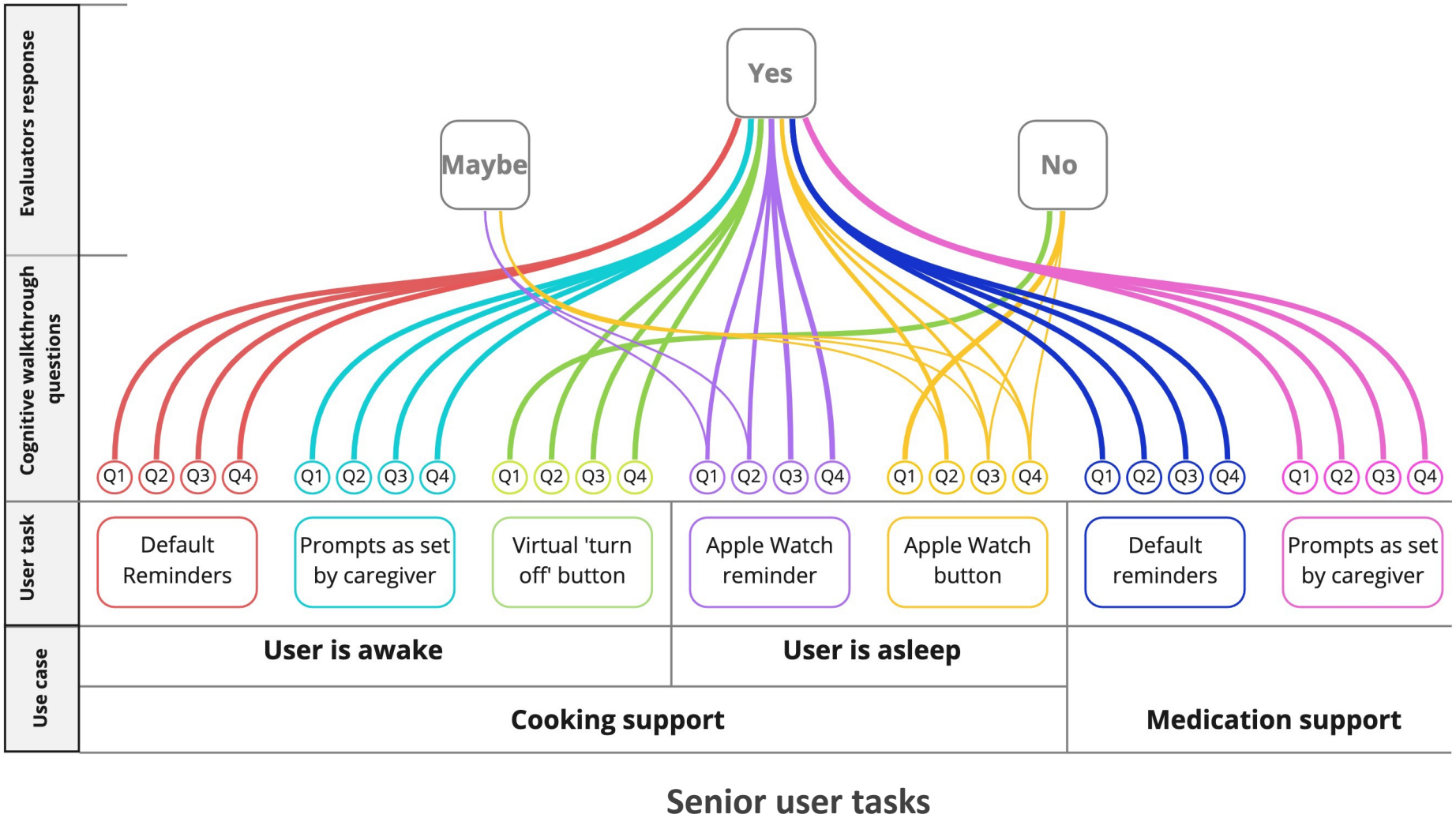




Fourth Study – Hi-Fi Usability Evaluation

Usability testing:

