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Learning Light - cognitive training and diagnostics with a light system

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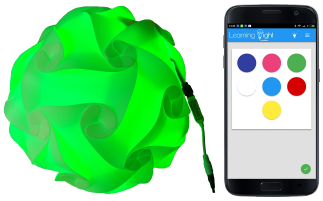

Learning Light

Abstract
This paper is focused on exploring new techniques of therapy, training or diagnostics people who have various problems with cognitive functions - reactions, attention deficit or visual memory. This can cover a large group of people - from ADHD kids to people dealing with stroke consequences. The methodology used here is based on interaction with both a real world item and a mobile application where the user has to pay attention to a light, which changes its color, and react to it using the application. This system is accomplished by setting up an Arduino controller that is connected to a phone or a tablet via Bluetooth. After receiving a command from the phone, the controller then sends a radio frequency signal to the light. Therefore, the application can measure the user's reaction time, which is necessary for keeping track with the therapy process or categorizing the user when being diagnosed with a cognitive problem.

Keywords: Cognitive training — ADHD therapy — Neurofeedback alternative

Supplementary Material: Demonstration Video

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1. Introduction

Our world is more and more riddled with issues and illnesses. Talking just about ADHD (attention deficit and hyperactivity disorder), 11 percent of American children, ages 4 to 17, are diagnosed with ADHD [1]. That is an incredible increase of 42 percent in just eight years. More than a half of these children are using medication, the rest is depending on behavioral therapy, experimental techniques or simply do not care. The issues might stay with a person also in his or her adult life. People with ADHD have significantly higher chance of ending up with a drug addiction, or cause of car accidents and so on. This is why this project might make a difference - those problems are growing fast, but the early diagnostics and good, affordable therapy options not fast enought.

The objective of this project, which I named Learning Light, is to try to help with diagnostics and then also with therapy or training. But it is not just ADHD - it can be used for memory training, color recognition and so on. There are many more possibilities of usage like peripheral vision training, examining which way the user tries to remember colors, connecting colors and items (logical training). When talking about diagnostics, it is important to make some sort of standard in declaring whether a child (or an adult) has some kind of problem. For example, there is no specific way to diagnose a child with some sort of a cognitive problem. It is usually being done by showing some pictures to a child, and according to the way the child responses, he is or is not diagnosed. But this system is built just on examiner's opinion. When we had a sample of chil-

dren without any problem and we could measure their reactions, memory and color recognition, it would give us better chance of a successful diagnosis of someone who is not responding so well.

There are plenty of mobile applications that are focused on similar issues - memory, reaction or attention training. But it also stays with the device, no real connection to any physical substance. On the other hand, there are products like FitLight [2] that are built from lights, but the point there is a physical training - the user reacts to the lights and has to touch them as soon as possible. My project stands somewhere in the middle - it combines the application with some physical item. I did not find any other product that would be the same as mine. As far as ADHD therapy goes, the most similar technique is called neurofeedback - a controversary method where a child puts an EEG helmet on his head that measures his brain waves. He or she sits in front of a computer and plays sort of a game where he or she needs to focus - and when the focus and attention is detected through the brain waves, the child is rewarded. This is how the child learns how to control his attention. The point is actually similar to my project, even though the execution is different.

Figure 1. A picture showing a simple use case of the Learning Light.

My solution is based on a light and a mobile application. The application controls the light using a controller based on an Arduino, a Bluetooth module and a RF transmitter. There are two basic modes now - the first is simply focused on the reaction time, where the user needs to react as soon as possible to a change of color. The second one focuses on memory - the light flashes a sequence of colors that has to be memorized by the user. After the sequence is completed, the user needs to recapture the sequence in the right order (see Figure 1). The reaction time is being measured by the appllication, giving a big potential in both diagnosis (making a sample of standard reaction time) and therapy or training. Keeping the score means raising user's desire to get better or beat his therapist/companion. It is an important gamification feature.

