Cashew: A Smart Home Solution for Families

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Introduction

Smart home technology allows people to use sophisticated devices to simplify their lives. A smart home uses ambient intelligence to monitor the home environment in order to provide context-aware services (Alma, Reaz and Ali, 2012). As the number of smart home devices increases, and more consumers adopt these devices, a key issue is emerging: How can users easily and efficiently interact with a multiple smart home devices and get them to work with each other in order to create a truly smart home?

Cashew is a smart home solution designed specifically for dual-income families. This demographic is well-poised to take advantage of the convenience that smart home technology offers if users have the ability to interact with it in a meaningful and relevant manner.

Cashew allows families to interact with each other and keep on top of their activities to helping them control their lives, not devices. The design goals of Cashew include:

- Allow for an organic (not rigid) evolution of routines
    - Exceptions are really part of the routine
    - Easily establish new behaviors and modify existing behavior
- Allow multiple, overlapping, and occasionally conflicting user goals
    - The smart home should know “who’s who”
- Make interacting with the smart home optional
    - It’s only there when you need it

This paper presents research around smart homes, including issues around smart homes as well as the specific needs of families. The design analysis for Cashew includes the analysis around the user, context, and tasks, the personas, the scenarios, the evaluation criteria and the conceptual model of the solution. Cashew’s prototypes are presented along with discussion about the feedback from each iteration that led to the final solution.

Research

This section presents literature and articles outlining the current state of smart homes.

Statistics about Smart Homes

A survey released by Coldwell Banker Real Estate and CNET evaluated trends regarding consumer adoption of smart home technologies (Snow, 2015):

- 1 in 4 Americans own smart home devices
    - Nearly half of all Millennials (ages 18 to 34) own smart home devices
- 91% of those who own smart devices would recommend them to others
- 87% said they make life easier; 72% get peace of mind from security systems
- Smart devices can save money (average of $1,100 per year)
- 76% use mobile devices to control smart home devices

Smart Homes and Families

Davidoff, Lee, Zimmerman and Dey (2006) discussed ethnographic studies related to the complexity of family life, specifically dual-income families with school-aged children. The researchers concluded that families feel at the mercy of, rather than in control of, smart home technology; families want control of their lives (time, activities, and relationships). Based on the research findings, the following seven design principles for smart home systems were recommended:

1. Allow for the organic evolution of routines and plans. Existing systems attempt to provide support for routines, but these are too rigid.
2. Easily construct new behaviors and modify existing behaviors.
3. Understand periodic changes, exceptions and improvisation- exceptions are not exceptional, but really part of the routine
4. Design for breakdowns - missing the bus; a sick day; late home from work
5. Account for multiple, overlapping and occasionally conflicting goals
6. The home is more than a location - the functional boundaries of the smart home exceed the physical location of the home and need to be accessible from anywhere
7. Participate in the construction of family identity - smart home should not just automate a task, but measure success in the larger value the task is a part of.

Issues with Smart Homes

Though users that are more tech-savvy are adopting smart home devices, the general public still has reservation about smart home devices whether it is due to fear of their complexity or

security purposes. However, among the users who use multiple smart of devices in their homes, a number of issues have surfaced with the existing array of smart home devices.

Complicated/decentralized controls

Although many companies (including Apple) are striving to provide a centralized software hub for users to interact with multiple smart gadgets, there is still no central hub from which to control all devices or to see all smart home information (Higginbotham, 2015).

Lack of automation/learning

In order to recognize the behavior of multiple home inhabitants, advanced pattern recognition is required (De Silva, Morikawa, & Petra, 2012). Existing smart home devices do not meet this requirement because they require extensive intervention from the user either to set up or maintain the functioning in unusual situations.

Lack of role-based access, security/profile

A truly smart home needs to identify who is present in the house and what capabilities are associated with them (e.g., what can a six year old control versus an adult? What can a guest control versus the homeowner?) Homes are shared, but many individual devices are not, and the system needs to allow different residents to control different aspects (Higginbotham, 2015).

Lack of accommodation for exceptions

Human behavior is, by and large, highly unstructured and unpredictable. Long term patterns of behavior is difficult for systems to learn, and exceptions to established behavior can present problems for the residents who are suddenly faced with a loss of control over their home (Davidoff et al., 2006).

Design Analysis

User Analysis

User demographics are dual-income families with school-aged children living in a home that are interested in technology, automating their lifestyle, saving money/energy, and maybe even environmentalism. There aren't any technical skills required outside of regular use of smartphone/apps to find information and communicate. Users should also understand how to use each of the devices in the home.

Primary users (parents, head of the household) goals in adopting smart home technology:

1. To simplify life
2. To automate life
3. To save money
4. To save energy/go green
5. For added security

Secondary users (teenagers, guests, domestic staff who visit the home) goals in interacting with smart home technology:

1. For entertainment, playing music, watching movies and games
2. For communication with parents

Context Analysis

Physical Context

Cashew is designed to be used within the home. When used inside of the home, Cashew is accessible from any room in the house using a "smart wallpaper" interface. This use of printed electronics allows the user to interact with Cashew from anywhere in the house, as needed. Cashew can identify who the user is using gait analysis sensors that are a part of the smart home. Cashew shows only relevant information for that user and allows customization of the view by user. User profiles allow the user to set preferences for devices (e.g. Audio system), timers, and other available controls.

When accessed from outside of the home, Cashew requires authentication in order to identify the user.

Social Context

Cashew can be used when other people are around, in a formal or informal setting. Cashew is designed not to infringe on the privacy of household members. In smart homes with motion sensors and connected devices, a huge amount of information can be captured about what a person is doing; Cashew does not convey all of this information, but rather only the information that is helpful to facilitate the family's routine as well as communication between family members.

Technical Context

Cashew requires the following technical components:

- Smart wallpaper with embedded sensors, microphones, and touch sensitive visual display.
- Motion sensors with gait analysis.
- A home Wi-Fi network with connections to all required components.

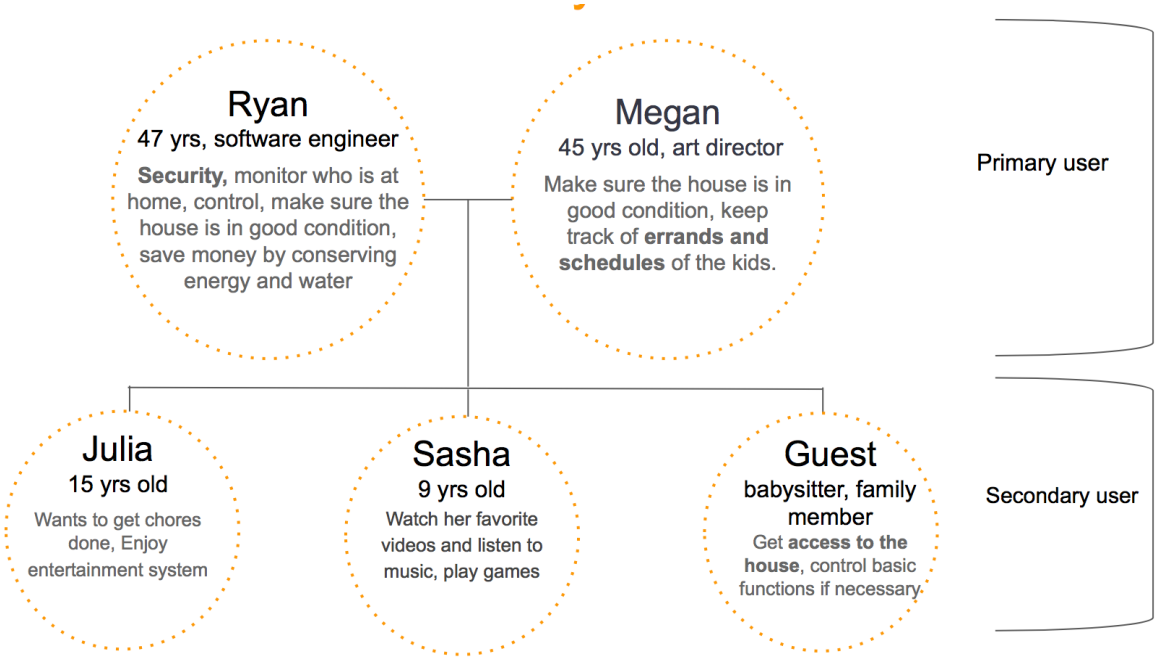
Task Analysis

The solution will support the following tasks:

1. Allow the user to access the system via the smart wallpaper.
2. Allow the user to see who else is or is not in the house.
3. Allow the user to see, at a high level, what other people in the house are doing (when appropriate).
4. Allow the user to communicate with family members, both inside and outside of the house (via intercom, email, text, phone, etc).
5. Allow the user to connect different devices in a sequence of events to facilitate easy completion of tasks (e.g., Open door when you come home > lights turn on > music comes on if it is Julia).
6. Allow the user to connect the solution to other apps to provide information and services (e.g., calendars, contacts, weather, traffic, music).
7. Allow the user to set preferences for views and devices depending on the time of day (early morning, morning, afternoon, evening, and night).
8. Allow the user to see the status of all connected smart home devices.
9. Allow the user to manually adjust the status of a connected device.
10. Allow the user to create and manage profiles for other users.

Personas

Because this solution is designed with families in mind, personas were developed around the Johnsons, a dual-income family with two children and an occasional guest to the house. As per the user analysis, the parents are viewed to be the primary users of the system while the children and guests are secondary users.



The Johnson Family Personas

To better understand the users of the system, a “pain and gain” analysis was done in order to parse out the opportunities for the interface to bring ease into the family's life.

Pain	Gain
The security of my family is the most important thing.	Confirm when doors are locked at night time when family leaves and house shut down send a simple notification
I don't want to have to control all the devices in my house separately and all the time	All smart devices can be controlled from the interface and have “automatic” control when appropriate.
I want the devices to work better together and communicate with each other	Devices interact with each other and one will set of the other off (e.g., doors being locked means lights, TV and music go off).
My family's needs changes from day to day; sometimes I forget to adjust the devices and this makes things difficult.	The system confirms when guest and kids are at the house and adjusts the devices to them even if they normally would not be there at that time.
My husband and I have to keep up with our kid’s schedule and activities; this is an area we can use help in.	The system incorporates kid’s activities and the family calendar in the interface.
When we are at the house, we want to spend time	The interface is not there to interrupt but as a tool

with our kids -- away from devices.	when needed.
Making sure the kids are up and getting ready while I am trying to prepare breakfast is one of the hardest times in our routine.	Show family status in the morning and provide a way to communicate with each other without walking to them.
It would be nice to have a way to more efficiently communicate with people in the house.	Provide an intercom that, with help of the sensors, knows where in the house the person you want to talk is located.

Secondary User - Julia, Sasha and Guest

Pain	Gain
When we come home, sometimes our parents are not here and we have to remember to lock the doors, which we forget sometimes.	The house locks the doors automatically when kids are home by themselves.
I like waking up to music and listening to it as I get ready, but I have to carry around my speaker and that becomes too much.	Have access to music playing everywhere System provides built-in speakers.
It's hard for me to wake up in the winter because it is still dark outside and I think it is not time yet so I go back to sleep.	The lights in the room turn on slowly as wake up time approaches to encourage waking up (depending on the season).

Scenarios

In order to guide the design of Cashew and understand the activities of the family around specific times, scenarios were developed for the two primary user personas (Megan and Ryan) during a typical weekday morning.

Cashew

5:30 AM - Ambient light shift in bedroom to prepare for wake-up alarm

6:00 AM - Alarm goes off

Megan

6:05 AM Megan is up. Cashew recognizes that she is up so the alarm turns off.

6:30 AM Megan gets dressed. Using Cashew, she can:

- Look at the current weather and forecast to know how to dress herself and the kids.
- Check the activities for the day.
- Check to see if the kids are up.

6:45 AM Get kids ready:

- Uses Cashew to check on Julia (once she's up, she takes care of herself).
- Helps Sasha get dressed and ready for school.
- In Julia's room, she uses Cashew to check on Ryan. She sees he is still asleep, so she drops the alarm into Ryan's blob to activate the alarm.

