# Interactive Device Design with Kinoma Create

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# MASTER OF ENGINEERING - SPRING 2015

## EECS

## Visual Computing and Computer Graphics

## Interactive Device Design with Kinoma Create

**Steven Hong**

This **Masters Project Paper** fulfills the Master of Engineering degree requirement.

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# Interactive Device Design with Kinoma Create

Master of Engineering Final Report

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# 1. Problem Statement

The goal of our capstone is to develop a new interactive device by following the product development cycle from user research through to a final, user-tested prototype. After a brainstorming process and consulting with potential users, we uncovered the common problem of forgetting items such as keys or wallets. These are items that are generally needed every day, but are easy to accidentally leave behind. There is also usually a cost associated with forgetting these items, such as being late to work or paying for a locksmith. We determined that an Internet of Things, connected device solution was appropriate for solving this common problem.

Our solution to this forgetfulness is a device called the reMINDer. It is a consumer product intended to help users remember to take their keys and wallet with them when they leave home. The reMINDer keeps track of these items via Radio Frequency Identification (RFID) tags, detected using RFID readers inside the device. It notifies the user through detecting the user walking to the door with a motion detector and blinking LED lights to attract the user's attention. The user is drawn to the device and is reminded to take their personal items resting on the device. Users interact with the reMINDer through the on-device screen that allows users to pair items with the device, and a smartphone app allows remote monitoring of the status of paired items.

Through following the design cycle, we iterated over multiple device prototypes, testing our device over a pool of six users. The form factor of the reMINDer underwent significant change from the initial bowl concept to the slim rectangular profile of the final prototype, providing a compact enclosure for the internal hardware while also providing sufficient reading area for the RFID readers. Feedback on the experience of using the device in daily life led to improvements on usability and shifting the main point of user interaction from the phone app to

the device itself. The final form of the reMINDer is a product of continual improvements and integration of user feedback over the course of multiple design cycle iterations, as shown in Figure 1.

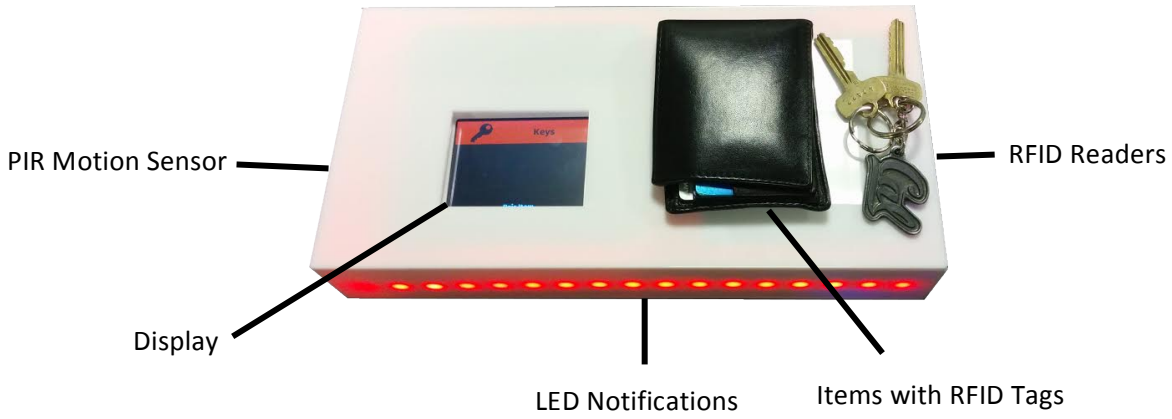


Figure 1: Final prototype of the reMINDer device.

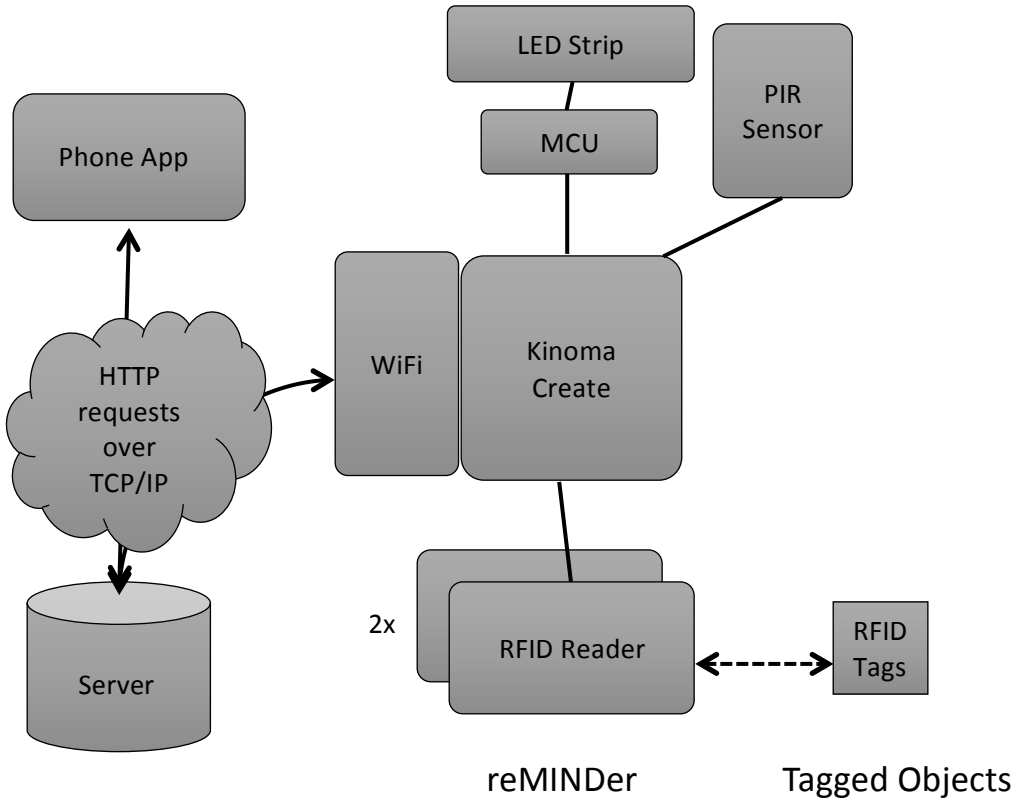


Figure 2: Block Diagram of the reMINDer

## 2. Industry/Market/Trends

Although the reMINDer is not intended for commercial release, we investigated the viability of the reMINDer from the perspective of a company seeking to commercialize the reMINDer. This section describes how we, as this hypothetical company, can improve our strategic positioning by focusing on our user experience in order to differentiate our product from competitors. We begin by exploring why the current trends in the broad Internet of Things (IoT) industry make this the right time to enter the industry as a loss-prevention solution. Using the Porter five forces analysis, a common framework used in industry to evaluate the strength of various threats to companies, we determined that the high level of competition and the threat of new entrants are the strongest forces against our strategic positioning (Porter 1979). Given the strength our competition, we find that focusing on creating a unique and seamless user experience will give us the edge we need over our competition. We conclude our industry analysis with a discussion of our marketing plans.

### Trends Within the Internet of Things

Our target industry, loss prevention, falls under the umbrella of the Internet of Things industry, but what exactly is the Internet of Things (IoT)? According to a Goldman Sachs research report, the Internet of Things describes devices such as everyday consumer objects that are connected to the network, enabling the use of software to manage new types of services or handle data gathered by such devices (Goldman Sachs 2014). The report suggests that by 2020, as many as 28 billion devices can be connected to the Internet, ranging from items such as bracelets to cars; the chart in Figure 3 (Strategy Analytics 2014) predicts a similar level of growth, particularly in the number of IoT devices connected to networks. Each device can be

customized to provide personal, interactive user experiences and provide new services, and many companies are quickly recognizing the potential of mass personalized devices connected to the Internet. It is reported that thirty percent of device makers today currently develop IoT devices, and about thirty-four percent more plan to develop IoT devices over the next two years (Olavsrud 2015). Predictions for the size of the IoT global market increased from $1.9 trillion in 2013 to over $7 trillion by 2020 (Wood 2015).