2. Technical design

In this chapter I would like to introduce the technical design of the Learning Light. The system is made of three main parts shown in Figure 2:

1. the light, which receives control signals at a given radio frequency from the controller,
2. the controller, which receives control signals from the application and transmits them at a given radio frequency to the light,
3. the mobile application, which controls the behaviour of the light. It uses device's Bluetooth for the connection to the controller.

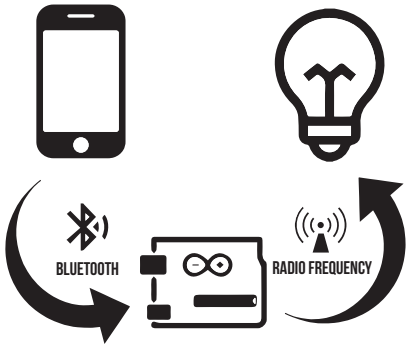

Figure 2. A structure of the Learning Light connection system.

2.1 The light

In my prototype the light is made of a RGB LED strip, a radio frequency receiver, a plug-in and a plastic cover that makes the light look like a lamp (Figure 3). The question here is whether to connect the RGB strip to the Arduino directly and change colors through analog pins, but in order to add more lights to one system, radio frequency is probably the best way.

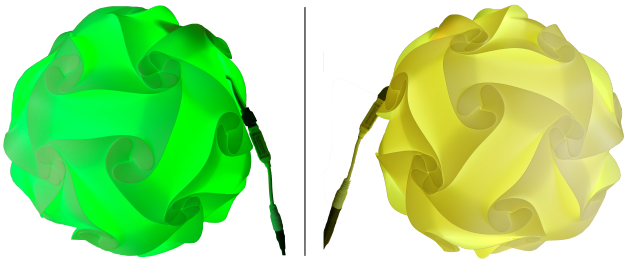

Figure 3. The light - a RGB strip connected to a RF receiver, all placed into a plastic cover.

The radio frequency receiver on the light is paired with a remote control. For my purpose, I needed to decode the signals from the remote control in order to control the light through my transmitter connected to Arduino. For that I needed an extra radio frequency receiver connected to Arduino that could decode the signals from the remote control.

2.2 The controller

The controller consists of an Arduino Leonardo and a breadboard with a Bluetooth module (HM-10) and a radio frequency transmitter connected to it (Figure 4). The Arduino reads messages from the application via the Bluetooth module and is programmed to simply translate these messages into a form that is acceptable for the light. The Bluetooth module is connected to 3.3 V and two digital pins, while the radio frequency transmitter is powered with 5 V and just one digital pin is enought for transmitting. For connecting the components I used information from Arduino Leonardo documentation [3].

The *Arduino* code works like a translator - it reads messages from the *Bluetooth* module defining the light's behaviour and then transmits them via radio frequency transmitter.

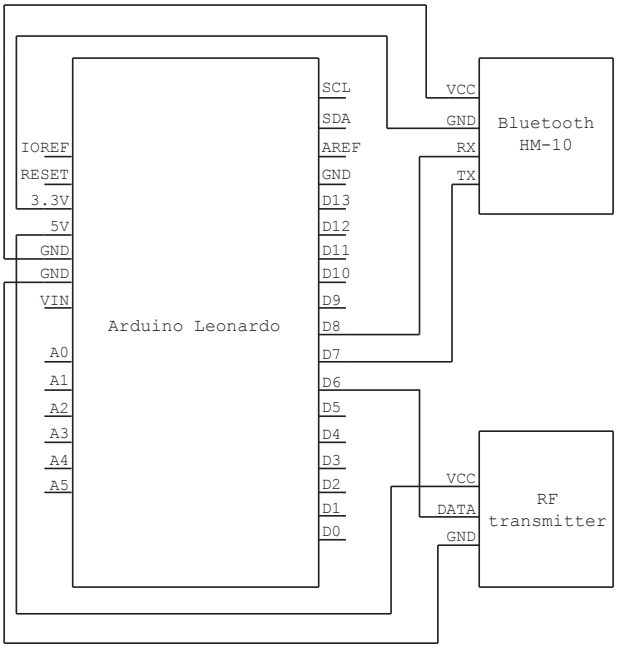

Figure 4. A picture showing the connection of the *Arduino*, the *Bluetooth* module and radio frequency transmitter

When buying a Bluetooth module (in my case HM-10), a buyer should be careful because there are a lot of rip-offs which look the same as HM-10, but react to slightly different control signals. For setting up my Bluetooth module I used HM-10 datasheet [4].