7:00 AM Prepare breakfast:

- Since Ryan is not a morning person, Megan prepares breakfast.
- Coffee is already prepared when she arrives in the kitchen.
- She prepares toast, oatmeal, and juice.

7:05 AM Family has breakfast:

- Ryan and Sasha are eating breakfast, but Julia has not made it to the kitchen.
- Megan uses Cashew to check on Julia. She uses the intercom to tell her to hurry.

7:30 AM Ready to leave:

- Checking Cashew, Megan sees a message from the soccer coach to call her.
- She uses Cashew to call her and leave a message.
- She checks to make sure that Sasha and Julia are ready, have their homework, books and coats.

7:45 AM Megan leaves the house with Sasha and Julia.

Ryan

6:00 AM Alarm goes off:

- Morning radio serves as audio alarm.
- Ryan ignores it.

6:45 A more aggressive alarm setting goes off:

- Louder, more intense audio alarm (sent from Megan via Cashew).
- Bedroom lights are set to full brightness.

6:50 AM Ryan is up:

- Quick shower (knows his temp preference).
- Ryan checks the weather and traffic situation for his commute on Cashew.

7:00 AM Breakfast:

- Helps Megan with Sasha's breakfast.
- Eats his and checks family activities for the day on Cashew.
- This gives Julia and Ryan a chance to coordinate the day around the schedule.

8:00 AM Ryan leaves the house:

- Since Ryan is the last to leave, the home automatically is set to away state once he exits.

Automated processes

5:00 AM

- Heat is adjusted for start of the day activities.
- Water heater activates so hot water is available for showers.

6:30 AM

- Coffee maker starts up.

7:30 AM Away state

- Heat/AC is adjusted.
- Security alarm is set.
- All appliances are turned off.
- Lighting is adjusted.
- TV, entertainment systems are turned off.

Evaluation Criteria

The following evaluation criteria will be used to ensure that Cashew addresses the identified problems with smart home devices and meets the needs of the users. The evaluation criteria cover the content to the system, how it adapts to the users and how easy it is to use.

Content

The interface should have a clear and standard content, with simple easy to understand language throughout and no technical terms. Organization of the content must be consistent with items remaining on the same location from one view to the next. Any smart home devices accessed through the interface should have similar approach to information presentation and level of detail in the information displayed.

Personalization

Because households have different demographics, the interface should be customized to each user group and allow the user to personalize his or her own view. Access to certain controls in the interfaces should also be limited based on the user, so the interface should control the information and access given to specific users.

Usability

The interface should fulfill these basic usability criteria:

- Learnability

    - First time use learnability, easy setup of new information
    - Language that matches users mental model
    - Clear feedback to tasks performed
- Efficiency
    - One-touch access to primary tasks
    - Associated tasks should be presented together
    - Ways to go back and undo settings; obvious recovery
- Safety
    - Warning when setting might be dangerous or inappropriate
    - Alert to dangerous or out of the ordinary occurrences
- Privacy
    - Identification of user through gait sensors (no need for input from the user)
- Satisfaction
    - Overall measure of value: saving time? Feeling more secure? Reducing stress? Saving money?

Conceptual Model

The following points summarize the conceptual model of Cashew:

- Users think of the house in terms of the people who live in the house, the family activities in and outside of the house, and the environments (living areas) within the house.
- Information not directly related to the physical house and devices may be more relevant to family members.
- Users do not want to actively manage appliances, heating/cooling systems, and other smart home devices. Users want to use these devices in order to help their routine run smoothly.
- Users should not have to rely on Cashew in order to do anything in the house. Cashew serves as a convenience.
- Cashew is an interface that allows family members to communicate easily, but more often than not, people prefer face-to-face communication.

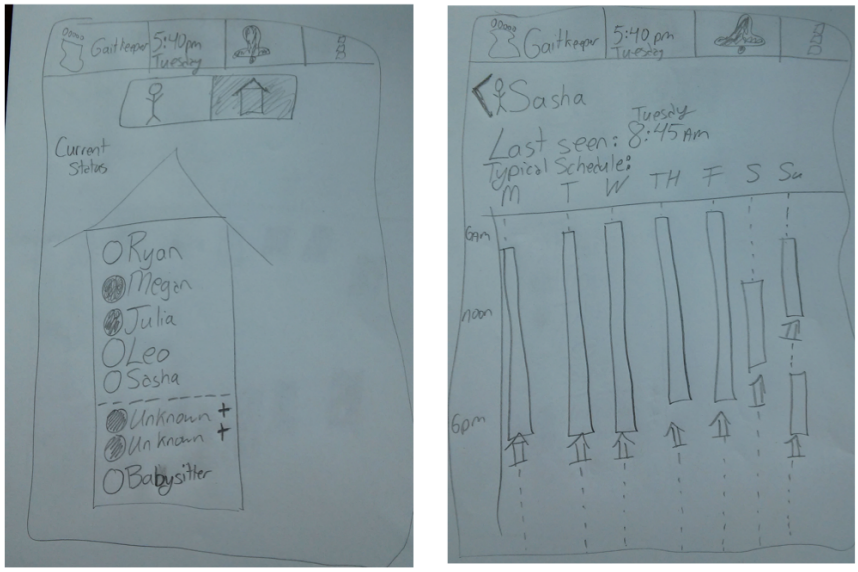
Prototype #1: Exploring

Prototype #1: Ideation

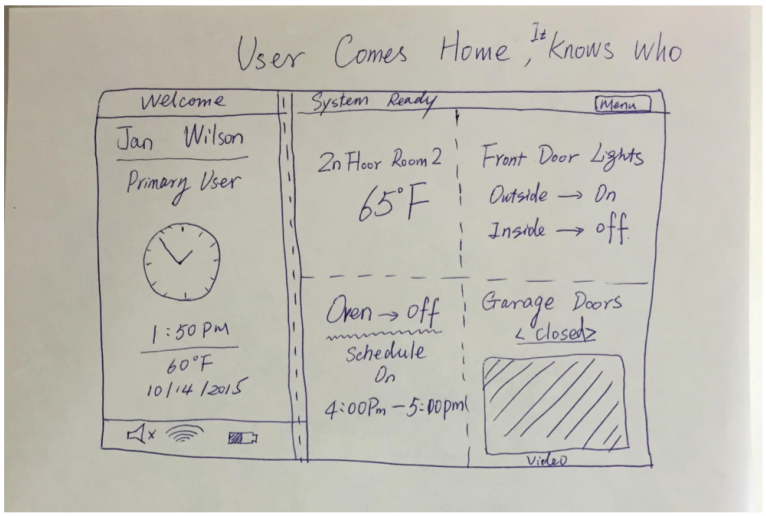
The initial prototypes for the solution focused heavily on the direct control of smart home devices, with the assumption that the solution would understand, adapt, and accommodate to the patterns of the home's inhabitants. Additionally, the prototype focused partially on the mobile aspect of the solution; the research indicated that a mobile component was important in order to take the control of the devices outside of the home.

Prototype #1 identified these components for the solution:

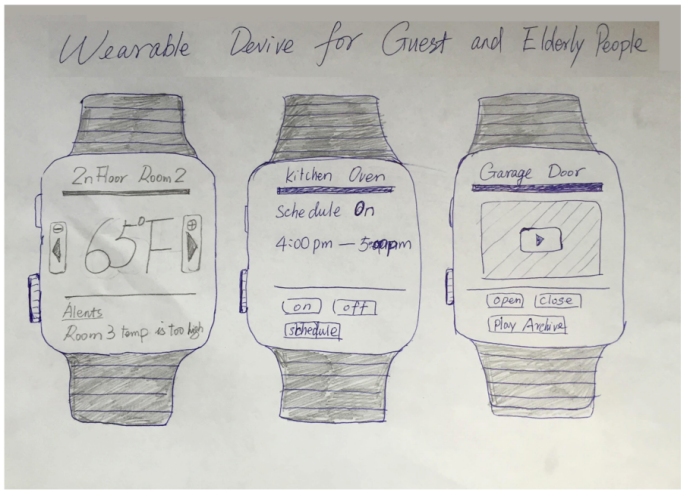
- Smart sensors
    - Use gait analysis to identify family members, their ages, and their location
    - Automatically recognize and interface with smart devices
    - Consolidate learning from devices by tracking individuals' interactions
- Dashboard user interface
    - List devices and their status
    - Provide override control of devices
    - Receive and respond to alerts
- Smart wearables
    - Track vital signs of individuals
    - Receive and respond to alerts
    - Automatically set at home state



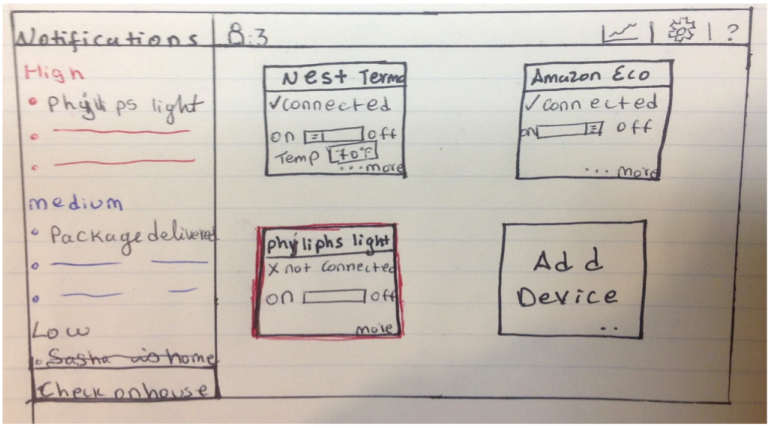
Prototype #1, Ideation #1: Gait Analysis to track movement and interactions of inhabitants



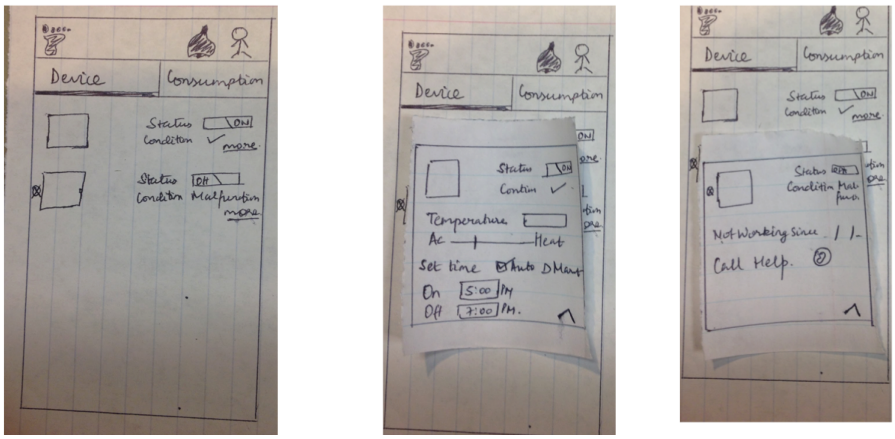
Prototype #1, Ideation #2: Dashboard using smart sensors



Prototype #1, Ideation #3: Wearable Devices for Guests



Prototype #1, Ideation #4: Dashboard for Devices



Prototype #1, Ideation #5: Mobile Component for Dashboard

Prototype #1: What we learned

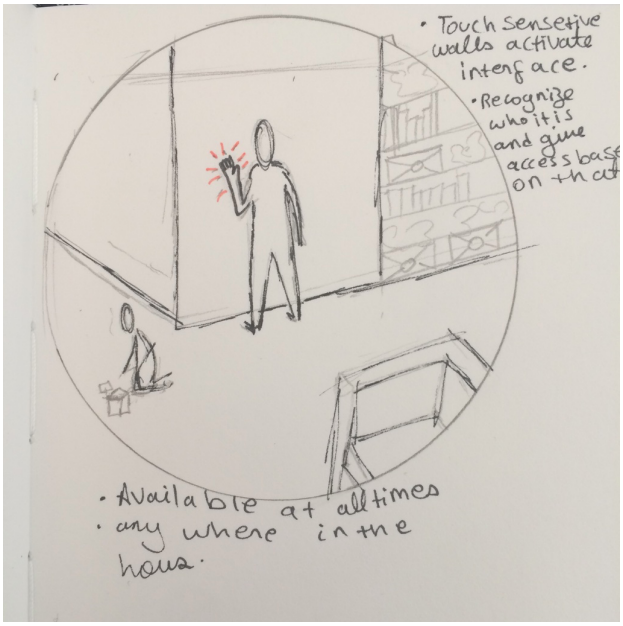
- The task analysis focused entirely on tasks that a user would want to complete with specific devices; this focus on specific tasks contributed to the prototype's emphasis on devices. Ideas need to be described in terms of life, not in terms of gadgets; functionality can be sacrificed for simplicity.
- The personas that informed prototype #1 had not yet focused on an inclusive family, and instead tried to cater to a disparate number of users and their needs.
- The mobile aspect of the solution wasn't as important as what is going on in the house. If the home design is good enough, there is not a need for an extensive remote control.