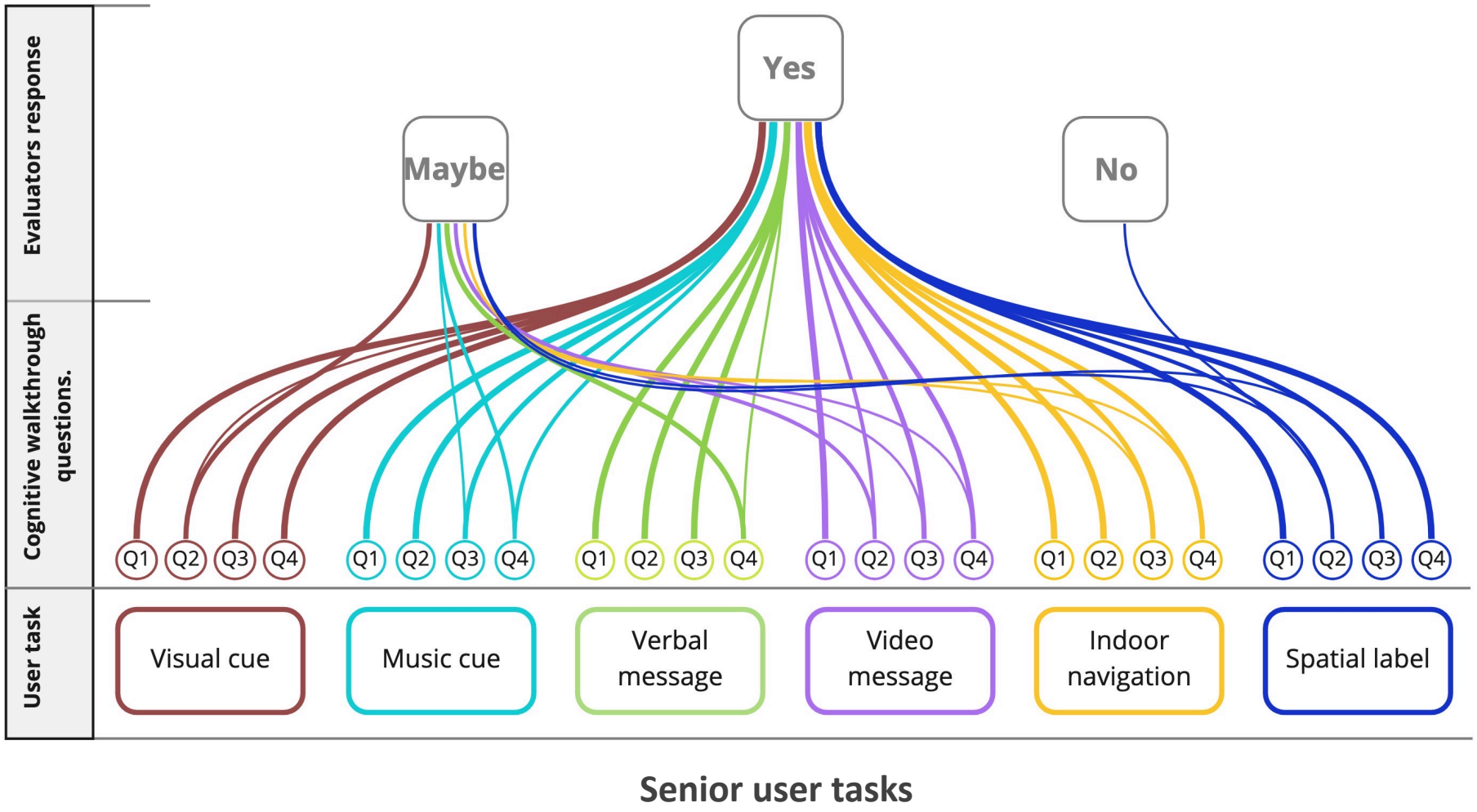
Cognitive walkthrough findings



Fourth Study – Hi-Fi Usability Evaluation

Usability testing:

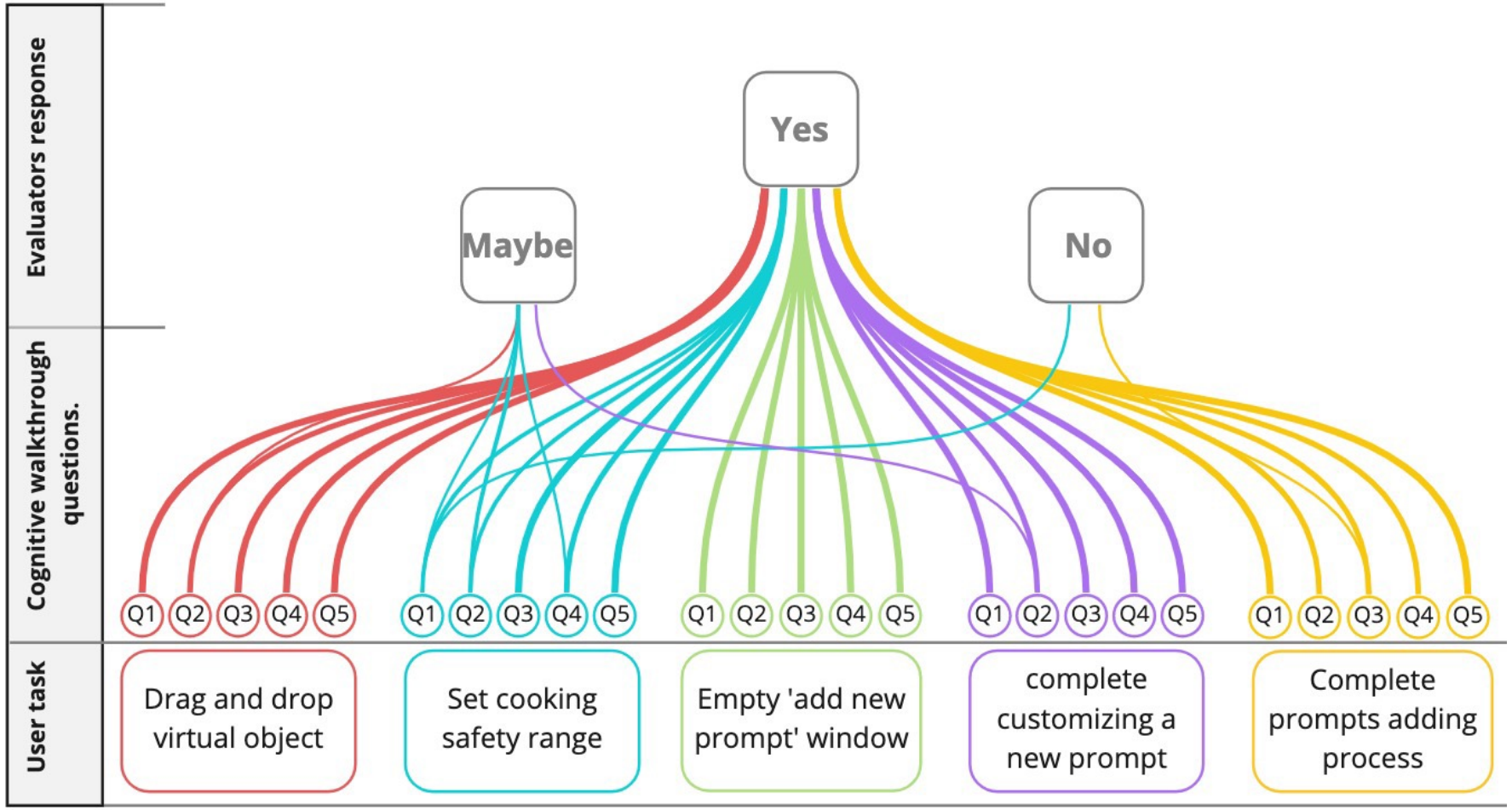
Cognitive walkthrough findings



Fourth Study – Hi-Fi Usability Evaluation

Usability testing:

Cognitive walkthrough findings



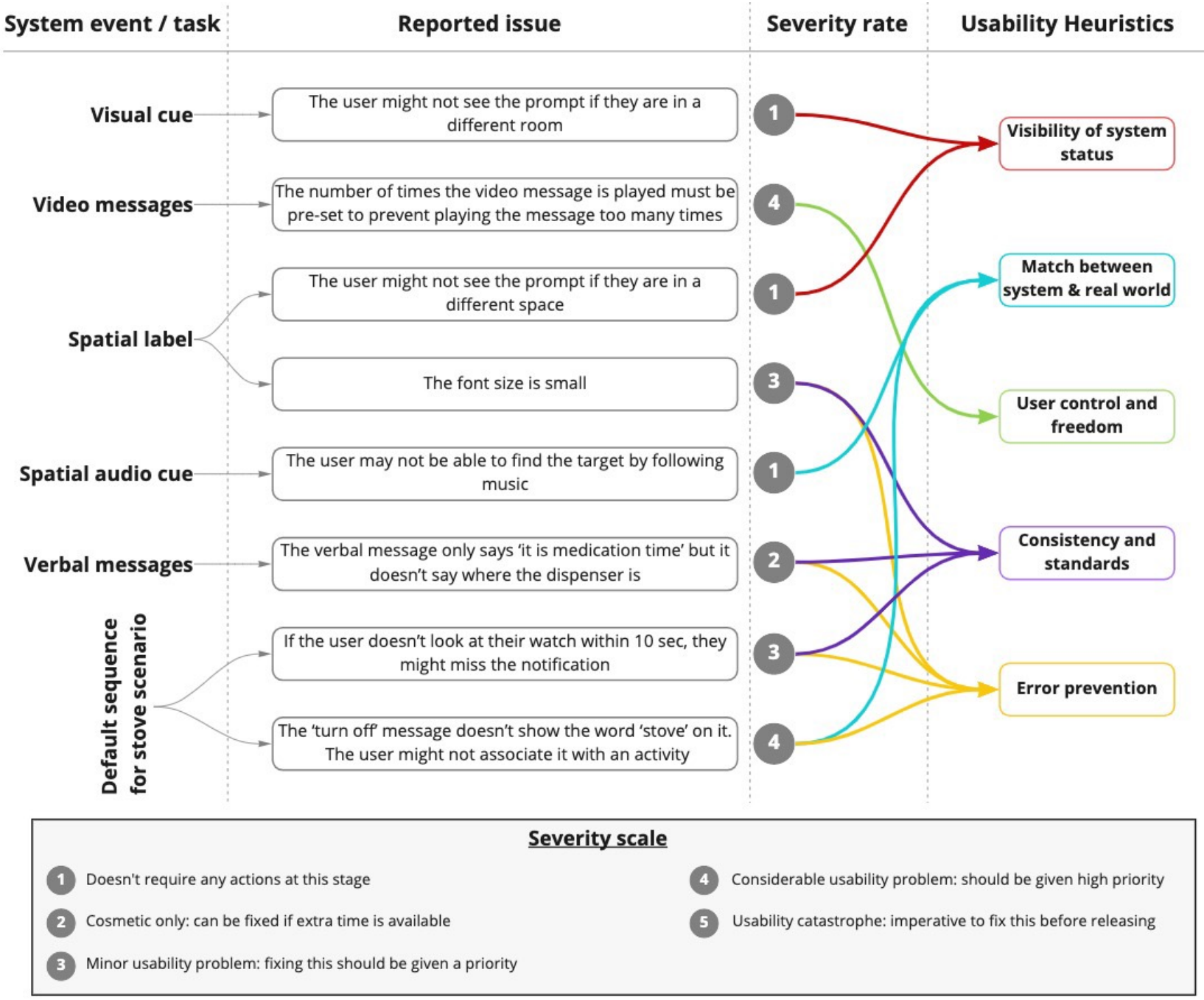
Caregiver user tasks

Fourth Study – Hi-Fi Usability Evaluation

Usability testing:

