Fostering Innovation:
Designing Technological Solutions to Proactively Encourage Informal Communication in the Workplace

by

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Abstract
I have designed, built, and evaluated three devices to encourage informal interactions in
the workplace. Previous research has found that such interactions can lead to increased
idea cross-flow, creativity, productivity, and innovation at large, though few attempts to
design architectural, organizational, or technological solutions have succeeded in achieving
this. I believe this is because these approaches tended to focus too much on fostering an
“ambient awareness” of fellow coworkers with hopes that it would indirectly lead to
increased informal interactions. My hypothesis is that proactively creating such
interactions as intermediated by a smart artifact in the office space would be more
effective. For this thesis, I have built two versions of a device called Food Groups, as well as
another one called Media Lab Mixer; Food Groups matches coworkers up to get lunch or
dinner together, while Media Lab Mixer uses game dynamics to encourage them to spend
more time socializing in a common space. After an initial study, the Food Groups devices
received little use and were largely ineffective at fostering informal interactions. Media Lab
Mixer, however, showed greater engagement and was more effective at creating the
desired results, though it did not have a lasting effect after it was removed.

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I am currently a research assistant in the Changing Places research group at the MIT Media Lab. For the three years prior, I worked as a web and mobile developer in the New York City startup scene. I started out at as an early employee at a file-sharing service called drop.io, and after it was purchased by Facebook in October of 2010, I spent some time at a fast-paced startup incubator called QLabs. During those years, I also helped found and build various other startups including a puzzling society and a crowd-funding business.

I graduated Summa Cum Laude and Phi Beta Kappa from Columbia University in 2008 with a major in Computer Science and a minor in Economics. At Columbia, I was heavily involved in the Association for Computing Machinery and worked in the Computer Graphics and User Interfaces lab. In my free time I focus on personal projects, which range from making games and puzzles to voice-activating my apartment. I grew up in Edison, New Jersey and currently live in Cambridge, Massachusetts.
Acknowledgements

In addition to my advisor, Kent Larson, who guided me through this thesis, I would also like to thank fellow Media Lab student Nick Gillian (of the Responsive Environments group), who greatly assisted in building and deploying the camera system used to gather data on use of the atrium space. Nick spent a large amount of time building the iOS application that took snapshots of the atrium, as well as the application used to tag those images. Without his work, the study of the atrium space would not have been possible.
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1. Introduction

Within every community, whether a workplace or city, each individual has a unique set of knowledge and skills. If only those individuals interacted more than geography and social conventions allowed, their combined experiences would be a boon for collaboration [1, 10], idea crossflow, creativity, productivity, and innovation at large [2, 4].

Unfortunately, people in the workplace tend to interact with each other less than a desired amount [2]. With the rise of the internet and wireless computing, the nature of work is drastically changing. Work is becoming increasingly distributed, with 86% of companies now allowing mobile work [5]. By 2013 it is predicted that more than 33% of employees world-wide will work from third party places such as coffee shops and the home [4]. This is in contrast to the historical practice of spending the day in a shared office space, where people have the opportunity to bump into each other and interact during the day.

This “out of sight, out of mind” problem of physical proximity is even an issue for workers that are physically co-located. In his seminal book on the subject, *The Organization and Architecture of Innovation: Managing the Flow of Technology*, MIT professor Thomas Allen famously found a relationship between the distance separating colleagues’ offices in a research and development institution and the probability that they would communicate at least once per week. As one can see, after a separation distance of just 50 meters, the chance of interaction drops to nearly zero [2].

![Figure 1.1: Called the "Allen Curve", this graph shows the exponential relationship between office separation distance and chances of communication among coworkers at a research and development institution. [2]](image)
And this is not just for face-to-face interactions. Nearly all forms of communication, even digital ones such as phone and email, trail off as well [2].

Without the repeated in person encounters, people simply tend to forget about each other. But managers know that having a frictionless flow of information across individuals and resources is critical for high performing, collaborative teams in the workplace [1, 2, 3, 10]. And despite the growing ability to work remotely, workers continue to show a preference towards coming into a shared office space, with more than 90% doing so, because of the access to and interactions with people and resources this provides [4, 5].

As Allen wrote, "Getting people to talk to each other is the only truly effective way of transferring knowledge and advancing the process of innovation." [2]

This thesis presents my work on “getting people to talk” in the workplace utilizing technological means. I have designed and built three physical devices – Food Groups Version 1, Food Groups Version 2, and Media Lab Mixer – and tested their relative effectiveness.

### 2. Prior Work

There is much prior work in the area of “getting people to talk” in the workplace, which tends to fall into one of three main categories: organizational, architectural, and technological. The goals of these approaches are generally the same, and almost all of them attempt to design systems that provide workers with an “ambient awareness” of the happenings within an office. The theory is that awareness leads to informal communication [1, 14], which in turn leads to innovation at large [2].
2.1 Organizational Approaches

Various organizational strategies are continually implemented on an informal basis by workplace managers. These include the restructuring of teams, the relocation of teams, and the creation of work/life programs such as workplace sport leagues and meet-up groups.

Some more formal research also falls into this category, such as SocioMetric Solution’s study of workers at a Bank of America call center. When managers were stumped as to why different teams had drastically different performance levels, they asked SocioMetric to help. After analyzing data on the teams’ interactions for six weeks, they “found that the best predictors of productivity were a team’s energy and engagement outside formal meetings” [6]. The recommended solution was simple: modify the workers’ break schedules so that people on the same teams had breaks at the same time. Despite being an unconventional solution, the managers tried it and it worked surprisingly well. The extra socializing and team bonding opportunities amounted to what was predicted as a $15 million per year increase in productivity.

2.2 Architectural Approaches

In the realm of architecture, planners focus on ways to design the structure and layout of buildings to encourage interaction within. Strategies include creating long hallways called “spines” [2,7,9] as well as centrally locating large atriums and common areas [2] to make the environment ripe for serendipitous encounters.

Figure 2.2.1: This image from Allen’s book examines the case study of the Technical University of Munich, which contains a long spine called the “street” that provides interaction opportunities for those who work there. [2]
Open office plans (those with no cubicles or private offices, but rather long, common tables in wide-open loft spaces) have also become popular lately among managers, because the line-of-sight environment lessens the barrier to entry for interacting with fellow coworkers. Approximately 60% of companies offer such a layout, and three-quarters of employees prefer it over traditional seating arrangements [8,9].

### 2.3 Technological Approaches

There is also an extensive amount of research into how technological systems can aid in increasing awareness in the workplace. Below is a timeline that I have compiled of work in this area from the late 1980's to present day. While not intended as a complete list, it is interesting to see how the various strategies coincided with what recently became technologically possible at that point in history, with audio/video techniques popping up in the late 80’s and early 90’s, 3D virtual world strategies arising in the mid-to-late 90’s, and wireless sensing and mobile hardware being explored in the 2000’s.

**Cruiser (1988) - Root (Bell Communications Research)**

Cruiser consisted of always-on video/audio links between local and remote offices and common areas as well as a “browsing interface” for unplanned social discovery. [10, 11]

**VideoWindow (1990) - Fish, et. al (Bellcore)**

The VideoWindow was a single, large, persistent audio/video connection between the break rooms of remote offices. A wall-sized screen, cameras, and microphones were situated in the room so that employees could chat with each other as if they were physically located in the same room. [12]
Figure 2.3.1: The VideoWindow [12] consisted of an always-on A/V link between the break rooms of two remote offices.

*PolyScope (1991) - Borning and Travers (Xerox EuroPARC)*

PolyScope was a system that piped in pseudo-real-time video streams from offices and common areas around the building to users' computers. The software displayed these streams in a simple-to-digest 2D grid for simultaneous viewing with the hopes of providing an ambient awareness of happenings in the workplace. [13]

*Vrooms (1991) - Borning and Travers (Xerox EuroPARC)*

Vrooms was a follow-up to PolyScope, which added the notion of “virtual rooms” that users could join. Video streams were thus grouped by room, which also came with various collaboration tools. [13]

*Portholes (1992) - Dourish and Bly (Xerox EuroPARC)*

Portholes was a technological improvement and interface extension of PolyScope and Vrooms, that made it work better for maintaining awareness of distributed teams across multiple sites. [14]
Figure 2.3.2: The team at EuroPARC explored ways to use video links between remote offices to provide coworkers an ambient awareness of each other. A screenshot from Polyscope is on the top left, Vrooms on the top right, and Portholes on the bottom. [13,14]

RAVE (1992) - Gaver, et. al. (Xerox EuroPARC)

RAVE was touted as a “media space.” It was similar to Vrooms in that it allowed for grouped audio/video connections between workers, but it also came with various extra “awareness” features and collaboration tools. There was a “background” feature which let a user set his or her desktop background to a video feed of a common area, a “sweep” feature which would rapidly search through video streams in hopes of finding something of interest, an auditory notifications feature called Khronika, and a “glance” feature which
used the A/V connection to peek into another’s office to check availability before initiating a call. The researchers also attempted to address the privacy concerns that plagued always-on video streams with a privacy control system called Goddard. [15]

Figure 2.3.3: Images from the paper on RAVE. On the right is a screenshot of the “glance” and privacy control systems. [15]

Tivoli (1993) - Penderson et. al. (Xerox Palo Alto)
Tivoli was a smart whiteboard that was intended to support informal collaborative meetings in the workplace. [16]

Montage (1994) - Tang, et. al. (SunSoft, Inc.)
Montage was a video conferencing tool, which more fully explored the “glance” feature. It was intended as a communication tool, but also as a means of coordinating when that communication would take place in advance. [17]
Peepholes (1996) - Greenberg (University of Calgary, CS Department)

Peepholes attempted to work around the privacy implications of always-on video by replacing raw feeds with “iconic presence indicators” that showed if someone was at his desk or not. It also attempted to provide an ambient awareness of colleague’s availability by playing short sounds when a user became available or busy. [18]

Figure 2.3.5: Peepholes explored using representations of people instead of raw video feeds. [18]
@Work (1996) - Tollmar, et. al. (Interaction and Presentation Laboratory)
Similar to RAVE, @Work was an instant messaging and video conferencing tool that introduced the notion of an away message, letting users specify their availabilities in order to provide an awareness of their activities to others. [19]

GroupWear (1998) - Borovoy, et. al. (MIT Media Lab)
GroupWear were technologically imbued name tags that conference goers would wear. At the conference, they would answer multiple choice questions on screens at various kiosks, which would program their badges with the answers. When attendees then interacted with each other, the name tags would display what answers they had in common with each other. This was intended to spark discussion and collaboration among attendees. [20]

MemeTags (1998) - Borovoy, et. al. (MIT Media Lab)
Part of the same body of work as GroupWear, MemeTags were similarly wearable badges that exchanged "memes" with each other. Before attending, conference goers would submit short sayings or ideas to a website, and when two badges got close to each other, they would exchange memes, which the wearer could accept or reject. [21]
AmbientROOM (1998) - Wisneski, et. al. (MIT Media Lab)
This was a project by the Tangible Interfaces group of the MIT Media Lab. While not directly related to promoting awareness of colleagues, it explored various potential mechanisms for subtly conveying ambient information in a workplace environment. [22]

3D Digital Environments (1999) - Lenman (Royal Institute of Technology)
This project explored the use of 3D virtual environments to support an awareness of distant colleagues. Students working together in distant locations kept a second monitor that displayed the virtual world, and they could have their avatars approach each other to get each other’s attention. [23]
**ActiveMap (1999) - McCarthy and Meidel (CSTaR)**

ActiveMap relied on a location tracking system installed in an office building to show where people were and who was with whom in real-time. Users could view a map of the building populated with icons representing their colleagues. Various features were explored to convey further ambient information, such as using transparency of the icons to indicate how “fresh” that person’s location reading was. [24]

**MediaCup (1999) - Gellerson, et. al. (University of Karlsruhe)**

The MediaCup was a regular coffee mug augmented with sensors and wireless technology to collect and record data about the handler of the mug as well as the general environment. In one application, data from the mug was piped into a remote office and converted to ambient sounds. [25]
Hummingbird was a fully custom piece of mobile technology that used chirping sounds, flashing lights, and a small LCD screen to give wearers notifications when colleagues were nearby. [26]

Contact Space (2000) - Jeffrey and McGrath
This was another 3D virtual world approach, but instead of requiring users to manually move their avatars, the system automatically grouped avatars depending on if their users were working on similar or related projects. [27]
**GroupCast (2001) - McCarthy et. al. (Accenture Labs)**
A screen placed in a highly trafficked hallway at Accenture Technology Labs could sense who was walking near it, look up their likes and dislikes, and display items of mutual interest to the passersby with the hopes of sparking informal chats. [28]

![Image](image.png)

**Figure 2.3.11:** This image shows an interaction scenario between users of GroupCast. Two coworkers stop to chat as they pass by a screen with a conversation-provoking display. [28]

**AutoSpeakerID (2002) - McCarthy et. al (Intel Research)**
Another awareness tool for conference goers, this project consisted of putting a name-tag-sensing RFID reader in a microphone so that when attendees asked a question during a session, their name and affiliation would automatically show up on large screens throughout the room. [29]

**Ticket2Talk (2002) - McCarthy et. al. (Intel Research)**
By the same research team as AutoSpeakerID, this project displayed “talking points” of interest to individual conference goers on large screens throughout the building. The hope was to facilitate conversation among attendees. [29]
Neighborhood Window (2002) - McCarthy et. al. (Intel Research)

By the same research team as Ticket2Talk and AutoSpeakerID, Neighborhood Window displayed mutual talking points among a group of conference goers who were gathered in a particular place. [29]

Figure 2.3.12: AutoSpeakerID automatically displayed the name of conference goers who asked a question at a talk. Ticket2Talk and NeighborhoodWindow also addressed social interaction issues at conferences. [29]

GossipWall and ViewPort (2003) - Streitz et. al.

The GossipWall was a generic ambient display for the workplace that was intended partly as an artistic installation and partly as a device to display information about happenings in the office. Proximity sensors in the wall allowed for different operating modes based on how far a user was from the wall, and switched between “Ambient”, “Notification”, and “Interactive” modes. A handheld device called the ViewPort allowed workers to view and update information posted to the wall. [30]
Figure 2.3.13: GossipWall was a large, ambient display that conveyed information to passing by workers via light patterns. The ViewPort allowed them to interact with it. [30]

Serendipity (2004) - Eagle and Pentland (MIT Media Lab)
Serendipity was a mobile application that used bluetooth proximity and a matchmaking algorithm to notify a user when he or she happened to be near someone else who shared something in common. The hope was to help discover and spark “serendipitous” interactions between people who might not have known the other existed. [31]

Figure 2.3.14: Serendipity used Bluetooth proximity to find nearby users of interest with the hopes of spurring serendipitous interactions. [31]
**Personal Aura (2004) - Rocker, et. al.**

Personal Aura was another custom piece of hardware that made use of the GossipWall platform. Users of the device could broadcast information about themselves such as their availabilities, which would then appear on the wall. The researchers developed a language of light patterns that indicated information like the team's general happiness level, their availabilities, and how many of them were around. [32]

![Image](image1)

**Figure 2.3.15: Personal Aura was a custom built device that let users display their availability information on the GossipWall. The top image shows the device, while the bottom shows how it interacts with the GossipWall. [32]**

**Nimio (2005) - Brewer et. al. (University of California)**

Nimio was a small, wireless, desktop-based artefact. Activity levels as sensed by embedded microphones and accelerometers were reflected on remote Nimios by colored LEDs. [35]
Figure 2.3.16: Nimio had various sensors and could cause remote ones to glow colors depending on activity levels in various parts of the office.