Prototype #2: Focusing

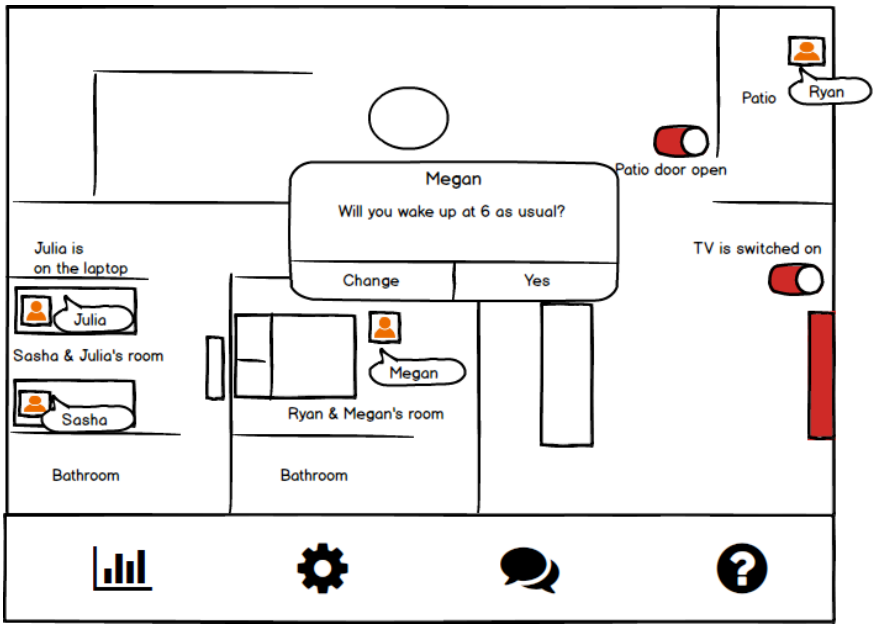
Prototype #2: Ideation

The next round of prototypes focused on providing an interface that aligned with refinements to the project focus, personas, and scenarios. The personas now centered on a single family and the scenarios focused on a typical weekday morning in the family's home. Instead of focusing so heavily on device control, other ways of allowing a family to control their lives were explored that allow the interface

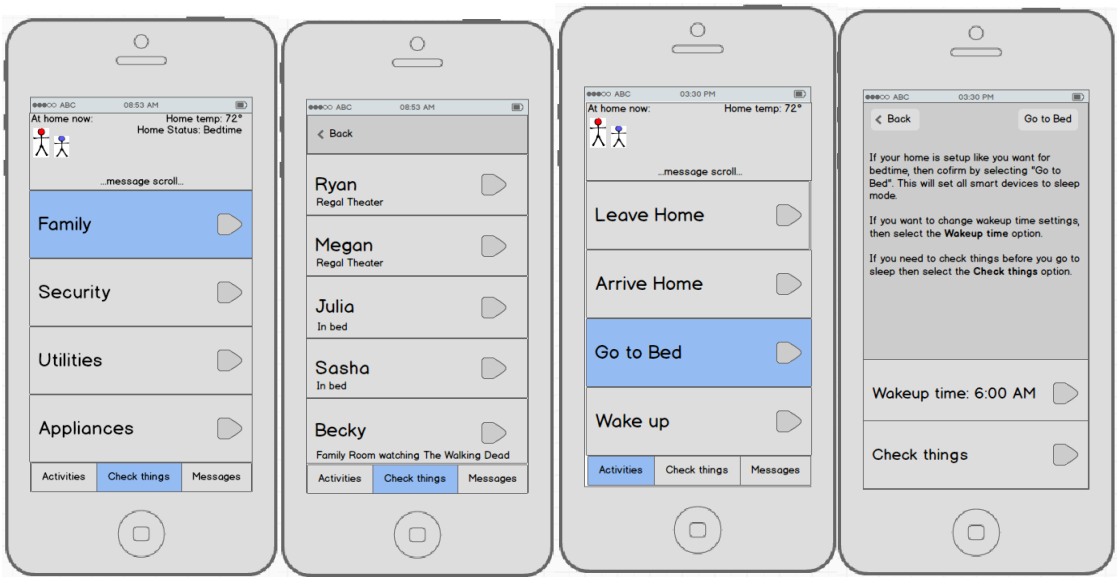
- To be accessible anywhere in the home. A touch sensitive wall interface combined with the smart motion sensors that would recognize who is accessing it and give appropriate access based on that.
- To give the status of the people in the house and which devices they are using.
- To provide reminders about family activities as well as the ability to check in with a schedule.
- To provide a way for the family members to communicate with others through the interface.



Prototype #2, Ideation #1: Touch sensitive wall



Prototype #2, Ideation #2: Map interface to provide information about family



Prototype #2, Ideation #3: Mobile Solution

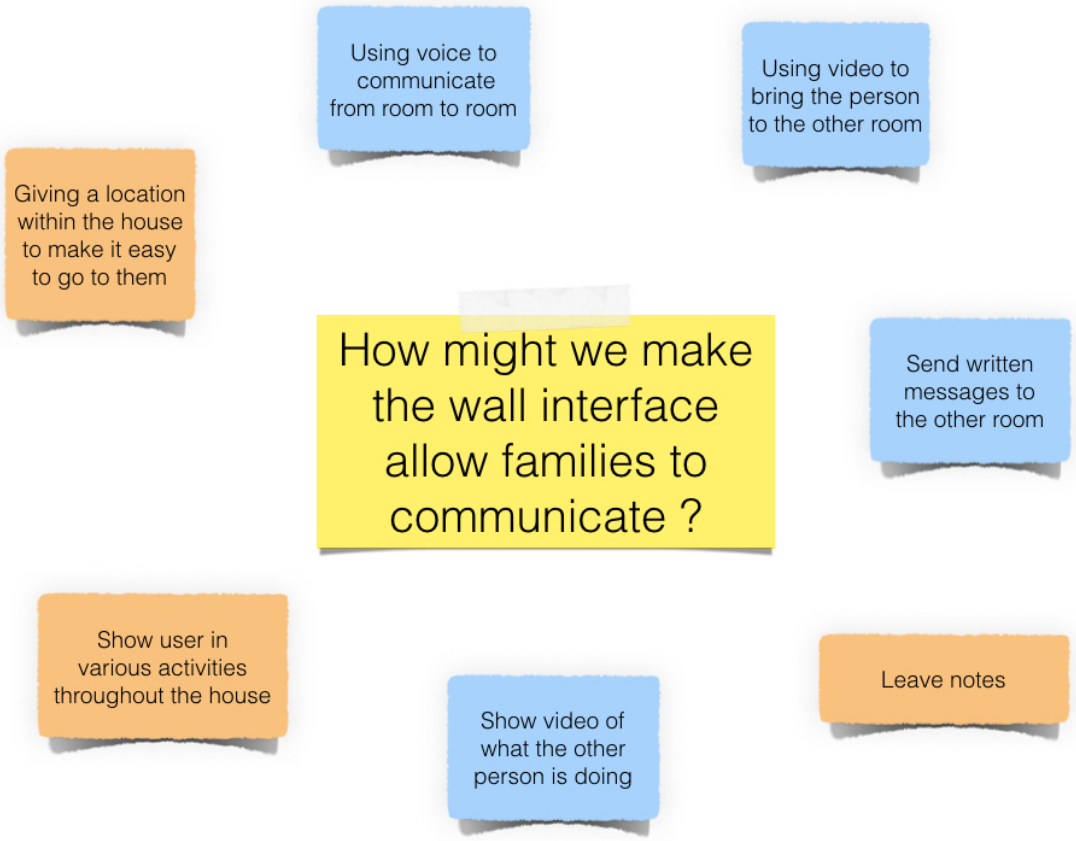
Prototype #2: What we learned

- The information displayed doesn't have to take a literal representation of the house. What are other ways of showing a home to a family?
- Need to provide the just enough information without showing everything (i.e., kids are at home but not specific location).
- Focus on one aspect of the control in-home or mobile.