Heuristic evaluation findings

Senior user tasks

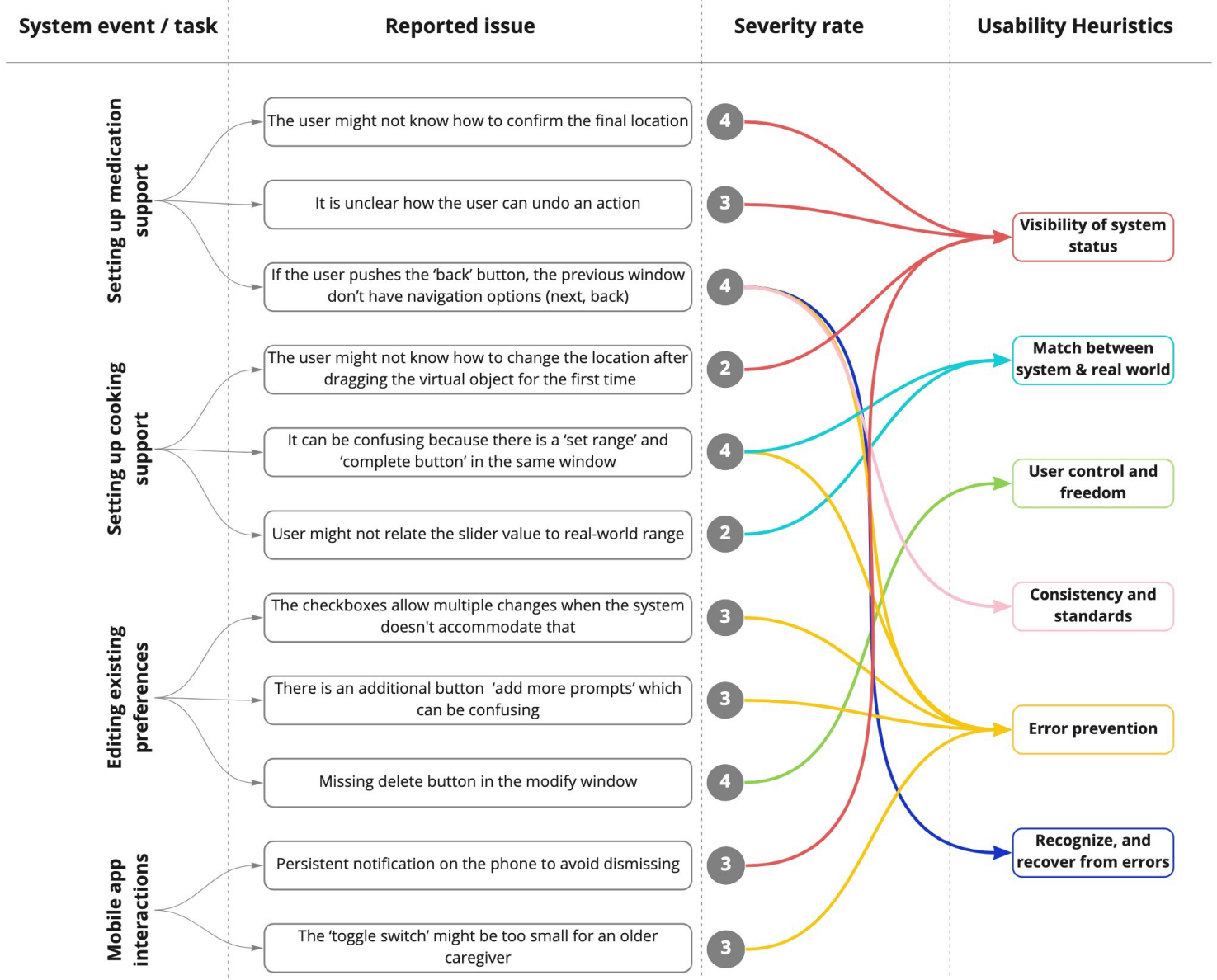


Fourth Study – Hi-Fi Usability Evaluation

Usability testing:

Heuristic evaluation findings

Caregiver user tasks



Design Critique Process

Table 1: Used key words and search string

"design critique" AND ("computer science" OR "HCI" OR "human-computer interaction" OR "human computer interaction" OR "UX").
"design crits" AND ("computer science" OR "HCI" OR "human-computer interaction" OR "human computer interaction" OR "UX")
"design critique" AND ("computer science" OR "software engineering" OR "HCI") AND ("interaction design" OR "human- centered design" OR "human centered design" OR "UCD" OR "task-centered design" OR "activity-centered design" OR "participatory design")
"design crits" AND ("computer science" OR "software engineering" OR "HCI") AND ("interacon design" OR "human- centered design" OR "human centered design" OR "UCD" OR "task-centered design" OR "activity-centered design" OR "participatory design")
"agile" ("design critique" OR design crits")

Table 2: The inclusion and exclusion criteria for each screening process

Screening process	Inclusion criteria	Exclusion criteria
Title screening	Titles that included "design critique" or "design crits". Or titles indicated to using or describing a DC process in the context of computer science and software engineering. Titles that indicated to discussing DC definitions.	All non-English language papers. Titles that didn't indicted to using DC to evaluate designs. Titles didn't' indicate to defining or describing DC processes.
Abstract screening	Studies that discussed the DC method in the context of UX research or computer science education, studies that mentioned conducting evaluations using DC on system prototypes. Studies that indicate to providing definitions of DC in the context of HCI or UX	Any theoretical study that did not perform any evaluation using design critique, studies that aren't related to computer science, systematic literature review paper that didn't discuss conducting design critique evaluation on prototypes were excluded.
Full paper screening	Papers were included if they properly described a DC process, the DC was applied practically in the context of a computer science related topics such as a user interface or user experience design, papers that discussed the definition or the importance of the DC method in the context of HCI or UX.	Studies that conducted DC but different fields such as biomedical engineering or industrial design as these field are out of the scope of this paper. Studies that mentioned conducting DC process but didn't provide any information beyond that. Sudies that didn't discuss DC in computer science education setup. Studies that didn't provide definitions of the DC in the scope of this paper.