*AwarePhone and AwareMedia (2010) - Bardham and Hansen*

This project was a mobile-phone-based system intended “to support context-mediated social awareness amongst mobile, distributed, and collaborative users.” An extensive study was conducted among clinicians in a hospital. [36]

In addition to these, there are also obviously all of the social media applications of today such as Facebook, Twitter, FourSquare, Highlight, Sonar, and instant messaging platforms such as ICQ, AIM, and GChat. While not specifically designed with the intent of increasing workplace awareness, these services tend to have the same effect. Users may be annoyed each time a friend posts a picture of a sandwich he is currently eating, but in the aggregate, these services provide a strong awareness of distant friends and colleagues. Some companies, such as Yammer, have even directly applied these tools to the workplace.

### 3. Approach

This thesis focuses on the technological route (as opposed to organization or architectural), and thus my work revolves around extending the body of technological research enumerated above. As mentioned, most of these strategies attempt to increase workplace awareness with the hopes of thereby increasing informal interactions. Putting this back in the context of the underlying goal of fostering creativity and innovation in the workplace, their strategies look like the following.
That is, ambient awareness of coworkers leads to informal interactions between them, which lead to idea crossflow and finally innovation. Many of the researchers even explicitly state that this what they are doing. In their paper on Portholes, Dourish and Bly say that “awareness may lead to informal interactions, spontaneous connections, and the development of shared cultures” [14]. And in their paper on RAVE, Gaver et. al. write that “general awareness often leads to serendipitous communication, in which an unplanned interaction may lead to the exchange of important information” [15].

In general, then, almost all of these solutions fit into what I call an “Observe/Present” framework. That is, either via manual user input or automatic sensing, the system observes what is happening in the workplace and then presents it to others via some interface. In the chart below, you may notice that some items fit into more than one category.

<table>
<thead>
<tr>
<th>Observe / Present</th>
<th>Raw Data Feeds</th>
<th>Filtered Data Feeds</th>
<th>Ambient Displays / Sounds</th>
<th>Virtual Worlds</th>
<th>Custom Hardware</th>
<th>Mobile Devices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual User Input</td>
<td>GroupWear, MemeTags, Ticket2Talk</td>
<td>Contact Space, Neighborhood Window</td>
<td>GroupCast, GossipWall and ViewPort</td>
<td>3D Digital Environments, Contact Space</td>
<td>Tivoli</td>
<td>AwarePhone and AwareMedia</td>
</tr>
<tr>
<td>Automatic Sensing</td>
<td>Cruiser, VideoWindow, PolyScope, Vrooms, Portholes, RAVE, Montage, Peepholes, @Work, AutoSpeakerID</td>
<td>Contact Space</td>
<td>Peepholes, AmbientROOM, MediaCup, Hummingbird, GossipWall and ViewPort, Personal Aura, Nimio</td>
<td>Cruiser, Vrooms, RAVE, Montage, Peepholes, ActiveMap, Contact Space</td>
<td>MediaCup, Hummingbird, Personal Aura, Nimio</td>
<td>Hummingbird, Serendipity</td>
</tr>
</tbody>
</table>

Figure 3.1: Most of the prior technological work in this area has followed the pattern of observing some feature of the workplace and presenting that data to employees via some interface. It was then largely expected that the employees would use that information to engage in informal socializing with their coworkers.

A problem with this approach, however, is that in practice, awareness rarely leads to interaction, and many of these researchers describe less-than-desired results with the use of their systems. Fish et. al. for example describe low conversation rates with the
VideoWindow (17%) compared to normal face-to-face encounters (41%), and in their conclusions state that “simply connecting two locations is not enough.” [12].

An interesting finding by Fish et. al., however, is that among those 17% of conversations, many of them started with talk about the VideoWindow itself. Without a conversation starter, it was still awkward for remote colleagues who didn’t know each other well to talk to each other. These sorts of observations along with inspiration from the GroupCast and MemeTags approaches have made me realize that perhaps the chain of events from above:

\[
\text{AWARENESS} \rightarrow \text{INFORMAL INTERACTIONS} \rightarrow \text{FLOW OF INFORMATION} \rightarrow \text{INNOVATION}
\]

is not the best strategy, but instead should be:

\[
\text{AWARENESS} \rightarrow \text{INFORMAL INTERACTIONS} \rightarrow \text{FLOW OF INFORMATION} \rightarrow \text{INNOVATION}
\]

That is, rather than focusing on creating an ambient awareness of happenings in the workplace and hoping it encourages informal communication (or designing solutions that simply support informal communication), it might be best to take a proactive approach in fostering informal interactions directly. Repeated encounters may thus raise a general awareness of colleagues’ skills and interests, which in turn would ease the flow of information and ideas between them. In general, I believe that opportunity is not the same as motivation, and simply presenting environmental information to users is not enough – we must take a more proactive approach in “getting people to talk”.

4. Food Groups
The Food Groups devices revolve around proactively connecting coworkers to eat together. Even in a highly creative and collaborative place like the Media Lab, students and faculty often eat meals alone at their desks or with the same small group of people over and over,
limiting the opportunity for serendipitous and varied social interactions. Mealtime thus seems to be a good space for interaction optimization.

Version 1 of the device employs a simple interface and revolves solely around lunch and dinner, while Version 2 is slightly more complicated but addresses various issues found with Version 1. The general strategy with both Versions 1 and 2, however, is to take the burden of initiating mealtime social interactions off of individuals and onto some third party system. The system, then, acts like the host at a party, proactively introducing people to each other.

4.1 Version 1

Food Groups Version 1 is a large, red button on a pedestal. Here it is shown in the 3rd floor atrium of the MIT Media Lab.

Food Groups Version 1 is simply a large button that is situated in a public, highly trafficked area of the workplace such as the Media Lab 3rd floor atrium. Those who are free for lunch or dinner one day swipe their ID cards on the front panel and hit the button. Around mealtime, the system matches coworkers who pushed the button up into groups of three or four, sends them an email introducing them to each other, and suggests a place and time for them to meet up.
The device is a physical object rather than a mobile app or website due to the out-of-sight-out-of-mind problem. A digital interface requires extensive messaging and advertising to get users to know about it, download it, and remember to repeatedly use it. A physical object that is intuitive to use and that users must regularly pass by solves most of these issues.

4.1.1 User Interaction

With Food Groups Version 1, users can sign up to participate in either lunch or dinner on the same day that they interact with it. To participate in lunch, users hit the button anytime between 7:00am and 12:15am, with matches being made and sent out at 12:15pm for suggested lunch times between 12:30pm and 1:30pm. To participate in dinner, they hit the button anytime between 1:30pm and 6:45pm, with matches being made and sent at 6:45pm for suggested dinner times between 7:00pm and 8:00pm.

In the following example, Jennifer realizes she will be at the lab late one night, and decides it would be nice to take a break from work and meet for dinner with others. She heads to the atrium and finds the Food Groups button. The lights on the front panel cycle on and off in an outward to inward direction, which draw her attention to a central box that reads, “Swipe Your Media Lab ID Card Here”. As she swipes her ID card, the lights on the front blink and the box beeps, indicating that it read her card successfully.

![Figure 4.1.1.1: Users swipe their ID cards on the front panel to identify themselves to the system.](image-url)
The arrows on the top panel then begin to blink in unison, drawing her attention to the button. When she pushes the button, the arrows light up one-by-one in a circular fashion like a “loading” icon, which indicates to her to wait a moment while it signs her up.

![Image](MIT%20Media%20Lab)  
*Figure 4.1.2: After swiping their ID cards, users hit the button to sign up for a meal.*

When the box finishes working, it beeps a short “success” tune, assuring Jennifer that everything worked as expected. Soon after, she receives a confirmation email that explains the rest of the process.

![Email](Food%20Groups)  
*Figure 4.1.3: After pushing the button, users receive a confirmation email with details about what to expect.*

The box then resets back to its initial state, and throughout the day other people independently sign up for dinner as well. They each also receive confirmation emails.
Throughout the day, potentially many other users independently push the button, putting themselves in the pool to be matched up with others for dinner.

At 6:45pm, those who pushed the button are matched up into groups of two, three, or four and sent an email suggesting a place and time to meet for dinner. In this example, Sandra and Jennifer are grouped together.

Sandra and Jennifer then use the email chain provided to coordinate amongst themselves their exact dinner plans that night.
If at any point during the sign up process something goes wrong (for example, the swiped card can not be read, the user hits the button before swiping the card, or the box loses internet connection), the box beeps an intuitive “failed” tune, which sounds like an “incorrect” buzzer on some game shows. If the user hits the button before swiping the card, in addition to the auditory alert, the lights on the front panel blink, as a hint to the user that he or she needs to swipe an ID card first.

After mealtime, users receive a follow-up email, which asks them to complete a short survey about their experiences (see Sections 4.1.3 and 4.1.4). In case they disliked the people they just ate with, they also have the option of clicking a link to never be matched up with those people again.

4.1.2 Build Process
Food Groups Version 1 consists of the wooden enclosure, the internal electronics, and an external webserver that handles most of the functionality.

4.1.2.1 The Enclosure
The enclosure and pedestal are made of Baltic Birch plywood. I designed the separate panels in AutoCad and used a CNC milling machine to cut them out.

Figure 4.1.2.1.1: Food Groups Version 1 is made out of flat panels of Baltic Birch plywood.
With an ample supply of clamps, I wood-glued the panels together to form the base, pedestal, and button housing.

Tabs and corresponding holes in these separate components allowed them to fit together snugly without any extra glue, forming the full enclosure.
I then stained it a dark mahogany color to give it a more professional look, as it was important that it fit in aesthetically with the office place environment.

Finally, I designed and laser cut arrow and stripe inserts out of half-inch-thick clear acrylic. Once cut, I sandblasted them so they would act as light diffusers for the LEDs behind them.

4.1.2.2 The Electronics

The device itself simply reads an ID card, blinks, beeps, and then passes off the user's ID number via WiFi to a backend webserver when the button is hit. The electronics consist of
an Arduino Mega, a WiFly shield, a ThingMagic M5e RFID reader and antenna, LEDs, a speaker, and a power strip. I also custom made a simple breakout board using Eagle to enable me to transmit serial data between the Arduino and RFID reader.

![Diagram of breakout board connections](image)

Figure 4.1.2.2.1: A custom-made breakout board enables the Arduino to talk to the RFID reader. On the left is the schematic, and on the right is the board layout as designed in Eagle.

I designed and laser cut mounts for the LED arrays, then secured everything to the inside of the enclosure.

![Laser cut LED mounts](image)

Figure 4.1.2.2.2: Laser cut LED mounts.
A Wiring sketch runs on the Arduino Mega to control all of the components. Upon boot up, it configures the RFID reader, connects to WiFi, and initializes all of the input and output pins. It then loops until an RFID card is present, at which point it blinks and beeps as described in Section 4.1.1, and then makes an HTTP request to the backend webserver to hand off the ID number.

The full Arduino source code for Food Groups Version 1 can be found in Appendix A.

4.1.2.3 The Backend Webserver

The backend webserver handles most of the Food Groups functionality. It is built with Ruby on Rails, uses an SQLite3 database, and is hosted on a virtual Linux-based machine available at foodgroups.media.mit.edu.

Upon receiving an ID number from the device, it looks up the user’s first name, last name, and email address in the Media Lab directory, and creates an entry in the database indicating that that user signed up at that particular time.
A cron job on the same machine that is scheduled to run everyday at 12:15pm and 6:45pm finds all such entries for the relevant meal, groups users together, and sends emails out to them as described in Section 4.1.1. The algorithm attempts to group people together in a mostly random fashion, but has a slight preference towards grouping users together who have not been grouped before. It aims to make groups of three or four, but will sometimes create groups of two or five if there are too few or too many people. If only one person signs up for a particular meal, it emails that person an apology message explaining the situation.

4.1.3 Experimental Procedure

I conducted a study of the device at the MIT Media Lab for several weeks in the Fall of 2012. The purpose of the study was to determine the effectiveness of Food Groups Version 1 on its ability to increase informal interactions in the workplace. Exemption for approval of the study was obtained from MIT’s Committee on the Use of Humans as Experimental Subjects (COUHES), and the study began on September 20th, 2012. I placed the button in the center of the 3rd floor atrium in the MIT Media Lab with a sign that explained the study. I sent two emails to the Media Lab community advertising the device, and most people passed by it everyday on the way to their labs as well.

Figure 4.1.3.1: The button was situated in the 3rd floor atrium of MIT’s E14 building. A sign next to it explained how to use it as well as the details of the study.
The button stayed in the atrium from September 20th until October 3rd, at which point I moved it to the 1st floor lobby near the elevators to increase visibility. Finally, on October 16th, I moved it to the 5th floor cafeteria area, again to increase visibility. It remained there for another week, until I removed it on October 23rd.

Everytime someone pushed the button, he or she was emailed a link to complete a survey. The survey was designed to determine how effective the technology was in creating social ties between coworkers that didn’t previously know each other, as well as how effective it was in spurring conversation that led to increased idea crossflow. The survey itself was accessed online via a web browser, and the questions were all multiple choice. To increase the chances that users would finish the survey, it displayed questions dynamically; users
potentially saw different types and quantities of questions based on their answers to previous ones to make it less painful to complete.

The first question was simply intended to determine if the user actually went out to eat as suggested:

1. Did you actually end up getting [lunch/dinner] with at least one of the people you were matched up with?
   - Yes
   - No

If the user answered “No,” the next question attempted to find out why:

2. Sorry to hear that. How come?
   - Something else came up.
   - I didn’t have time.
   - I forgot.
   - I didn’t want to hang out with one or more of the people I was matched up with.
   - I didn’t want to go to the restaurant the others wanted to go to.
   - Other. (Please explain)

In such a case, that was the end of the survey for the user. If instead the user answered, “Yes” to Question 1, the next question asked who actually came along:

3. Great! Who in your group actually came?

[Group Member 1]:
   - Yes
   - No

[Group Member 2]:
   - Yes
   - No

[etc]
If the user answered, “No” to all of these questions, the survey was over. Otherwise, it began to figure out the level of interaction the group previously had with each other:

4. On a scale of 1 to 5, 1 being least well, how well did you know each of these people before today?

[Group Member That Actually Came 1]:
  o 1 (I never knew [Group Member That Actually Came 1 Name] existed before today.)
  o 2
  o 3
  o 4
  o 5 (We were very good friends before today.)

[Group Member That Actually Came 2]:
  o 1 (I never knew [Group Member That Actually Came 2 Name] existed before today.)
  o 2
  o 3
  o 4
  o 5 (We were very good friends before today.)

[etc]

Next, it asked about the details of their conversation and social interaction at the meal, with the hopes of finding out if their interactions might have led to increased idea crossflow, creativity, or innovation:

5. On a scale of 1 to 5, 1 being the least, how much did you enjoy getting [lunch/dinner] with [Group Member That Actually Came 1 Name]?
  o 1 (Not at all.)
  o 2
  o 3
  o 4
  o 5 (A lot! It was great!)

6. Did you learn anything interesting (of any form) from [Group Member That Actually Came 1 Name] at [lunch/dinner]?
  o Yeah! (Please explain.)
  o No, not really.
7. Did talking to [Group Member That Actually Came 1 Name] give you any ideas that are directly related to your own research, projects, or interests?
   o Yeah! (Please explain.)
   o No, not really.

8. Do you think you'll hang out with [Group Member That Actually Came 1 Name] again sometime in the future on your own?
   o Yes.
   o No. (Please explain.)

[etc]

The second to last question aimed to determine if the restaurant and time suggestions influenced the user’s decision to actually go:

9. Almost done! Did you and your group end up going to the suggested restaurant at the suggested time?
   o Yep, we did exactly what you suggested.
   o We went the the suggested restaurant but chose a different time.
   o We went to a different restaurant but at the time you told us.
   o Nope, we chose a different restaurant and time.

Finally, it asked for general comments:

10. Last one! Do you have any other comments about Food Groups?
    o Yes (Please explain.)
    o Nope

The system also sent a follow up survey to every user who filled out the first survey exactly one month later. The goal was to determine how their interactions with the people they ate with the month before changed over time, and whether in the interim they formed relationships that impacted the direction of their research or personal projects.