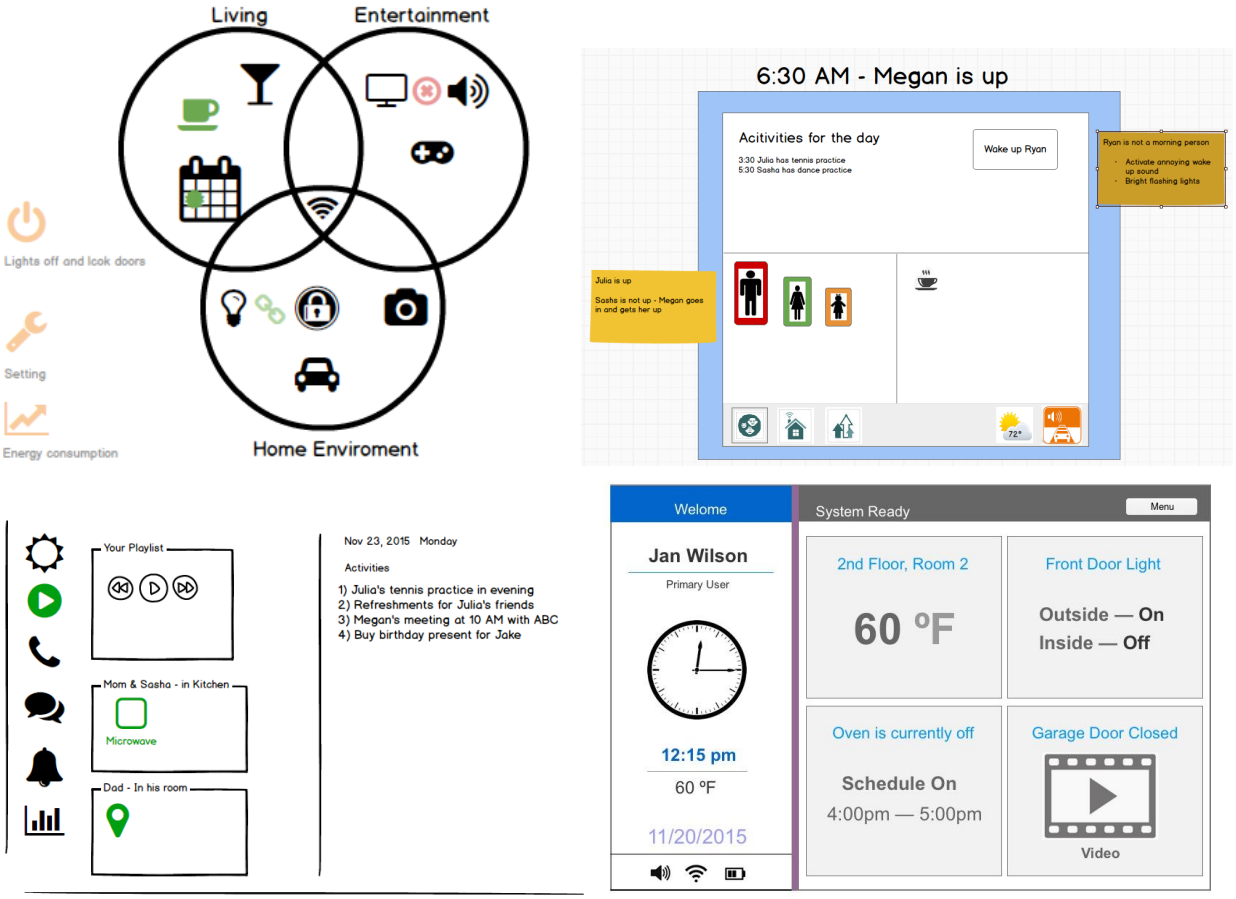
Prototype #3: Refining

Prototype #3: Ideation

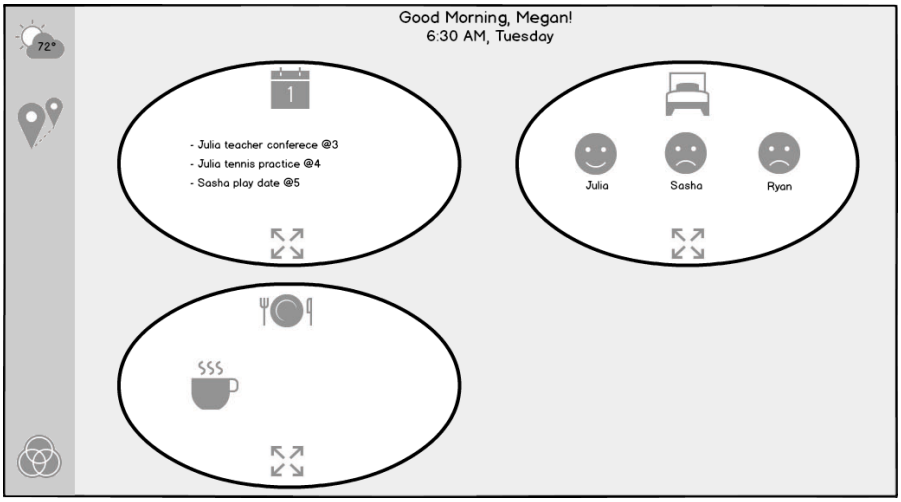
The third round of prototyping focused on other ways to show the family in the smart home other than a literal map representation and explored the interactions at a more practical level. Family members, activities, and home devices were represented in “blob” circles that allowed the user to touch and interact with that person, place, or thing appropriately. The design also emphasized the interface as a communication tool between family members. Additionally, the scenarios were refined to include the idea that the interface should not have to be used by the family to go about their daily routine; the interface is available as a helper, but most families prefer face-to-face communication and interaction.



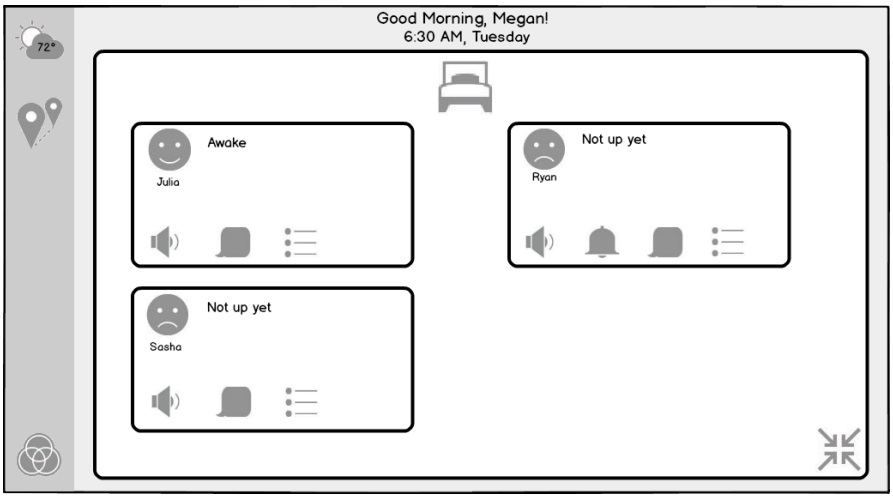
Prototype #3 “How might we” exercise to figure out ways to allow families to communicate through the interface.



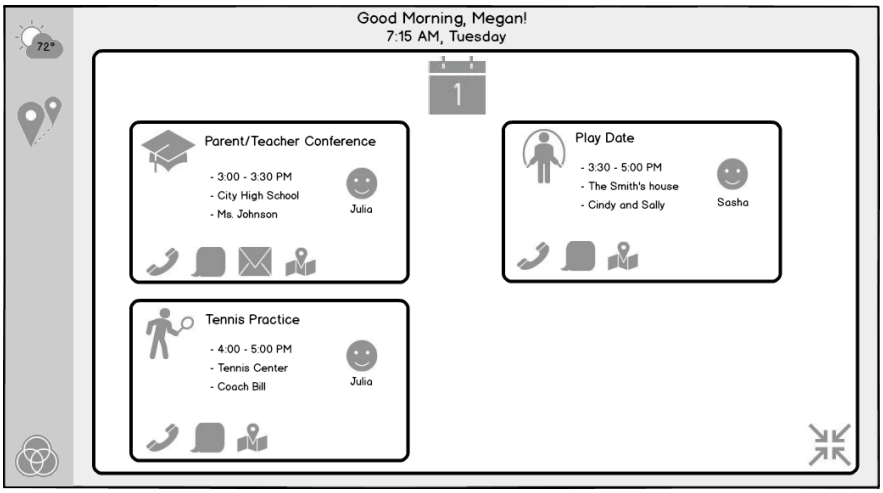
Prototype #3 Different iterations of information display



Prototype #3 main "blob" screen showing activities, devices, and the family.



Prototype #3: Drilling into the family blob



Prototype #3: Drilling into the activity blob

Prototype #3: What we learned

- Focus on a more interactive interface (e.g., being able to move icons into blobs).
- Hide the complexity that the user doesn't need to use as often
- Figure out the syntax and semantics for the blobs and map it to the activity
- Don't rely only on color to indicate status.
- Build trust in the system over time. Consider what the cost of a misunderstanding is (e.g., an unlocked house is more important than a heater is on).
- Balance the amount of automation with giving the user some control (e.g., user can lock their doors and everything in the house is shut down).
- The interface is there when you need it and can help you out as much as it can. This is a powerful concept.

Prototype #3: Feedback on interface semantics

Feedback from Prototype #3 lead the team to focus on the interface semantics. As Islam and Islam (2015) discuss, interface signs are the communication artifacts of interfaces with which the user interacts. The semantic of interface sign (key element) refers to the meaning (referential or intrinsic) of an interface sign. For example, the home sign in a web page refers to getting the home page/main page of the website. Understanding the semantics of interface signs properly allows users to go directly to the content of interest. Islam et al. also found the following principles of ontology mapping in interpreting the meaning of interface signs:

- Users use single or multiple ontologies to interpret the semantic of the interface sign. An interface sign may belong to a single or multiple ontologies.
- A proper matching between ontology/ontologies referred to by an interface Sign and one(s) owned by the participants leads users to interpret the semantic of interface sign correctly.
- Ontology conflict (i.e users are confused with ontology/ontologies that need to consider to interpret a sign) increases the users' perceived interpretation difficulty and decreases the accuracy of sign's interpretation.
- When multiple ontologies are referred to by an interface sign, a familiar ontology supports an unfamiliar ontology to understand the semantic of the interface sign.

While designing semantics we will concentrate on the following questions:

1. What could be the referential meaning of this sign‘?
2. Why do you think this is the meaning of this sign?
3. When interpreting this sign how intuitive it is to you (from 1 to 9)

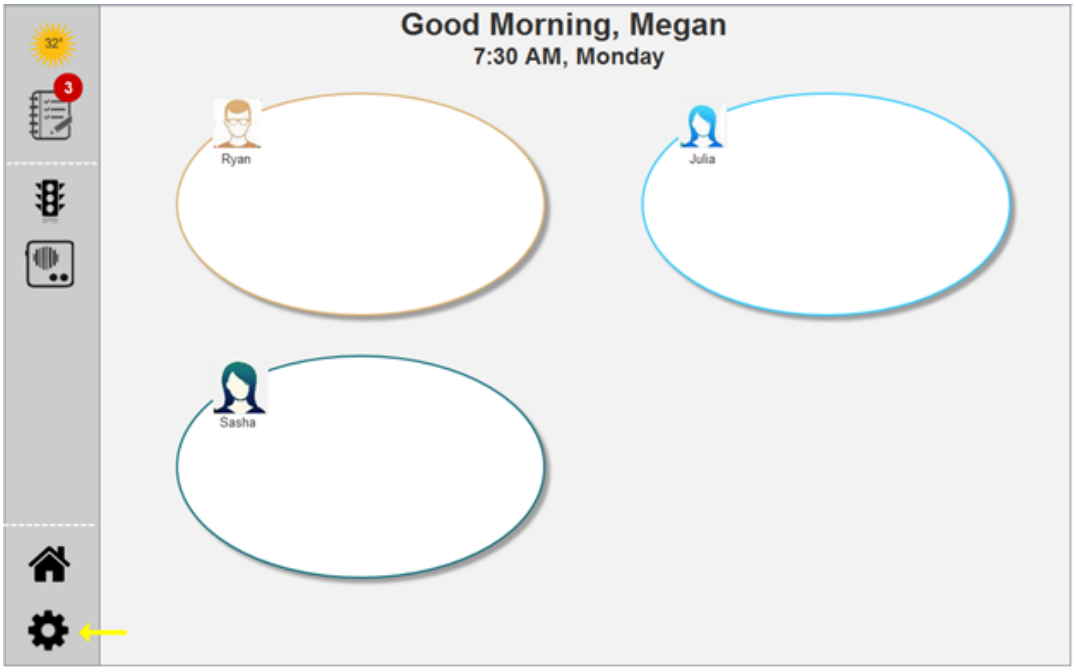
Based on this, the team decided the "blobs" will be people based (family members) and the devices are the next level, and only if the users wants to see them.

Cashew: The Solution

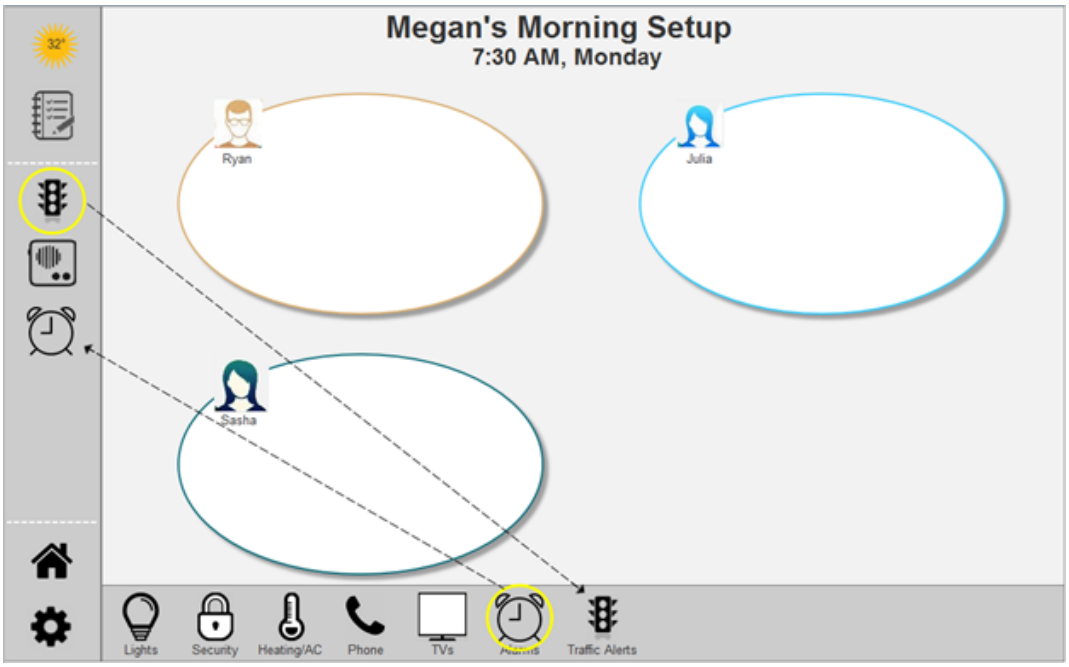
Cashew (CommunicAteS HElps Wall) takes advantage of smart home technology in order to allow families to go about their daily lives with having to worry about devices and gadgets. The solution achieves this goal by using the following components:

- **Smart sensors with gait analysis**: This technology allows the home to identify the inhabitants of the house in terms of where they are in the house as well as who is accessing Cashew. The users see a personalized view of Cashew without having to identify themselves. The user can see a high-level view of whom else is in the house and what they are doing.
- **Smart wallpaper**: Paper with embedded electronics available through the walls of the home allows the user to access and interact with the interface. The user can access Cashew from anywhere, tap and drag elements of the interface, and communicate with other people in the house using embedded microphones.
- **Learnability**: Cashew learns about specific individuals in the house and what their routines and preferences. For example, Cashew can know if a user always turns the heat up at 5pm and learn to do this for them. Though the user can explicitly set preferences (i.e., alarm goes off at 6am), this can be done through Cashew or through the alarm itself. Cashew uses this information to help inform the “time of day” activities that are presented through the user interface.