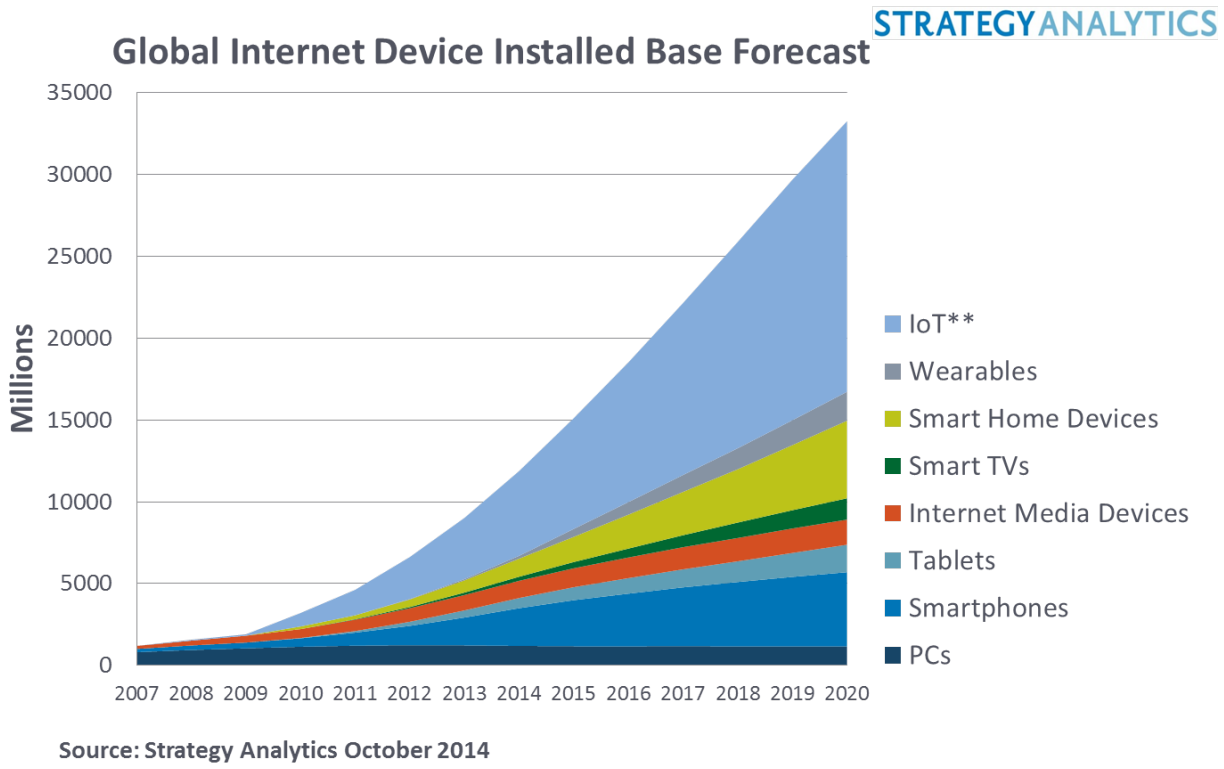


Figure 3: Projected growth in number of installed Internet devices, with Internet of Things connected devices experiencing the most growth in the projected time period

The main benefits of participating in the Internet of Things industry are apparent in terms of financial cost and future prospects for our product. The rise of IoT corresponds directly with significant technological changes; these include drastic reductions in the cost of sensors, the

popularity and widespread use of smartphones, nearly universal wireless coverage, and inexpensive processing that allows devices to both connect to networks and manage an inflow of data (Goldman Sachs 2014). The widespread availability of these resources means that we have less financial burden in creating our product. This allows us to develop our reMINDer technology, conduct user tests, and refine based on user feedback, all without being constrained by parts and development costs. Additionally, high profile acquisitions such as Google's acquisition of Nest, a startup that produces smart thermostats for the home, illustrate corporate opinion that connected devices are the future of hardware (Forbes 2015). Research showing that companies spent $14 billion to acquire IoT-related companies in 2014 (451 Research 2015) indicates that many companies share this belief in IoT as the future of hardware. With companies willing and eager to invest in the potential of IoT startups, this is the right time to bring our ideas to market and gather attention to ourselves with our device and unique user experience.

**Competitors**

Within the Internet of Things category there are several companies attempting to address the problem of losing small personal items, such as wallets and keys. These companies all belong to what we call the industry of loss prevention. Most competitors' products within the industry of loss prevention require affixing a large tag to each item a user desires to track, increasing the profile of the object and making it awkward and unwieldy to carry around (Cohen 2014). Most of these alternative solutions assist users with finding items once they are lost, in contrast with the reMINDer, which attempts to prevent loss of items in the first place. The reMINDer is plugged in to a regular power outlet and comes with Radio Frequency Identification (RFID) tags that are very slim (almost the thickness of a sheet of paper) and do not require

replacing. We will analyze three of the main competitors to the reMINDer: the traditional bowl, the Tile, and Trackr.

## The Traditional Bowl

The traditional bowl provides an inexpensive solution to the problem of forgetting personal items. It is also commonly available, as many people own spare bowls. To use the traditional bowl, you place the items in your bowl when you come home and take them out as you leave. The items are consolidated in one location. Not forgetting these items, however, still entirely relies on memory as there is no interactive experience. The bowl cannot catch a user's attention as he walks to the door. This is where the reMINDer is different. The reMINDer adds interactions to the traditional bowl in an attempt to remove the dependency on memory so that the users are reminded when to remove and replace items. This solution is simpler for users and more likely to prevent forgetting items since the recall has been replaced with recognition (Budiu 2014).

## Tile/TrackR

Tile is a product designed to be tethered to a key chain or affixed to an item a user wants to track in order to find it if lost, as shown in Figure 4 (Nzama 2014). Each Tile holds a Bluetooth Low Energy (BLE) beacon making it quite bulky, and often the largest object on a keychain, as some users have pointed out (Bonnington 2014). Tile users must replace their Tiles every year or more frequently depending on usage, at $20 per Tile (Bonnington 2014), since Tile's battery is non-replaceable. To assist users in finding their lost item, the Tile device is capable of emitting sound. However, this capability alone may be insufficient to locate the lost

item. One user described his inability to hear the sound emitted from the Tile due to ambient noise even when it was placed in his pocket (Cohen 2014).

The most novel feature of Tile is the ability to find objects with the help of other users of its phone application or through "crowd finding". Assuming there are many millions of Tile users, the phone applications can assist with finding other users' objects securely over the network. However, the most obvious flaw with this idea is that all these users would have to have their Tile application open. Even if this issue were circumvented, the service would only be useful once Tile has gained mass adoption, which is currently not the case.

TrackR is another company that offers an interactive solution to loss prevention, using a small, coin-sized device that attaches to valuables such as keys, wallets, and cell phones and pairs with a smartphone app; the device and app interface are pictured in Figure 5 (TrackR 2015). TrackR utilizes Bluetooth technology to track items that have the tracking device attached. A smartphone app provides information on proximity of the item and allows the user to ring the device so users can find their items via sound. Like Tile, TrackR also provides support for tracking items when they are outside Bluetooth range in the form of Crowd GPS, in which users who also have the TrackR app installed on their smartphone can provide a user's phone with updates if they are in range of the user's lost item.