The first question directly mirrored Question 4 from above, to determine how their relationships changed over the course of the month:
11. On a scale of 1 to 5, 1 being least well, how well do you know each of these people now?

[Group Member That Actually Came 1]:
1 (I never see or interact with [Group Member That Actually Came 1 Name].)
2
3
4
5 (We are very good friends.)

[Group Member That Actually Came 2]:
1 (I never see or interact with [Group Member That Actually Came 2 Name].)
2
3
4
5 (We are very good friends.)

[etc]

For each group member to whom the user answered option 3 or lower, the user was then asked:

12. Why do you think you and [Less Well Known Group Member 1 Name] haven’t interacted much since your [lunch/dinner]?
   o We just haven’t had time.
   o [Less Well Known Group Member 1 Name]’s office is far away from mine so we forget about each other.
   o [Less Well Known Group Member 1 Name] is nice, but we don’t have much in common to do or talk about with each other.
   o [Less Well Known Group Member 1 Name] and I don’t really get along.
   o Other. (Please explain.)

12. Why do you think you and [Less Well Known Group Member 2 Name] haven’t interacted much since your [lunch/dinner]?
   o We just haven’t had time.
   o [Less Well Known Group Member 2 Name]’s office is far away from mine so we forget about each other.
   o [Less Well Known Group Member 2 Name] is nice, but we don’t have much in common to do or talk about with each other.
   o [Less Well Known Group Member 2 Name] and I don’t really get along.
   o Other. (Please explain.)

[etc]

For each group member to whom user answered option 4 or higher on Question 1, the user was finally asked:
13. In what capacity have you interacted with [Well Known Group Member 1 Name] since your [lunch/dinner]?
   o Our interactions were related to our research/projects/ideas.
   o Our interactions were in a social context.
   o Both of the above.

13. In what capacity have you interacted with [Well Known Group Member 2 Name] since your [lunch/dinner]?
   o Our interactions were related to our research/projects/ideas.
   o Our interactions were in a social context.
   o Both of the above.

[etc]

In addition to these two surveys, I also informally interviewed people at the Lab before, during, and after the deployment of Food Group Version 1 to gauge their level of interest in and interaction with the device.

As a final data collection method, the backend webserver was obviously able to keep track of who hit the button when and who was grouped with whom.

4.1.4 Results

Results with Food Groups Version 1 were less than desireable. Over the five-week study, the button was only pressed 35 times total among 18 unique users, and only 8 meal groups were successfully formed (a majority of the time only one person pushed the button for a given meal, and thus could not be matched up with anyone). Five of the 8 meal groups consisted of 3 people, while the remaining 3 consisted of two people.

Out of the 18 users, only 12 answered any survey questions, and only 1 answered any of the follow-up survey questions. For 2 of the 8 meal groups that were formed, no one answered any survey questions.

According to Question 1 of the survey, 3 of the 6 meal groups for which we have survey data did not actually meet up. One of those, according to Question 2 of the survey, was
because “Something else came up,” another was because, “I forgot,” and the last was, as explained by the user, because “The other people forgot.” The first of these was for a group of 3, and the latter two were for groups of 2.

According to Question 3 of the survey, of the remaining 3 meal groups for which we have survey data, almost everyone showed up. Only in one case did one of the group members not show up to the meal, however since this was a group of 3, there were still two people who attended.

According to Question 4 of the survey, three pairs of people never knew the other existed before their meal (the first answer), one pair was fairly unfamiliar with each other (the second answer), and three pairs were somewhat familiar with each other (answers three and four). No one had said they were good friends before eating together. Perhaps not so surprisingly, these answers matched up very well among the pairs of people; for example, no one had said they were good friends with someone who said they never knew the other one existed before.

According to Question number 5, everyone at least somewhat enjoyed the experience. Everyone answered 3 or higher, with only two people choosing option 3, one choosing option 4, and 9 choosing option 5.

The results of Question 6 are similar, with only 4 people saying they didn’t learn anything interesting, and 8 saying they did. Again, not so surprisingly, the two who answered option 3 from the previous question said that they did not learn anything interesting, while most of those who answered option 4 or 5 from the previous question said they did. Only two people who answered 5 from before answered this question negatively.

For Question 7, five people said that they did not learn anything useful for their research or personal projects from one of their group members, whereas 7 did. These answers again correlate fairly well to Questions 6 and 5. Only one person who answered “No” to Question
6 answered “Yes” to question 7, and only two who answered “Yes” to Question 6 answered “No” to Question 7. The rest answered, “Yes” to both Questions 6 and 7.

Despite the answers to Questions 5, 6, and 7, most people indicated in Question 8 that they intended to hang out with their group members again. Only one person answered negatively, and that person had also happened answered low on Question 5 and “No” on Question 6, so it is not so surprising.

According to Question 9, no one exactly followed the suggested places and times. One group went to the suggested restaurant at a different time, one group went to a different restaurant at the suggested time, and the other group chose both a different restaurant and time.

No significant insights were obtained from general comments in Question 10.

Unfortunately only one person answered the follow-up survey, and that person indicated that he almost never interacts with his two past group members anymore (answers 2 and 3 from Question 11). According to Question 12, this is because their offices are far away from each other and they simply forget about each other (answer 2).

Despite the low response rate for the surveys, it does seem as though people who went tended to enjoy the experience and get something out of it. Overall, usage of the device was low, indicating its ineffectiveness, but responses from the surveys show some hope. Perhaps if the button were placed in a different workplace environment, it would be more effective.

The data collected by the webserver on button pushes is summarized in Figure 4.1.4.1.
As one can see, there was an initial novelty effect when the device was first released, with most of the button pushes happening within the first week, and a rapid tapering of use occurring in the four subsequent weeks. Of the meal times for which at least one person pushed the button, eleven had only one person push the button, and obviously no meal groups were formed at those times. There was a fairly even split between lunch and dinner sign ups, with 18 total sign ups for lunch, and 17 for dinner.

Some interesting insights from Food Groups Version 1 come from my more informal interviews with people before, during, and after the study. Before even building Food Groups, I presented the idea to numerous students and faculty at the lab (around 20), and sentiment seemed overwhelmingly positive. Nearly everyone excitedly said it was a great idea and when asked how frequently they thought they would use it, most responded that they would use it at least once per day. Most of these people also said that they ate lunch alone while working or with their own research groups every day, and they were excited to have an easy way to meet new people at the lab (especially the newer students).
Despite this, however, usage of the button remained extremely low when launched, and almost none of the people that I interviewed used the button at all (only two did). I followed up with them during and after the study to ask why they hadn’t used it yet despite their previous enthusiasm, and found the following trends:

1. Most people felt it was socially awkward to spend a long period of time with people they didn’t know.
2. Some people felt anxious to participate when they weren’t sure how many other people had already pushed the button for a particular meal. They were worried about being the only one, or perhaps being matched up with only one other person.
3. Others were willing to meet up with new people, but were so busy that they couldn’t fit lunch or dinner into their schedules ahead of time.
4. Some were willing to meet up with new people, but still tended to take the easier route of getting food with people they already knew.
5. Some people didn’t pass through the atrium on a regular basis and didn’t know the button existed.

I addressed problem 4 during the study by moving the button to more readily visible and highly trafficked locations in the lab, but it had no obvious effect. I then set out to address problems 1, 2, and 3 by building Food Groups Version 2.
4.2 Version 2

Food Groups Version 2 is an iteration on Version 1 that attempts to address the problems discussed in the previous section. There are four main new features:

1. In addition to lunch and dinner, users have the option to also sign up for coffee, snacks, or drinks.
2. Each option dynamically displays how many other people are currently signed up for it.
3. “Mealtime” occurs at a single, specified time instead of during a time range.
4. There is a web interface for signing up in addition to the physical buttons.

Feature 1 is intended to address the social awkwardness and busy schedule issues (problems 1 and 3 from the previous section) by providing options with shorter time commitments. For example, groups can now meet up at the vending machines for the “snacks” option, chat for five minutes while they all pick out what they want, and then casually disperse. A similar interaction could be seen with the “coffee” and “drinks” options. This is in comparison to the lunch and dinner options of the previous device, which usually entails at least a 30-minute time commitment.
Feature 2 is intended to address the social anxiety issue (problem 2 from the previous section) by publicly displaying how many other people have already pushed the button for the various options. In addition to easing the anxiety related to jumping into an unknown social situation, the feature also proactively encourages people to sign up by displaying the relative popularities of the options.

![Image](image.jpg)

*Figure 4.2.2: Each button on the device has a small LCD screen next to it that displays the type of meal, the meal time, and the number of other people that have already signed up for it.*

Feature 3 addresses the busy schedule issue (problem 3 from the previous section) by solidifying when the various meal times are. With the previous device, the system suggests a time within an hour-long time range, making it difficult for busy people to guarantee they can participate. This device instead uses specific times that don’t change, making it easy for people to fit it into their schedules.
Finally, feature 4 addresses the accessibility issue (problem 4 from the previous section) by providing an alternative way to sign up besides physically pushing the button. The URL for the web interface was advertised alongside the device as well as in various emails announcing the device to the Media Lab community.

Figure 4.2.3: The web interface for Food Groups Version 2 directly mirrors the physical interface. Instead of swiping ID cards, users enter their Media Lab username, and instead of pushing a button, they click one.

4.2.1 User Interaction

The user experience with Food Groups Version 2 is very similar to that of Food Groups Version 1. A user who wishes to participate can either visit the physical button or the website.

If he chooses to go to the button, he swipes his ID card on the left panel. The surrounding arrows blink and the box beeps, indicating that the card was successfully read. The buttons at right then light up next to the meal options that are still available at that time of day (if, for example, it were currently 1:00pm, the 11:00am coffee option would not light up). The user pushes the button next to the option he wants to sign up for, at which point the button lights cycle on and off in a linear fashion, indicating that the user should wait while the
device signs the user up. Once everything completes successfully, the box beeps a “success”
tune, and resets back to its original state. The user soon after receives an email (nearly
identical to the Food Groups Version 1 confirmation email) confirming that he has
successfully signed up.

If instead the user chooses to visit the website, he types his Media Lab username in the
form at left, and clicks a button next to one of the meal options at right. He is then sent an
email with a confirmation link that he must click to complete the sign up. This is necessary
because otherwise users would be able to sign each other up without their knowledge.
Once he confirms, he is sent the same confirmation email that users who push the button receive.

At “mealtime”, those who signed up for that meal are matched up into groups of two, three,
or four and sent an email suggesting a place for them to meet. Groups then use the email chain provided to coordinate amongst themselves their exact plans.

If at any point during the sign up process something goes wrong (for example, the swiped
card could not be read, the user hits a button before swiping the card, or the box loses
internet connection), the box beeps an intuitive “failed” tune, which sounds like an
“incorrect” buzzer on some game shows. If the user hits a button before swiping the card, in
addition to the auditory alert, the arrow-shaped lights on the left panel blink, as a hint to
the user that he or she needs to swipe an ID card first.

After mealtime, users receive a follow-up email, which asks them to complete a short
survey about their experiences (see Sections 4.2.3 and 4.2.4). In case they disliked the
people they just hung out with, they also have the option of clicking a link to never be
matched up with those people again.
4.2.2 Build Process

Like Version 1, Food Groups Version 2 consists of the wooden enclosure, the internal electronics, and an external webserver that handles most of the functionality.

4.2.2.1 The Enclosure

The device itself is much smaller than Food Groups Version 1. I designed the enclosure in AutoCad, laser cut it from quarter-inch-thick plywood, and screwed it together. The front panel has holes cut out for the speakers, arrow-shaped lights, buttons, and LCD screens. It also contains laser-etched markings for the title and instructions. The back panel has hinges for easy servicing of the electronics.

As with Food Groups Version 1, there are arrow-shaped light diffusers embedded in the enclosure made from laser cut and sandblasted clear acrylic.

4.2.2.2 The Electronics

The internal electronics are very similar to that of Food Groups Version 1. As before, it consists of an Arduino Mega, WiFly shield, ThingMagic M5e RFID reader and antenna, the custom-built reader-to-arduino interface chip, speakers, LEDs, and a power strip. In addition, it also has five light-up arcade-style buttons and five corresponding LCD screens. As with Food Groups Version 1, all of these peripherals feed into the Arduino and are wired up according to the pin specifications in the code running on the Arduino.

Upon boot up, the Arduino configures the RFID chip using serial commands, connects to WiFi, initializes the LCD screens, and sets up the rest of the input and output pins. It then makes a request to the backend server to see what labels should go on each of the buttons and how many people have pushed those buttons so far. Once it receives that information, it displays it on the screens. It then causes the arrow-shaped lights to blink until an RFID card is detected, at which point it sends the ID to the backend webserver via an HTTP request. It cycles the button lights in sequence until it receives a response, at which point it
sends a success or failure tune to the speaker, depending on the type of response it received.

The full Arduino code for Food Groups Version 2 can be found in Appendix B.

4.2.2.3 The Backend Webserver

The backend webserver for Food Groups Version 2 is also very similar to that of Version 1 – in fact it is largely the same code (see Section 4.1.2.3). The major changes mostly involve handling more than two “meal” types for sign up, group creation, and email wording. There are also extra endpoints for the device to retrieve the number of sign ups for each meal as well for the new homepage sign up form.

4.2.3 Experimental Procedure

The experiment for Food Groups Version 2 used the same COUHES exemption status as for Version 1. Starting on December 4th 2012, I put the device near the coffee machines on the 5th floor of the Media Lab, as it is a highly trafficked area. The reasoning for the placement choice was that as people waited by themselves for their coffee to be made, they would presumably have seen the device and have had both the time and motivation to sign up for one of the options.

![Image](image.jpg)

Figure 4.2.3.1: Food Groups Version 2 was situated near the 5th floor coffee machines of the Media Lab. The sign in front showed users how to get an ID card if they didn't yet have one, and the top of the device displayed the URL for the web-based sign up form.
I left the device at that location for roughly two and a half weeks until December 21st. Unfortunately, during that time there was a memory allocation bug in the software which caused the device to stop working after about 10 minutes, which likely decreased its usage. I removed the device on the 21st for servicing, and reintroduced it to the Lab after the holidays on January 16th 2013. It remained there for the duration of the day, but was (unfortunately) stolen at 11:42pm that night according to the webserver logs, and it was never recovered.

4.2.4 Results

Due to the technical issues that occurred during the Food Groups Version 2 experiment, there is very little data on its usage. During the time it was available, only 3 distinct people interacted with it, only 5 buttons were pushed, and only 2 groups were created. Four survey questions were answered, however they all indicated that none of the groups in fact met up.

Of the 5 button pushes, none were for coffee, one was for lunch, two were for snacks, one was for drinks, and one was for dinner.

No one signed up via the web interface.

Like Version 1, it seems as though Food Groups Version 2 has potential, but I would obviously need to run further studies to know for sure.

5. Media Lab Mixer

Media Lab Mixer is the third and final device that I have built as part of this thesis. It is a complete departure from the Food Groups strategy, and attempts to use gamification techniques to spur increased and varied social interaction in the workplace.
I have actually built four of these devices, which are intended to be situated near casual furniture groupings in a building's common space. When people sit down near one, they keep their ID cards on the top panel and earn points for hanging out there. They earn more points the longer they remain there, the more people they are there with, and the more “new” people they are there with. A leaderboard keeps tracks of point totals, and winners are announced to the community each week.

5.1 User Interaction
The Media Lab Mixer boxes are situated in the center of furniture groupings in a common space within the workplace. Three of the four sides have screens that cycle between displaying a summarized version of the game's instructions and the week’s highscore list. The back panel is static and always displays the game’s instructions.
As an example, when David sits down near one of the boxes, the bold white stripes on the sides attract his attention to the box. Curious, he takes a closer look and sees the instructions on the back panel.

After reading the instructions, he takes a look at the top panel, which contains further messaging that reiterates that he needs to place his ID there to play.
He lays his ID flat on the top panel, and the box blinks and beeps, indicating that it read his card successfully. Within seconds, his picture appears on all three of the side screens, confirming his presence and also displaying his current point acquisition rate and overall total.

