INFO 4410 B.A.R.

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INTRODUCTION

The Bartender Assistant Robot (or B.A.R.) is a modular interactive robot that uses light and motion to improve communication between the bartender and bar patrons. The goal of the B.A.R. is to facilitate interactions between bartenders and bar patrons in a loud and busy environment with minimal interference into already existing interactions.

In our ideation process we found that one of the main barriers to communication between bartenders and patrons is noise. It is also difficult for bartenders to keep track of who is up next to order. All of these issues often culminate in impatient patrons. Our design goals are: to help facilitate wait times in bars; to help bartenders keep track of the queue; to ease communication among the bartending staff regarding who has been served or who has been waiting for a while; and to help regulate bad behavior.

The product design had several important components that were integrated into a functional system. There was a linear motion track, operated by a stepper motor and remotely controllable on one axis through an IOS app called Blynk. There was a lightbulb attached to this linear motion system, which was also controlled through another IOS app; the lightbulb could be controlled in luminosity and hue of light. Finally, we had an acrylic box covering the whole system, with crumpled paper attached to the top and sides. The overall product was a bartop, with a diffused light, which could move up and down and change in brightness and color. The final prototype is designed as a single unit, with the intention for several of these units to be placed side-by-side to create a bar counter.

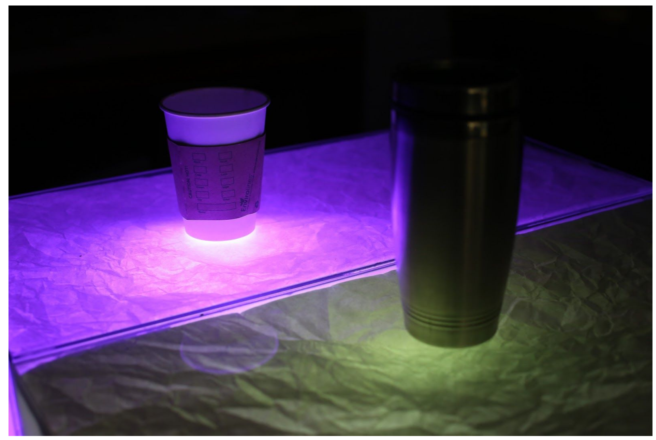


Figure 1. An image of the final prototype

RELATED WORK

1. Light signaling

In order to better support bartenders' work in a dimly lit and loud environment with a robot agent, we considered a number of potential signaling methods, and arrived at using light as the mode of signaling. Research in perceptual psychology has long examined the process of covert visual orienting, or how people choose to attend to different objects within their visual fields [3, 8]. Covert visual orienting is controlled by two modes, exogenous and endogenous. The more important mode relevant in our robotic design is the exogenous mode of control, which describes the "reflexive orienting" as a response to stimuli in the environment such as a flash. As Muller and Rabbitt's 1989 paper demonstrated, such reflexive orienting is best triggered by peripheral cueing, such as a flash of light. Using a flash of light in the peripheral, the shift in people's attention can be triggered automatically with low effort. These experimental results in perceptual psychology provided evidence for the effectiveness of choosing light as a signaling mechanism.

2. Implicit interaction

The framework for the design of implicit interaction has been beneficial to the consideration of human-robot collaboration, as it seeks to utilize the practices and cultural norms human established to inform the design of robotic agents in order to better streamline the process of interaction [1, 3]. Specifically, Ju discussed how the framework "divides the space of possible interactions" between the agents involved in an interaction, using two axes of attentional demand and initiative. It structurally organizes robotic agents and the types of interactions they afford into four quadrants - foreground interaction, background interaction, reactive interaction and proactive interaction. Examining robotic and interaction design through an implicit design framework make the discussion of which more productive.

3. Prior lighting design

We now look at two prior robot designs that utilize light as a mode of signaling and communication in order to facilitate better collaboration between robotic and human agents.

1. Robot Light Skin

The team behind RLS wished to design an apparatus that better robot agents' ability to aid human operators [6]. As the manufacturing industry shifts from full-automation to a production philosophy of human-industrial robot collaboration, authors recognized the important role of communication plays in fully realizing the kind of collaboration envisioned. They took inspiration from Andon lights, which in the context of visual management, "support lean production systems as a means of indicating machines' status". Tower lights are representative of traffic lights, which are able to communicate effectively messages that are perceivable by those visually capable, without much significant cognitive workload on the individual.