Figure 4: The Tile device (Nzama 2014)


Figure 5: The TrackR device and associated smartphone app (TrackR 2015)

We aim to differentiate ourselves from competitors like Tile and TrackR in such aspects as technology used and approach to loss prevention. In contrast to the battery-powered Bluetooth beacons both Tile and TrackR use, RFID tags are powered wirelessly from the reMINDer via electromagnetic induction, removing the need to ever replace the tags. More importantly, though, Tile and TrackR seek to prevent loss by enabling users to locate their personal items when they are lost. Our device aims to address the issue even earlier by preventing users from forgetting their items in the first place. The need that we see exists at the moment of remembering or forgetting to take personal items along. One can use tracking technology to locate missing items, but the problem of items going missing will continue to persist with such a solution. By addressing the moment of forgetfulness before it occurs and notifying users to take their items, our reMINDer solves the same problem as TrackR but at a point in time farther upstream. We expect that young, busy working professionals will find our solution attractive; our device is designed to slip seamlessly into their daily routines: get up in the morning, shower, brush teeth, get dressed for work, grab keys and wallet from reMINDer, walk out the door.

In addition to these competitors within our industry, there are also the threats of new entrants as well as substitutes from other industries. Through our own user studies and experiments we have come to understand existing substitutes that our target users currently use. Users typically have a designated region or area in their home where they keep items when they leave or enter their home, for example a regular bowl or a key hanger. However, these substitutes provide poor interactive interfaces. The reMINDer helps its users by providing visual feedback as they step out and into the door, reinforcing the habits that will prevent losing the items. In addition, a service feeds information about the contents of the reMINDer to a smartphone

application that can be useful for book keeping and sharing items amongst several members in a household.

We previously described trends that make entering the IoT industry with reMINDer attractive, but these trends also make entrance into the IoT space attractive for other new entrants as well. As described earlier our goal is to differentiate our product significantly through an exemplary user experience. Through multiple prototype iterations we have accumulated valuable user feedback for creating a user experience in line with user expectations, and new entrants would need to spend valuable time performing user tests to refine their own devices and user experience before going to market. In addition, our access to the Kinoma team at Marvell will give us an advantage in the manufacturing of hardware products, one of the biggest barriers for most hardware startups.

In order to differentiate ourselves from this strong competition, we must create a unique user experience. Whereas many of our competitors rely purely on their effectiveness at finding an item you have lost with no regular interaction with the user, the reMINDer relies on daily interactions that build habits. This is our major differentiator and we must continue to innovate and emphasize this point in order to maintain an advantage. Since the user interacts so often with the reMINDer, these interactions must be seamless and unparalleled in order to compete. By staying ahead of the curve with this user experience we can greatly reduce the strength of the force from competition.

**Market**

We will sell directly to our end-users via our website, making our users our customers as well. We have segmented our market, and our initial target users are young professionals. We are

targeting this group because our interviews have shown that they are the most likely to forget items at home due to the fact that they most frequently leave their homes to go to work and social events. In preliminary user interviews, three out of five interviewees said that they regularly forgot to bring their wallet, keys, and other personal items with them. Since they forget their items so frequently, they have the most to gain by using the reMINDer. In addition, ninety percent of those aged eighteen through thirty-four own a smartphone, the highest percentage of any age group (Harland 2015). Given that a smartphone is a requirement to use the reMINDer, this cements the case for young professionals.

The Porter five forces market analysis model lists customers as a potential threat, defining buyer power as the ability to put a company under pressure. There are four main reasons why customers have low buyer power over our product. First, the reMINDer does not represent a large portion of their income. These are young professionals with stable jobs, an Internet of Things device for under $100, our target price point, is not a large portion of their income in the way that an item like a car would be, which would drive up their buying power. Second, as was mentioned when discussing suppliers, the reMINDer is a complex product that cannot be reproduced easily by the average customer. It is far more convenient for customers to purchase a reMINDer device, compared to creating their own interactive solutions. Third, the industry is non-standardized. Customers will be attracted to devices that have unique features and styling, such as the reMINDer, which offers a unique user experience unlike that of other competitors. Finally, the possibility of future upside from our product makes it so that our customers will be less price sensitive. For instance, paying a visit to the locksmith after locking oneself out of the house can cost anywhere from $35 to $100. These potential future savings

push buyers to be willing to pay more for our product. With these four reasons in mind, the strategic position for our customers is weak.

Our marketing will serve to further improve our strategic position by pushing on this last point. We aim to emphasize the future savings which can be either financial (from reducing costs from lost items or using services like locksmiths) or in terms of stress (by removing the need to worry about forgetting something for years to come). This plan will show our customers the true value they are getting from our product, putting the strategic power firmly on our side.

## 3. IP Strategy

In this section, we will analyze intellectual property protections applicable to our project and what we can do to protect our competitive advantage using IP protections. As patents are the primary method of protecting intellectual properties of invented devices, we first examine the patentability of our device from different angles. Our analysis shows that a design patent on product's physical enclosure will be our initial best bet at protecting our competitive advantage. We then look at the impacts of having a design patent on our enclosure, whether it is worth pursuing, and the risks involved should we choose not to apply for a patent at all.

As we concluded above in our discussion on strategy, the path to standing out in the loss prevention industry and in the broader scheme of the Internet of Things is to differentiate the reMINDer based on a unique and seamless user experience. There are three core components that make up the user experience of the reMINDer. These are the hardware configuration that directly provides the functionality for storing items and issuing notifications to the user, the software running on the device's hardware and in the mobile app that control user-device interactions, and the physical enclosure that dictates how users are to use their personal items in conjunction with the reMINDer. Intellectual property protections for any of these components will provide protection for the way in which we achieve our user experience. An examination of the patentability of these components reveals that our most promising prospects for intellectual property protections lie in patenting the enclosure with a design patent.

On the hardware side, patents provide strong, broad protections but are costly in terms of wait time. To protect intellectual property concerning our hardware configuration, we would need to have a utility patent, which protects the functional aspects of our device. This would provide broader protection for our product, since competitors would not be able to copy the way

the reMINDer operates to provide the unique user experience. However, utility patents take a long time to obtain; Eric Waltmire of Erikson Law Group, PC estimates the wait time to be thirty-two months on average (Waltmire). This is certainly an option to consider but not our most promising bet for the near future.

Looking at the software side of things, we find that the software patent landscape is uncertain and unlikely to provide adequate IP protections. As defined by the Foundation for a Free Information Infrastructure, a software patent is a patent on any performance of a computer realized by means of a computer program (Josefesson 2005). In a recent 2013 case, *Alice Corp vs. CLS Bank*, the Supreme Court ruled that the software patent disputed in the case was invalid due to the software simply being a series of basic computer functions implementing an abstract idea (Robertson 2014). Since the *Alice* case, however, what exactly constitutes an abstract idea in the legal sense has not been established (Casey et. al 2015). With the legality of software patents being questioned in Supreme Court itself, it is unlikely that we will find much hope for solid protections in software patents.

This leaves us with the applying for a design patent on the enclosure. Design patents protect the ornamental features of a product and so do not protect the product's functions from being copied. However, the wait time is shorter for a design patent at an estimated one to two years compared to the wait time for a utility patent (Neustel Law Offices). The success rate is higher as well when compared to utility patents; Patent Info.Net reports an eighty percent conversion rate for design patent applications into actual design patents, compared to twenty-five for utility patents (Patent Info.Net). Additionally, a design patent gives us protection on the overall user experience, as companies that copy our functionality will have to apply it to a unique design that may not be optimal for supporting such functionality. Design patents can be used

effectively to defend against infringement, as in the case of Apple and its D'087 patent on the iPhone's design. Based on this patent alone, Samsung was found to have infringed upon Apple's design patent with the Samsung Galaxy S 4G and two other phone models, and the total damages in this case totalled $163,018,625 (Nowotarski 2013). From this analysis it is clear that, while a utility patent is a form of protection we should investigate and strive for, in the short term a design patent is our best bet at protecting our user experience.

A design patent would help establish the reMINDer team as user experience experts. However, applying for a patent of any kind is an expensive and time consuming process. A UC Berkeley law survey of 1300 high tech entrepreneurs claims that the average cost of filing a patent is $30,000, a high cost for resource poor entrepreneurs (Stuart et al. 2009). Patents are viewed to be less useful in our industry than in other like like biotechnology and medical devices (Stuart et al. 2009). Even if we were to obtain patents, we are unlikely to be in a position to afford the cost of using them to protect ourselves in the near future.