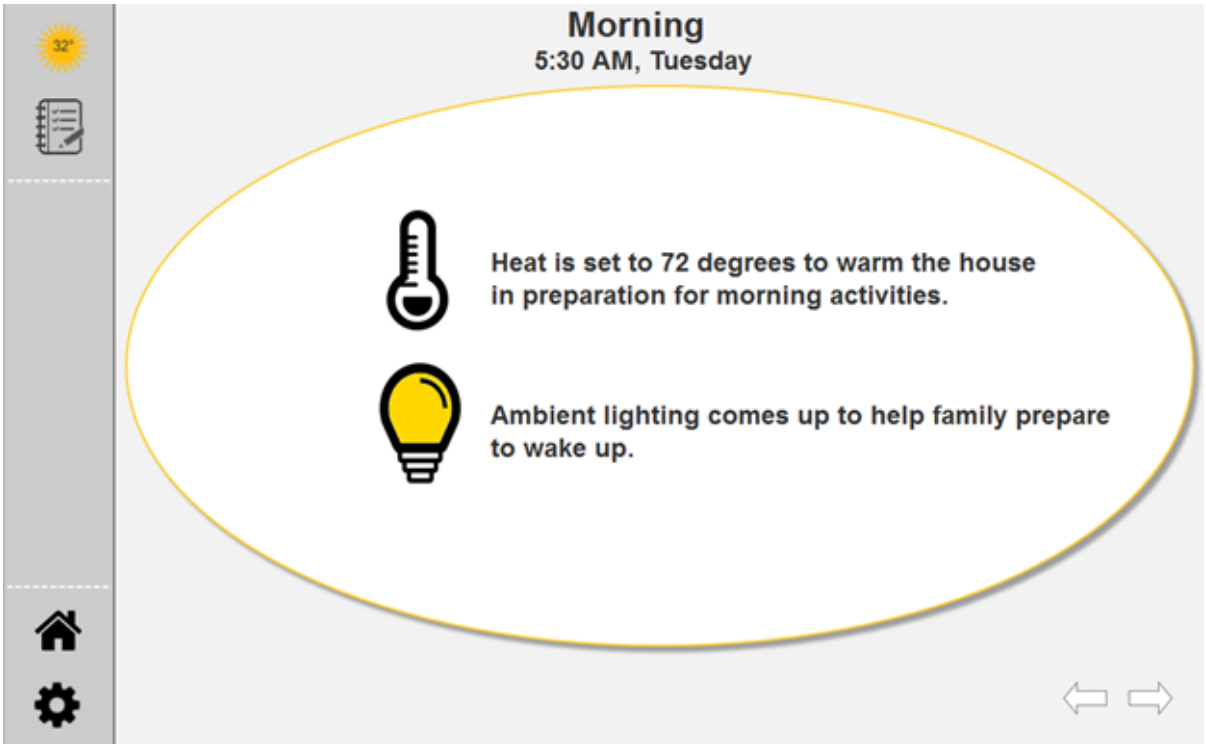
Final Prototype



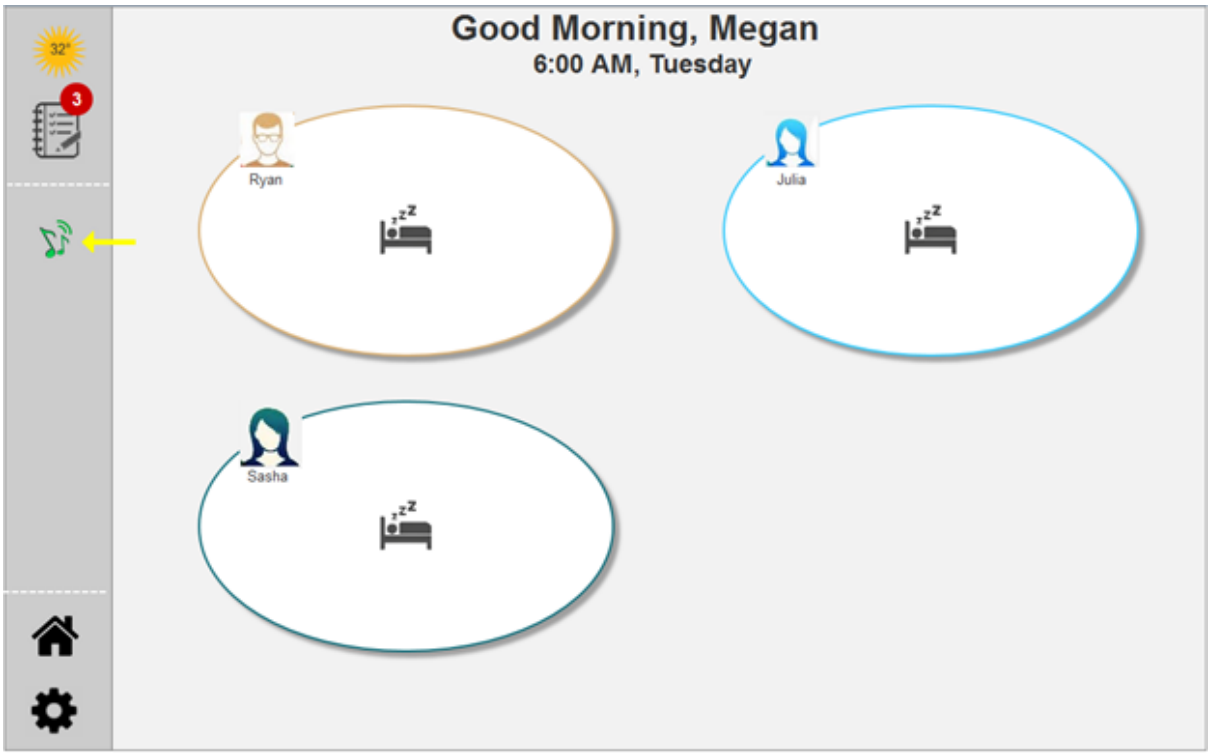
Final Prototype: Megan's Morning wall. She clicks on the setup icon to configure her morning menu.



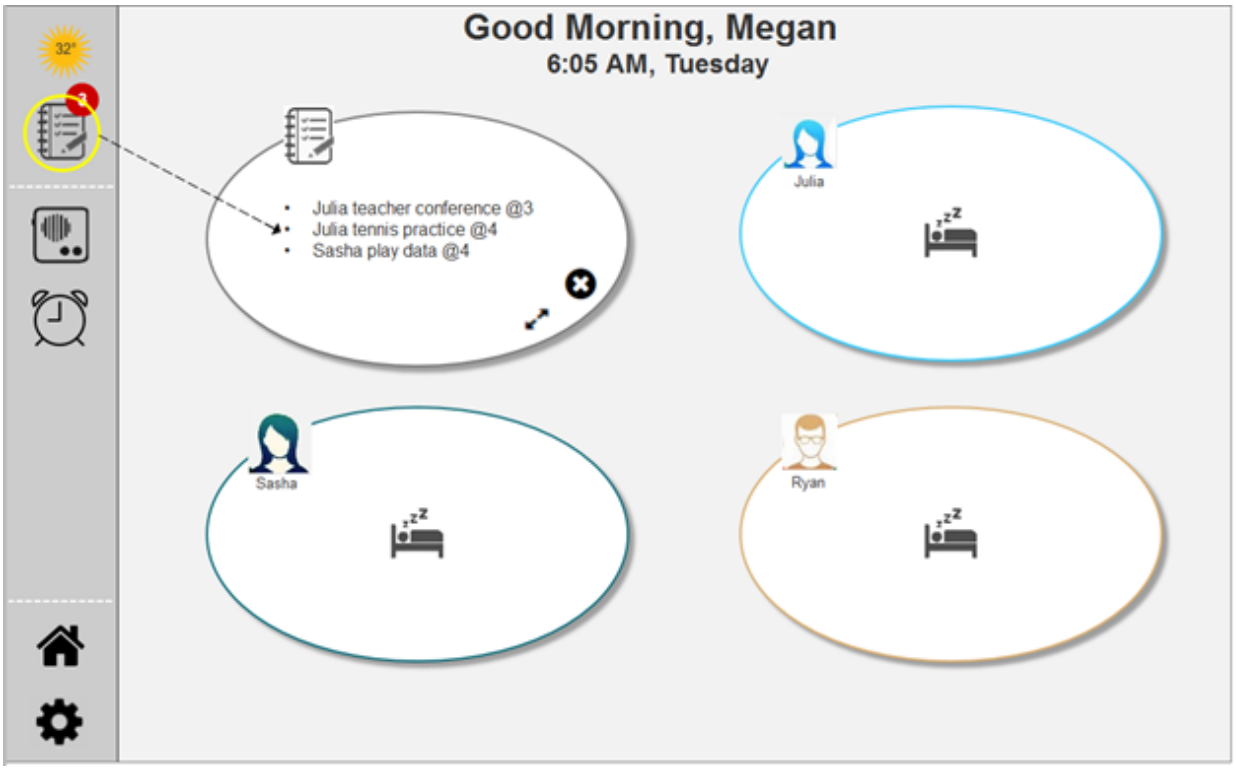
Final Prototype: Megan changes her morning setup by dragging the Traffic icon off and the Alarm icon on.



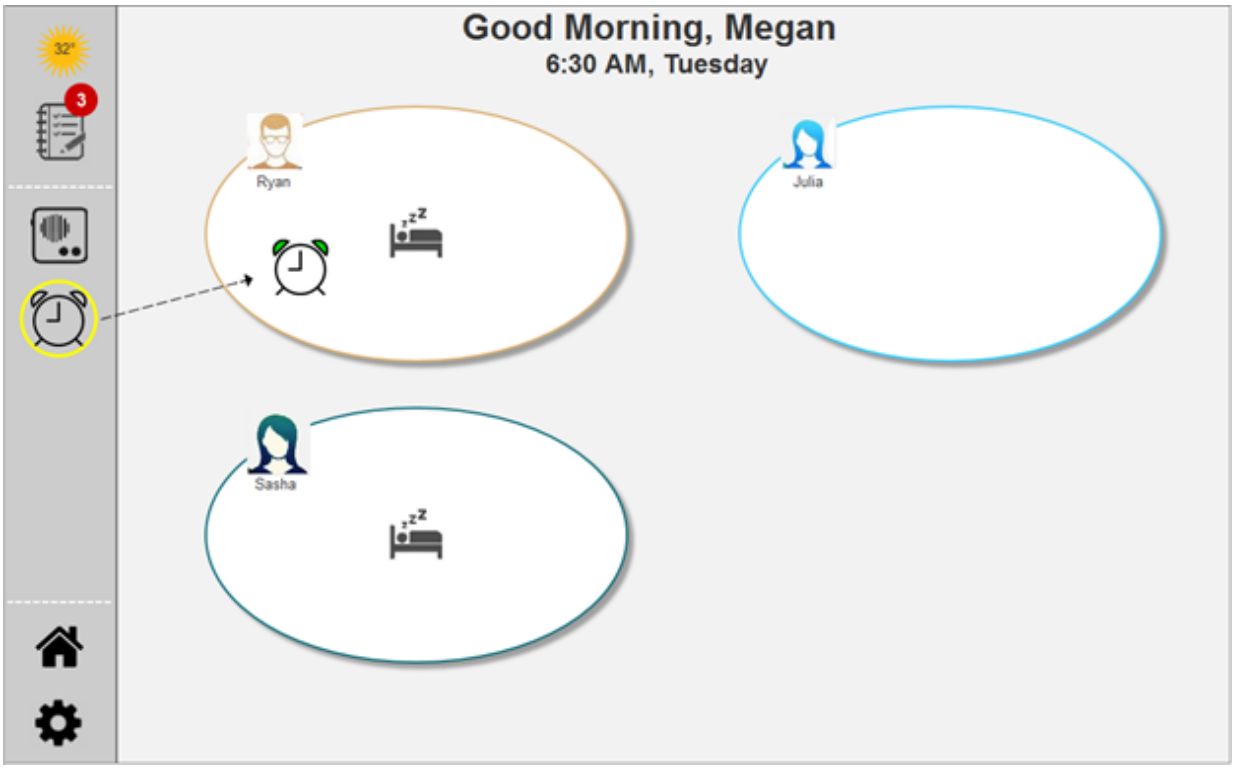
Final Prototype: Cashew prepares for Tuesday morning activities by turning on the heat and changing the lighting.



