Creating an emotive robotic face to inspire trust in telepresence and autonomous rehabilitation activities

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INTRODUCTION

Motor impairment disorders, caused by disorders, such as cerebral palsy, or accidents throughout life, such as stroke, affect millions of people each year and cost billions of dollars for treatment and rehabilitation. [1] Even after initial treatment, many people suffering from such disorders will spend extended amounts of time in care facilities, undergoing further rehabilitation. Given the number of people suffering from these afflictions, as well as the cost of rehabilitation, it is simply not possible for therapists to be able to provide a quality rehabilitation service to every patient. [2] Thus, to both lighten the load on caregivers, as well as increase the quality of rehabilitation services, groups have begun efforts to implement robots in the rehabilitation process. These robots come in many different forms.

The design of a robot is incredibly important to its function, especially in a scenario where there is minimal human supervision. If the design does not invoke confidence and trust in the human patient, they will not cooperate, and the robot will not be able to aid in rehabilitation no matter how helpful it is. [3] One method to invoke this trust is to create a robot that does not merely act as a device, but rather as a social agent, which interacts with the patient directly in the context of rehabilitation.

In general, social robots have found success, especially among children. The THERAPIST robot, which Lil'Flo takes inspiration from, for example successfully acts as a social agent by participating in exercise games with children dynamically, altering its actions based on individual patients' needs. [4]

In a study by Calderita et al, the children seemed to react well to THERAPIST, not rejecting or moving away from the robot, and moving and speaking fluently and naturally around it. Although it cannot be directly quantified, these actions seem to indicate a degree of trust from the child subjects towards THERAPIST. [4] The version of THERAPIST used in the study is based on a bear, and it is thus not able to emote to the extent a human would, primarily due to the lack of a human face. Since most of human emotional expression comes through the face, a non-human face is an inherent disadvantage. If this version of THERAPIST was able to inspire such trust, then the rationale is that, as research suggests, a humanoid robot would be able to inspire even greater trust, and the performing of human-like activities such as emoting would only increase this bond of trust. [3] The THERAPIST group seems to have similar thoughts, as they have since moved to the more humanoid NAO robot as a base. We wish to take the success of the THERAPIST system even further and create a social humanoid robot with greater emotional capacity than the THERAPIST.

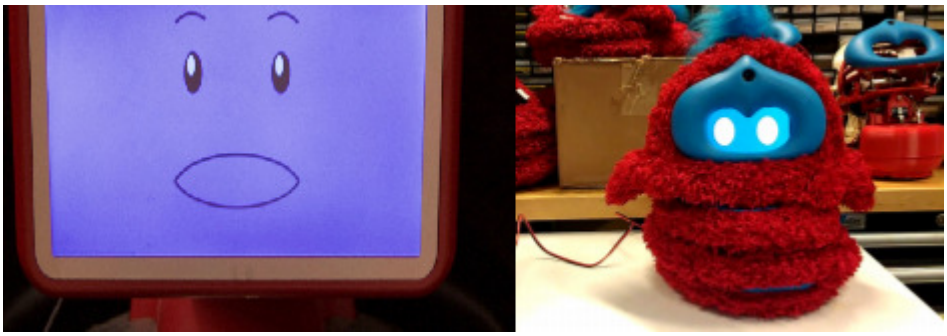

Figure 1: Baxter and Tega, two robots that utilize digitally emotive faces

One of the most recognizable factors of our previous attempt at a socially assistive robot (Fig. 2.), Flo's face was that fact that it was static. [2] Many robotic faces either remain static or utilize mechanically driven emotive systems (e.g. mechanical muscles). [3] We believe that the use of a digitally emotive face would be beneficial to robot patient interactions, when compared to a static face. We have begun to work on Lil'Flo, a successor to Flo that, among other features, would have a digitally emotive face, as opposed to a static or mechanically emotive one. Other robots, such as Baxter and Tega, have also tried a similar approach to their face design, but their size and forms mean they fulfill inherently different roles than what Lil'Flo is designed to do. [5, 6] We will now move towards explaining Lil'Flo's generalized role, and the design decisions that arose because of this role.

Lil'Flo's Purpose

Lil'Flo is the successor to the original Flo project, and is designed to be a hybrid telepresence and autonomous rehabilitation aide. It will be comprised of two parts, the base, which acts as the telepresence portion, and comes with a screen to allow patients to communicate directly with a therapist over long distances, and a humanoid portion, which acts as the semi-autonomous rehabilitation aide, and interacts directly with the patient through exercise games and limited conversation, potentially without the need for direct supervision by therapists in the far future. In the short term, Lil'Flo will be able to interact with patients in a limited fashion, through preprogrammed movements and voice lines, but steps are being taken to implement greater autonomy in Lil'Flo. This autonomy would allow it to dynamically formulate and change a rehabilitation plan based on the capabilities of the patient, as well as meet patients directly in remote areas, without requiring supervision.