RLS therefore is a visual signaling and indication system authors hope to implement in an industrial manufacturing unit. The device is a soft apparatus that will cover an industrial robot's wrist and upper arm. The device utilizes different colors as indication of system state.

Authors further conducted user studies with 12 participants recruited from their host institutions. Using a repeated measure within-subjects 2x2 design, the authors examined signal light type and participant position and their impacts reaction time, hit rate, task performance, ease of monitoring, and visual fixation and dwell. Researchers further employed an eye tracker installed within what appears to be a pair of safety glasses, to further validate their design considerations. These experimental measures were able to prove the effectiveness of RLS, and showed lower miss rate and higher performance.

2. Real World Interface Pioneer

Separately, [4] details the exploration of using visual cues as communication mode as well, in the context of the design for a mobile robot, aptly named *Real World Interface Pioneer.* The bot has mobility and was able to perform simple tasks such as playing a ball-passing game with a human participant. Authors' interest in visual cues led them to produce a light-emitting visual communication system that relies on the frequency of light emission to code different meanings onto robotic behavior. The bot additionally is outfitted with a vision module that detected different colors to evaluate the position and area of the blobs detected by the module. The communication module is able to produce four types of meaning, again using the manipulation of frequency in light emission. Authors conducted experiments with the Real World Interface Pioneer and human participants. Human participants were given flashlights manipulated to emit light comprehensible to the robotic agents. Authors concluded that the method has its limitations.

DESCRIPTION OF OVERALL DESIGN

Our design process followed four main threads: the overall interaction design and the design and implementation of the three light modalities: movement, diffusion, and color.

Interaction Design

Initial Design

Description of initial design question, issues that bar teams deal with. Some of our initial designs included the DJ bot and the Piano Bar:

DJ bot

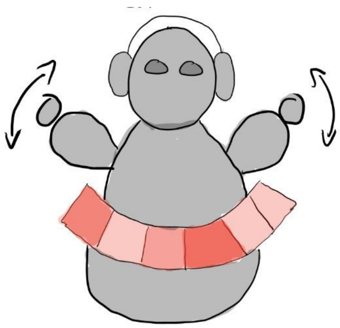


Figure 2. A sketch of the DJ bot

The DJ bot is a small anthropomorphic robot that resembles a DJ. The idea for this was to place a small robot, about a foot in height and width elevated above the bar and centrally located. This DJ Bot would have a "Turn Table" attached to it with multiple lights of varying intensity on it. The bot would nod, or dance with the rhythm of music while the turntable luminates sections of the bar that needs assistance.

The patrons would see this as an overseeing dancing robot but to the bartenders, more of a communication tool. The areas of the bar with higher intensity would indicate where help is needed. However, potential problems can occur from this. Answering questions like, how will this bot distinguish between who has been served at the bar and who has not. This key question made us to evolve our robot to a different design.

The Piano Bar

The Piano Bar is a modified bar with a surface divided into tracks that hinge. creating a seesaw motion that allows bar patrons and bartenders to slide cups back and forth. This would presumably be used in situations in which a bar patron needs service and had an empty cup, or when a bartender is giving a drink to a patron. We decided against it because it could very easily lead to spills and be intrusive to the bartender.

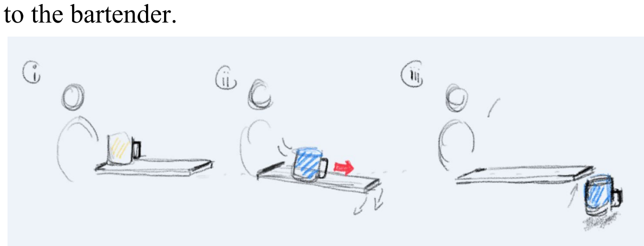


Figure 3. A sketch of the Piano Bar

B.A.R.

We eventually landed on the B.A.R.--the Bartender Assistant Robot, integrated with the setting of a bar, much like the Piano Bar. However, the B.A.R. that uses light as an indicator as opposed to movement of the bar's surface. In line with keeping the B.A.R. as unobtrusive as possible, any movement of the bar would be too disruptive to patron's experience.