He hangs out there for a little while and notices as the screens occasionally display the highscore list.
Figure 5.1.5: The three screens every so often briefly display the top ten users on the highscore list. This allows users to get a sense of their relative rankings, which incentivizes them stay there longer and convince others to sit with them. Here, last names are redacted for anonymity purposes.

Seeing that he is far away from the top ten and that his score is increasing fairly slowly at one point per second, he calls over some friends who are passing by to hang out with him. As more people show up, they all begin earning more points per second. Since the screens are on three of the four sides of the box, other passersby catch glimpses of what’s going on, and also stop to chat and earn points.

Figure 5.1.6: As more people sit down at a particular furniture grouping, they put their IDs on the box and everyone earns points more quickly.
Over the next few days, people gradually decide to spend more time working in public rather than alone in their offices, and large groups form, making the common space become fairly lively. Even people that are not participating in the game begin to join the others simply because of the enjoyable social interactions it affords.

![Figure 5.1.7: Large groups occasionally form around the device after a short time.](image)

As the week progresses, users earn more and more points, and excitedly await the moments when they overtake others on the leaderboard. On Sunday night, the top three winners are announced to the community, and points reset for the coming week. Because everyone starts on a level playing ground on Monday again, even users who were far behind or hadn’t played in previous weeks are still eager to play in the new week and have a chance at getting their names on the highscore list.

### 5.2 Build Process

Despite its functional dissimilarity from Food Groups, the design and physical architecture of the Media Lab Mixer device is actually very similar to that of the Food Groups devices. It again consists of a wooden enclosure, arduino-based internal electronics, and a backend webserver that handles most of the heavy lifting.
5.2.1 The Enclosure

I designed the enclosure for the boxes in AutoCAD and cut them out with CNC tools from half-inch thick Baltic birch plywood. For each box, three of the side panels have 3/8” deep pockets so that the screens can be snugly inlaid, and the back panel has holes for the speaker and power cord.

The original plan for the top panel was to place a clear bowl on top of it, in which users would keep their ID cards. The top panel was thus originally also cut from the wood with a circular hole in the center for the bowl. Subsequent testing, however, showed that such a set up made it difficult to read the RFID cards since they inevitably became densely stacked on top of each other. I therefore eventually replaced the top panel with a half-inch thick piece of laser cut, sandblasted, clear acrylic, on which users would spread their cards out flat.

![Figure 5.2.1.1: The enclosures for all four boxes are CNC cut from half-inch thick Baltic birch plywood.](image)

Using a circular saw angled at 45 degrees, I gave all of the side panels beveled edges so that they would fit together at the seam in a more aesthetically pleasing way. I then wood-glued the four sets of four panels together, making the four box shells.

Before screwing on the top or bottom panels or adding any electronics, I coated all of the outer surfaces in primer and spray painted them black.
I then laser cut some stencils out of a thick oak tag material, and spray-painted on white stripes and game instructions.

Using L-brackets and short wood screws, I secured the bottom panels in place and added felt bottoms to prevent the boxes from getting scratched. The top panel is held less-permanently in place with magnets for easy servicing of the internal electronics.

### 5.2.2 The Electronics

As with the Food Groups devices, the internal electronics simply serve to pass off the RFID data to a backend webserver, which handles all of the game logic.

Inside each box are an Arduino Mega, WiFly shield, ThingMagic M5e Compact RFID reader and antenna, my custom-made reader-to-arduino interface chip, a speaker, LEDs, three
Android tablets, and a power strip. The components are wired up as specified in the sketch running on the Arduino.

![Image](image.jpg)

Figure 5.2.2.1: The Android tablets fit into the pockets on the inside walls of the Media Lab Mixer boxes, and most of the remaining electronics sit loosely in the rest of the box. The card antenna is situated in a central position close to the top panel for best scanning results, and ultra-bright LEDs are secured alongside it. The speaker is secured to the wall near slits on the back panel so it can be easily heard.

Upon boot up, the Arduino configures the RFID chip, connects to WiFi, and initializes all of the remaining input and output pins. It then runs in a loop continually sending the ID numbers of all of the RFID cards it finds in range to the backend webserver via an HTTP request. When sending the RFID data, it also sends a `table_number` parameter to uniquely identify from which box the data is coming, and each box is separately configured with a different value from 1 through 4. If at any point it finds more cards in range than it has previously seen, it causes the speaker to beep and the LEDs to blink to acknowledge the cards’ presence.

The Android tablets simply load a webpage from the backend webserver to display who is currently sitting at that table. The URLs the tablets display are uniquely configured for each box and are set to match the `table_number` of the corresponding Arduino. In this way, the people that get shown on the tablets of a given box match up with the ID cards placed on it.
The full Arduino code for Media Lab Mixer can be found in Appendix C.

5.2.3 The Backend Webserver

As mentioned, the backend webserver for Media Lab Mixer contains most of the game logic. It is built with Ruby on Rails, uses an SQLite3 database, and is hosted on a virtual linux-based machine.

The main endpoint on the webserver is the one which accepts the list of ID numbers from the boxes. Upon receiving such a list from a given box, it looks up the corresponding users in the Media Lab directory and creates entries in the local database to record that those users are present at the given table number at the current time. For each user, it also records how many other users are there at the same time as well as how many of those other users this user has never hung out with before. Given these values, it figures out how many points per second each user should receive and updates their current point totals. Finally it creates additional database entries to mark down that these users have now hung out with each other so that the next time they appear together they don’t get additional “newness” points.

To account for network latencies and glitches in the RFID reader, there is a one minute timeout on user presences. That is, even if a user’s ID number doesn’t get sent to the webserver in every request, as long as the server sees it again within one minute, it is still counted as having been there the entire time. After one minute of being absent, it no longer records the user’s presence.

There are obviously also additional endpoints which render the users currently at a given table as well as the highscore list for the tablets to display.

5.3 Experimental Procedure

I conducted a study of the Media Lab Mixer devices in the atrium of the MIT Media Lab for several months in the Spring of 2013 and obtained exemption for approval of the study
from MIT’s Committee on the Use of Humans as Experimental Subjects (COUHES). The primary purpose of the study was to determine the effectiveness of game dynamics on the ability to increase and vary informal interactions in the workplace. A further goal was to compare the technological intervention to more standard architectural interventions.

Starting in early January, I mounted a camera to the ceiling of the 3rd floor atrium, which began taking pictures of the space every 15 minutes. Due to its distant location and top-down orientation, it is impossible to identify individuals, but one can use the images to determine how many people are in the space and if they are there alone or as part of a group. Every two weeks I introduced a new “intervention” in the atrium space that aimed to increase its use. After the study was over, I individually labeled the people, groups, and things in each image, and aggregated and analyzed the data with custom-made software. In this way, I was able to get a sense of how the use of the atrium changed over time. I would again like to acknowledge Nick Gillian for building the camera system and image tagging software.

The timeline for the study went as follows:

**Baseline: January 8th through January 22nd**

The study began on January 8th 2013, and from the 8th through to the 22nd I simply left the atrium as it initially was – empty. These two weeks were intended as a way to gather a baseline against which I could compare future results.
Figure 5.3.1: This image from January 21st shows the initial configuration of the atrium during the baseline period. As one can see, it was typically empty, but occasionally people passed through or remained there for a little while to have a conversation.

**Furniture: January 23rd through February 4th**

On January 23rd, I added sofas, armchairs, and small coffee tables to the space. I arranged the furniture in groupings so that people could sit together in small groups, but also have private options as well. The furniture remained there for the rest of the study, though this two-week period with just furniture remained only until February 4th. It was intended as a way to compare the impact of my technological intervention against an architectural one.

Figure 5.3.2: This image from January 25th shows the furniture in the atrium. During this period and for a majority of the rest of the study, the sofas, chairs, and tables were arranged in three distinct groupings.
**Furniture + Coffee: February 5th through February 17th**

On February 5th, I worked with facilities to move coffee machines and vending machines to the space as well. This served as a second architectural intervention, akin to rearranging a break room. The hope was that as people got their morning coffee, they would decide to sit down for a few minutes with others. This stayed for the rest of the study as well, but this two-week period with just furniture, coffee, and food remained until February 17th.

![Image of coffee machines](image.png)

Figure 5.3.3: Two coffee machines and two vending machines were placed in the 3rd floor atrium as part of the second intervention in the study.

**Furniture + Coffee + Media Lab Mixer: February 18th through March 3rd**

On Monday, February 18th I put out three of the Media Lab Mixer boxes at the centers of the three furniture groupings. I advertised their existence in an email to the Media Lab community, and left them there for four weeks total. During this particular two-week period, users played solely for the benefit of earning points and seeing their names on the leaderboard. No prizes were awarded.
Figure 5.3.4: This image from February 26th shows the Media Lab Mixer boxes on the coffee tables at the center of each furniture grouping.

**Furniture + Coffee + Media Lab Mixer + Individual Prizes: March 4th through March 10th**

During the third week of the Media Lab Mixer game, I awarded prizes for first, second, and third place winners each week. The third place winner was given an RC helicopter (financial value of $69.99), the second place winner was given a Sphero robotic ball (financial value of $129.99), and the first place winner was given an iPad Mini (financial value of $329.00). This period was used to determine how individual financial incentives affected user participation in the game and people’s desire to socialize with others in the atrium space.

Figure 5.3.5: When offering prizes to the winners of Media Lab Mixer, the big screen in the atrium advertised the available prizes. As in the previous two weeks, it also cycled between showing the instructions and highscore list for the game.
During the fourth week of the Media Lab Mixer game, I offered a community prize to the Lab. As advertised in emails and on the big screen in the atrium, the deal was that if the Lab as a whole earned 2,000,000 points total, the Lab would get a single, but valuable prize of general interest to the community. This week was intended to determine how community incentives differed in impact from individual incentives.

During this final two-week period, I removed the Media Lab Mixer devices, but left the furniture and coffee machines. The goal was to determine the after effects of the gamification techniques and incentives on the continued use of the atrium. For example, it was conceivable that incentivizing people to socialize would have negative consequences on their post-incentivized desire to socialize. Would use of the atrium increase, decrease or remain constant after the game's absence?

During the course of the 3-month study, there were numerous scheduled and unscheduled events that may have affected the data. The full timeline of significant dates and times for the study is below:

<table>
<thead>
<tr>
<th>Date</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>January 7th, midday</td>
<td>The camera is installed and the study begins collecting baseline data.</td>
</tr>
<tr>
<td>January 9th – January 16th</td>
<td>Technical issues with the camera set up cause a complete loss of data for this period.</td>
</tr>
<tr>
<td>January 21st – January 22nd</td>
<td>An event called the Festival of Learning takes place at the Media Lab, bringing an unusually high number of people to the atrium throughout the two days.</td>
</tr>
<tr>
<td>January 23rd</td>
<td>The furniture is put out in the atrium.</td>
</tr>
<tr>
<td>February 1st, 9:30am</td>
<td>Due to an upcoming speaker event, the furniture in the atrium is removed.</td>
</tr>
<tr>
<td>February 1st, 3:00pm to 4:00pm</td>
<td>A speaker event at the Lab brings a high volume of people to the atrium.</td>
</tr>
<tr>
<td>February 2nd, 3:45pm</td>
<td>The furniture is returned to the atrium in a different arrangement.</td>
</tr>
<tr>
<td>February 5th</td>
<td>The coffee machines and vending machines are installed in the atrium, but there are electrical troubles with the coffee machines, causing them to not work.</td>
</tr>
<tr>
<td>February 7th</td>
<td>The coffee machines are fully working.</td>
</tr>
<tr>
<td>February 8th – February 10th</td>
<td>Winter storm Nemo hits Boston and MIT is closed.</td>
</tr>
<tr>
<td>February 18th</td>
<td>The Media Lab Mixer boxes are put out in the atrium, and the points-only version of the game begins. Atrium use is low since MIT is closed for President's Day.</td>
</tr>
</tbody>
</table>
During the course of the study, nearly 7300 images were taken of the atrium space, and I manually labeled all of them with the image tagging software.

### 5.3.1 Image Data

During the course of the study, nearly 7300 images were taken of the atrium space, and I manually labeled all of them with the image tagging software.
5.3.1.1 Image Data Acquisition

For each image, I tagged people, groups of people, sofas, armchairs, coffee tables, large tables, the ping pong table, and the relative sizes and positions of each. For each snapshot in time, this method thus gathered data on:

1. the raw number of people in the atrium
2. the raw number of groups in the atrium
3. the sizes of those groups
4. the raw number of chairs, sofas, and tables in the atrium
5. the number of people and groups using chairs, sofas, and tables
6. whether or not the ping pong table was in use

Figure 5.3.1.1.1: The custom-built image tagging software that I used allowed me to tag the relative positions and sizes of various objects in the atrium. I used the convention of surrounding a tag with another tag to indicate that the former is “using” or is a “part of” the latter. In this example, a Group tag (yellow) surrounds the 6 Person tags (orange) on the bottom left, indicating they are there together as a group. Also, a SmallTable tag (light blue) surrounds the upper left Person tag in same group, indicating that that person is using the table.

Due to technical limitations and anonymity requirements, it was impossible to figure out if a given individual was the same in any two frames, so this method did not gather data on the length of time any individual spent in the atrium, or with whom those individuals interacted.
As mentioned above, various events at the Lab caused lost or skewed data in multiple instances. When analyzing minute-to-minute and day-to-day data from the overhead camera, I included these outliers, but I omitted them when calculating averages and other statistics. Specifically, the following times were omitted:

<table>
<thead>
<tr>
<th>Date Range</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>January 9th – January 16th</td>
<td>Omitted because of loss of data.</td>
</tr>
<tr>
<td>January 21st – January 22nd</td>
<td>Omitted because of an artificially high number of people.</td>
</tr>
<tr>
<td>February 1st, 9:30am – February 2nd, 3:45pm</td>
<td>Omitted because the furniture was removed and because of an artificially high number of people.</td>
</tr>
<tr>
<td>February 21st, 1:00pm – February 25th, 9:45am</td>
<td>Omitted because the furniture and Media Lab Mixer boxes were removed, and because of an artificially high number of people.</td>
</tr>
<tr>
<td>February 28th, 10:00am to 2:40pm, 8:00pm – 11:00pm</td>
<td>Omitted because of loss of data.</td>
</tr>
<tr>
<td>March 6th, 9:15am – March 7th 2:00pm</td>
<td>Omitted because the furniture and Media Lab Mixer boxes were removed, and because of an artificially high number of people.</td>
</tr>
<tr>
<td>March 8th, 4:00pm – 5:00pm</td>
<td>Omitted because of an artificially high number of people.</td>
</tr>
<tr>
<td>March 9th, 6:00pm – March 10th, 2:00am</td>
<td>In preparation for an upcoming party, the furniture and Media Lab Mixer boxes are removed from the atrium.</td>
</tr>
<tr>
<td>March 9th, 10:45pm – March 10th, 1:45pm</td>
<td>Omitted because the furniture and Media Lab Mixer boxes were removed, and because of an artificially high number of people.</td>
</tr>
<tr>
<td>March 19th, 9:15am – March 20th, 2:00pm</td>
<td>Omitted because of loss of data.</td>
</tr>
<tr>
<td>March 28th, 10:00am – March 29th, 12:00pm</td>
<td>Omitted because the furniture was removed and because of an artificially high number of people.</td>
</tr>
<tr>
<td>April 1st, 12:00pm – 1:00pm</td>
<td>Omitted because the furniture was removed and because of an artificially high number of people.</td>
</tr>
</tbody>
</table>

5.3.1.2 Image Tagging Procedure

Due to the poor quality of the images and the poor lighting in the atrium at night, it was often very difficult to accurately determine what was what in each photo. Even when the images were clear, it was still somewhat difficult to figure out if people were there together as a group or alone, or whether or not they were “using” a particular piece of furniture or not. As I began tagging, I thus followed a certain procedure so that I would at least tag the images consistently. This section describes that procedure.