2.3 The application

The method I decided to use is called *hybrid application development*. Basically, hybrid applications are developed with *HTML*, *CSS* and *JavaScript* and then compiled to native mobile platform by *Cordova* (which I used) or *PhoneGap*. This means that I did not need to use any big *IDE* like *Android Studio* and had the opportunity to compile the application to both *Android* and *iOS*. Of course, there are downsides - the hybrid application's performance is far from fully native application's performance. But in this case this was not a problem because the Learning Light application does not require complex data operations or graphics, just basic *CSS*.

I used *Materialize CSS* because at this time, *Material Design* is one of the most common ways of developing an application or a web. There is a lot of features already completed (plus responsiveness), which means that creating a layout of the application was simplified. The application uses one of the *Cordova*'s native Bluetooth plugin that just needs to know the other module's name in order to connect to the controller. Then it is easy to send a control signal when a color change is needed. Other useful plugins I used were for serving phone's buttons, vibrations and access to memory in order to save the highscore.

Figure 5. An image of the Learning Light's welcome screen and the screen after successful connection.

One more important plugin I used is the *Crosswalk web runtime*, which replaces the device's default *WebView* and ensures united view and code execution. The problem is that on each device that uses different operating system there is a difference in my application's view and moreover, even in executing the *JavaScript*. This plugin also improves performance, so

the view is more smooth even on older devices. The only downside is that the application's size is significantly larger.

3. Usage

In this section the system is explained as a whole. After powering the light and the controller, the user needs to connect the application and the controller. After a connection is established, a top navbar and a menu is shown (see Figure 5). The top navbar consists of two buttons - one for turning on and off the light, second for menu toggle.

There is also a dynamic connection status button placed in the bottom right of the screen (Figure 8). If the connection is successful, it shows a green checkbox. When the connection is interrupted, a red exclamation mark is shown. In this situation, after tapping this button, a new connection attempt is made.

3.1 Reaction training

There are two main modes in the menu. The first of them is purely about the reaction time - the light flashes by some color and the users have to press as soon as possible a button of a color they see. If they press the right color, then the light flashes with another color right away. The settings for this mode include the game length (in seconds or in color changes) and a color shuffle, i.e. after a successful click, the interface with the color buttons shuffles and makes the training more difficult (see Figure 6).

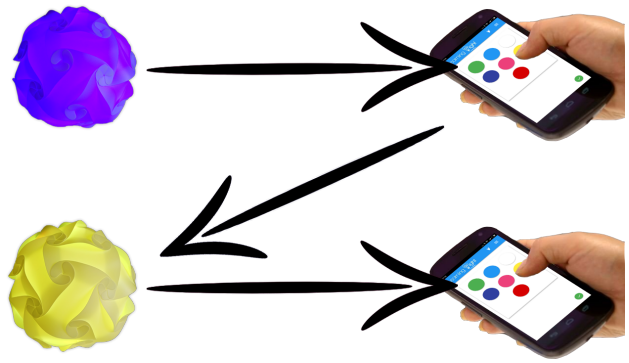

Figure 6. An example of reaction training. When a color flahses, the user needs to react as soon as possible.

3.2 Memory training

The second mode is a sequence, which can be far more tricky because the users need to use their memory. The point is to remember a sequence of colors that the light makes and then reconstruct the sequence in the application's interface (see Figure 7). The settings are the same as for the reaction training plus the sequence length (the longer the sequence is, the harder it is to remember the right order) and the time between the color changes. There is a skip button when the users forget the sequence, so a new one is flashed.