However, a design patent would provide some advantages. The Berkeley Law survey revealed that although patents are viewed less useful in some industries, startups with venture backing tend to hold more patents regardless of industry (Stuart et al. 2009). This is in line with the generally accepted view that investors value patents, but may also suggest that venture capitalists encourage the pursuit of patents once they invest in a startup. In addition, patents are valued by larger corporations who are far more capable of protection with their use. As a result companies are sometimes primarily for their intellectual property as demonstrated by Google's acquisition of Motorola (Roberts 2014). For the reMINDer team however we may consider a design patent primarily to establish credibility of our unique design. It is unlikely to hinder copy cats but it may bolster support for original design.

Forgoing a design patent is potentially risky for the reMINDer due to the low barrier to entry in our industry. While the technology may be difficult for a customer to replicate on their own, a competitor such as Sony could very quickly design and go to market with a similar device. This would decrease our market share, and given the number of such possible competitors we could be pushed out of the market altogether due to our lack of resources to compete. A patent would hinder these competitors from simply replicating our product, allowing us a stronger hold on the market.

To further improve our position we can pursue measures in addition to a design patent. In particular, we intend to focus on innovation over protection (Ferrill et al. 2013). This is a technique which the fashion industry has used for many years, relying on changing their designs before they can be copied in order to maintain their competitive advantage. By constantly improving and altering the design of the reMINDer we can stay ahead of our competitors. They can choose to copy our designs, but they will always be a step behind if they do so. This strategy adds a second layer of protection beyond a design patent in order to address the strong threat of new entrants.

# 4. Technical Contribution

Our capstone project is made up of three main components: hardware, software, and task-centered design. As a team, we worked on all aspects of the capstone project together due to a collective lack of prior experience in the different aspects of designing and building an interactive device; however, in this series of technical contributions papers, each of us describes one of the three main components that make up the reMINDer project. In their papers, my teammates Sean McQueen and Codanda Appachu will describe the hardware and software components of our project, respectively. In this section, I will describe the aspect of task-centered design and the importance of rapid iteration and incorporation of user feedback into the design process for our interactive device. I will discuss the two different design methodologies that our team considered, the Universal Traveler Cycle and the Waterfall method, explain our choice of Universal Traveler Cycle over the Waterfall method, and review the progression of our project with respect to the timeline defined by the Universal Traveler Cycle.

## Universal Traveler Cycle

In their book *The Universal Traveler*, Koberg and Bagnall define a design cycle consisting of seven steps. In order, these steps are acceptance, analysis, definition, ideation, idea selection, implementation, and evaluation (Carle 2014). For our project, we have consolidated these seven steps into a cycle with three overarching phases: design, prototype, and evaluate. The design phase covers initial task analysis, user observations, and idea conception, covering similar ground as the first four steps of the Universal Traveler method. The acceptance step indicates the initial allocation of time, resources, and responsibility for designing a system for some set of users. Analysis covers understanding users, the tasks they perform, and the goals users have in

mind when they perform the tasks in order to achieve. The definition stage focuses the process on the appropriate level of detail at which the system addresses users. Ideation and idea selection make up the creative engine through which an approach to addressing user needs is generated, evaluated, and selected. Finally, implementation and evaluation test the actual design built by designers and determine real user feedback to the system. For our project, we have consolidated these seven steps into a cycle with three overarching phases: design, prototype, and evaluate. A diagram of this modified cycle is presented in Figure 6 (Carle 2015). The design phase covers initial task analysis, user observations, and idea conception, covering similar ground as the first four steps of the Universal Traveler method. The prototype phase is identical to the implementation phase, and the evaluation phase remains the same in both processes.

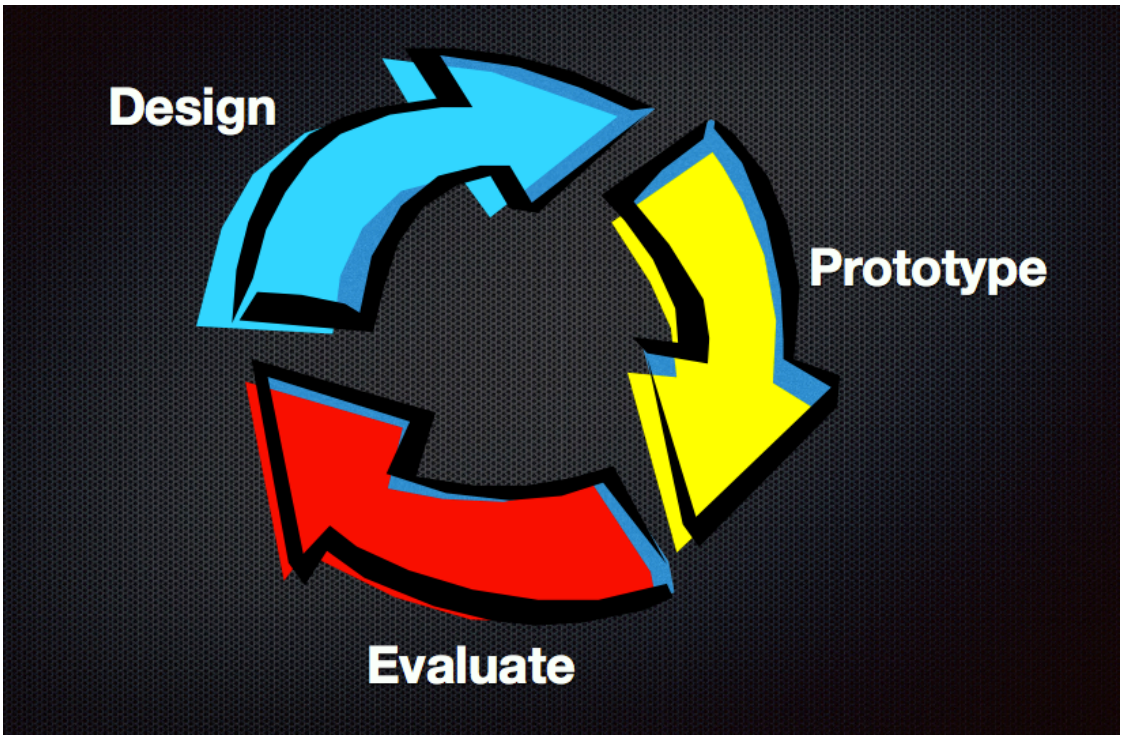


Figure 6: Modified design cycle (Carle 2015)

Design Phase

The design phase begins with an initial brainstorm phase in which team members rapidly build up a large quantity of potential product ideas in the interest of generating a single or select few ideas that can be pursued further. The brainstorming phase follows several ground rules as developed by the design firm IDEO: sharpen the focus, have playful rules, number the ideas, build and jump, the space remembers, stretch your mental muscles, and get physical (Fredman 2002:54-56). In short, the ideas produced, while focused on the problem articulated at the start, are creative and innovative, cover many different approaches, and utilize mediums other than text, including sketches, diagrams, and even acting out usage scenarios. Once the ideas have been generated, the team collectively votes to advance with an idea. The idea selection process takes into account factors such as the existence and severity of the problem the idea addresses, the target user group for the proposed system, availability of materials, and market window, among other factors (Carle 2014). In the analysis stage, the team answers questions about the tasks to be performed with the system being designed through user interviews and observation. These questions include who the target users for this system are, how do users perform these tasks already (if at all), how often these tasks would be performed, and what tasks users desire in the system. Beyer and Holtzblatt, in their book *Contextual Design*, list four principles of observing users using techniques of contextual inquiry: gain the context in which a user performs tasks, gain the details of the overall experience as opposed to a summary of the experience, get good user data through observation, and partner with the user in order to engage users in conversation about their work and the tasks they perform (Beyer and Holtzblatt 1997: 46-54).