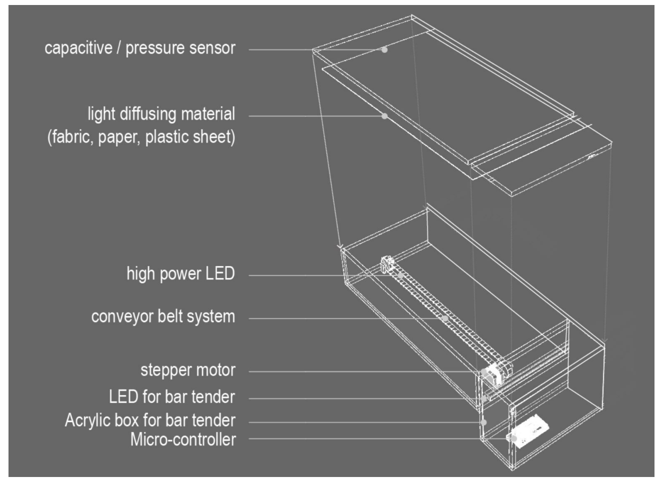


Figure 4. Exploded axon diagram showing components of one module of B.A.R, including acrylic box panels, light diffusion paper, LED bulb, track system, motor, timing belt and micro controllers.

1. Surface Light

The B.A.R. has a translucent surface so that patrons can see the movement of a light underneath the surface. Upon tapping the surface light, the light moves from the patron to the bartender, indicating to the patron, the bartender, and all other patrons at the bar that a patron in that area is seeking service. Once the bartender has served the patron, they tap the light and the surface light slides back to the patron

2. Indicator Light

There is a row of indicator lights on the bartender's end of the bar, unable to be seen by the patrons, corresponding to each surface light. When a surface light is tapped by a patron, the indicator light turns on. On the bartender's side, the brightness of the indicator lights designate the recommended order in which the bartender should attend to patrons. We also discussed the use of color as an alternate modality to brightness.

We decided to keep the order of service requests hidden from patrons so that patrons could only see how many areas were requesting service. This is because we wanted to maintain the autonomy of the bartenders, and allow them to make the final decision on who to serve and when, without pressure from patrons.

3. Interaction Scenarios

We initially designed for the following three interaction scenarios, ranging from simple to increasingly complex to allow for the B.A.R. to be useful in any bartending team/patron combination:

1. A one-to-one interaction between a bartender and a patron
2. A multiple patron interaction in which many patrons seek service from a bartender at the same time, ranging from two patrons to a full bar.
3. The same multiple patron interaction as described above, but with the number of patrons outnumbering the available seats at the bar. Groups of patrons not at the bar may walk up between barstools, seeking service

To design for the most complex interaction, we decided that the tracks of surface lights should not correspond to each bar stool. This would create complications in a situation in which every patron at the bar was interacting with their light, and multiple external groups of patrons approached the bar: there would be no way for them to indicate that they needed service.

We decided that each surface light track would indicate an area of the bar that the bartender should attend to. We recognize the powerful role that eye contact between a patron and bartender makes in initiating an interaction; the bartender being attentive to the correct area of the bar on a busy night and seeking the patron who needs service would be enough to initiate an interaction.