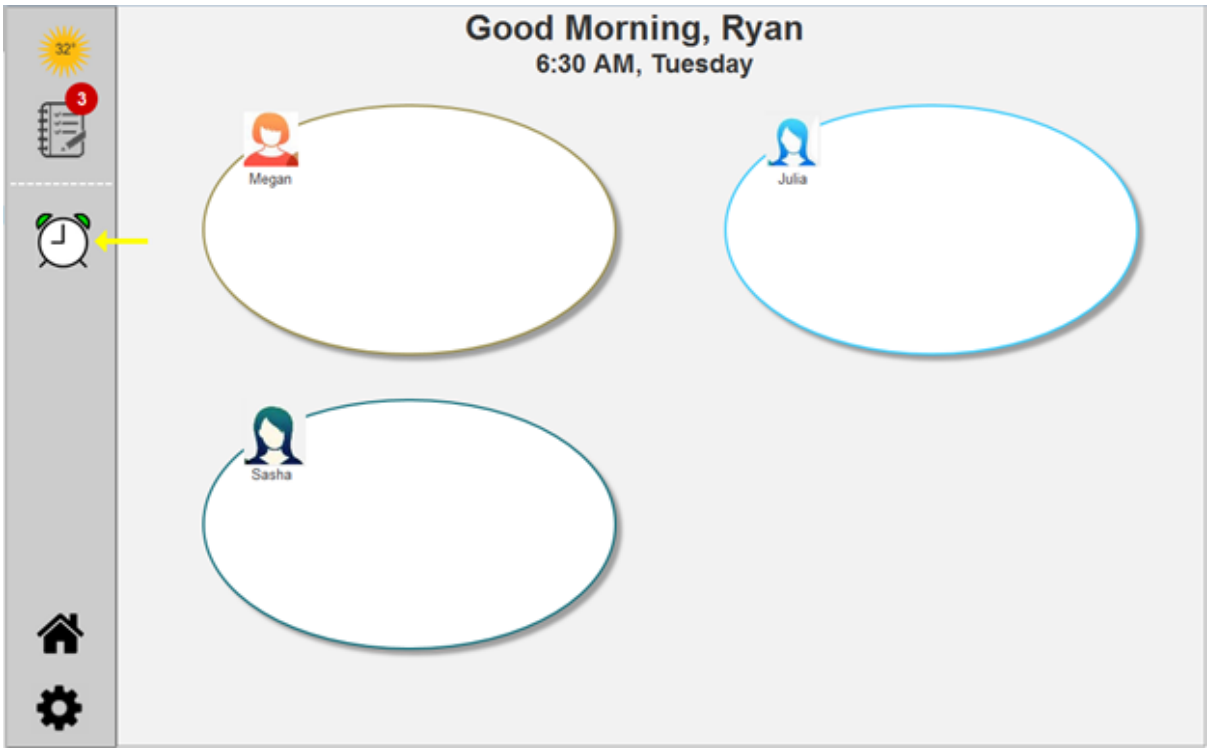
Final Prototype: Megan's Alarm goes off at 6:00 AM as indicated by the music in her morning menu.



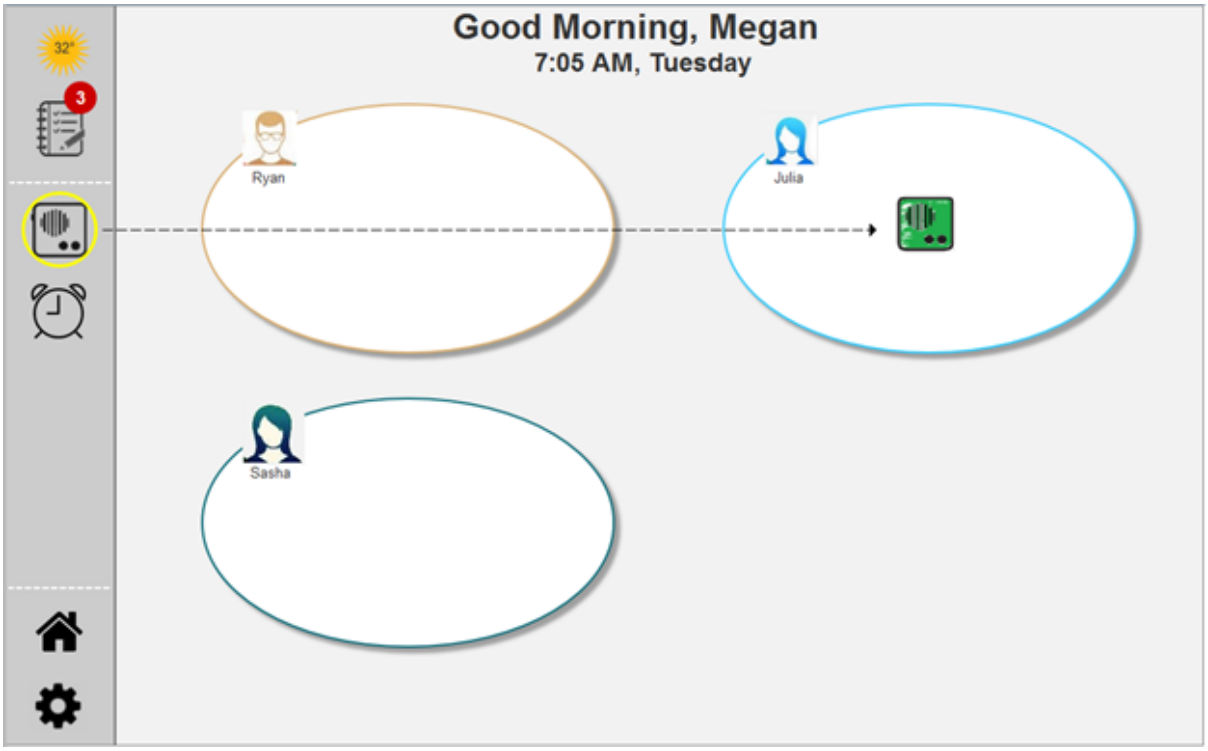
Final Prototype: Megan's does a quick check of the day's schedule.



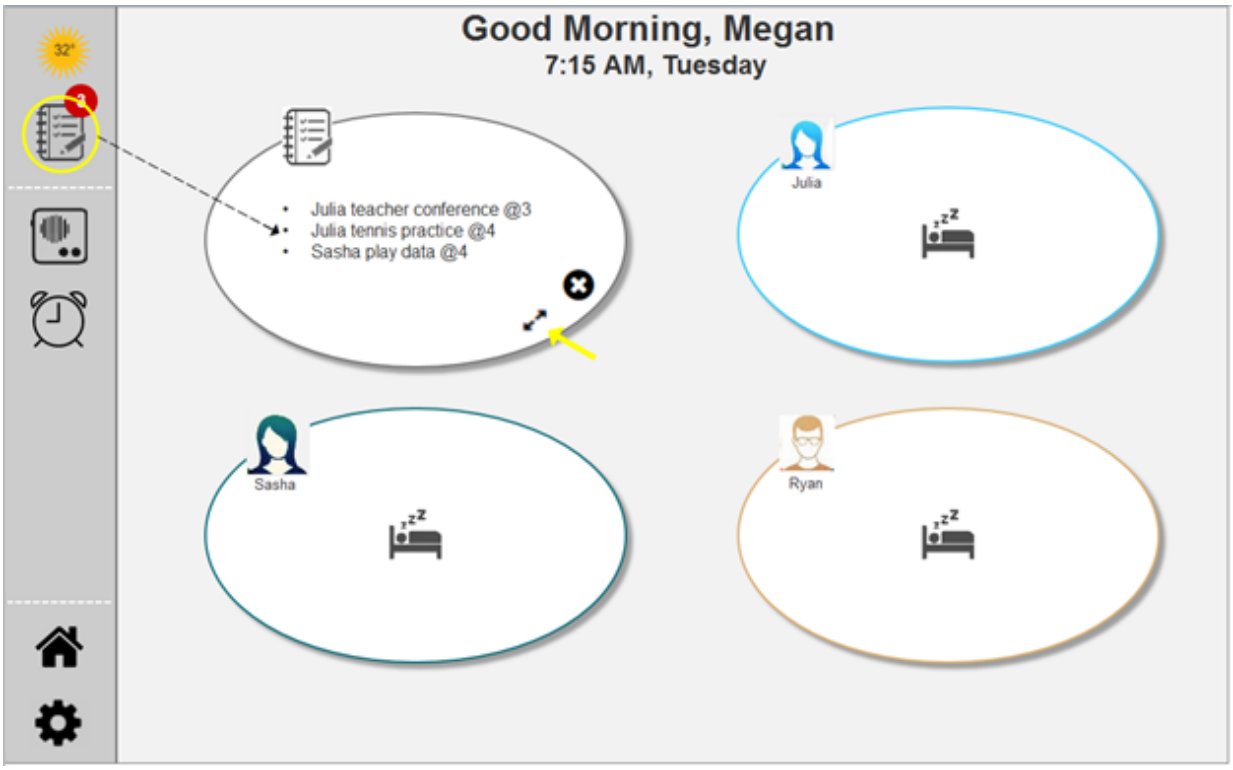
Final Prototype: It's 6:30 and Ryan is not up yet. Megan drags the alarm into his blob. She can leave it there to recur every morning.



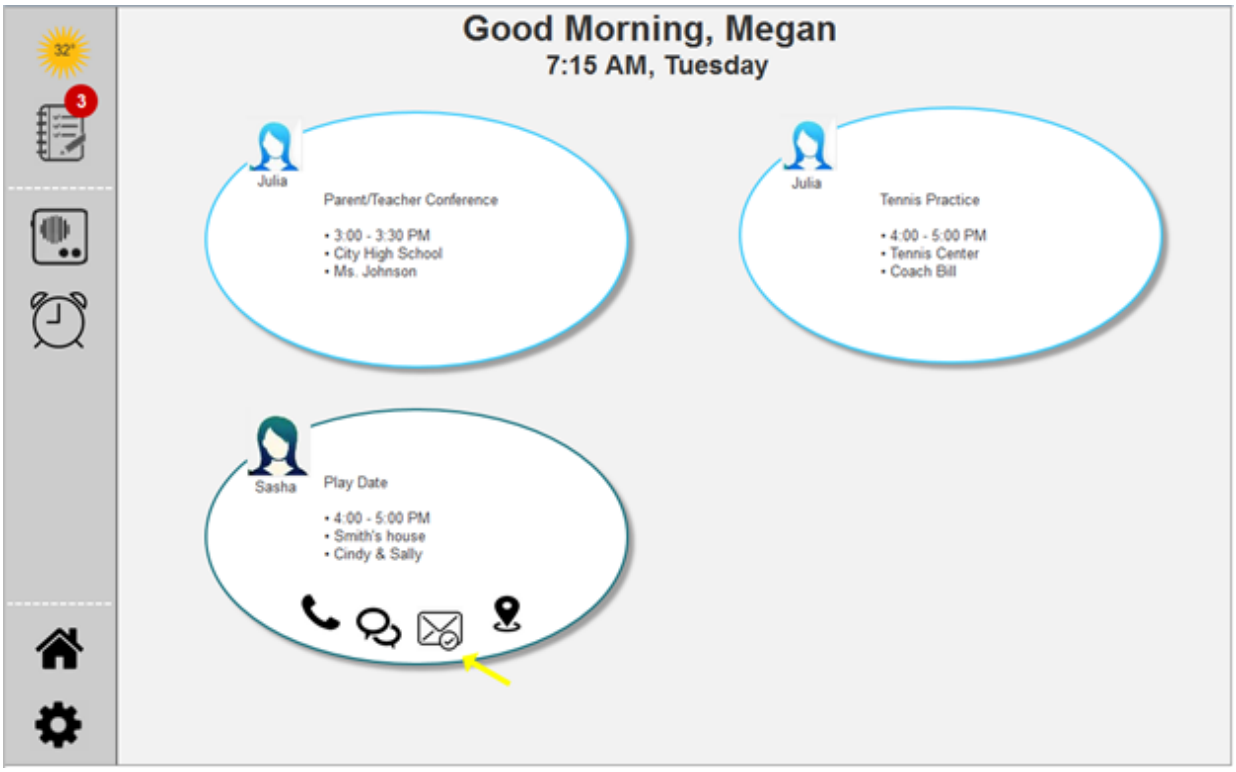
Final Prototype: Ryan's blob showing the alarm, which Cashew will shut off after he gets up.