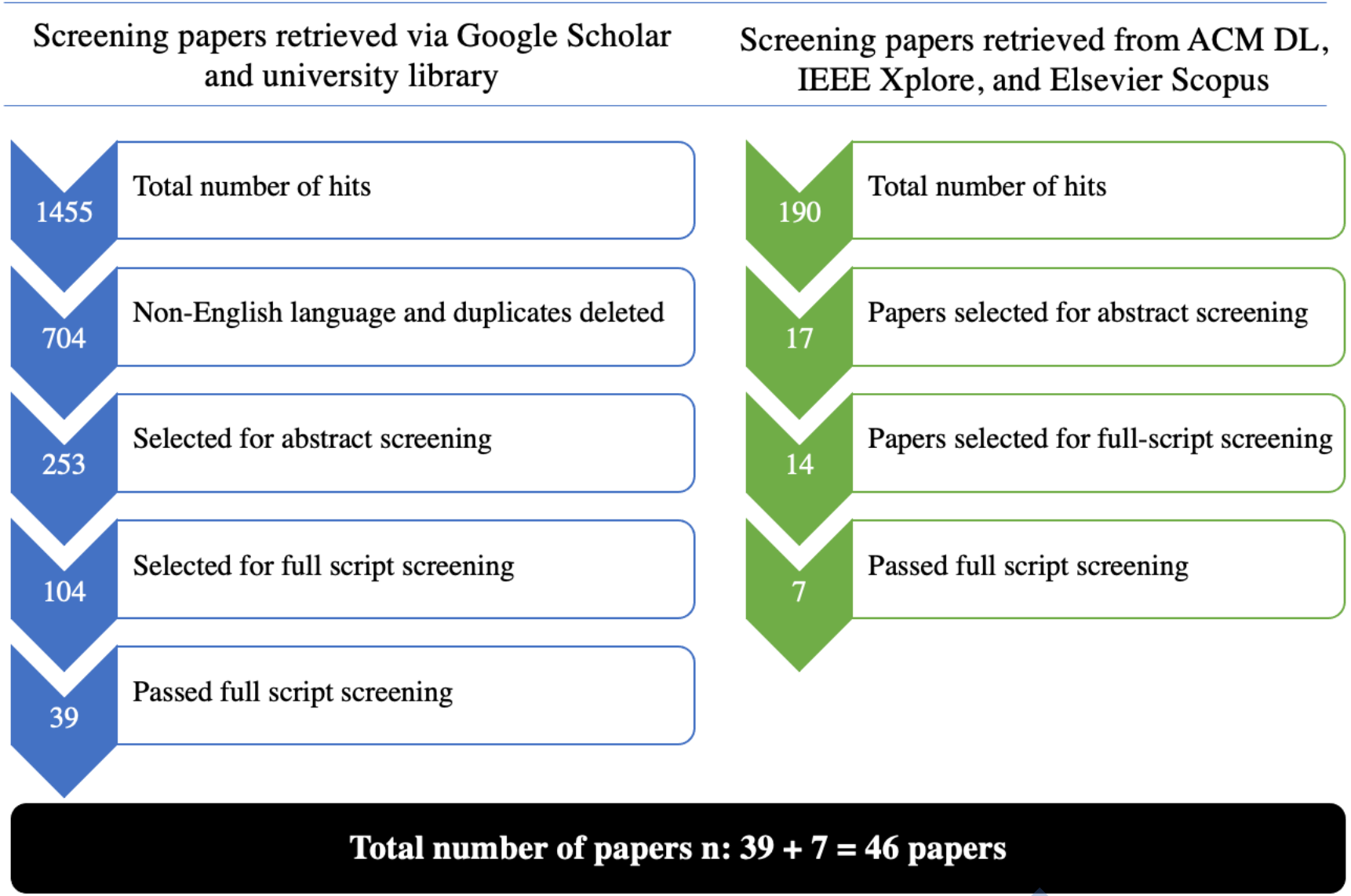
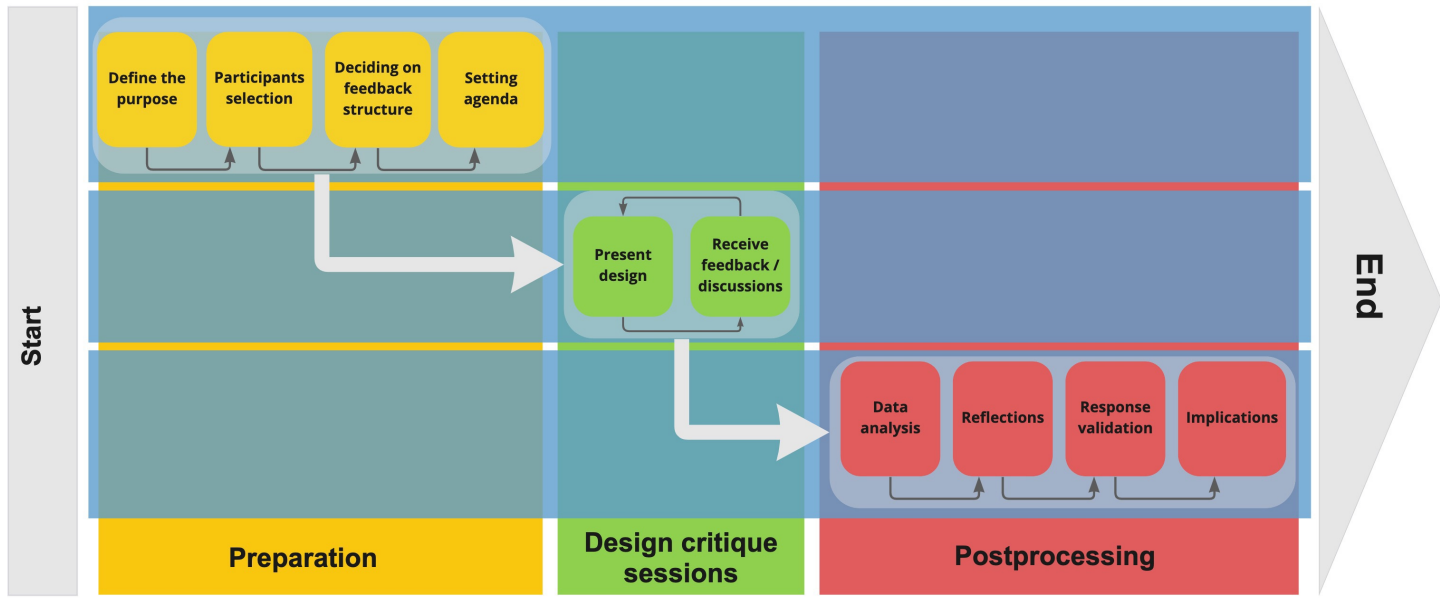
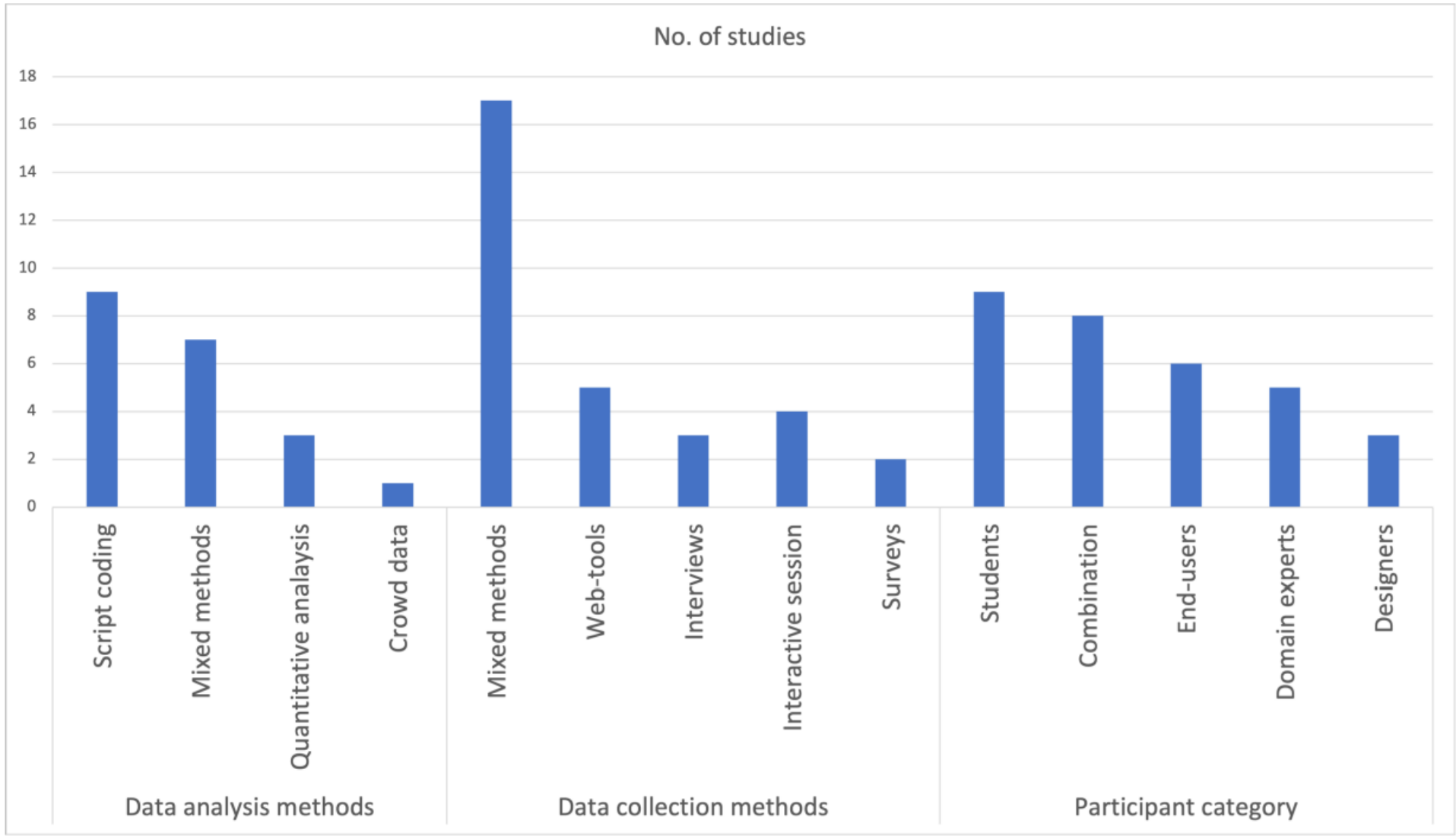