**Tagging People**

In general, I only tagged people that were present in the 3rd floor atrium, whether or not they were fully in the frame. The camera often caught glimpses of people on the 4th floor or on the 2nd floor stairwell, but since this study is about the 3rd floor atrium space, I didn’t tag them.
Tagging people in the atrium was fairly straightforward in daytime images. People showed up very clearly whether they were standing, walking, or sitting. It was somewhat more difficult when they were half off camera, but I was able to use my knowledge of human anatomy and look for legs, arms, and heads to make an educated guess as to whether an off-screen blob represented a person or not. Whenever I was in doubt I chose not to tag it as a person.

Night time images were slightly more difficult. People often appeared as dark blobs against the floor, and when they were sitting on a sofa or chair they tended to blend in as well. One tactic I used to determine if a person was present was to flip between chronologically consecutive images and look for changes. Often times I could see a blob on a chair shift
from frame to frame, and I considered that moving object a person. Another helpful trick was to look for computer screens. People in the atrium often were working on their laptops, which obviously give off tell tale glows.

Figure 5.3.1.2.3: This two-image sequence from January 30th demonstrates how I tagged people in night time photos. The photo on the upper left (6pm) shows two people working on their laptops in the furniture grouping at left. Given the poor lighting in the room, it is conceivable that these are just laptops sitting on the couches without people using them, but as the upper right photo shows, whenever I saw a laptop, I assumed there was a person there. The bottom left photo (6:15pm) shows two blobs appearing (one on the upper couch at the far left, and one next to the lower couch on the far left). The photo on the lower right shows that I assumed these moving blobs were people. Note that sofa, chair, table, and group tags are left out here for clarity.

Tagging Groups
One of the main purposes of this study was to determine if people were interacting more or less with other people, and thus one of the things I tried to determine in the photos was how large of a social “group” people were a part of while hanging out in the atrium. In general, I considered people to be part of a group if they were directly interacting with each other or were there while participating in the same activity. This, however, was a fairly
subjective thing to determine; in a still frame without the appropriate context, any physically co-located or distant set of people could arguably be said to be part of a group or not part of a group. In determining whether or not people were part of the same group, I thus used the following rules:

1. If two or more people were standing near each other and facing each other, they were likely talking to each other and thus part of a group. If they were facing opposite directions, or simply walking past each other, they were not tagged as a group.

2. People sitting together in the same furniture grouping while there were other empty furniture groupings available were tagged as part of the same group, since this indicates they most likely knew each other, otherwise they would have sat alone in the other available chairs. Those sitting in separate furniture groupings were never tagged as a group.

3. If all furniture groupings were occupied by at least one person, the people within a given furniture grouping were not necessarily all tagged as one group, since they

Figure 5.3.1.2.4: This image from February 7th shows two groups of people. I tagged the two people on the upper right as a group because they are near each other and facing each other, and I tagged the two people on the bottom left as a group because they are sitting in the same furniture grouping while the furniture grouping to the right remains empty. Note that sofa, chair, and table tags are left out here for clarity.
might have conceivably been sitting there together solely out of a lack of additional space. In such a case,

a. if when flipping from image to image chronologically, people showed up at the same time within the same furniture grouping, they were tagged as part of the same group.

b. if instead people did not show up exactly at the same time,
   i. but were facing each other or sitting close to each other (i.e. on the same sofa or on two nearby chairs) while the rest of the grouping was unoccupied, they were tagged as a group.
   ii. and were sitting on distant sides of the grouping while the middle remained empty, they were not tagged as a group.

4. Whether or not there were other empty furniture groupings or whether or not people showed up together, if people remained together in the same furniture grouping for four or more frames (an hour or more), they were from then on tagged as part of the same group.

5. If two people were playing ping pong together, they were tagged as a group.

To represent which people were in the group, I used the convention of resizing the group tag to completely surround the person tags. Thus, if the center of a person box fell within the bounds of group box, the data analysis software knew to consider that person a part of that group.

*Tagging Sofas and Chairs*

The relative sizes of the furniture pieces were not important, so for the most part I just placed small tags on top of where they were located in the image rather than resizing the tags to fit the pieces perfectly. I considered a person to be “using” a sofa or chair if he was sitting, lying, or leaning on the seat or arm of the piece. To signal to the data analysis software that a person was using a sofa or chair, I surrounded the person tag completely with the sofa or chair tag, similar to the way groups were tagged. Occasionally other furniture items than the ones I put in the atrium popped up in the images briefly, but for consistency sake I did not tag them. I only tagged the purple sofas and chairs.
**Tagging Tables**

As with the sofas and chairs, the relative sizes of the tables were not important, and I often simply placed small tags over them rather than resizing the tags to fit perfectly. I labeled the small wooden coffee tables as “small tables” and the large round fold-up tables as “large tables”. I considered a person to be “using” a given table if he was resting his laptop, notebook, coat, coffee, or other item on it. There were also situations in which people put their feet up on or were directly sitting on the tables, and I considered them to be using the tables as well.

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**Figure 5.3.1.2.5:** This image from February 26th shows a typical tagging scenario involving sofas and chairs. The Sofa and SmallChair tags surround the Person tags, indicating that those people are sitting in those pieces of furniture. Note that group tags are left out here for clarity.

**Figure 5.3.1.2.6:** This image from February 4th demonstrates when and why I tagged people as using a table. The people at top and bottom left have their feet up on the table, while the person at bottom right has as item on the table. They are thus all tagged as using a table. Note that the bottom sofa tag is left out for clarity.
As with groups, sofas, and chairs, for the most part I surrounded a person tag in the table tag to indicate that the person was using it. For a little while in the tagging process, however, I accidentally reversed this convention; that is, I surrounded some of the large table tags with the group tags to indicate that the people in the group were using it. The data analysis software takes care of accounting for this issue. Whenever I was in doubt I chose not to tag a person as using a table. Occasionally other tables than the ones I put in the atrium popped up in the images briefly, but for consistency sake I did not tag them. I only tagged the wooden tables.

**Tagging the Ping Pong Table**

Sometimes the Media Lab ping pong table appeared in the atrium, and I thought it would be interesting to analyze its use as well. Whenever two people were playing ping pong, I surrounded the two person tags with the ping pong table tag, and also surrounded those people with a group tag.

![Ping Pong Table Tagging Example](image)

*Figure 5.3.1.2.7: This image from February 4th shows a typical tagging scenario involving the ping pong table. Note that other tags are left out here for clarity.*

### 5.3.2 Media Lab Mixer Data

In addition to gathering data from the overhead camera, I also collected a significant amount of data from the Media Lab Mixer devices. Since users placed their ID cards on the boxes, the system was able to collect more fine-grained data, such as:
1. how long each individual spent in the atrium in one sitting and in total
2. with whom those individuals spent their time in the atrium
3. with how many known or new people those individuals spent their time

As previously mentioned, the Media Lab Mixer game ran for four weeks total. Between weeks, I reset point totals back to zero, but kept around data on who sat with whom during previous weeks. So for example, if person A sat with person B during Week 1, A and B were no longer “new” to each other during Week 2.

5.3.3 Survey Data

Further, after the Media Lab Mixer boxes were removed from the atrium on March 18th, I sent surveys around the Lab to gather some more qualitative data on everyone’s use of the atrium space. I emailed a link out to the Media Lab community to fill out an online survey, and also personally handed out printed surveys to people in the Lab as they passed through the atrium.

Question 1 of the survey simply split the respondants into two groups: atrium users and non-atrium users.

1. Have you hung out in the atrium at all since the purple couches and coffee tables were put there in January?
   - Yes
   - No

If respondants said “No” to Question 1, they were asked to explain why.

2. If you answered “No” to question 1, why do you think that is?
   - My office is just more comfortable.
   - Its hard for me to get work done in the atrium.
   - I’m uncomfortable being around so many people I don’t know.
   - Other (please specify)

Questions 3 and 4 dealt with how and why people used the atrium.
3. How frequently have you hung out in the atrium for more than 5 minutes at a time since January?
   o At least once per day.
   o At least once every other day.
   o At least once every few days.
   o At least once every week.
   o Almost never.

4. Please rank the following in terms of their relevance in your decision to hang out in the atrium.

<table>
<thead>
<tr>
<th>The Furniture</th>
<th>Not Relevant</th>
<th>A Little Relevant</th>
<th>Fairly Relevant</th>
<th>Very Relevant</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Coffee</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The Vending Machines</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The Media Lab</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixer Game</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The Other People There</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The Privacy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other (please specify)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Questions 5, 6, and 7 more directly tried to determine if users’ interactions in the atrium actually led to increased idea crossflow or productivity.

5. How many new people have you met while hanging out in the atrium?
   o None.
   o A few
   o A lot
   o Too many to count

6. How frequently have you learned something interesting or useful related to your research, schoolwork, or personal projects while talking to someone in the atrium?
   o Never
   o A few times
   o Quite often
   o Almost always

7. How many times have you met someone new in the atrium which ended up continuing as a sustained personal or professional relationship?
   o None
   o A few
   o A lot
   o Too many to count
Questions 8, 9, 10 dealt with user engagement with Media Lab Mixer.

8. Did you ever play the Media Lab Mixer game (by putting your ID on one of those black and white striped boxes)?
   o Yes
   o No

9. If you answered, "No" to Question 8, why do you think that is?
   o I didn’t know it was there.
   o I didn’t have a Media Lab ID card.
   o I didn’t want it to seem like I was slacking off in the atrium.
   o I just wasn’t interested in playing.
   o I thought it was a cheap way to get people to socialize.
   o Other (please specify)

10. If you answered, "Yes" to Question 8, now that the game is over, do you think you will continue to hang out in the atrium anyway?
    o Yes
    o No (please explain)

5.4 Results

Most of my results come in the form of data from the aforementioned sources, but there is also substantial anecdotal evidence from individuals who were involved in the study.

5.4.1 Data Results

There are first a few important points to note about the following data analysis. For the image tagging data, because very few people were ever in the atrium at night regardless of outside factors, I analyzed day and night time data separately, considering 8am to 8pm to be the “day” and 8pm to 8am to be the “night”. I focused mainly on the day time data, however, because of the added reason that the night time tagging data was likely more inaccurate than the day time data. Further, when talking about the number of people and groups in the atrium, it should be noted that this refers to the number of people tags and group tags in the images, and not the people and groups themselves. So for example, if a person had hung out in the atrium for an hour, he would have been tagged four times across four images, and thus counted as four separate people during the analysis. In this
way, one can think of the “number of people” and “number of groups” as more like abstract metrics that take into account both the number of unique people and groups that were in the atrium and how long they remained there. Finally, it should be noted that in determining the effectiveness of the various interventions in increasing the sought-after traits of creativity, productivity, and innovation, I generally use a “more is better” philosophy. Building upon past research [2], I assume that more people, more groups, larger groups, and more interaction in general lead to more of the desired traits in an organization. This may still a debatable relationship, but for the purposes of this thesis, I assume it holds true.

That said, perhaps the most immediately telling data comes from looking at the usage of the atrium on an intervention-by-intervention basis.

![Graph](image)

**Figure 5.4.1.1:** The average number of people in the atrium per day per intervention. Levels increased from intervention to intervention as expected, and then decreased in the final two weeks when the Media Lab Mixer game was removed from the atrium.

This graph shows the average daily number of people that were in the atrium during the various two-week intervention phases. The number of people clearly increased with each added intervention as intended, and then decreased in the final phase when the Media Lab Mixer game was removed. The largest gains occurred between the Furniture/Coffee/ML Mixer (Points) phases, with smaller gains between the Baseline/Furniture and ML Mixer
(Points)/ML Mixer (Prizes) phases. The Post ML Mixer phase dropped to almost exactly the same level that was present before the game was introduced.

A similar trend can be seen with groups of people in the atrium.

![Bar chart showing the average number of groups in the atrium per day per intervention.](image)

**Figure 5.4.1.2:** The average number of groups in the atrium per day per intervention. As with the average number of people, levels increased from intervention to intervention, and then decreased in the final phase when the Media Lab Mixer game was removed from the atrium.

That is, there was a small increase in the number of groups of people in the atrium between the Baseline/Furniture phases, larger increases between the Furniture/Coffee and Coffee/ML Mixer (Points) phases, and a drop after the ML Mixer (Prizes) phase to slightly higher but roughly the same pre-game levels. One difference here, however, is that the number of groups went down between the Points/Prizes portions of ML Mixer, though the values are so close that it may not be significant.

This seems to indicate that both the architectural interventions and the technological one were effective in achieving the desired results. Furniture and coffee attracted people to the atrium, and adding game dynamics on top of that only helped more. Offering financial incentives, though, had a much smaller, if any effect on bringing people to the atrium and “getting them to talk”. Further, the game dynamics were shown to likely not be a sustainable solution here; once the Media Lab Mixer boxes were removed from the atrium, usage of the space went back almost exactly to how it was before. One alternative
interpretation of the final two weeks, though, could be that, because it happened to coincide with Spring Break at MIT, people and group levels were artificially low, and thus might have actually been higher than pre-game levels under normal circumstances. It is hard to say with certainty though.

Either way, this same curve can also be seen over and over again when considering usage of the furniture in the atrium over time.

![Graphs showing average daily number of people using various furniture items in the atrium.](image)

**Figure 5.4.1.3:** The average daily number of people using various furniture items in the atrium. These curves have roughly the same shape as those in figures 5.4.1.1 and 5.4.1.2, though they are more likely caused by the changing number of people, and not the interventions.

These, however, can more likely be attributed simply to the changing number of people and groups in the atrium rather than to the interventions themselves. As the following graph shows, the fraction of people in the atrium who were using furniture items remained fairly invariant over the course of the study. That is, at any given time during the day, roughly
between 75% and 85% of the people in the atrium were using a sofa, chair, or table. Basically, it seems as though if there is a comfortable environment with places to sit and work, people are likely to use it, regardless of other factors.

Interestingly, the average group size in the atrium also remained relatively constant over time, almost always staying between 2.5 and 3.5.
Figure 5.4.1.5: The average group size per intervention.

This is at least some evidence against the effectivenesses of the various interventions. Under the assumption that more is better, it would have been great to see that the interventions increased average group sizes, however this was not the case.

Taking a step back, it’s interesting in and of itself to see how the number of people in the atrium changed in each photo over time and as it related to special events in the Media Lab atrium and at MIT.
As one can see, there were clear day/night cycles with spikes occurring mid-day and tapering down towards the beginning and end of each day. Special events like lab-wide lunches and speakers also clearly brought many people to the space.

Night time trends tended to actually be very similar to day time trends, though often at lower levels, and slightly more sporadic at times.
Figure 5.4.1.7: Night time graphs of average number of people, average number of groups, and average group size.

The average number of people per intervention at night followed roughly the same intervention-to-intervention increases and decreases, while the average number of groups initially deviated from the pattern, showing an odd Baseline-to-Furniture decrease instead of increase. The average group size still remained relatively constant at night, mostly swinging between sizes of 2 and 3, but with an odd spike up to about 3.75 in the Post ML Mixer phase.
Furniture utilization trends at night were also similar, but because of their lower levels, they swung a little more unpredictably from intervention to intervention. Overall though, the percent of people in the atrium at night using furniture also remained fairly constant over time, staying roughly between 75% and 85% just like during the day.

The data from the Media Lab Mixer game sheds some more light on this particular four-week period. When looking at these results, it is important to remember that the game started over at the beginning of each of the four weeks and awarded points during the first two weeks, individual prizes during the third week, and a community prize during the fourth week.
Looking at the day on which users started playing the game in a given week, we can see that in the Points phase, the decision to play was slightly more random than in the Prizes phase. That is, it was possible to have a relatively high number of people start playing mid-week when the game was “just for fun”, whereas that motivation was lost in the final two weeks. The clear, downward trend in Weeks 3 and 4 shows that once actual prizes were offered, people either got in early or did not even bother to play. Also interesting to note is that the total number of users who played the game went down between Weeks 2 and 3, when the game switched from offering points to individual prizes. And even though it went back up again in Week 4, it still did not reach pre-prize levels.