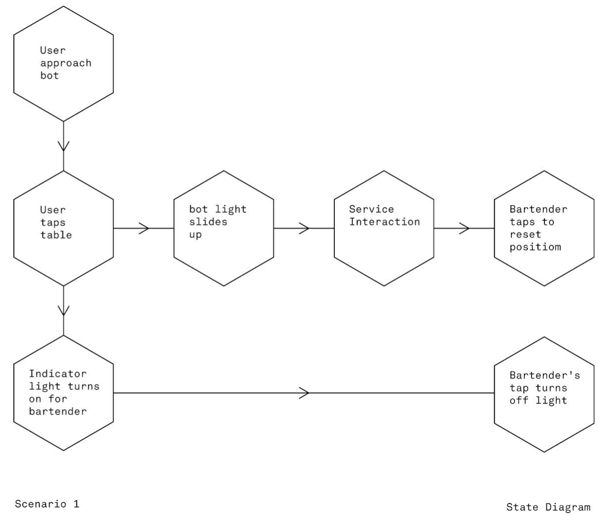


Figure 5. *Scenario 1:* An interaction between a single user and the bartender

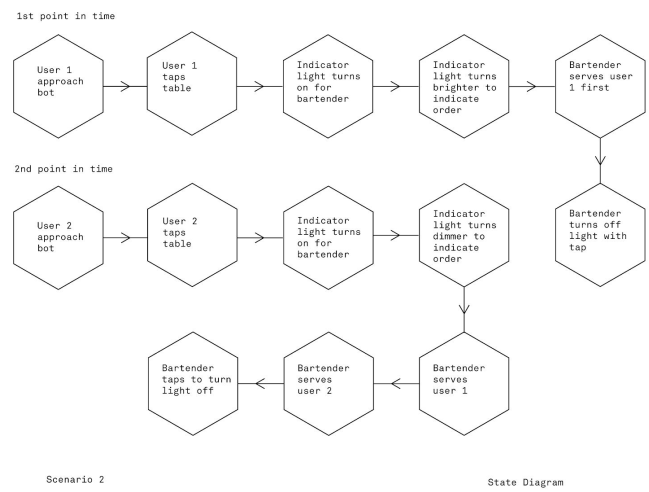


Figure 6. *Scenario 2:* An interaction between two patrons and a bartender

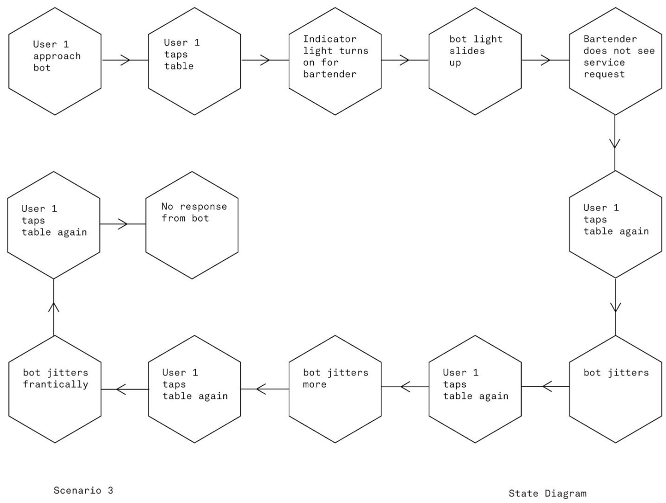


Figure 7. *Scenario 3:* In this scenario, a user is impatient and/or the bartender is unresponsive.

During user testing we interviewed a bartender who shared that some of the worst interactions with patrons that they have are when inebriated patrons get increasingly loud and invasive when trying to get a bartender's attention, in some cases even touching or grabbing the bartender's arm. To prevent this, we designed the surface light to mimic the mood of the patron, and make the patron feel as though their concerns are being heard by moving with an animated jitter, and in some user tests even turning red. Eventually, the robot is unresponsive, as we did not want to infinitely reward or engage with aggressive and impatient behavior.

Initial Evaluation

Since we were creating a very small scale prototype, we decided not to include the bartender signal light. In addition, focusing on only two modules was the best option for us in terms of maximizing quality and being time- and cost-effective.

Modified Design + Implementation

We decided on creating one track per module, and creating two modules. Since we would only be demonstrating with two modules and tracks, we did not deem the bartender indication system necessary for this prototype, although it would still be included in any future full-scale prototype.

Final Performance

The final prototype worked well to demonstrate modularity and single-person/two-person interactions. The main limitation is that it cannot demonstrate interactions between large groups of patrons and bartending teams. This smaller-scale prototype serves as a proof-of-concept for the affordances of the interface.

Movement of light

Initial Design

The motion of the light source was the most crucial aspect of the robot. The light source itself needed to be intense enough to capture the attention of both patrons and bartenders whilst still being able to communicate its affordances. Our initial approach involved the use of an LED strip and a moving bulb on a track. The LED strip would be easy to control and movements would have a large range of motion. However the LEDs themselves would have been too small, making it difficult to communicate affordances. Even when a matrix was set up, containing multiple rows of LED strips, there was little diffusion visible on the surface. As such, we decided to utilize one large LED bulb that would move along a track, from one side of the module to the other. This bright, multicolor bulb controlled through bluetooth provided the intensity needed to gain attention in a high stimulus environment.