Figure 2: Flo, the predecessor to Lil'Flo

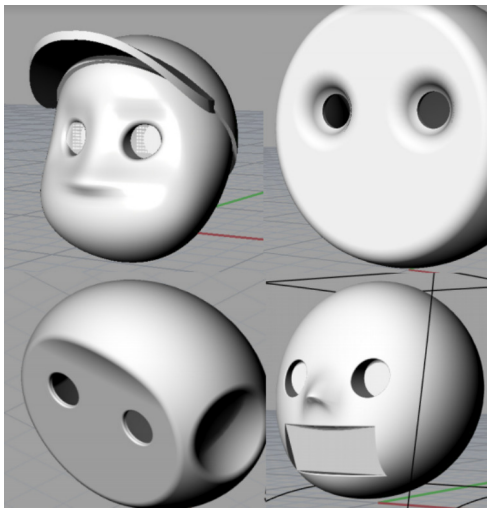

Figure 3: Various prototype head designs, ranging from more abstract to more humanlike

Success with Flo in the past has indicated that there is potential for a robot of this style. [2] However, the NAO robot that acts as Flo's base, while very effective, also has a very steep price tag associated with it, often costing thousands, if not tens of thousands of dollars. Lil'Flo is meant to be a cost-effective project that is can be used in a variety of situations and environments, which do not possess the resources to purchase or maintain something so expensive. However, Lil'Flo is also planned to be a highly actuated robot, potentially capable of near complete autonomous behavior, and so cheaper off the shelf robots are unlikely to have the capability to handle what Lil'Flo needs to do. Thus, we find a need to develop our own robot, constructed from relatively cheap and easy to procure materials, to keep the price of Lil'Flo in the hundreds of dollars, rather than the thousands or tens of thousands of dollars. Going forward, we will focus on the general design and process behind Lil'Flo's current face, which we believe to be crucial to Lil'Flo's success as an emotive robot.

METHODS

Current Designs

Considerable progress has already been made on potential designs for Lil'Flo. The basic logic behind Lil'Flo's aesthetic is simplicity, which allows patients, particularly pediatric patients, to feel like they can relate and bond with Lil'Flo without being overwhelmed. At the same time, this avoids a directly human-like design, as these often fall into the "uncanny valley", and do not evoke positive emotions. [3] This simplicity allows the face to be the driving factor to creating that bond, so the face's aesthetic has been carefully crafted. One part of this is that the face uses LEDs to convey

Figure 4: Lil'Flo head current

emotional state. This is because we believe that the use of LEDs both allows Lil'Flo to more easily convey a wider range of emotions than mechanically driven emotive faces, while at the same time keeping the simple, clean aesthetic that we desired from Lil'Flo.

In addition to the face, the general head shape of Lil'Flo was designed in an attempt to evoke comfort. The current design was chosen from a host of other conceptual designs, some modeled after the faces of children, some more flat or rounded (Fig. 3). The current shape was eventually selected as it provided a good balance between an overly simplistic design and a fully human-like design, as it maintains something of an abstract form, while still retaining human-like features. We find this to be an acceptable balance between the familiarity of a human and the comfort of a toy (Fig. 4). Until the uncanny valley is reached, the inclusion of human-like traits generally has a positive effect on the acceptance of a given aesthetic [3]. The ideal, therefore, is to find a balance, where the robot has enough human traits to allow the subject to bond effectively with it, while also not appearing too human, which would drive people away. This line of logic led to, for example, the addition of the "ears" that Lil'Flo has. They are, in keeping with the design philosophy, relatively simple constructs, spherical shapes that attach to the sides of the head. The idea of adding the structures was purely based on aesthetics, with the idea that the existence of these ears would help add human qualities to what had thus far been a humanoid, but certainly not human-like, head, while giving patients the impression that the robot can hear them. Nonetheless, a straw poll was taken among members of the Rehabilitation Robotics Lab, comparing the design with ears and the design without ears. Small scale shells of both designs were 3D printed, to give voters a full view of both heads from all angles. Ultimately, the lab unanimously voted in favor of the ears.

The design process is always based on two major factors: functionality and aesthetic. Functionality is considered first, and involves considering what would help Lil'Flo be able to perform its duties effectively, and what would hinder it. The durability of the design, the ease and cost of assembly, and whether Lil'Flo is capable of moving are all part of the umbrella of functionality. After that, the aesthetic is considered. As has been stated above, we have already decided on an appropriate aesthetic for Lil'Flo. To have any part of Lil'Flo not match this aesthetic could produce an immediate negative reaction from the patient, or to the creation of false expectations for Lil'Flo's capabilities, leading to a general loss of trust and cooperation once these expectations are shattered [3]. Thus, it is paramount to make sure that any addition to Lil'Flo maintains a consistent aesthetic. This involves analyzing many functions of a given part, including its appearance in relation to the rest of Flo, any and all sounds it may make, and what information a given part may convey.