This seems to indicate that points and the intrinsic satisfaction of being in the top ten on a public leaderboard are more effective in engaging a broader audience than prizes. Rewards only motivate a small subset of people, and seem to actively turn off latecomers and casual players.

Despite the range of people playing the game, depth of engagement tended to be shallow, especially in the first three weeks. Histograms of the number of Media Lab Mixer players who ended up in various total point ranges at the end of each week show this shallow engagement, with the majority of players in Weeks 1 through 3 having earned between 1 and 10,000 points and a quick tapering of the number of players in the higher ranges.
Figure 5.4.1.10: The number of Media Lab Mixer players who ended each week within various point ranges.

When a community prize was offered in Week 4, however, there was a greater depth of involvement, with fewer people having earned lower point totals and more people having earned higher point totals (the curve basically shifted down and to the right). Further, although the total points earned by all players increased between the Points and Prizes phases (Weeks 2 and 3), it was a very small and almost insignificant change compared to the change between individual and community prize weeks (Weeks 3 and 4), consistent with the change described in total users.

The exact same trend can be seen in the number of hours players spent playing the game each week. This makes sense because while hours were not directly proportional to points, players generally earned more points the more hours they spent with the game.
As with point totals, Weeks 1 through 3 show a shallow engagement with the game, with most players having spent less than an hour in the atrium. Week 4, however, again shows a broader involvement, with more people having spent much larger amounts of time and a less sharp drop off from those on the lower end. Again similar to the other metrics, total hours spent dropped between Weeks 2 and 3, and skyrocketed in Week 4. Having a common goal to work towards thus seems to motivate people significantly more than working to earn prizes for themselves.

Upon examining points earned and hours spent on a day-by-day basis, another interesting pattern emerges. Specifically, points and hours gradually decreased from Monday through Thursday each week, jumped up to relatively high levels on Friday, and then sharply declined over the weekend.
Figure 5.4.1.12: Total points earned by all Media Lab Mixer players per day for each of the four weeks. Values of zero that are not marked with "Missing Data" are actually zero.
A possible explanation for this is that people naturally become less motivated to play a game over time, but as they approach a deadline to reach a goal (to be one of the top ten or top three at the end of the week), they have a sudden resurgence of motivation to achieve the goal just before the deadline. Those who were far away from being on the Media Lab Mixer top ten list by Friday likely gave up, but those who were within reach probably spent a larger amount of time that day to try win the game by the end of the week. This seems to validate the decision to reset the points each week, which created recurring goals and deadlines. Had the game lasted the entire four weeks, there would have likely been near-zero engagement in the middle two weeks, and only a small resurgence at the end. This same pattern can also be seen in average group size per day over the four weeks.

Then again, another possible explanation could simply be that Friday is the end of the work-week and people just tend to be more social then. Further, the sharp drop off over the weekend could simply be because it's the weekend, and much fewer people are around then. Again, it is difficult to tell.

Breaking up time spent by players even further into an hour-by-hour basis, one can get a feel for what time of day usage peaked.
Figure 5.4.1.14: Minutes spent per hour by Media Lab Mixer players over the four weeks. Labels are added above each local peak.

As one can see, usage of the game tended to peak in the mid-afternoon, with occasional secondary daily spikes occurring late at night.
The diversity of the social interactions in the atrium is also of interest, and can be gauged by looking at when people first sat together in a group while playing Media Lab Mixer.

![Graph showing new relationships formed by week](image)

**Figure 5.4.1.15:** The number of "new relationships" formed during each week of Media Lab Mixer.

There was a more than two-fold increase in cross pollination between Weeks 1 and 2 of Media Lab Mixer, then a sharp decline moving into the Prizes phase of Week 3. It increased again with community prizes in Week 4, though not to quite the same level as during the Points phase of Week 2. Assuming again that greater diversity in social interaction increases the sought-after traits of creativity, productivity, and innovation in an organization, it seems as though these results support the previous conclusions. That is, the more intrinsically motivating points schema was more effective than prizes, but within the realm of prizes, community goals were much more effective than individual goals.

Survey data adds to this story. There were 42 total respondants, with 18 respondants who filled out the online survey, and 24 who filled out the pen-and-paper version.

Question 1 shows that a majority of people in Media Lab did in fact use the atrium space in some capacity since the study started.
Of those that did not use the atrium, though, the two main reasons seemed to be that the setup was not conducive to productive work and lacked a sufficient amount of privacy.

As the results show, fifty percent of people who did not hang out in the atrium said it was because it was hard to get work done there, while the 62.5% who answered, “Other” made comments like, “It feels too open as a space. I like to work in cafes but not in such a large
open area with people walking around above and all around,” and “No privacy. Good for socializing, not good for private work.”

Of those that did hang out in the atrium at some point, though, most were there a few times per week, and still a relatively high number of people were there every day.

![Bar chart](image)

**Figure 5.4.1.18: Results from Question 3 of the survey.**
Survey graphs were produced with SurveyMonkey.

According to Question 4, the furniture was clearly the biggest attractor to the atrium, which is a contrast to the findings from the camera that showed that the smallest increase in usage of the atrium occurred between the Baseline and Furniture phases.
Interestingly, though, Question 4 also shows that the presence of other people in the atrium was a fairly large attractor as well. This leads me to believe that perhaps the larger increases shown in Figure 5.1.4.1 between the Furniture/Coffee and Coffee/ML Mixer (Points) phases may have actually been caused by the increase in people that occurred between the Baseline/Furniture phases. It is possible that a core group of people started spending more time there because of the furniture, but then more and more people joined in not because of the furniture, coffee, or game, but because of the greater social interaction that atrium began to afford. Those who answered “Other” to this question listed some extra items as being relevant to them, such as “lighting” and “sleep”.

Questions 5, 6, and 7 attempted to gauge more directly whether interactions in the atrium led to increased productivity at the Lab. On some level it seems as though this was in fact the case, with large percentages of people saying that they had met “a few” new people, learned “a few” new things, and had “a few” sustained relationships.
Question 8 shows that more than half of the people who hung out in the atrium played Media Lab Mixer at some point, and Question 10 seems to imply that this was a sustainable way of getting people to hang out in the atrium, with over 80% of players saying they would continue to utilize the atrium space after the game. This roughly supports the findings from the camera, which shows that usage of the atrium space remained at about 70% of what it was during the Prizes phase.
Of those that did not play the game, though, a large portion of them said it was because they didn’t have the right ID card needed to participate. Had messaging around how to obtain an ID card been clearer, usage of the game might have been higher. However, a comparable number of people said they simply were not interested in playing the game, and a few said they thought it was “a cheap way to get people to socialize.”
5.4.2 Anecdotal Evidence

There is also substantial anecdotal evidence that supports some of the findings from the previous section. The following anecdotes were all related to me at some point over the course of the last five weeks of the study.

A few users commented on their motivations to play Media Lab Mixer. One power user who was in the top ten list each week excitedly played the game every day, saying that she had never been on a highscore list before and really wanted to see her name on the big screen. This user spent most of her time each week working in the atrium in order to play the game and regularly brought large groups of friends and colleagues with her. During Week 4 of the game, this user went on to organize the Media Lab community in an effort to reach the 2,000,000 point collective goal. With over three-quarters of a million points yet to go, she set up a “movie night” that Friday, which drew between 15 and 20 people to the atrium for a few hours. In her email to the Lab she said:

So! Movie in the living room (third floor atrium)? Wreck-it Ralph at, say, 6p? A gaggle of us community points devotees will be hanging out on the couches. Sit with us, and bring your ML ID! Imagine: just one hour of at least 24 people collecting points, and we’ll blast past the 750,000 we still need to win the community challenge!

This user thus served as one of those social “seeds,” who was motivated to use the atrium because of the interventions, but who also fostered increased interactions between friends and strangers alike.

Another user who sat in the atrium and interacted with other players quite frequently was so fascinated by the social dynamics that arose from the game, that he wrote a brief paper on it for a class. In it, he relates his observations as a player of Media Lab Mixer on the “etiquette” that naturally arose from the gameplay, as well as a slew of dubious strategies he noticed that other people used to get ahead in the game. To start, he writes:

Behavioural changes started emerging almost immediately and, at least by accounts of people who knew them well, many people started acting in entirely unexpected ways because of the game.
Then he goes on to discuss the various methods of cheating that arose, and how others reacted to them:

> Although I was never a witness to this myself, I heard from several different sources about someone taping their card to the bottom of the box overnight, with the intention being that the sensor would still pick up the RFID chip on it and record the points without anyone noticing. What was interesting in this instance was that enforcement of the rules came from the players themselves: anytime a sensor picked up a card, it would display the player for that card on a small screen on the side of the box. It only took one player the following morning to notice the people on the screen not corresponding to the physical reality for them to examine the box and find the offending card and, even more so, to take the extra step of removing it themselves.

He continues:

> At the social level, by far the most common transgression was leaving one’s card behind even when not actively being in the atrium space. This minor transgression had the added benefit of plausible deniability, as it was often the case people just forgot the cards when leaving the space and it was impossible for other players to tell when this was done in good faith or as an attempt to rack up additional points (especially when trying to leave a card on a box overnight). When this started become a recurring pattern for specific players, other players would actively call them out for this behaviour directly and in their absence. But what became an almost standardised response to cards for absentee players was the controversial act of taking someone’s card off the box. The strict boundaries for this action were unclear – Were they still around? Were they coming back soon? Should I let them know? [...] Leaving your card behind quickly become morally reprehensible, a form of abuse, and it was especially aggravating towards players in the top positions in the leaderboard who saw this as attempts to climb positions and would often take cards off with less friendly attitudes.

He also describes some much more elaborate methods that he observed, such as those who used “a packet sniffing technique to figure out how the boxes were relaying back information to the server doing the aggregation, then [faked] the requests to that same server over and over to rack up points.” However, he commented that, “creativity and elaboration were given some positive recognition.”

To wrap up, he says:

> As the stakes got higher (prizes for the top three positions in the leaderboard were introduced in the second week), conversations about transgressions become a lot more frequent and impassioned.
Overall, this user's observations and his motivation to write them down and analyze them, exemplify how not only he, but many people at the Lab, became very engaged in this simple game. And like the power user previously described, these people likely served as seeds that brought a varied group of other people into the foray as well.

In support of the assumption that increased informal interactions leads to increased idea-crossflow, creativity, and productivity, numerous users related specific, serendipitous interactions that they had with others in the atrium. One user described how she was having trouble designing a particular circuit one day while sitting out in the atrium, and was discussing her problem out loud with a friend. Another user, whom she did not know, but who happened to be sitting with them in the same furniture group while playing Media Lab Mixer, overheard her conversation. This user happened to be familiar with her problem and worked with her over the next hour to help her solve it.

Yet another user related how, because of the physical location of the research group he was in, he never had much of a chance to socialize with others at the Lab. When the furniture was put in the atrium though, it gave him a new workspace option, and he has since met a “huge” number of new people that he never knew existed before.

On the longer-term effects of the Media Lab Mixer game, a few users made comments about how the game impacted them. One user who worked hard to get on the top ten list during the first week of the game mentioned how her goal was just to win one week for the sake of glory, but then got so used to working in the atrium that she continued to do so in the subsequent weeks even though she stopped playing the game. Similarly, a casual user related how he continued to hang out in the atrium after the game was removed because he started to enjoy working and socializing with the new people that he had met in the atrium during the game.

There were also at least half a dozen people who reported to me that they chose to hang out more frequently in the atrium, not because of any intervention in particular, but simply because other people were there.
One non-user, however, actively disliked the game, and related to me how everytime she passed through the atrium it actively “lowered [her] quality of life.” She did not like seeing her colleagues absorbed in what she thought was a shallow game and a cheap way to increase social interactions.

6. Conclusions and Future Work
The goal of this thesis was to design an all-purpose smart artifact that could be easily placed in an office environment and actively foster informal interactions and thus creativity, productivity, and innovation within the organization. My belief has been that, while the architectural design of a workplace is important in achieving these traits, a carefully crafted technological solution could be more effective. My design goals were to build a device that was compact and easy to install (as opposed to, for example, a sensor network that would require elaborate installation and configuration), simple and intuitive to operate and use, and clearly effective in producing the desired results. While I do believe I was able to accomplish some of these goals, it was unfortunately harder to achieve the full ideal than I had thought.

While the Food Groups devices had very positive feedback at first, they ended up receiving very little use. The devices attempted to overcome the social stigmas involved in personally asking strangers to hang out by acting as a third party intermediator and providing an activity (lunch or dinner) as an “excuse” to socialize, but they ended up creating more social stigmas than they solved. Many users did not like the “blind date” feel of the interaction and were nervous to get themselves locked into awkward social situations.

Based on the positive initial feedback and results from the surveys, though, I would say there is still some hope for the Food Groups strategy of acting like a “host at a party”. It seems conceivable to me that in a different environment, the Food Groups button could actually thrive and be quite valuable to the community. In the future, I would like to run more extensive studies with the button, in which I test it across different workplace
environments. It would be interesting to see how it fairs at small, medium, and large sized companies, as well as companies with startup cultures and more corporate cultures. Perhaps there needs to be more of a critical mass of people in an organization and/or a certain type of culture that is more motivated to socialize in order to make the button more effective.

The study in the atrium revealed some much more interesting results. Both the architectural interventions of the furniture and coffee machines and the technological intervention of Media Lab Mixer had significant use and significant impacts on the ability to drive more and varied usage of the atrium. While none of the interventions were able to increase average group sizes, they were all effective in increasing the number of people and groups that made use of the atrium. This fact combined with survey and anecdotal data strongly suggests that informal interactions as well as creativity, productivity, and innovation were indeed produced by these interventions.

The furniture and coffee seemed to have a larger impact on this than Media Lab Mixer, though a great deal of engagement and interaction was in fact created by the game. The features of the game design that worked best were the simple and intuitive rules, the real-time and public displays of score, the frequent resetting of points, and the absence of monetary reward. The rules directly rewarded the desired interactions and were easy enough to understand that new players quickly knew how to get involved. The displays gave real-time feedback to users on their actions so they readily knew how to modify their behaviors to progress in the game. The resetting of points created recurring goals that kept the playing field level and kept users motivated to play. Finally, when users played the game “just for fun” without prizes, engagement was at its highest. As some users commented, adding money to the mix “cheapened” the experience. In the realm of prizes, though, community-based incentives (as opposed to individual incentives) were the most effective because they gave people a similar, selfless reason to play. Unfortunately game dynamics turned out to not be a sustainable solution; once the game was removed, usage of the atrium went back to exactly what it was before the game was introduced. It is, however, conceivable that such a game could be used indefinitely within an organization.
Another interesting lesson that I learned during the study of the atrium is that people themselves are also major attractors of other people. If an organization can get a core group of people, via whatever means, to regularly use a common space, others will naturally join them. Thus, it is possible that only minor interventions are needed to achieve a desired level of interaction. Whether the organization creates a slightly more comfortable common space or simply runs a small marketing blitz to increase use of a space, as long as a few people start using the space regularly, it can snowball into a larger effect.