Screening papers retrieved via Google Scholar and university library
1455
Total number of hits
704
Non-English language and duplicates deleted
253
Selected for abstract screening
104
Selected for full script screening
39
Passed full script screening
Screening papers retrieved from ACM DL, IEEE Xplore, and Elsevier Scopus
190
Total number of hits
17
Papers selected for abstract screening
14
Papers selected for full-script screening
7
Passed full script screening
Total number of papers n: 39 + 7 = 46 papers

Table 3: The thematic framework with the code references

Themes	Codes	Paper count
Preparation	Define the purpose	23
	Participant's selection	23
	Setting agenda	14
	Deciding on feedback structure	11
Conducting DC sessions	Present design	32
	Receiving feedback	27
Post Processing	Data analysis	26
	Reflections	20
	Response validation	9
	Implications	24




No. of studies
18
16
14
12
10
8
6
4
2
0
Script coding
Mixed methods
Quantitative analysis
Crowd data
Mixed methods
Web-tools
Interviews
Interactive session
Surveys
Students
Combination
End-users
Domain experts
Designers
Data analysis methods
Data collection methods
Participant category

General Slides

Motivations

To Whom it may Concern

My name is JUNE S. JONES

I am 90 YEARS OLD,

I suffer fm ALZEIMERS

~~[illegible]~~

If I have to stay in HOPITAL for SOMETHING LIKE A BROKEN BONE

~~WHAT~~ HOW COULD I MANAGE?

WHO WOULD HELP ME??

WITH MY LACK of MEMORY and

MY LACK OF UNDESTANDING

HOW WOULD I KNOW HOW TO

CALL ITS NURSE ? EXPHALEN

MY TROBLE? FOR MY FIRST TIME

I HOSPITAL I WOULDBE VERY

FRIGHTENED. PLEASE

PLEASE MY DAUGHTER

STAY WITH ME

John's Campaign

for the right to stay with people with dementia

for the right of people with dementia to be supported by their family carers

STAY·WITH·ME

Latest: In the chaos of rolling lockdowns in SOME care homes, blanket visiting bans in SOME hospital wards and the government's belief that tearing up guidance will put all (not just SOME) family access back to normal it has become more obvious than ever that a legal right to a care supporter for anyone who is vulnerable is the only clear route to ensure human rights for EVERYONE. Thank you Dan Carden MP (and others) for your hard work on a letter to the Secretary of State.

About

Blog

Resources

Supporters

Facebook

Facebook (Care)

Facebook (Wales)

Twitter

About

Nicci and John Gerrard

John's Campaign is named after Dr John Gerrard, who died in November 2014 after a catastrophic stay in hospital. His story - the story of how this campaign came to be - is told eloquently by his daughter Nicci. Her article sparked our campaign.

Dementia is incurable and terminal yet its progression is not linear. John Gerrard was 'living well' with Alzheimers before he was cut off from his family, his normal routine and his familiar surroundings. Delirium (acute confusion) is extraordinarily dangerous for people who are already living with dementia. Families bring reassurance and familiarity (the clue is in the word!). They are also quick to notice when things are not right, even when a person cannot communicate for themselves.