Mechanical Design

Early on, we found a need to determine how we would like to partition Lil'Flo's head. We decided early on that Lil'Flo should be designed with the idea that it can easily be taken apart and put back together when needed, to allow for modularity and easy replacement of both the internal components and the head structure, potentially reducing costs. This required that the head be partitioned, making it multiple parts, and allowing us to easily open Lil'Flo's head and retrieve or replace what we needed to. We went through several iterations that bisected the head from various planes, but found that many of them created new complications in the design that would have made the assembly of Lil'Flo lack both durability and accessibility, particularly in the screen area. Eventually, we decided on a more rounded cut around Lil'Flo's forehead (Fig. 5). This kept the cut from making the assembly of the face more difficult, while also maintaining the aesthetic appeal of Lil'Flo (i.e. the cut creates something of a crude hairline for Lil'Flo reminiscent of human heads, but once again avoids creating a realistic humanlike appearance.

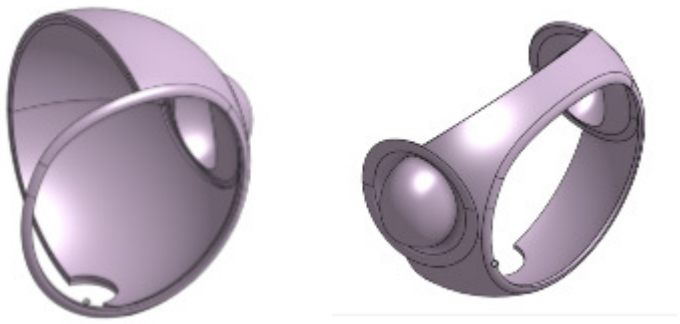

Figure 5: Prototype Lil'Flo head partition (left) v. current (right)

Lil'Flo's face is an epoxy resin, tinted to a smoky black color using colorant, that is cast directly into a completed head. Since Lil'Flo's eyes and mouth are represented by relatively bright LEDs, steps were taken to obscure the internals, which in turn gives us the ability to construct the internals of Lil'Flo's head as we please. However, we found that simply adding too much colorant led to the color becoming too strong for the LEDs to shine through. Additionally, since we were using relatively small amounts of epoxy to create the screen, the ratio of colorant to epoxy became a matter of great importance to the project. Due to a lack of sufficient data correlating volume of

colorant to volume of epoxy, we developed our own methods, both to find colorant to epoxy ratio for our needs, as well as methods to add very small amounts of colorant. For example, due to the relatively low volume of epoxy we need, we found that even the minimal amount of colorant that could be applied via a supplied dropper was far too much. We therefore formulated a method of "chain diluting" colorant-epoxy mixtures, or taking small amounts of mixture with relatively large concentrations of colorant, and diluting it with epoxy that lacked colorant. Through this, we were able to achieve acceptable levels of transparency for our face.

Interior

Since the face is designed to be smoky, which obscures the internals, we are not required to focus on the aesthetic of the head's interior, as it will never be seen. Thus, everything about the face internals is based on the mechanics of the design. The main considerations for the internals of the head were that it be able to be assembled or disassembled quickly and easily, and that it be robust. To aid in both, efforts were made to make the internal design as rigid as possible, so that it would not move under expected loads. Because of this design philosophy, we opted to go for a branching type design, where a small platform is in the center of the head, which attaches to the neck and allows for rotation, and acts as a hub of sorts, with all other parts of the head internals branching off of this platform, including the supports (Fig. 6).

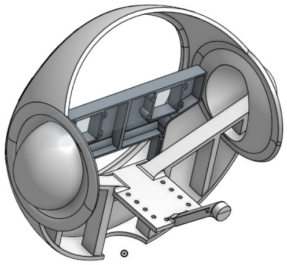

Figure 6: Isometric view of Lil'Flo head internals

CONCLUSION

As we develop Lil'Flo's aesthetic, we are also developing the functions that will allow Lil'Flo to perform the socially assistive role that it is designed for. This includes methods by which Lil'Flo can see and focus on patients, noticing unnatural movements or behaviors far more easily than a human eye. In order for these functions to be fully utilized, however, the patient must first be able to accept the presence of Lil'Flo without significant issue. This is doubly true if Lil'Flo is to be interacting directly with the patient through exercise games, as we intend. Thus, we have conveyed the aesthetic decisions that we believe will be most beneficial to Lil'Flo's functions and future success.

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