Beyer and Holtzblatt maintain that the best way to understand users is the direct way: to go to where users are, observe what they do, and talk to them about it.

Prototype Phase

The next phase in the design cycle is the prototyping, or implementation, phase. The prototyping phase answers questions about the design of the system through exploration and testing. Stephanie Houde and Charles Hill of Apple Computer Inc. note that the three important aspects of an interactive system are role (ways in which the system is useful to a user), look-and-feel (concrete sensory experience a user has while using the system), and implementation (how the system actually works) (Houde and Hill: 3). Prototypes created in this phase of the process test one of these three aspects or all three aspects together in an integration test. Additionally, Houde and Hill mention the advantages of using simple prototypes to gain immediate and useful user feedback, such as in the case of designers using a pizza box to quickly evaluate form factor for a portable computer (Houde and Hill: 10). In our capstone project, we initially utilized a series of quick and cheap prototypes to test assumptions about our users and create proof-of-concept prototypes for our hardware and software implementations. Once we had tested these different aspects of our product, we created a series of integration prototypes to evaluate the overall user experience for using our device.

Evaluation Phase

The last phase in our design process is the evaluation phase. In the early stages of development, the evaluation phase answers focused questions on the individual aspects of the overall system. Early implementation prototypes used to demonstrate proof-of-concept are

evaluated on whether or not the prototype succeeds at performing the intended functionality, scalability into future prototypes and production, and compatibility with other aspects of the system, such as other implementations of different functionalities. Early role prototypes can be evaluated using the Wizard of Oz methodology described in a paper by Maulsby, Greenberg, and Mander, in which human "wizards" simulate a system to test the viability of a proposed system implementation; this gives useful data on the usefulness of proposed features and system usability without having to actually construct a working system prototype (Maulsby et al. 1993). In testing more sophisticated prototypes, such as integration prototypes combining the different functionalities and interfaces of a proposed system together into a single package, more formal user studies can be run to gain feedback on the coherency of the overall system and test assumptions made about how users will use the overall system.

**The Waterfall Model**

In determining which design process to use for our project, we also considered the traditional Waterfall approach as defined by Winston Royce in 1970. Unlike the design cycle, the Waterfall approach marks a clearly defined beginning and end to development, as depicted in Figure 7 (Waterfall Model 2015). The Waterfall approach starts with a Requirements phase in which all specifications are gathered at the start of the process. The Design phase takes those specifications and incorporates them into a system design, which is implemented in the Implementation phase. The Verification phase verifies that the completed system matches user expectations. In the last phase, Maintenance, the system has been rolled out to users and changes are made to the system as problems arise over the course of system use. (Hughey 2009).

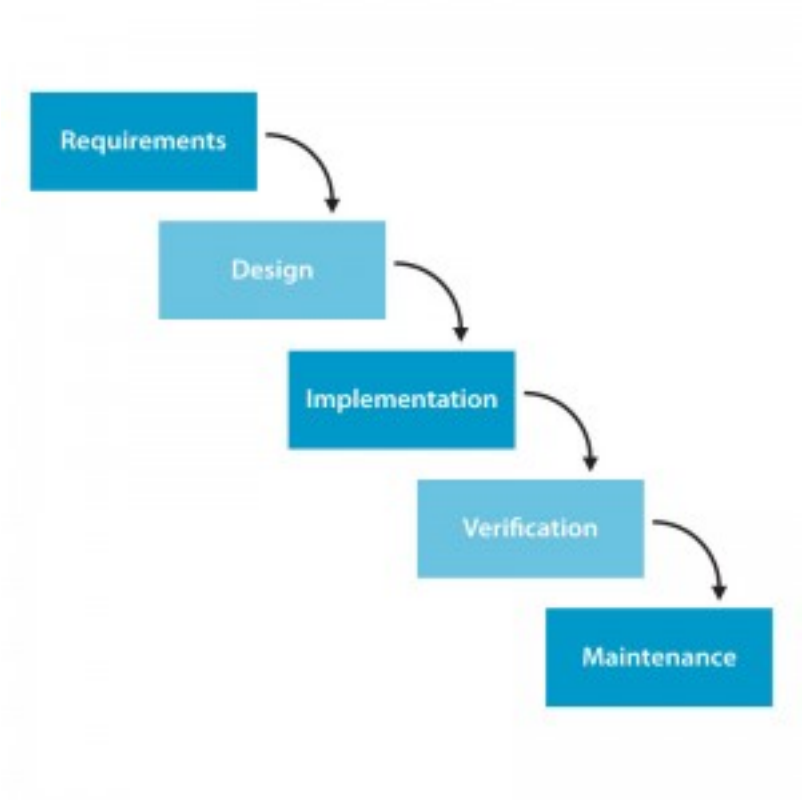


Figure 7: Waterfall method (Waterfall Model 2015)

In contrast to the design cycle, the Waterfall approach is very structured, with well laid-out expectations from the beginning and a clear step-by-step approach to meet those initial expectations. Testing can be easily carried out according to pre-defined scenarios defined in the Requirements phase, and total cost can be evaluated for the course of the entire process due to having all specifications and designing completed in the first phases of the process. However, we determined that the Waterfall approach would not be appropriate for our purposes of building an interactive device. The Waterfall approach fails to account for users' own lack of ability to completely communicate everything they want in a system at the start, particularly if the system exists to provide new, unique experiences as our interactive device is deigned to do. Under the Waterfall approach, if the end product does not meet user expectations when it is rolled out,

expensive re-engineering is required to account for expectations the user was unable to articulate at the beginning. Under the design cycle, frequent evaluation of intermediate prototypes ensures that user feedback is gained, evaluated, and resolved before moving on with system development. This allows for flexibility in redesigning system components as necessary in response to user input. Given the centrality of user expectations and usability concerns for interactive devices, we decided to develop in accordance with the design cycle over the Waterfall approach.

**Progression Through the Universal Traveler Cycle**

In following the design cycle, we first began by brainstorming a collective twenty ideas for a new interactive device designed to answer some existing user need. We then voted for our individual top three choices, based on the criteria of whether the idea addressed an existing user need, uniqueness of the idea, and viability of creating an interactive device to meet the user need, and discussed the results of our voting. Through this process we decided to build an interactive device that would address the problem of users forgetting personal items such as keys and wallets at home. We determined that problem was one that many people face daily and could be solved using an interactive device to notify users to pick up their items before they walk out the front door, and that our approach was a unique approach overlooked by existing interactive devices. Figure 8 includes several hand-drawn storyboards depicting common use cases for our device that we envisioned; these highlight situations that users would encounter on a regular basis and how users would interact with the device in the given situation.