John's Campaign has a single, simple message: no one should enforce disconnection between family carers and those who need their expert knowledge and their love. This principle is applicable everywhere: in the doctor's surgery, the A&E ward, the dementia assessment unit and the care home.

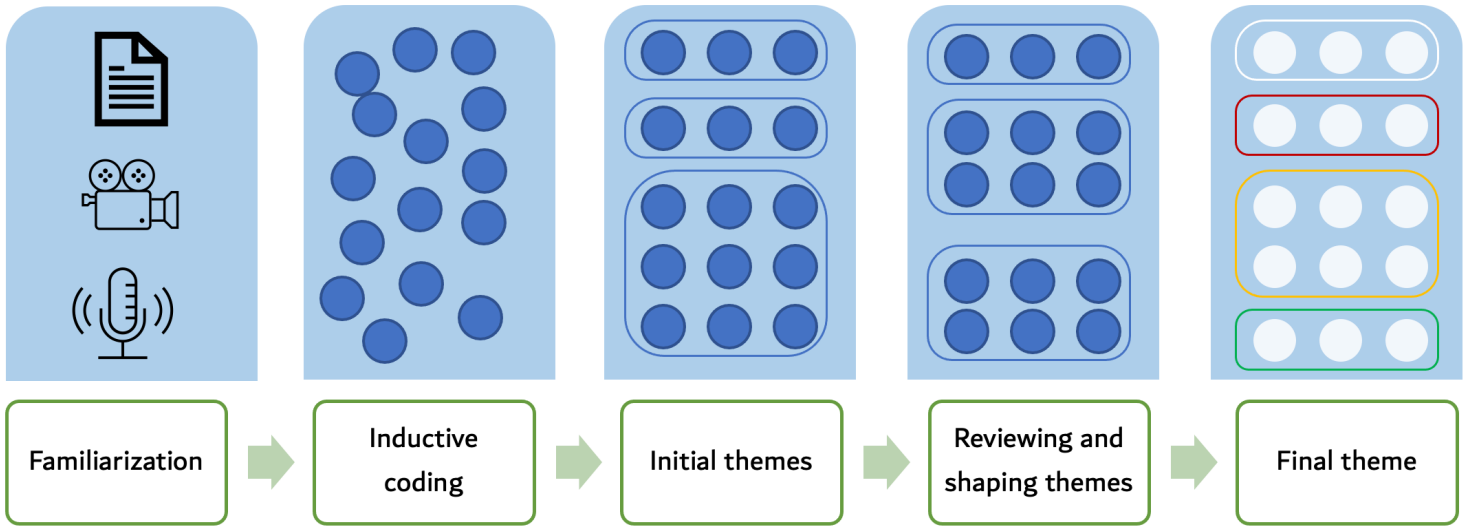
Contributions to Related Area of Knowledge

- Contributions to supportive smart home systems extended to other populations
- Contributions to supportive mixed reality applications
- HCI: systematic method of evaluating such systems

Qualitative Analysis Procedures

Reflexive thematic analysis approach by Braun and Clarke

- Familiarization of data
- Coding of data
- Creation of initial themes
- Iteratively reviewing and shaping the themes
- Final theme generation



Suggestions for Future Research

- Implement our recommendations and conduct field testings
- Follow our steps to introduce more use cases and investigate similarities and differences
- Explore virtual immersive communities
- Integrate exergames

Research Significance

- Support the senior user directly
- Could have an impact on the persons, their family and eventually the health care system
- Usability VS usefulness
- Paves the road for future researchers

Surprising Results

- The number of user research in the literature
- Errorless learning method
- The importance of UI language

Steps Taken to Counter the Limitations

Systematic literature review study:

- Followed guidelines of Kitchenham and Stuart
- Conducted searches on different platforms
- Refined search strings multiple times
- Analyzed results twice, 8 months apart
- Discussed classification with supervisors and reiterated

Steps Taken to Counter the Limitations

Design critique:

- Attempted to randomize participant recruitments
- Used similar sets of questions
- Used neutral language to run the sessions
- Conducted reflexive thematic analysis
- Guided by Braun and Clarke

Steps Taken to Counter the Limitations

Usability evaluation:

- Two steps evaluation process
- Developed tailored questions for the cognitive walkthrough
- Used established usability heuristics and severity rating
- Collected evaluators results anonymously

Why This Methodology?