Initial Evaluation

The bulb is easy to control and very vibrant in a dark environment. However, we focused on the diffusion of the bulb as one of our main design aspects. We needed a way to diffuse the light through the surface in a way that was similar to a circular button. To do this we tried a few different options. In the earlier stages of development we used a cup with the bottom of it cut out to display the circle. This first design was not working in the way we wanted to so we tested different types of materials for the surface. Different types of paper and acrylic was matched with each other until we found the perfect diffusion. The paper was crumbled too, which added a softer feel to the light.

Modified Design

We decided on the motorized track approach. The implementation required us to both order various components and leverage 3D printing and laser-cutting for custom fixtures.

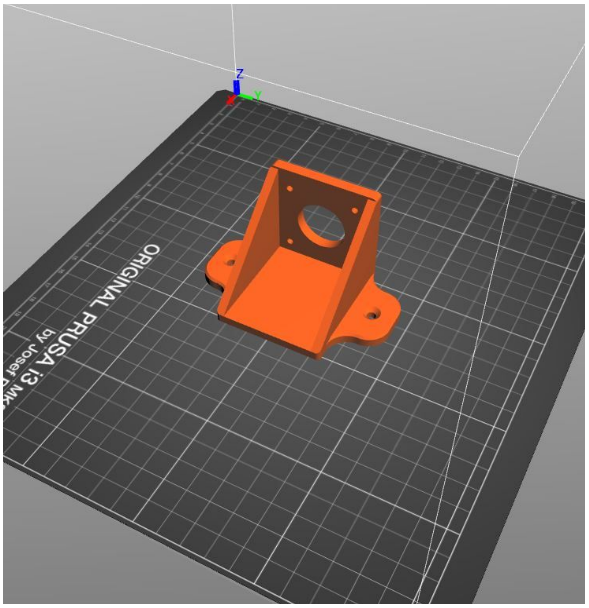


Figure 8. A 3D printed bracket to secure the stepper motor onto the plywood baseboard

Our design of the track was constructed as follows: a platform fitted with linear motion rods on both ends, parallel to each other. They were held down with stances on each end. A holder for the bulb was created and oriented between the two rods and connected at the same spot. The holder was easily able to slide from one end of the module to the other by way of a rubber pulley was powered by a stepper motor. This setup allowed for seamless linear motion, multiple gesture implementation, and the right height for the intended level of diffusion.