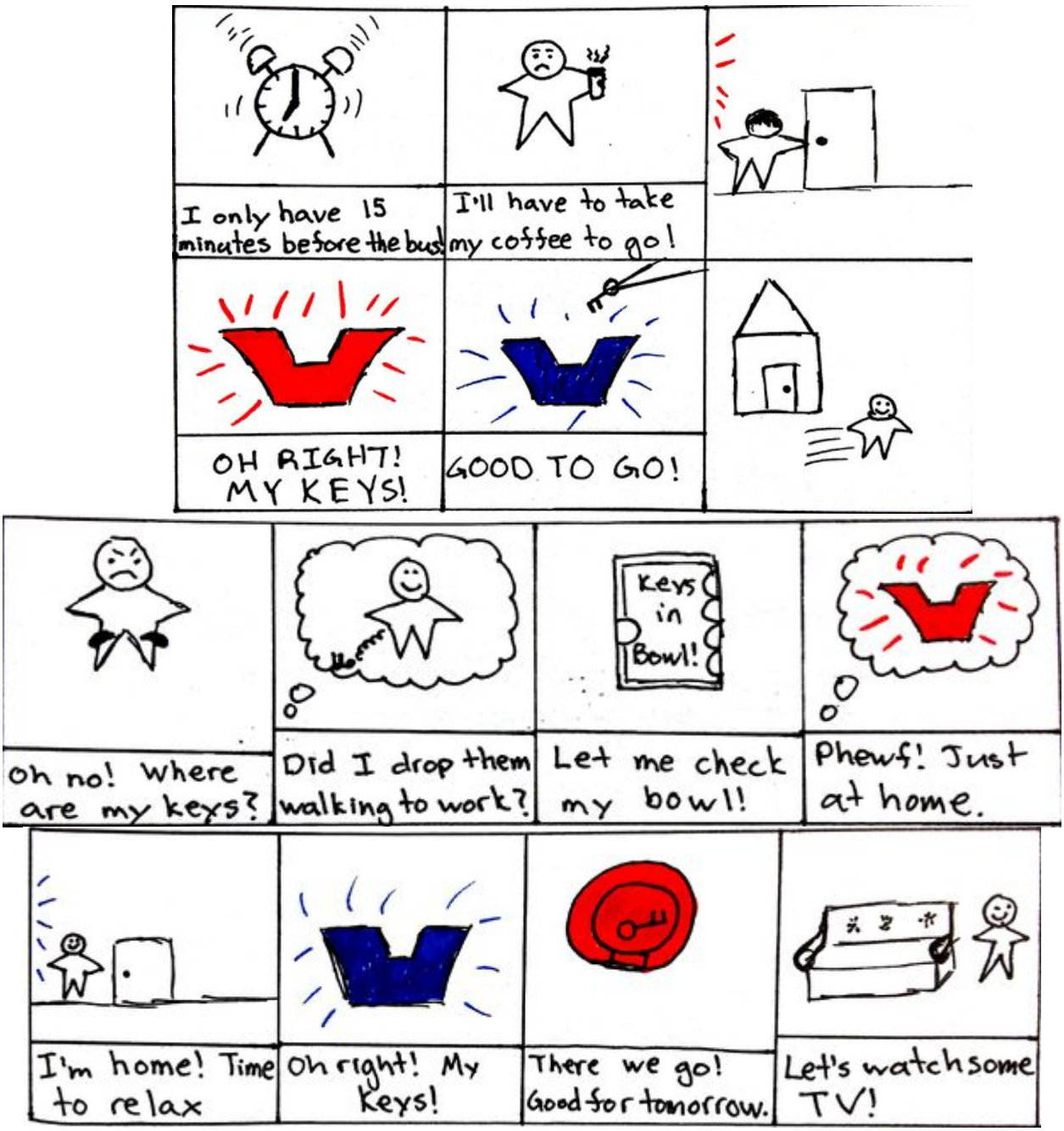


Figure 8: Initial hand-drawn storyboards for different use scenarios. Top: User is reminded to grab keys before leaving the house. Middle: User is able to use a smartphone app to check status of his items. Bottom: User is reminded to replace keys on device when coming back home.

We next determined our target user group, performed a series of user interviews, and conducted market research to verify our assumptions that the problem of forgetting items was

one that many people had and was not already solved in the way we had proposed with existing devices. We hypothesized that young, urban professionals would be affected most by the problem of forgetting personal items since they frequently transition between the home, work, and social events, and also that they would be the user group most likely to adopt an Internet of Things, interactive device solution to this problem. Based on this assessment of our target user group, we conducted a series of contextual inquiry interviews with various young professionals, observing them in daily life context. Based on user feedback, we determined that forgetting items at home was a persistent problem for young professionals and that many had not invested in technology that would help them remember their personal items before leaving the house (see Appendix). Figure 9 depicts existing solutions that some interviewees implemented in their homes to help them remember their keys, wallets, and other personal items. Overall, our interviewees expressed interest in a device that would notify them to take their personal items with them before they leave the house and remind them to put them back in the same place when they return home. Based on this feedback, we came up with the idea of developing a smart "bowl" device that would consolidate a user's personal items and notify users to take/store their personal items as they leave or return to the home. The key tasks associated with this device are: 1) Remind users to grab their items as they leave their homes; 2) Remind users to place items back in the bowl as they enter the home; 3) When a user is away from home and needs to check the status of their items, they can check using a smart phone app. Through conducting research on companies offering interactive device solutions to loss prevention, we verified our assumption that our approach was unique from other approaches currently on the market.

Figure 9: Existing user solutions used by initial interviewees. Interviewees noted that they still forgot items even with these solutions in place.

For our initial prototyping and evaluation phases, we laid out five questions that we wanted to answer: 1) How effectively can RFID be used as the mechanism for detecting items; 2) What information should be conveyed to the user through the smartphone app; 3) What types of notification are effective in directing a user to pick up their items from the bow; 4) Is the bowl form factor convenient and appealing to users; 5) How do we notify users to pick up their items at specific times (ie. Before they leave the home/put items back when they enter home). We addressed these questions in two phases of early prototype building. In our first phase, we built a proof-of-concept prototype to test hardware functionality and determine what technology to use for our device, as well as look-and-feel prototypes for the smart phone app and form factor of the bowl device. Our device needed technology to detect users' personal items so that the device can notify users of items still in the bowl that the user is forgetting to bring with them and of the need to replace items in the bowl when the user is back home. To determine which technology to use,

we researched different methods of detection, such as low-energy Bluetooth, pressure sensors, and light sensors, before making a preliminary decision to use RFID (Radio-Frequency Identification) based on range, power, and ease of implementation concerns, and developed an implementation prototype to test its viability. My teammate Sean McQueen discusses this in greater depth in his paper describing the hardware aspect of our project. We created a rough mock-up for the smart phone app to determine what information we would display and the general layout of information and also constructed some visual prototype using Solidworks to model the external design of our device. In our first prototyping phase, we evaluated our prototypes within the team, coming to a general consensus on the direction in which we wanted to develop the smart phone software and the underlying detection technology to be used. We agreed on using RFID as the means of notification based on the implementation prototype, and we agreed on utilizing the smart phone app as the main interface for the bowl, allowing users to configure the reMINDer and pair personal items with it through the smart phone app.

In our second prototyping and evaluation phase, we continued to test look-and-feel with clay prototypes modeling the external appearance of the device, as shown in Figure 10. We also developed a preliminary smart phone app in the Kinoma programming environment and conducted small-scale user experiments on the effectiveness of different notification methods. In the user experiments, we tested the effectiveness of phone notifications, light notifications, and sound notifications in drawing users' attention and found that only three of the ten subjects responded to phone notifications, while four of eight subjects responded to a solid, non-blinking light and eight of eight subjects responded to blinking light or sound notification. From this experimental data, we determined that using blinking light notifications would be most effective in drawing user attention to the bowl. In evaluating the clay look-and-feel prototypes, we came

to an internal consensus to use a circular, conventional bowl design for consistency with the original idea. The resulting circular bowl concept is depicted in Figure 11.