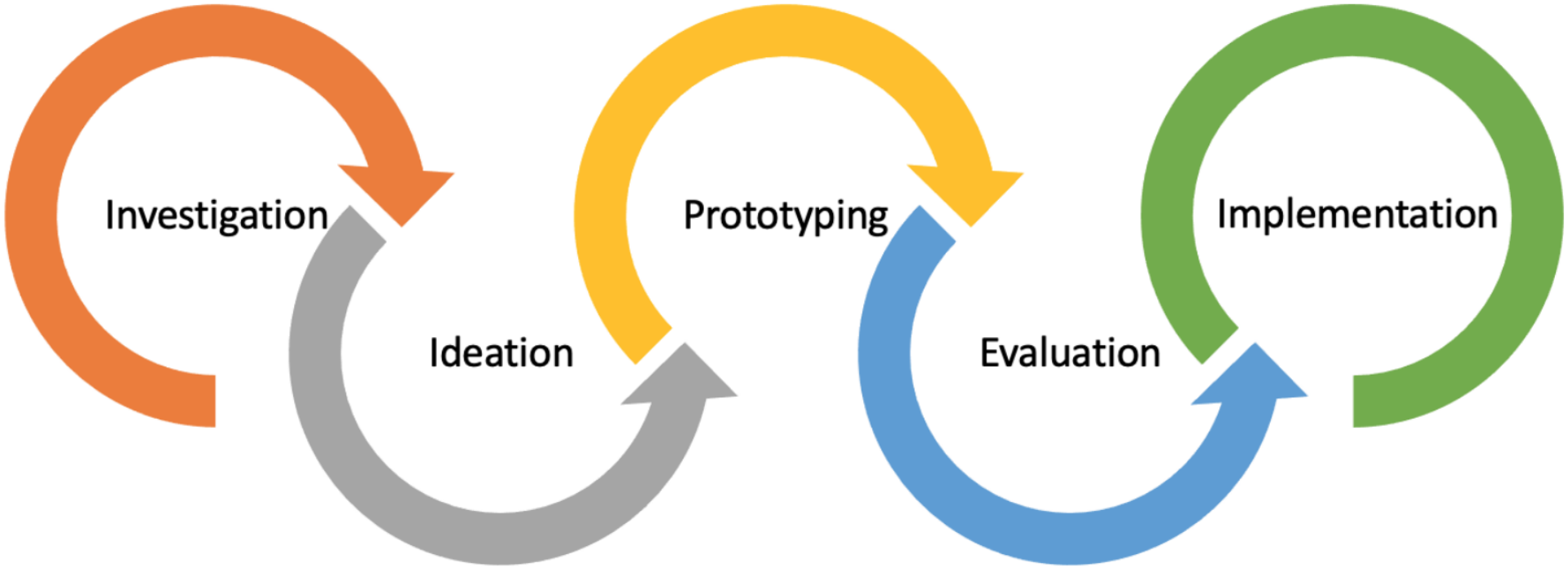
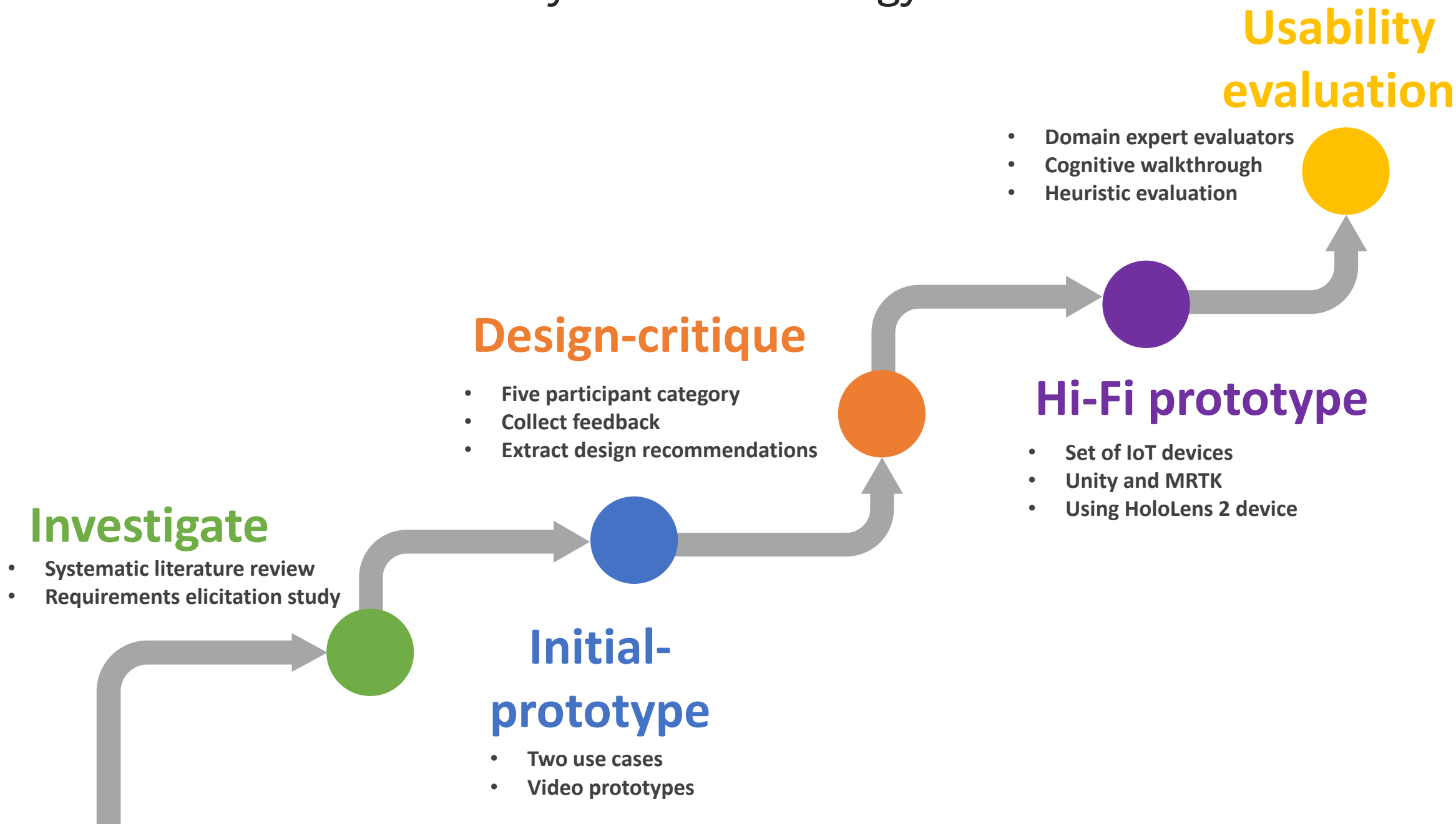


Figure 3.1: The User-Centered Design process applied in this research

Why This Methodology?



Ethical Implications

Steps and behavioral actions:

- Always assume competence when dealing with participants
- Respect and empathy
- Consent
- Share materials prior to study

Design:

- Rely mainly on sensor data
- Avoid intrusive technologies
- Support a sense of agency while assuring user safety is a priority

Strongest Points

- Went beyond introducing and testing technology, instead, we developed generic recommendations
- Presented a comprehensive process of designing, evaluating and developing such technology
- Introduced a systematic method of conducting design critique studies with different participant categories