One of the design goals I aimed for while creating Media Lab Mixer was to make it as broadly appealing to the community as possible in order to achieve the most engagement with it possible. The result from above, however, indicates that this isn’t too necessary. As long as the device can attract a core group of people, others will follow anyway. In the future, then, it may even be better to tailor a game or other technological intervention to a small subset of highly motivated and highly connected people rather than to the whole community at large.
7. References

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Below is the full code that ran the Arduino Mega powering version 1 of Food Groups.
void setLowPowerMode()
{
  // The maximum time required to boot the application
  // firmware is 65s.
  // There will be release to release variation in actual boot
time but it will always
  // be less than the maximum.
  // The maximum time required to boot the application
  // firmware is 65s.
  // There will be release to release variation in actual boot
time but it will always
// Digital I/O
// digitalWrite(UPPER_LEFT_ARROW_PIN, HIGH);
// digitalWrite(UPPER_RIGHT_ARROW_PIN, HIGH);
// digitalWrite(LOWER_RIGHT_ARROW_PIN, HIGH);
// digitalWrite(LOWER_LEFT_ARROW_PIN, HIGH);
// digitalWrite(RIGHT_MIDDLE_READER_BAR_PIN, HIGH);
// digitalWrite(LEFT_INNER_READER_BAR_PIN, HIGH);
// digitalWrite(CENTER_READER_BAR_PIN, HIGH);
// digitalWrite(LEFT_OUTER_READER_BAR_PIN, HIGH);
// digitalWrite(RIGHT_OUTER_READER_BAR_PIN, HIGH);
// digitalWrite(UPPER_LEFT_LL_PIN, HIGH);
// digitalWrite(UPPER_LEFT_UL_PIN, HIGH);
// digitalWrite(UPPER_RIGHT_LL_PIN, HIGH);
// digitalWrite(UPPER_RIGHT_UL_PIN, HIGH);
// digitalWrite(Lower_RIGHT_LL_PIN, HIGH);
// digitalWrite(Lower_RIGHT_UL_PIN, HIGH);
// digitalWrite(Lower_LEFT_LL_PIN, HIGH);
// digitalWrite(Lower_LEFT_UL_PIN, HIGH);
// digitalWrite(CENTER_LEFT_PIN, HIGH);
// digitalWrite(CENTER_RIGHT_PIN, HIGH);
// digitalWrite(UPPER_MIDDLE_PIN, HIGH);
// digitalWrite(LOWER_MIDDLE_PIN, HIGH);
// digitalWrite(LEFT_MIDDLE_READER_BAR_PIN, HIGH);
// digitalWrite(RIGHT_MIDDLE_READER_BAR_PIN, HIGH);
// digitalWrite(UPPER_MIDDLE_READER_BAR_PIN, HIGH);
// digitalWrite(LEFT_OUTER_READER_BAR_PIN, HIGH);
// digitalWrite(RIGHT_OUTER_READER_BAR_PIN, HIGH);
// digitalWrite(UPPER_OUTER_READER_BAR_PIN, HIGH);
// digitalWrite(LEFT_INNER_READER_BAR_PIN, HIGH);
// digitalWrite(RIGHT_INNER_READER_BAR_PIN, HIGH);

  for(int i = 0; i < 8; i++)
    digitalWrite(REALTIME_OTG_PIN, HIGH);
  return true;
}

// LED FUNCTIONS
***************
void turnAllLEDsTo(int state)
{
  return turnAllRFIDLedsTo(state);

  digitalWrite(REALTIME_OTG_PIN, LOW);
  digitalWrite(REALTIME_LEFT_PIN, LOW);
  digitalWrite(REALTIME_RIGHT_PIN, LOW);
  digitalWrite(REALTIME_UP_PIN, LOW);
  digitalWrite(REALTIME_DOWN_PIN, LOW);
  digitalWrite(REALTIME_MIDDLE_PIN, LOW);
  digitalWrite(REALTIME_LEFT_OTG_PIN, LOW);
  digitalWrite(REALTIME_RIGHT_OTG_PIN, LOW);
  digitalWrite(REALTIME_UP_OTG_PIN, LOW);
  digitalWrite(REALTIME_DOWN_OTG_PIN, LOW);
  digitalWrite(REALTIME_MIDDLE_OTG_PIN, LOW);
}

void turnAltLEDsTo(int state)
{
  for(int i = 0; i < 8; i++)
    digitalWrite(REALTIME_OTG_PIN, HIGH);
  return true;
}

// Alert LED
void turnAllAlertLEDsTo(int state)
{
  for(int i = 0; i < 8; i++)
    digitalWrite(REALTIME_OTG_PIN, HIGH);
  return true;
}

void turnAltAlertLEDsTo(int state)
{
  for(int i = 0; i < 8; i++)
    digitalWrite(REALTIME_OTG_PIN, HIGH);
  return true;
}

// Control LED
void turnAllControlLEDsTo(int state)
{
  for(int i = 0; i < 8; i++)
    digitalWrite(REALTIME_OTG_PIN, HIGH);
  return true;
}

void turnAltControlLEDsTo(int state)
{
  for(int i = 0; i < 8; i++)
    digitalWrite(REALTIME_OTG_PIN, HIGH);
  return true;
}

// Alert LED
void turnAllAlertLEDsTo(int state)
{
  for(int i = 0; i < 8; i++)
    digitalWrite(REALTIME_OTG_PIN, HIGH);
  return true;
}

void turnAltAlertLEDsTo(int state)
{
  for(int i = 0; i < 8; i++)
    digitalWrite(REALTIME_OTG_PIN, HIGH);
  return true;
}

// Control LED
void turnAllControlLEDsTo(int state)
{
  for(int i = 0; i < 8; i++)
    digitalWrite(REALTIME_OTG_PIN, HIGH);
  return true;
}

void turnAltControlLEDsTo(int state)
{
  for(int i = 0; i < 8; i++)
    digitalWrite(REALTIME_OTG_PIN, HIGH);
  return true;
}

// Alert LED
void turnAllAlertLEDsTo(int state)
{
  for(int i = 0; i < 8; i++)
    digitalWrite(REALTIME_OTG_PIN, HIGH);
  return true;
}

void turnAltAlertLEDsTo(int state)
{
  for(int i = 0; i < 8; i++)
    digitalWrite(REALTIME_OTG_PIN, HIGH);
  return true;
}

// Control LED
void turnAllControlLEDsTo(int state)
{
  for(int i = 0; i < 8; i++)
    digitalWrite(REALTIME_OTG_PIN, HIGH);
  return true;
}

void turnAltControlLEDsTo(int state)
{
  for(int i = 0; i < 8; i++)
    digitalWrite(REALTIME_OTG_PIN, HIGH);
  return true;
}

// Alert LED
void turnAllAlertLEDsTo(int state)
{
  for(int i = 0; i < 8; i++)
    digitalWrite(REALTIME_OTG_PIN, HIGH);
  return true;
}

void turnAltAlertLEDsTo(int state)
{
  for(int i = 0; i < 8; i++)
    digitalWrite(REALTIME_OTG_PIN, HIGH);
  return true;
}

// Control LED
void turnAllControlLEDsTo(int state)
{
  for(int i = 0; i < 8; i++)
    digitalWrite(REALTIME_OTG_PIN, HIGH);
  return true;
}

void turnAltControlLEDsTo(int state)
{
  for(int i = 0; i < 8; i++)
    digitalWrite(REALTIME_OTG_PIN, HIGH);
  return true;
}

// Alert LED
void turnAllAlertLEDsTo(int state)
{
  for(int i = 0; i < 8; i++)
    digitalWrite(REALTIME_OTG_PIN, HIGH);
  return true;
}

void turnAltAlertLEDsTo(int state)
{
  for(int i = 0; i < 8; i++)
    digitalWrite(REALTIME_OTG_PIN, HIGH);
  return true;
}

// Control LED
void turnAllControlLEDsTo(int state)
{
  for(int i = 0; i < 8; i++)
    digitalWrite(REALTIME_OTG_PIN, HIGH);
  return true;
}

void turnAltControlLEDsTo(int state)
{
  for(int i = 0; i < 8; i++)
    digitalWrite(REALTIME_OTG_PIN, HIGH);
  return true;
}

// Alert LED
void turnAllAlertLEDsTo(int state)
{
  for(int i = 0; i < 8; i++)
    digitalWrite(REALTIME_OTG_PIN, HIGH);
  return true;
}

void turnAltAlertLEDsTo(int state)
{
  for(int i = 0; i < 8; i++)
    digitalWrite(REALTIME_OTG_PIN, HIGH);
  return true;
}

// Control LED
void turnAllControlLEDsTo(int state)
{
  for(int i = 0; i < 8; i++)
    digitalWrite(REALTIME_OTG_PIN, HIGH);
  return true;
}

void turnAltControlLEDsTo(int state)
{
  for(int i = 0; i < 8; i++)
    digitalWrite(REALTIME_OTG_PIN, HIGH);
  return true;
}

// Alert LED
void turnAllAlertLEDsTo(int state)
{
  for(int i = 0; i < 8; i++)
    digitalWrite(REALTIME_OTG_PIN, HIGH);
  return true;
}

void turnAltAlertLEDsTo(int state)
{
  for(int i = 0; i < 8; i++)
    digitalWrite(REALTIME_OTG_PIN, HIGH);
  return true;
}

// Control LED
void turnAllControlLEDsTo(int state)
{
  for(int i = 0; i < 8; i++)
    digitalWrite(REALTIME_OTG_PIN, HIGH);
  return true;
}

void turnAltControlLEDsTo(int state)
{
  for(int i = 0; i < 8; i++)
    digitalWrite(REALTIME_OTG_PIN, HIGH);
  return true;
}

// Alert LED
void turnAllAlertLEDsTo(int state)
{
  for(int i = 0; i < 8; i++)
    digitalWrite(REALTIME_OTG_PIN, HIGH);
  return true;
}

void turnAltAlertLEDsTo(int state)
{
  for(int i = 0; i < 8; i++)
    digitalWrite(REALTIME_OTG_PIN, HIGH);
  return true;
}

// Control LED
void turnAllControlLEDsTo(int state)
{
  for(int i = 0; i < 8; i++)
    digitalWrite(REALTIME_OTG_PIN, HIGH);
  return true;
}

void turnAltControlLEDsTo(int state)
{
  for(int i = 0; i < 8; i++)
    digitalWrite(REALTIME_OTG_PIN, HIGH);
  return true;
}

// Alert LED
void turnAllAlertLEDsTo(int state)
{
  for(int i = 0; i < 8; i++)
    digitalWrite(REALTIME_OTG_PIN, HIGH);
  return true;
}

void turnAltAlertLEDsTo(int state)
{
  for(int i = 0; i < 8; i++)
    digitalWrite(REALTIME_OTG_PIN, HIGH);
  return true;
}

// Control LED
void turnAllControlLEDsTo(int state)
{
void playMelody(byte *melody, int length, int volume)
{
  for(int melodyIndex = 0; melodyIndex < length; melodyIndex++)
  {
    if (note == 'p')
      analogWrite(SPEAKER_PIN, 0);
    delayMicroseconds(500);
  }
}

int frequencyForNote(char note)
{
  if (note == 'p')
    return FREQUENCY_LENGTH;
  else
    return FREQUENCY_LENGTH;
}

void playMelody(byte *melody, int length, int volume)
{
  for(int melodyIndex = 0; melodyIndex < length; melodyIndex++)
  {
    int note = melody[2 * melodyIndex];
    if (note == 'p')
      analogWrite(SPEAKER_PIN, 0);
    delayMicroseconds(500);
  }
}

digitalWrite(LowerLeftArrowPin, state);

if (note == 'p')
  analogWrite(SPEAKER_PIN, 0);
else
  delayMicroseconds(500);

for(int melodyIndex = 0; melodyIndex < length; melodyIndex++)
{
  int note = melody[2 * melodyIndex];
  if (note == 'p')
    analogWrite(SPEAKER_PIN, 0);
  delayMicroseconds(500);
}

/* BUTTON FUNCTIONS */
bool buttonWasPressed(bool state)
{
  if (state == LOW)
    return true;
}

if (millis() - buttonPressAt < BUTTON_HIT_TIMEOUT)
  return true;

/* SOUND FUNCTIONS */
int frequencyForNote(char note)
{
  if (note == 'p')
    return FREQUENCY_LENGTH;
  else
    return FREQUENCY_LENGTH;
}

void playMelody(byte *melody, int length, int volume)
# Appendix B: Food Groups Version 2 Arduino Code

Below is the full code that ran the Arduino Mega powering version 2 of Food Groups.
Serial.println("Verifying firmware...");
for(int i = 0; i < length; i++) {
  LCDS[i].clear();
  LCDS[i].begin(16,2);
  delay(1000);
  delay(1000);
  turnAllLedsTo(HIGH);
  cycleRFIDLeds();
  cycleFetchBtnLabels();
  gatherResponse();
  blinkRFIDLeds();
  sendReadTagRequest();
}

if (readerResponseSuccess()) {
  Serial.println("Reading tag...");
  int readTimeout = 0x03E9;
  uint8_t command[5] = { 0x03, 0x21, highByteOf(readTimeout), lowByteOf(readTimeout), 0x00 };
  sendTMRequest(command,5) ;
}

void sendTMRequest(uint8_t *command, int length) {
  responseReceived = false;
  crcCheck = 0x0F0F;
  for(int i = 0; i < length; i++)
    CRC_calcCRC(crcCheck,command[i]);
  resetReaderResponse();
  Serial.write(S0H);
  for(int i = 0; i < length; i++)
    Serial.write(command[i]);
  Serial.write(highByteOf(crcCheck));
  Serial.write(lowByteOf(crcCheck));
  lastOpCode = command[1];
}

void waitForResponse() {
  while(!Serial.available()) { return; }// busy wait
  uint8_t header = Serial.read(); // S0H
  if (!header) { Serial.println("Failed to join WiFi network...");
    responseReceived = true; return;
  } else {
    uint8_t numBytesRead = 0;
    responseReceived = true;
    return;
  }
  if (readerResponseSuccess()) {
    Serial.println("Hmm, the first byte was not the header 0x0F");
    numBytesRead = 0;
    responseReceived = true; return;
  }
  readerResponse[0] = header;
  while(!Serial.available()) { return; }// busy wait
  Serial.println("Hmm, the first byte was not the header 0x0F");
  numBytesRead = 0;
  responseReceived = true; return;
}

if (header == S0H) {
  Serial.println("Hmm, the first byte was not the header 0x0F");
  numBytesRead = 0;
  responseReceived = true; return;
}

bool sendReadTagRequest() {
  Serial.println("Reading tag...");
  int readTimeout = 0x03E9;
  uint8_t command[5] = { 0x03, 0x21, highByteOf(readTimeout), lowByteOf(readTimeout), 0x00 };
  sendTMRequest(command,5) ;
}

void sendTMRequest(uint8_t *command, int length) {
  responseReceived = false;
  crcCheck = 0x0F0F;
  for(int i = 0; i < length; i++)
    CRC_calcCRC(crcCheck,command[i]);
  resetReaderResponse();
  Serial.write(S0H);
  for(int i = 0; i < length; i++)
    Serial.write(command[i]);
  Serial.write(highByteOf(crcCheck));
  Serial.write(lowByteOf(crcCheck));
  lastOpCode = command[1];
}

void waitForResponse() {
  while(!Serial.available()) { return; }// busy wait
  uint8_t header = Serial.read(); // S0H
  if (!header) { Serial.println("Failed to join WiFi network...");
    responseReceived = true; return;
  } else {
    uint8_t numBytesRead = 0;
    responseReceived = true;
    return;
  }
  if (readerResponseSuccess()) {
    Serial.println("Hmm, the first byte was not the header 0x0F");
    numBytesRead = 0;
    responseReceived = true; return;
  }
  readerResponse[0] = header;
  while(!Serial.available()) { return; }// busy wait
  Serial.println("Hmm, the first byte was not the header 0x0F");
  numBytesRead = 0;
  responseReceived = true; return;
}

if (header == S0H) {
  Serial.println("Hmm, the first byte was not the header 0x0F");
  numBytesRead = 0;
  responseReceived = true; return;
}

bool sendReadTagRequest() {
  Serial.println("Reading tag...");
  int readTimeout = 0x03E9;
  uint8_t command[5] = { 0x03, 0x21, highByteOf(readTimeout), lowByteOf(readTimeout), 0x00 };
  sendTMRequest(command,5) ;
}