Figure 10: Clay prototypes of the external design

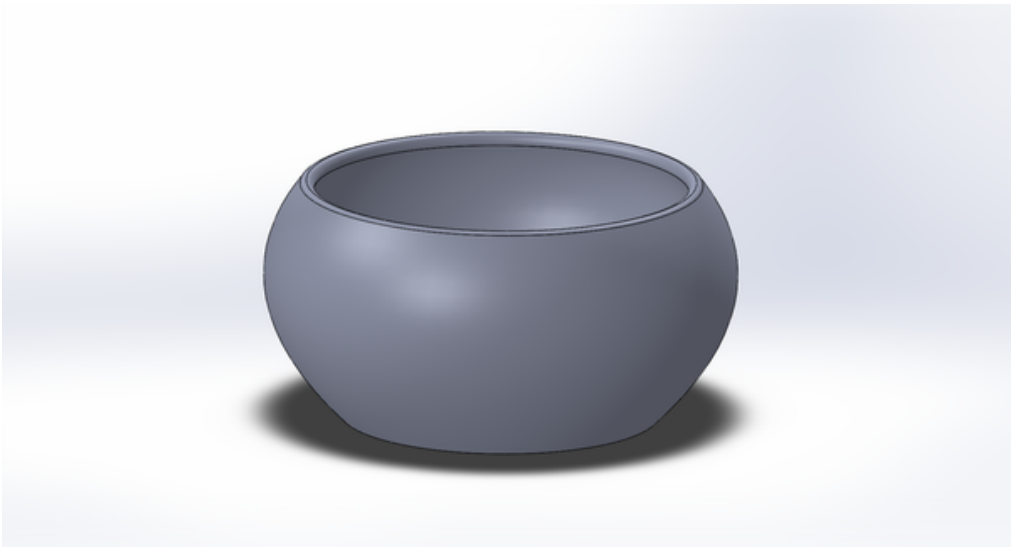

Figure 11: SolidWorks model of initial external design

After the initial rapid prototypes, we entered the prototyping phase for creating our first integration prototype to combine all the different hardware, software, and design aspects of the device together into a single reMINDer device. In this phase, we completed the hardware configuration to provide our core functionalities of detecting the presence of personal items in the bowl using RFID, coordinating LED lights to glow and blink as the means of notification, and using a motion sensor to detect a user's presence and trigger the light-based notifications. We also refined the interface of the smart phone app and finalized the communications between the reMINDer device and smart phone app for tracking item status. However, due to a collective lack of experience with industrial design, we made several rapid iterations of the external enclosure. We discovered that the circular bowl profile was difficult and costly to produce via methods of laser-cutting and 3D printing that were available to us in the CITRIS Invention Lab. Figure 12 shows a cardboard prototype we developed that demonstrated to us the difficulty of producing and utilizing a circular bowl design. Due to the difficulty of using a circular bowl profile, we switched the design to be more rectangular and box-like in order to better

accommodate the hardware configuration inside the device and for ease of production. Our final design for the integration prototype utilized a flat lid without a bowl-like indent on the top for aesthetic appeal and took on a box-like appearance to accommodate the form factor of the Kinoma Create itself, as shown in Figure 13. While this form factor differed greatly from what we had originally anticipated, the functionality of the device was unaffected.

Figure 12: Cardboard prototype of external design, prior to moving away from the bowl concept. The prototype was time-consuming to produce and assemble, and did not accommodate the internal hardware configuration.


Figure 13: First-generation prototype of the reminder device. Users interact with the device using the phone app, which provides basic information about status of items and allows user to pair items with the device.

The final phase of our project involved an evaluation of our integration prototype through user testing and qualitative feedback. In an initial test with our advisors, we discovered flaws with our design that made our initial prototype unsuitable for actual user testing. One of these flaws was the need to remove the lid and maneuver through a forest of wires to start up or restart the device, and our new design will address this issue through easy access to the Kinoma Create's power button. Another flaw was the small detection area of the RFID board we were using; the small area for placing items in meant that users would have to precisely place their items over the reader for detection to work. This had a negative impact on usability, as users would not want to waste time having to perfectly position their items for detection to work. Based on this feedback we constructed a new prototype. We experimented on various external antenna specifications to overcome the small reading area on the device; these experiments are

pictured in Figure 14 and elaborated on in more detail in teammate Sean McQueen's report. We also redesigned the form factor and user interfaces to take advantage of the Kinoma Create's large touch screen. In the new configuration, item pairing and device configuration are handled through the touch screen on the device itself, while the phone app is used as a remote monitoring application to track the status of personal items. The new configuration is pictured in Figure 15 and features a much slimmer profile and a touchscreen for user interaction, along with a redesigned phone app.

After conducting small-scale test with our advisors in preparation for conducting a user test with real users unfamiliar with our device, we sent the reMINDer prototype to a user outside the team for several weeks of testing. The user placed the reMINDer device in a location next to the front door in the same spot that he would normally place his keys and wallet. While our user initially expressed skepticism about the reMINDer's ability to attract user attention once the novelty factor wore off, this turned out to not be the case. After two weeks, we found that our user had become accustomed to using the reMINDer in daily life. He kept his wallet and keys on the reMINDer while at home and found the LED notification lights useful in reminding him to take his items when leaving the apartment. During the test period, our user reported zero instances of forgetting his keys and wallet at home. He also reported an initial learning period in which he had to learn where to place his wallet and keys such that the RFID reader inside the device would recognize his items. In future work, demarcating the reader area clearly to show where items should be placed would be an immediate improvement to the device.

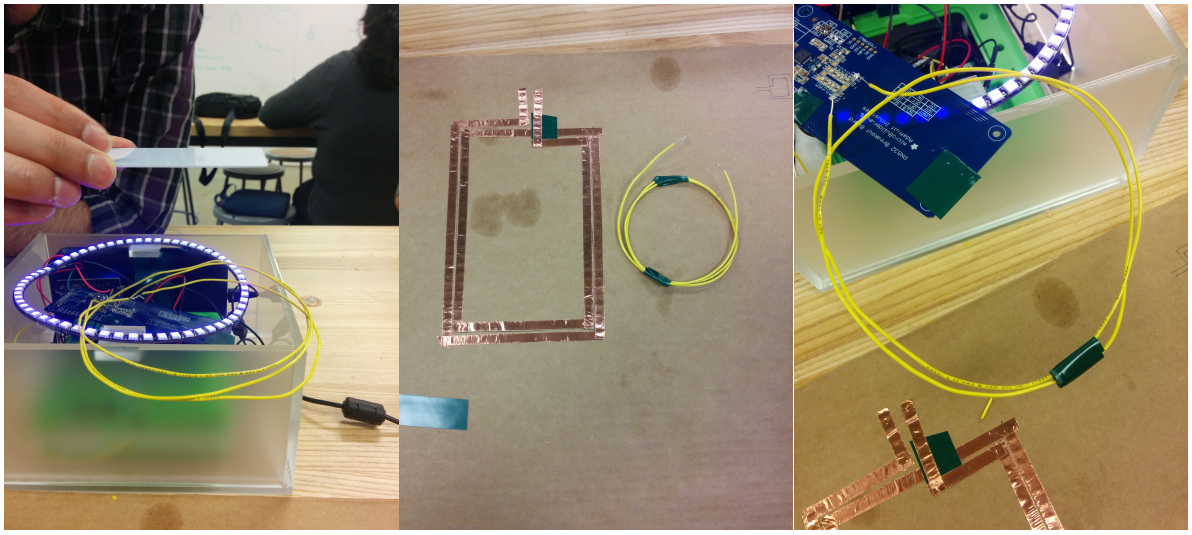

Figure 14: Testing RFID external antenna configurations in the lab


Figure 15: Second-generation prototype of the reMINDer. The screen on the reMINDer device allows users to pair items with the device, while the phone app is primarily used to remotely check status of paired items.

The design cycle is a crucial part of our capstone project, as it reinforces the need to constantly check in with users and evaluate how well our device meets with user expectations. Without this framework to guide our approach to development, we could have been on the path to developing an exciting interactive device packed full of features and functionalities that users would not actually need, an interface that confuses users, culminating in a product that users do not actually need. The intermediate user feedback from the different phases of the design cycle keeps the product focused on addressing the core problem of forgetfulness in a way that is intuitive and easy for consumers to use.

## 5. Concluding Reflections

In comparison to our original plans, we are slightly behind schedule. At the time of the writing of this report, we had originally planned to complete user testing and proceed on to building a finalized prototype. As described in the previous section, we are in middle of the user-testing phase and have not yet proceeded onto building the finalized prototype. One contributing factor to being behind schedule was the usability flaws with our initial prototype. Though the initial prototype proved that our idea could work, we had to redesign and create a second-generation prototype to address these flaws and make the device suitable for testing. We had not originally anticipated needing time to make extensive revisions to our initial prototype prior to user testing, so this led to an initial delay in the device development cycle.