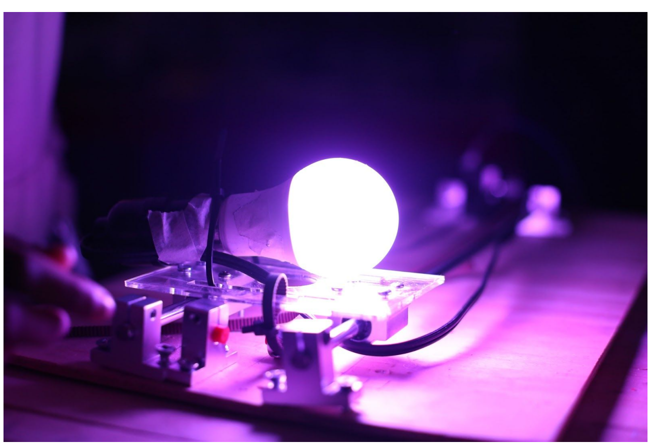


Figure 9. The surface light track

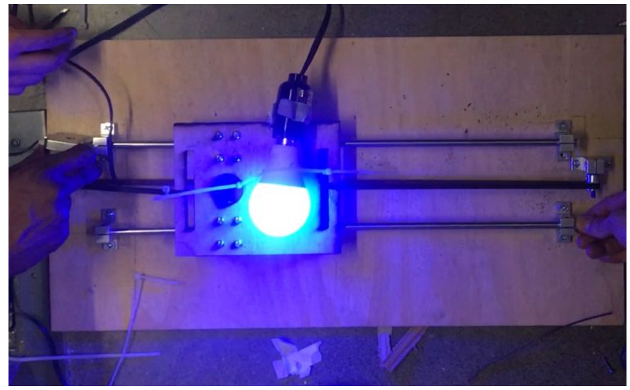


Figure 10. An aerial view of the surface light track

Implementation and Final Performance

We ended up constructing two of the modules described above, each with its own timing belt, track, and bulb. To enable motion, we fitted each puttley to a stepper motor. Both motors were connected and powered by a single microcontroller. The steppers each required 9V of power whilst the microcontroller could only output 5V. As such we made use of a 9V bridge connected to a servo driver. The direction and gestures of the lights were programmed onto the microcontroller and controlled via a mobile app. We made use of Blynk, a popular internet of things (IoT) platform, to enable this wireless control interface. Although our implementation leveraged WiFi communication, the platform allows for Bluetooth and wired approaches. This allowed for Wizard of OZ (WoZ) style movement that we used during testing and presentation. When users performed the prescribed gestures, the light would glide across the table. A resting slow pulse from the bulb was implemented when no one interacted with the bar. Once a user interacted with it, the color would change and coordinate with the stepper to make a unique interaction. Once the light reached the other side and the user would be attended to by the bartender. The light would change back to the original color and glide back to the starting position upon the completion of this transaction.

Light diffusion

Initial Design

Either a layer of diffusing material moving vertically, or static diffusing layer

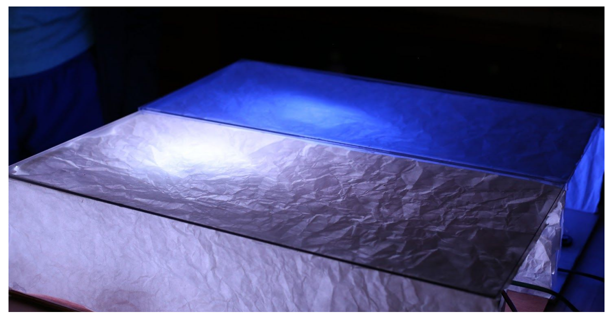
The diffusion of the bulb was an important design choice that we had to make. Since we finalized the linear motion with the track, the light diffusion went through some evolution processes. First we considered adding another degree of freedom which would involve vertical motion. This vertical motion would only be for the paper material that was below the acrylic surface. The problem that arises from this, was the tautness of the paper. If we pulled too tight, the paper would rip. So even pulling on the four corners as tight as possible led to the paper sagging in the middle. Not only was this inefficient for our desired use, it also did not look appealing. Instead we crumpled the paper to provide this texture in a randomized way. The light slightly diffused both ways as it glided along the track. This effect actually acted a little differently than we expected but overall came out better. The intensity was never too strong or two soft but varied in between the two in the right manner.

Upon further developing the mechanism for moving the actual lightbulb down the track, we realized it was [alreadymore complicated than we thought]. Issues with the amount of space in the box was a big factor. The systems are placed on top of an already existing bar so it can not be too tall. Bar tables are already set at a height appropriate for patrons, so we do not want to manipulate this factor too much. Our final design stands 6 inches in height and two feet in length. The two feet is the average length of a bar table. Also each system is a foot wide. This width was a crucial part of our design because we do not want to interfere with the current interactions, only facilitate. So for example, if someone is a few people back from the bar but wants a drink, they have to wait until they have space to get to the bar. Once there, they will notice the diffused light in the state of rest and be able to interact with it.

Modified Design

Adding another modality--amount of light diffusion--did not make sense at this point in testing, as we did now know what it would signal. Due to time constraints wanted to focus on honing in our design of what the other existing modalities (movement and color).

However, in user testing, we discovered an application for varied diffusion. We cut out a coffee cup and encircled the light bulb with it to create more of a "button" effect, and over half of users tapped as a response. Other responses consisted of swiping and hovering, so for the most part users picked up on the physicality of the interaction with minimal guidance. Users were either told that it was a bar robot, or that it was a robot, and were told to interact with it however they see fit. In some of the cases in which users were told it was a bar, there was also a coffee cup placed on the bar.



Figures 11. and 12. The surface light with and without the paper cup, showing the difference between and increased "button" look and a more diffused one

Implementation

We decided to place the surface of the table, two inches from the light. This close spacing facilitated a circular light that we were looking for. Compared to the proximity of the box, it was a perfect fit. A patron can easily identify which light for them to use and interact. As you can see in Figure 6 and 7, the light is very strong in the middle and fades in slightly different directions along the outside. This idea was helping users identify that the light was just one tap interaction, rather than using their finger to follow the light.

Final Performance

The final performance worked very well. Our participants describe our design as "futuristic" and "compelling". The use of this bot was easy to identify to the users even when given minimal insight.