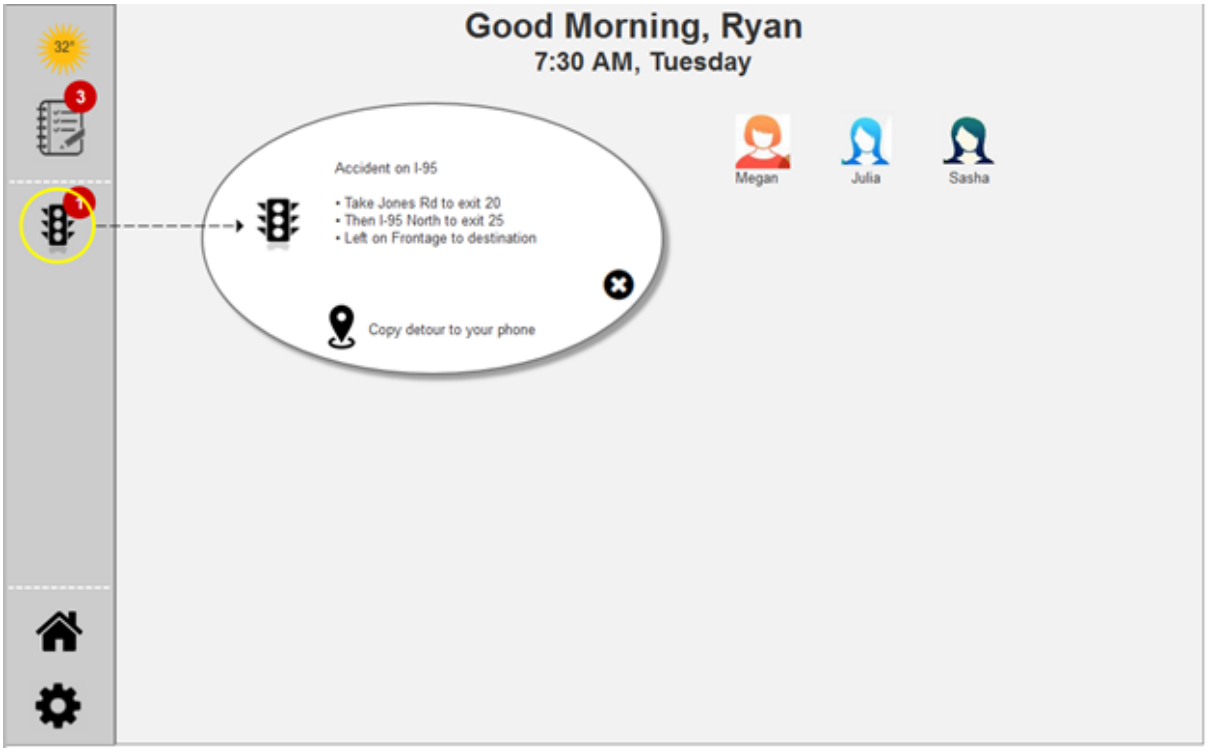
Final Prototype: Everyone is in the kitchen eating breakfast except Julia. Megan calls her on the intercom and tells her to hurry up. Megan doesn't need to know exactly where Julia is because Cashew does.



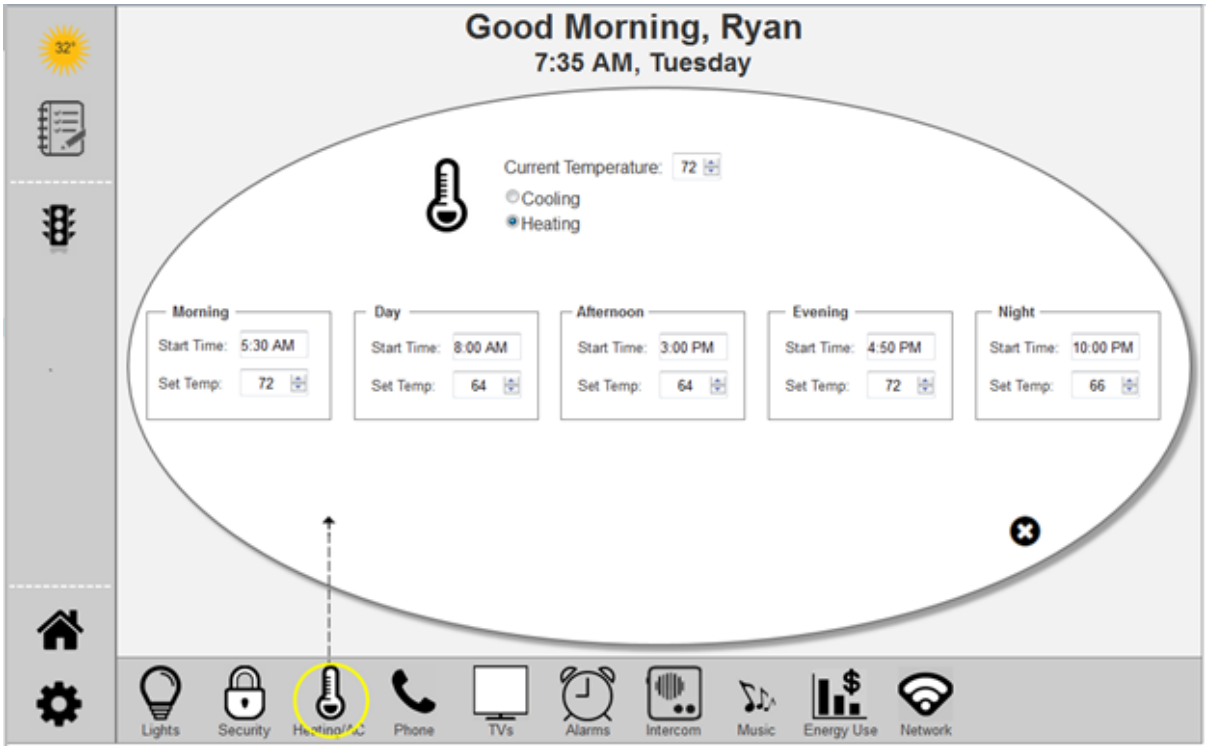
Final Prototype: Megan and Ryan coordinate the day's schedule. Megan can expand the activities blob to see the details.



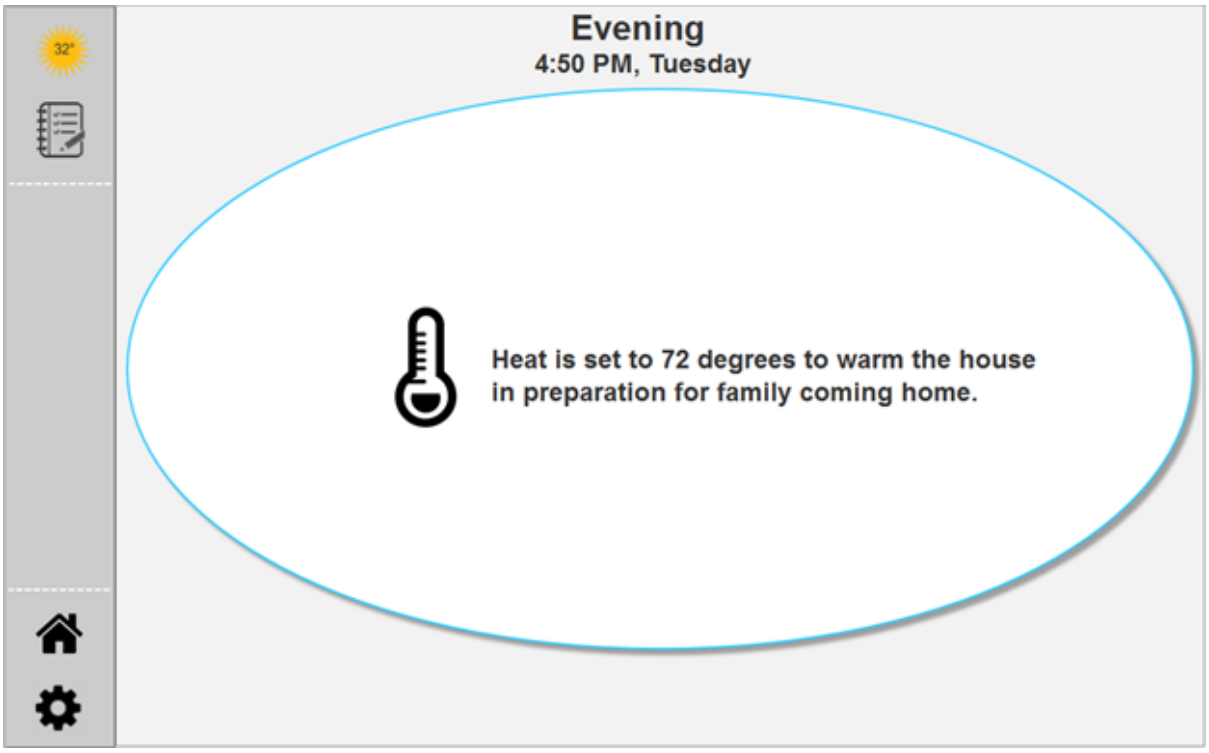
Final Prototype: Megan can click on any of the blobs and initiate an action.



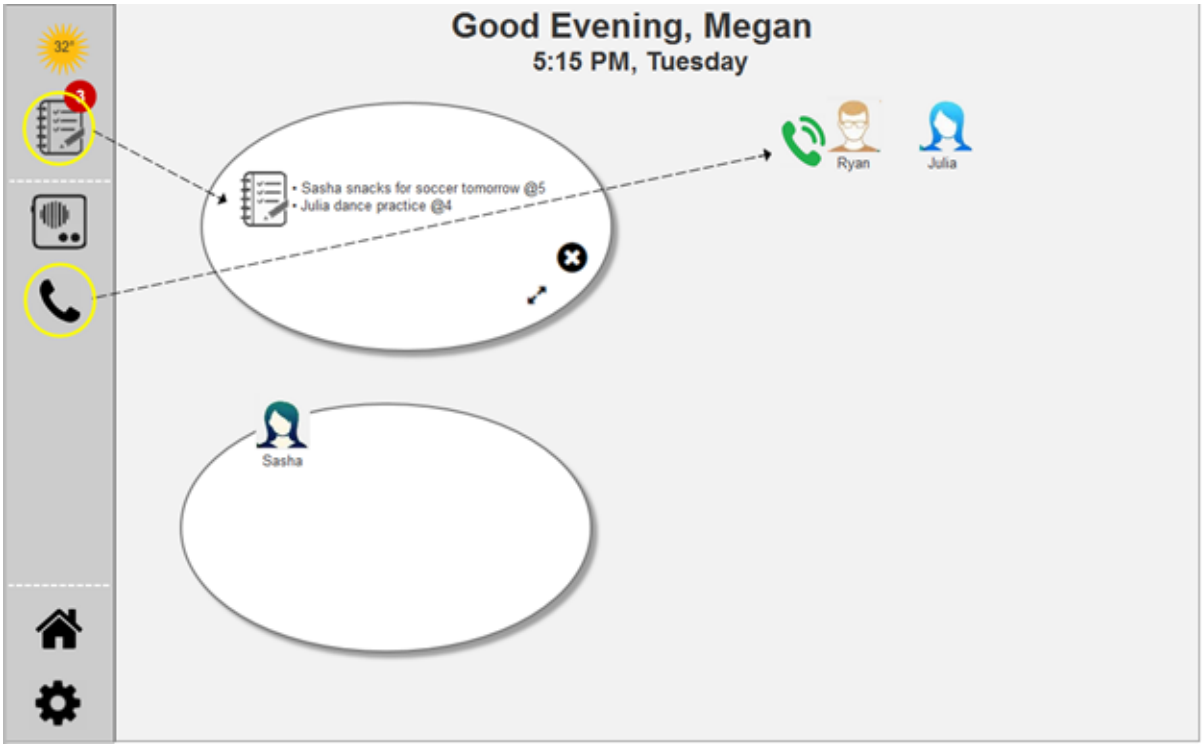
Final Prototype: Ryan checks the traffic alert on his wall. He can copy the detour information to his phone. The rest of the family has left for work and school.