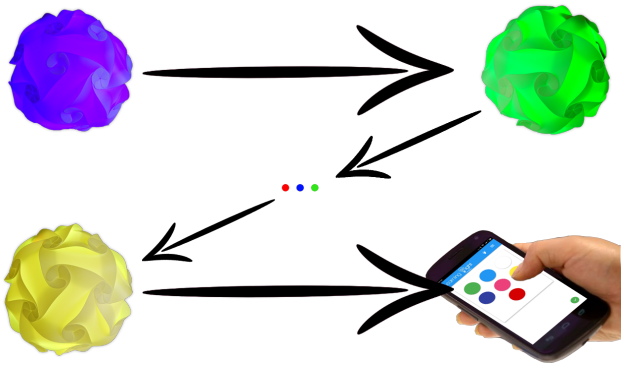

Figure 7. An example of memory training - the light flashes a sequence of colors. After the sequence is flashed, the user needs to reconstruct it in the right order.

3.3 Other options

After both modes end, an average reaction time and a graph with training process are shown to the users (see Figure 8). The users can also set their name and save the average reaction time to the *Highscores*. This feature should be helpful with improving the users' motivation to be better. After consulting this with experts, there should be a version for the smallest kids (until 3rd or 4th grade in primary school, when they start to understand how graphs work), where instead of a graph or average reaction time, there should be something more likeable for them - like a scale in number of smiles (good result - five smiles, bad result - one smile).

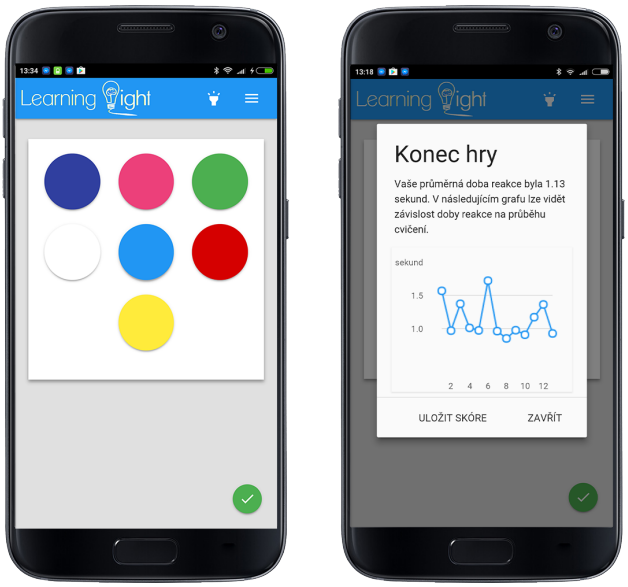

Figure 8. A picture showing a training and a screen after the training ended.

There is also a *Lamp mode*, where the users can control the light as they want to, and the *Help* section, where the explanation of using the Learning Light is written.

There is one little problem with getting an improvement when using Learning Light. It is commonly known that each therapy (when speaking about any cognitive function problem) must be executed regularly. This is sometimes an issue for parents whose child has ADHD - they tend to give up on their child or themselves because they think they failed and they are bad parents. That is why each therapy should be combined with behavioral therapy which teaches the parents how to communicate with their ADHD child.

4. Conclusions

According to the experts from the psychological field, Learning Light is a project that has a potential in several fields. Not only in ADHD therapy, but also in diagnostics, or for elderly people who have problems with memory or other cognitive functions. The important fact to bear in mind is that Learning Light differs from other applications developed for cognitive training - the user is not only focused on a phone or tablet, but also has to pay attention to something that is physically present in the room. For the kids, there is a parallel with a teacher saying something and the kid that needs to write it down, but simultaneously pay attention.

The technical design I decided for leaves a big potential for improvement of the product. The radio frequency transmitter connected to Arduino ensures that more lights with radio frequency receivers could be added relatively easily. In that case, the user's attention would have to get even higher, alongside with spacial orientation. There is also a room for adding more features to the application - more training modes, logical training etc. I already had some meetings in Pedagogical and Psychological Counselling Centre of Brno and with other experts from this field, so the product is adjusted to the needs of therapy and training. The next step would be to get in touch with therapists and start planning the production.

My conclusion (which originated mainly from the meetings I had) is that this project could make the therapy and training of cognitive functions at least a little bit better and more accessible. That is why Learning Light migh be worth it.

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