Color of light

Initial Design + Implementation

The most important function that the modality of color performs in the current prototype is to display the affordance of tapping. We implemented this by using the MagicLight wifi light bulb. We alternated between a light and darker blue to create "breathing mode".

Initial Evaluation

During user testing about half of all users tapped the bot on the surface light, demonstrating that "breathing mode" effectively affords a tap interaction.

Final Performance

The breathing mode worked effectively as we intended in the final prototype. Breathing mode also worked equally effectively with a range of colors, as long as the range was between a more and less saturated version of the color.

FUTURE WORK

Hardware

Based on user feedback, alternative clear materials can be considered for the case construction. Current acrylic shell is not sturdy enough to be used as a table surface, more rigid and higher grade plexiglass may be tested. The regular stepper motor used in the project granted a smooth movement for the light bulb, however, the speed is difficult to control and in some cases faster jittery motion can not be achieved, other types of motors can be explored. While the original design intention was to create light boxes that are thin enough to rest on existing bar table, the final product was too tall, lower tracks and smaller light bulbs can be considered to lower the height of the box. Additionally, as suggested by users, LED strips might be a better choice instead of one singular light bulb that may add more interesting light motions and effects to the interaction. Also current track only allows one direction of move, two stepper motors can be used to construct a laser-cutter style bed to create finer movement in two directions. Overall, the circuit design can be improved to be more integrated into the box. The initially proposed bartender side box can also be fabricated to include in future experiment.

Interaction

Currently there are a few controlled variables for interaction including color, breathing motion and light movement. More complex elements can be programmed to increase the variety of interaction. For example, rapid blinking can be associated with higher attention demand or a suggestion for a dangerous situation. A game style interface can be implemented during non-busy hours, so the interaction is more social and casual than task driven. Degrees of light focus and diffusion should also be a controlled parameter. Horizontal light movement or light-light interaction can be programmed to improve patron-patron communication.

Design

There are many potential design improvements. First, a latch system can be implemented for better box to box connection. Since the bar table is a high impact surface, it must be able to withstand large amounts of force and load, the light box can not be too delicate and must be designed to last longer, resilient to smashing and vandalism and be easy to clean and maintain. Additionally, current box design is a fixed length. To better fit to any table width and be truly modular, another set of track system can be embedded so the boxes can be pulled to extend or retract upon needs. Other non-rectangular module shapes can also be explored. Hexagon and triangles would certainly require other types of arrangements and hence may create more varied effects and visual outcomes. Lastly, tests for different materiality should be conducted to include multi-sensory inputs such as touch, sense and even verbal commands.

Implementation

As tested in the Green Dragon cafe on the Cornell campus as well as in the lab, the product did not receive optimal testing conditions. To be more realistic, contacts can be made with local bars to test the light boxes in real situations. Other similar experiment environment can also be included such as restaurants, clubs, activity centers and hotel lounges. Also, the final design only has 2 units side by side, to fulfil the original design intent, multiple light boxes will be constructed that can populate the entire length of the bar table. A more detailed true experiment can be constructed with control groups and intervention groups to verify the validity and reliability of the design. Data can be systematically collected through interviews, surveys, observation and other quantifiable measures, followed by statistical analysis to provide better understanding and support arguments for design conclusions.

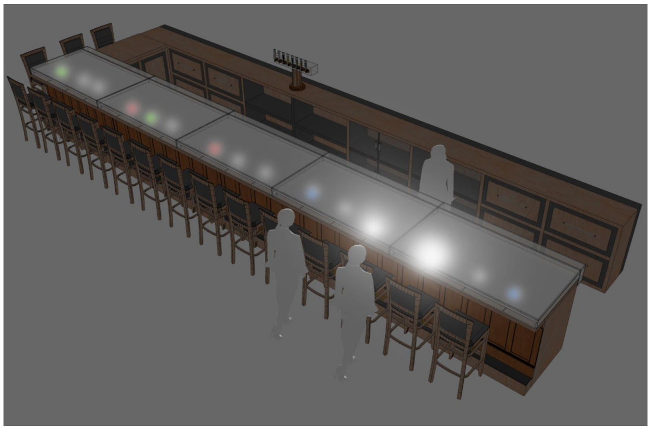


Figure 13. An example of a fully implemented B.A.R.

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