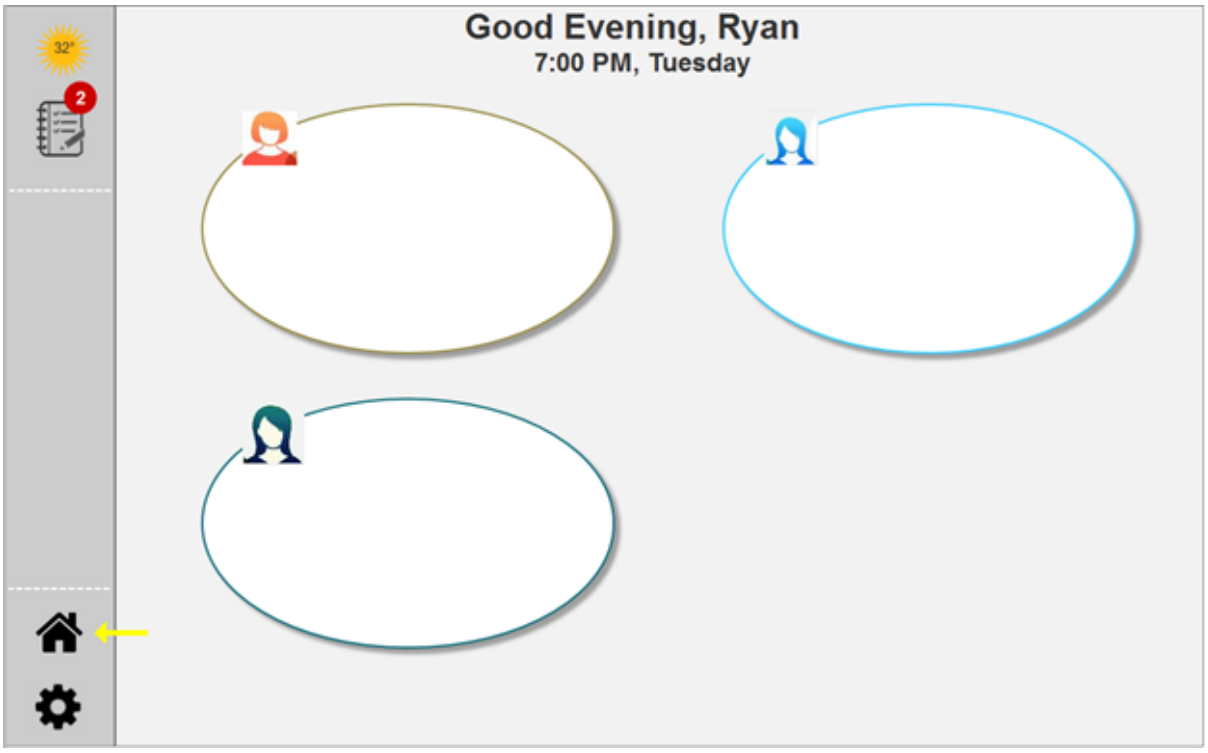
Final Prototype: Ryan checks the Heat settings before he leaves for work. He can set each time manually or the system can learn over time from the native controls.



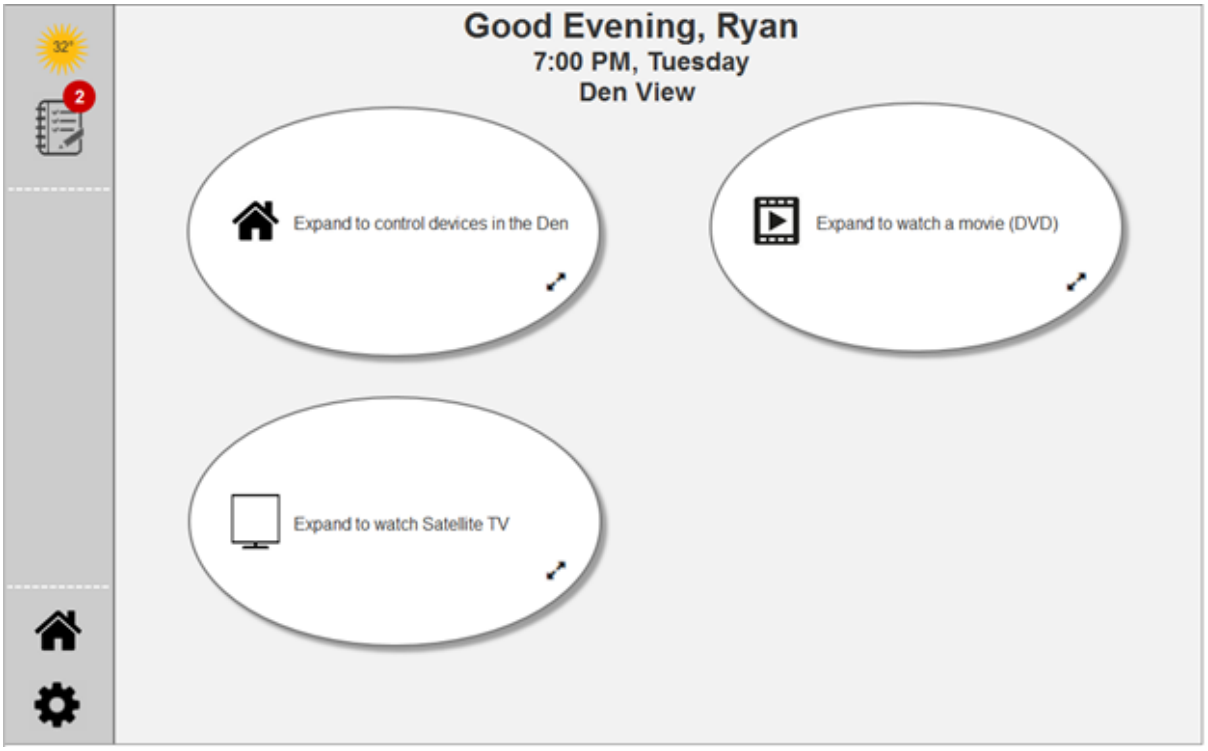
Final Prototype: Cashew turns on the heat to make the home comfortable for the families return.



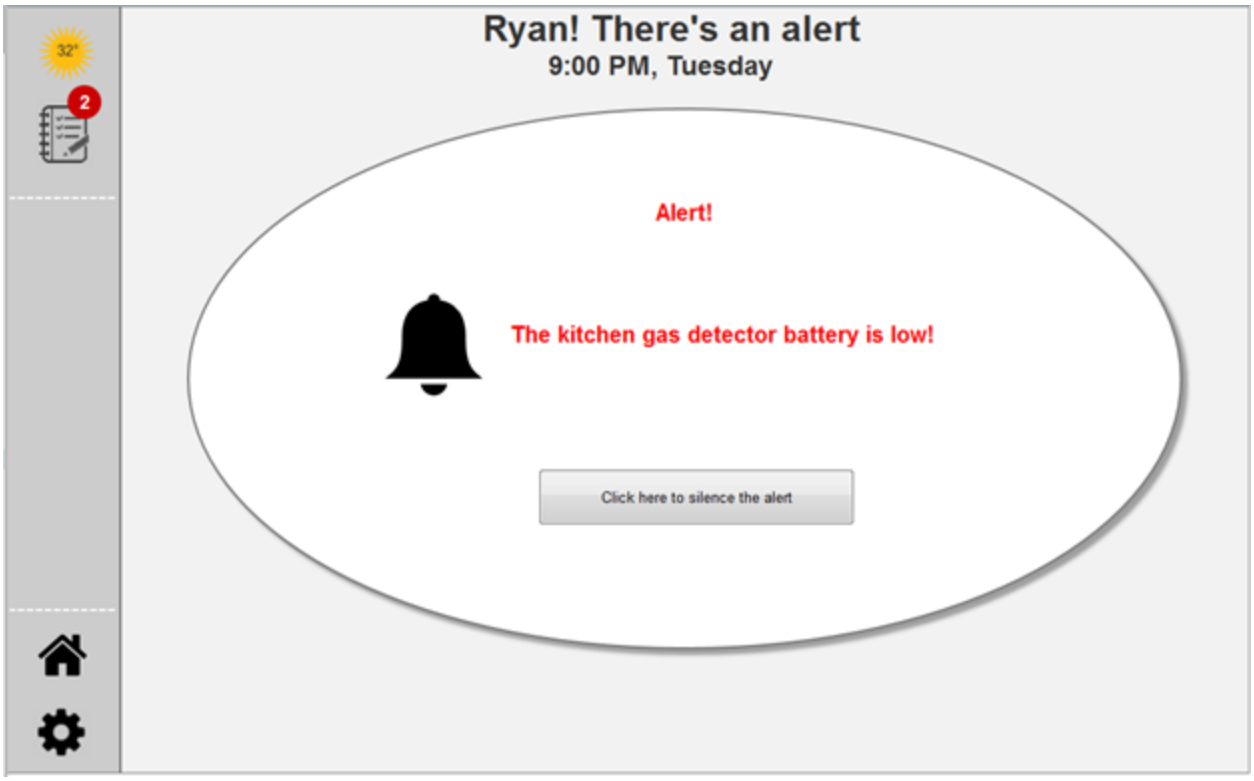
Final Prototype: Megan returns home with Sasha. Ryan and Julia are not home yet. She checks the schedule and is reminded that they need snacks. She calls Ryan to ask him to stop at the store.



Final Prototype: Ryan is in the Den and wants to control the room. He clicks the Home icon to toggle Cashew into Room View.



Final Prototype: In Den view Ryan can control the devices, which run automated actions (e.g., watch a movie) to setup all devices appropriately and adjust lighting.



Final Prototype: Before going to bed Ryan gets an alert.

Discussion

The design process of Cashew lead the team to unexpected places. The initial research provided the team with an idea of focusing on the needs of families, which was consistent throughout the project. However, early in the process, the team decided on a mobile app solution. But after feedback from prototype #1, more attention was paid to exploring other ideas in through brainstorming, which greatly helped the rest of the process. The project focus, scenarios, and personas were refined before the team began another iteration.

Prototypes #2 and #3 yielded valuable feedback, and the team worked well together to process and incorporate the feedback into the subsequent designs. Although different designs were explored, the team never strayed too far from the refined project focus, scenarios, and personas. Having put these stakes in the ground early in the process allowed the team focus on getting the interface and the interactions “right” for the final solution.

Cashew is a solution that addresses the needs of families in the home without being too intrusive or forcing dependence. The final design abides by the project focus by emphasizing the family’s life in and around the home, not the family’s devices or gadgets. In this way, the final design of Cashew is a good solution that satisfies the user needs that were identified through the initial research and analysis.

One aspect of the design that should be considered is how realistic the underlying technology is. Having an efficient and effective smart home solution that relies on emerging technology like gait analysis motion detectors and smart wallpaper with sensors, microphones, and other controls may not be in the foreseeable future. And when it is, will people be comfortable with the amount of technology that surrounds them? Even if Cashew is designed not to convey all of the information that it is capturing about the user’s activities in the house, the feeling of intrusion may make many users uncomfortable. On the other hand, it could be very helpful technology in special cases (for the elderly, for toddlers, for disabled individuals). Like all emerging technology, social and psychological implications must be balanced with utility and helpfulness.

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