void sendTMRequest(uint8_t *command, int length) {
  responseReceived = false;
  crcCheck = 0x0F0F;
  for(int i = 0; i < length; i++)
    CRC_calcCRC(crcCheck,command[i]);
  resetReaderResponse();
  Serial.write(S0H);
  for(int i = 0; i < length; i++)
    Serial.write(command[i]);
  Serial.write(highByteOf(crcCheck));
  Serial.write(lowByteOf(crcCheck));
  lastOpCode = command[1];
}

void waitForResponse() {
  while(!Serial.available()) { return; }// busy wait
  uint8_t header = Serial.read(); // S0H
  if (!header) { Serial.println("Failed to join WiFi network...");
    responseReceived = true; return;
  } else {
    uint8_t numBytesRead = 0;
    responseReceived = true;
    return;
  }
  if (readerResponseSuccess()) {
    Serial.println("Hmm, the first byte was not the header 0x0F");
    numBytesRead = 0;
    responseReceived = true; return;
  }
  readerResponse[0] = header;
  while(!Serial.available()) { return; }// busy wait
  Serial.println("Hmm, the first byte was not the header 0x0F");
  numBytesRead = 0;
  responseReceived = true; return;
}

if (header == S0H) {
  Serial.println("Hmm, the first byte was not the header 0x0F");
  numBytesRead = 0;
  responseReceived = true; return;
}

bool sendReadTagRequest() {
  Serial.println("Reading tag...");
  int readTimeout = 0x03E9;
  uint8_t command[5] = { 0x03, 0x21, highByteOf(readTimeout), lowByteOf(readTimeout), 0x00 };
  sendTMRequest(command,5) ;
}

void sendTMRequest(uint8_t *command, int length) {
  responseReceived = false;
  crcCheck = 0x0F0F;
  for(int i = 0; i < length; i++)
    CRC_calcCRC(crcCheck,command[i]);
  resetReaderResponse();
  Serial.write(S0H);
  for(int i = 0; i < length; i++)
    Serial.write(command[i]);
  Serial.write(highByteOf(crcCheck));
  Serial.write(lowByteOf(crcCheck));
  lastOpCode = command[1];
}

void waitForResponse() {
  while(!Serial.available()) { return; }// busy wait
  uint8_t header = Serial.read(); // S0H
  if (!header) { Serial.println("Failed to join WiFi network...");
    responseReceived = true; return;
  } else {
    uint8_t numBytesRead = 0;
    responseReceived = true;
    return;
  }
  if (readerResponseSuccess()) {
    Serial.println("Hmm, the first byte was not the header 0x0F");
    numBytesRead = 0;
    responseReceived = true; return;
  }
  readerResponse[0] = header;
  while(!Serial.available()) { return; }// busy wait
  Serial.println("Hmm, the first byte was not the header 0x0F");
  numBytesRead = 0;
  responseReceived = true; return;
}

if (header == S0H) {
  Serial.println("Hmm, the first byte was not the header 0x0F");
  numBytesRead = 0;
  responseReceived = true; return;
}

bool sendReadTagRequest() {
  Serial.println("Reading tag...");
  int readTimeout = 0x03E9;
  uint8_t command[5] = { 0x03, 0x21, highByteOf(readTimeout), lowByteOf(readTimeout), 0x00 };
  sendTMRequest(command,5) ;
}
responseNumBytesReceived == 0;
if (responseLength == 0)
    for(int i = 0; i < 256; i++)
        (readerResponse[i] == 0);
}

void readRFIDTag() {
    uint8_t* RFIDTag = new uint8_t[16];
    uint8_t* CRCReg = new uint8_t[16];
    for(int i = 0; i < 16; i++)
        RFIDTag[i] = 0;
    // Clear the CRC register.
    CRCReg[0] = 0;
    // Shift the bits over in the data byte
    for(int i = 0; i < 16; i++)
        RFIDTag[i] = RFIDTag[i] >> 1;
    // Shift over the CRC mask
    CRCReg[0] = CRCReg[0] >> 1;
}

uint8_t highByteOf(uint16_t) {
    return (uint8_t)((uint8_t)(highByte & (255 << 8)) >> 8);
}

uint8_t lowByteOf(uint16_t) {
    return (uint8_t)((uint8_t)(lowByte & 0X0000) << 8);
}

void playMelody(byte* melody, int length, int volume) {
    analogWrite(SPEAKER1_PIN,0);
    analogWrite(SPEAKER2_PIN,0);
    delayMicroseconds(500);
    for(int i = 0; i < length; i++)
        if((melody[i] & 0X10) == 0)
            delayMicroseconds(500);
    return;
}

void cycleRFIDReader() {
    if (digitalRead(RFID_PIN) == HIGH)
        digitalWrite(RFID_PIN,LOW);
    if (digitalRead(RFID_PIN) == LOW)
        digitalWrite(RFID_PIN,HIGH);
}

Serial.println("connected to food groups...");
res = sendRfidToWeb();
if(res)
    Serial.println("success = ");
10. Appendix C: Media Lab Mixer Arduino Code

Below is the full code that ran the Arduino Mega powering Media Lab Mixer.

```c
#include <Serial.h>
#include <Wire.h>
#include <Wire.h>
#include <JSON.h>

// define CRC_Poly (unsigned int)x1021
#define CRC_Poly (unsigned int)0x1021

#include <ICRMACROS.h>

int numRfidCardsPresent;
int responseLength;
int responseNumBytesReceived;
boolean responseReceived;
uint8_t tags[15][RFID_TAG_LENGTH] = {{0}};
unsigned long rfidCardSwipedAt;
uint8_t lastOpCode;
unsigned int curCrcReg;

#define WIFI_TIMEOUT 10000
Client client(WEB_HOST, 3001);

int SUCCESS_VOLUME = 1023;
byte SUCCESS_MELODY[] = "2c1p1c6C";
#define SUCCESS_MELODY_LENGTH 4

int FAIL_VOLUME = 650;
byte FAIL_MELODY[] = "3q";
#define FAIL_MELODY_LENGTH 1

byte NOTES[] = {
    'q', 'c', 'd', 'e', 'f', 'g', 'a', 'b', 'C'};
#define NUM_NOTES 9

#include <SPEAKER_PIN.h>
#define SPEAKER_PIN 5

#include <NOTE_LENGTH.h>
#define NOTE_LENGTH 30

int CARD_SWIPED_VOLUME = 1023;
byte SUCCESS_MELODY[] = "2c1p1c6C";
#define SUCCESS_MELODY_LENGTH 4

int FAIL_VOLUME = 650;
byte FAIL_MELODY[] = "3q";
#define FAIL_MELODY_LENGTH 1

byte NOTES[] = {
    'q', 'c', 'd', 'e', 'f', 'g', 'a', 'b', 'C'};
#define NUM_NOTES 9

#define LED_PIN 7
#define WEB_HOST "foolgroups.media.mit.edu"
#define WIFISSID "HZT"
#define WIFI_TIMEOUT 10000

// define LED_Pin
#define LED_PIN 7

// define Web Reader Settings
#define RFID_READER_SETTINGS

// define Serial
#define SERIAL

void parseOutBtnLabels(aJsonObject* jsonObject)
{
    aJsonObject* btn5IsOn = aJsonObject::getObjectItem(jsonObject, "btn5IsOn");
    aJsonObject* btn4IsOn = aJsonObject::getObjectItem(jsonObject, "btn4IsOn");
    aJsonObject* btn3IsOn = aJsonObject::getObjectItem(jsonObject, "btn3IsOn");
    aJsonObject* btn2IsOn = aJsonObject::getObjectItem(jsonObject, "btn2IsOn");
    aJsonObject* btn1IsOn = aJsonObject::getObjectItem(jsonObject, "btn1IsOn");
    aJsonObject* btn5Label = aJsonObject::getObjectItem(jsonObject, "btn5Label");
    aJsonObject* btn3Label = aJsonObject::getObjectItem(jsonObject, "btn3Label");
    aJsonObject* btn2Label = aJsonObject::getObjectItem(jsonObject, "btn2Label");
    aJsonObject* btn1Label = aJsonObject::getObjectItem(jsonObject, "btn1Label");
    btnsOn[4] = (btn5IsOn == aJson_True) ? 1 : 0;
    btnsOn[2] = (btn3IsOn == aJson_True) ? 1 : 0;
    btnsOn[1] = (btn1IsOn == aJson_True) ? 1 : 0;
    withOthers[4] = btn5Label->valuestring;
    withOthers[3] = btn3Label->valuestring;
    withOthers[2] = btn2Label->valuestring;
    withOthers[1] = btn1Label->valuestring;
}

void showBtnLabels()
{
    for(int i = 0; i < NUM_BTNS; i++)
    {
        Serial.print(LCDS[i].getTime());
        Serial.println(LCDS[i].getText());
    }
}
```
NewSoftSerial rfidSerial(2,4);
void setup() { // start the debugging output
  Serial.begin(9600);
  pinMode(LED_PIN,OUTPUT);
  pinMode(SPEAKER_PIN,OUTPUT);
  digitalWrite(LED_PIN, LOW);
  rfidSerial.begin(9600);
  boolean res = configRFIDReader();
  // connect to the wifi network
  res = connectToWifi();
  pinMode(SPEAKER_PIN,OUTPUT);
  if(!res)
    res = configureRFIDReader();
  rfidSerial.begin(9600);
  delay(1000);
  // set up pins
  pinMode(LED_PIN, OUTPUT);
  pinMode(SPEAKER_PIN, OUTPUT);
  pinMode(SPEAKER_PIN, OUTPUT);
  digitalWrite(LED_PIN, LOW);
  delay(1000);
  oldNumRfidCardsPresent = numRfidCardsPresent;
  sendCardData();
}
void bootUpFail() {
  // busy wait
  while(rfidSerial.available() <= 0);
  for(int i = 0; i < length; i++)
    rfidSerial.write(highByteOf(readTimeout[i]), lowByteOf(readTimeout[i]));
  rfidSerial.write(SOH);
  sendTMRequest(command[2]);
  boolean sendReadTagMultipleRequest() {
    Serial.println("Reading tag multiple...");
    uint8_t command[6] = {0x00, 0x2A, 0x00, 0x00, highByteOf(readTimeout[0]), lowByteOf(readTimeout[0])};
    sendTMRequest(command[2]);
    return true;
  }
  boolean clearTagBuffer() {
    Serial.println("Clearing tag buffer...");
    uint8_t command[6] = {0x00, 0x2A};
    sendTMRequest(command[2]);
    return true;
  }
  boolean sendTagData() {
    Serial.println("Sending tag data...");
    uint8_t command[6] = {0x00, 0x2A, 0x00, 0x00, highByteOf(readTimeout[0]), lowByteOf(readTimeout[0])};
    sendTMRequest(command[2]);
    return true;
  }
  boolean connectToWifi() {
    Serial.println("Connecting to WiFi...");
    uint8_t command[6] = {0x00, 0x2A, 0x00, 0x00, highByteOf(readTimeout[0]), lowByteOf(readTimeout[0])};
    sendTMRequest(command[2]);
    return true;
  }
  Serial.println("Failed to connect to WiFi...");
  return false;
}
void getTagBuffer() {
  // busy wait
  while(rfidSerial.available() <= 0);
  for(int i = 0; i < length; i++)
    rfidSerial.write(highByteOf(readTimeout[i]), lowByteOf(readTimeout[i]));
  rfidSerial.write(SOH);
  sendTMRequest(command[2]);
  return true;
}
void getTagBufferResponse() {
  // busy wait
  while(rfidSerial.available() <= 0);
  for(int i = 0; i < length; i++)
    rfidSerial.write(highByteOf(readTimeout[i]), lowByteOf(readTimeout[i]));
  rfidSerial.write(SOH);
  sendTMRequest(command[2]);
  return true;
}
void getTagBuffer() {
  // busy wait
  while(rfidSerial.available() <= 0);
  for(int i = 0; i < length; i++)
    rfidSerial.write(highByteOf(readTimeout[i]), lowByteOf(readTimeout[i]));
  rfidSerial.write(SOH);
  sendTMRequest(command[2]);
  return true;
}
void getTagBufferResponse() {
  // busy wait
  while(rfidSerial.available() <= 0);
  for(int i = 0; i < length; i++)
    rfidSerial.write(highByteOf(readTimeout[i]), lowByteOf(readTimeout[i]));
  rfidSerial.write(SOH);
  sendTMRequest(command[2]);
  return true;
}
void sendTMRequest(uint8_t *command, int length) {
  uint8_t command[length+2] = {0x00, 0x2A};
  sendTMRequest(command);}

if (readerResponseSuccess()) {
  // busy wait
  while(rfidSerial.available() <= 0);
  for(int i = 0; i < length; i++)
    rfidSerial.write(highByteOf(readTimeout[i]), lowByteOf(readTimeout[i]));
  rfidSerial.write(SOH);
  sendTMRequest(command[2]);
  return true;
}

if (readerResponseSuccess()) {
  // busy wait
  while(rfidSerial.available() <= 0);
  for(int i = 0; i < length; i++)
    rfidSerial.write(highByteOf(readTimeout[i]), lowByteOf(readTimeout[i]));
  rfidSerial.write(SOH);
  sendTMRequest(command[2]);
  return true;
}

if (readerResponseSuccess()) {
  // busy wait
  while(rfidSerial.available() <= 0);
  for(int i = 0; i < length; i++)
    rfidSerial.write(highByteOf(readTimeout[i]), lowByteOf(readTimeout[i]));
  rfidSerial.write(SOH);
  sendTMRequest(command[2]);
  return true;
}
while(!readerResponseAvailable()) { // wait Serial.println("Hmm, the first byte was not the header 0xFF"); numBytesRead = 0; responseAvailable = true; return; }

readerResponse[0] = readerSerial.read(); // CRC 0

if(readerResponse[0] == 0) { // CRC 1
    return;
}

Serial.println("There was no response, or reading the
status word failed.");
else if (i > 0 || numBytesRead > 0) { +
    Serial.println(readerResponse[i] ? HEX); Serial.print(readerResponse[1],HEX);
    readerResponse[1] = rfidSerial.read();
    // CRC 2

    for(int i = 0; i < 256; i++) {
        Serial.print(tags[i][j],HEX);
        while(rfidSerial.available() <= 0);
        // busy wait
        while(rfidSerial.available() <= 0); // CRC 3
        delayMicroseconds(freq);
        analogWrite(SPEAKER_PIN,volume);
    }

    for(int i = 0; i < 4; i++) {
        // Shift the bits over by one.
        curCrcReg = (curCrcReg >> 1) + 0x80;
    }

    while(rfidSerial.available() <= 0); // busy wait
    Serial.println("got response..."); retur
// allow time to receive data
delay(100);

char response[256] = '{'0'};
int nextI = 0;

boolean foundBody = false;
boolean lastWasN = false;
int consecNCount = 0;

while (client.available() > 0 && nextI <= 255) {
  char c = client.read();

  if (c == 'n') {
    consecNCount+=1;
    if(consecNCount == 1) {
      client.read(); // get rid of the /r!!!!!!!!!!!
    } else {
      consecNCount = 0;
    }
  }

  else {
    consecNCount = 0;
    nextI++;
  }

  //
  get rid of the "/r!!!!!!!!!!!

  if(foundBody) {
    if(consecNCount == 2) {
      Serial.println("found body...");
      foundBody = true;
    }
    Serial.print(c);
  }

  else if(consecNCount == 1) {
    Serial.println("parsed response: ");
    Serial.println(response);

    // hack to test if this is a json response
    if(response[0] != '{') {
      Serial.println("bad response from server...");
      return false;
    }
  }

  if (client.available() <= 0) delay(100);
}

aJsonObject* jsonObject = aJson.parse(response);
aJsonObject* success = aJson.getObjectItem(jsonObject, "success");
Serial.println("success = ");
Serial.println((success->type) == aJson_True ? "true" : "false");

boolean res = (success->type) == aJson_True;
aJson.deleteItem(jsonObject);
return res;