Another contributing factor to being behind schedule was a lack of well-defined milestones and deadlines for the second semester of our project. Previously, in the first semester, we relied upon the structure for our Interactive Device Design class to guide our progress; this resulted in being on-schedule and meeting our first-semester overall objective of having an initial prototype completed by the end of the semester. However, in the second semester, we were no longer held to a class structure with well-defined assignment specifications and well-defined deadlines. As a result we spent much more time than necessary creating the second-generation prototype to rectify usability issues in our initial prototype, leading to the user-testing phase being delayed. We had a general idea of what we needed to accomplish by the end of the second semester, but without a proper schedule we failed to allocate our time properly to ensure steady progress over the course of the semester.

In terms of project management, we would have benefited greatly in the second semester from having a series of explicit milestones and deadlines to keep us on track. One idea that could

have worked to prevent us from falling behind schedule is to have drafted a work schedule with milestones and deadlines and submitting it to our advisors to keep us accountable for meeting deadlines on time. Another possibility would have been to explicitly select a project manager from among the team members who would be responsible for tracking actual progress against projected progress, setting weekly agendas, and scheduling work sessions to ensure we hit our milestones on time.

Future research on this project should be focused on usability and adapting the device to fit user expectations of use. While we plan to receive and incorporate user feedback into a finalized version of our device, more extensive testing and iteration through different prototypes would be necessary to transform the device from a prototype to a market-ready product that can be sold for consumer use. In particular, industrial design for the reMINDer should be researched, as our team has limited knowledge in this area.

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# 7. Appendix

## User Interviews

These interviews were conducted in our initial design phase, in which we had decided to pursue the reMINDer concept and designated our target users as young professionals. We conducted a series of contextual inquiry interviews in which we interviewed people at their homes and gained the context in which the reMINDer would fit into their daily lives. We interviewed five different people; the summaries of these interviews are listed below. Of the five interviewees, three replied that they encountered problems with remembering personal items, and none of them had invested in technology to help them remember their items.

### Interview 1

This user has three main items that he takes with him each day: a set of keys, his wallet, and his phone. He shares that he forgets his wallet or keys almost every week and has to call his girlfriend to check if he left them at home or to help him search for them. He has tried to put a bowl system in place where he puts his items when he comes through the door and grabs when he leaves. The placing in the bowl does not seem to be an issue for him since he does not like having items in his pockets and just naturally removes them. He does regularly forget to grab them from the bowl as he walks by to leave.

He starts his daily routine at the table in the kitchen where he eats breakfast with his phone already in his pocket. He then walks over to where he stores his shoes and jackets and grabs them. He heads over to the door where he puts on the shoes and jacket, then grabs his keys and wallet from the bowl and puts them in his pockets. He then leaves through the door, locking it behind him. When he comes back, he puts his keys straight in the bowl. He removes his wallet

and places it in as well. He then takes off his shoes and jacket and puts them away, and then goes to the kitchen for a drink or snack. The phone stays on him for the entire duration.

When asked about whether he has considered investing in technology to aid in remembering his items, he answers that he has considered it, but has not made the purchase because he feels that he knows where his items are, in the bowl. The problem is remembering to take them, and these systems would notify him too late once he is already out of the house. He thinks that the reMINDer would definitely help him remember to take his items assuming that the light or other notification catches his attention enough. Right now he just walks by without thinking, so it would need to really grab his attention. He also thinks it would be helpful to be able to check the contents of the bowl when he is gone so that his girlfriend does not have to check when he has forgotten things.

What was unique about this interview was that he has already recognized the problem and made efforts to solve it with the use of the bowl, but it really has not helped him out. He also does not have problems with putting items in, but only taking them out.

Interview 2

The interviewee takes four things with him each day: keys, wallet, phone, and a briefcase. He occasionally leaves his wallet at home, and sometimes misplaces his keys, but they are usually in an old pocket where he finds them before he leaves. He and his housemates have magnetic hooks on the back of the door where they keep their keys, and he personally leaves his wallet on his desk when he gets home.

He begins his daily routine by sitting at the dining table for breakfast and browses on his phone as he does so. He then puts the phone back in his pocket, goes over to his desk and grabs

his wallet, and then heads to the door where he puts on a jacket and a pair of shoes. As he opens the door, he grabs the keys off their hook on the back of the door and then leaves and locks the door behind him.

Upon re-entering the home, he takes off the jacket and hangs it up. He then takes off his shoes as well. He heads over to his desk and takes out his wallet and puts it down. At this point he realized that he had left his keys in his jacket pocket and went back, grabbed them from the pocket, and put them back on the hook.

When asked if he had considered purchasing any technology for tracking misplaced items, he said that he had not because he did not perceive it to be a major problem. I described the reMINDer, and he thought that it would help him remember his wallet since his keys and wallet would be in the same place. He does not currently forget his keys since they are right on the door as he leaves. He does forget to put them back when he comes home, so he felt that the notification would help him remember to take them out of this pocket and put them back. He then told me that for him personally, the bowl would have to be able to hold and handle the keys of the other people living in the house as well. It would need to be able to indicate different notifications since the different people leave at different times. He was also concerned about the size of the device, since he did not have a convenient location to place it and he would prefer a hanging solution.

This interview was unique because he didn't really consider forgetting his personal items to be a huge problem for him, but definitely still encountered the problem and thought notifications would be helpful.

Interview 3

The third interviewee is a program manager at Google working with the Consumer Operations team. She is a part-time MBA student and also has a busy social life outside of school and work. She transitions to and from her home frequently. She chants the mantra "wallet, keys, cellphone" each time she leaves the house in order to remember to bring her items. She commonly carries several other items along with her, including work badge, laptop, charger, phone charger, jacket, gym clothes, and backpack

Misplacing her keys or phone is frustrating, as she often has to fumble around her backpack to find her car keys. She also noted past incidents of forgetting her cell phone and sunglasses. Her routine is to keep all her items in her backpack, occasionally having to retrieve items left in the car. She expressed interest in buying a product to help her find items that she may have left in the car or at home, suggesting that notifying her before she left the house would be helpful.

This interviewee represents our target market - a young professional who transitions often between work, home, the gym, and social events; keeps up with a busy social life; and is willing to pay for the convenience of having a device to assist her with finding her keys, wallet, and other items as she rushes between these destinations.

Interview 4

This interviewee was an acquisition program manager for the DOD, transitioning to investment banking. He travels frequently and spends about 150 days of travel each year. Items carried on person include car keys, phone and wallet. He avoids having to carry house keys by using an electronic lock keypad for the front door. At home items are kept in the same place

except for the phone, which has to be frequently charged near a wall outlet. Staying organized is a priority, but identified as a cognitive strain.

The subject has not considered purchasing technology for tracking misplaced items because of the perceived bulk it will add to the items carried during travel. When the reMINDer concept was described, the subject was doubtful of its utility as a frequent traveler.
On occasion the subject leaves the house without any items, such as to go jogging. While describing his ideal scenario the subject expressed in interest in technology like Apple Pay which would allow the subject to leave only carrying his phone, replacing the need to carry a wallet or keys.

Interview 5

This interviewee was an architect and urban planner living in the city but slowly transitioning to a quieter lifestyle as an agricultural manager in the countryside. Travel between city and country for work and leisure is a priority. His lifestyle includes attending shows, events, and musical performances few times a week.

Items picked up during the morning routine include home keys, car keys (depending on the vehicle), wallet, credit cards, drivers license, club cards and smart phone. As a countryside dweller, the subject expressed the need to change gear, clothing and accessories carried depending on the weather as well as the demands of the agricultural plantation for the day. These items may include an umbrella, hat, rain jacket, rain boots, torch pen and pencil, and GPS device. The subject places most items in a specific location on the table but often misplaces spectacles that are removed when using the washroom or combing hair.

The interviewee described some variations to the reMINDer concept once it was described, such as an interactive tray that outlined items and the lack of items placed on the tray through the use of silhouettes.