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Stories from an unfinished prototype: a seemingly never-ending loop of practice and research

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This pictorial presents the role prototyping played in developing The Non-myth of the Noble Red, a tangible narrative and a design case for this type of Interactive Digital Narratives (IDN). It discusses the challenges and insights gained from it, among them, the importance of accounting ergonomic principles when prototyping artefacts, embracing the physical properties of working materials during the prototyping process, considering the potential pitfalls of relying too heavily on technical knowledge, and the importance of compartmentalizing and prioritizing during the ideation process. Finally, the pictorial concludes with an analysis of the role played by the action of prototyping and the importance of the continuous dialogue between the designer/researcher and the artefacts created.

Keywords: prototyping; interactive digital narrative; tangible narrative; The Non-myth of The Noble Red

I am writing this pictorial from my perspective as a design practitioner and researcher—hence the relatively uncommon, first-person voice of this text—to share a personal account and a reflection of the prototyping and development processes of The Non-myth of the Noble Red, a tangible interactive narrative. This narrative questions mythological stereotypes, integrates Brechtian methods as inspiration for alternative approaches to authoring and looks at physical-computationally enhanced paper puppets as interaction vehicles. In this pictorial, I will first establish the context of this work: the role of prototyping in design research, along with a brief characterization of tangible interactive narratives. I will introduce a specific design case: The Non-myth of the Noble Red (hereafter, The Non-myth). Then, I will focus on illustrating the prototyping process and the thought behind specific aspects of the design of The Non-myth while discussing various pitfalls and challenges. Finally, I will conclude the pictorial with a brief reflection on the role played by the action of prototyping during the entire creative process.

1 Introduction: a quick overview of prototyping

Prototyping is crucial to design research and its related processes—of course, complemented by methods such as sketching, mapping, or journaling, to name a few. Prototypes can play multiple parts: they can represent ideas, explore the way they look or how these ideas can be implemented (Houde & Hill, 1997), externalise them (Lim et al., 2008), and imagine, describe, or explain those ideas (Koskinen et al., 2011). Prototypes can be experimental components (Wensveen & Matthews, 2014) or means for

enquiry, either as probes (Gaver et al., 1999; Schulz & Hornecker, 2022) or provotypes (Bardzell et al., 2012; Jensen et al., 2022). They can also be vehicles of enquiry—as processes that are documented, analysed, and assessed (Gagnon-King et al., 2023; Lambrichts et al., 2020) or research archetypes (Nachtigall, 2017; Wensveen & Matthews, 2014) —where they embody one or more concepts in a single, physical artefact. They are not solely one thing or the other but research components that can have many purposes and uses simultaneously. Whichever way prototypes are described and classified (Petrakis et al., 2019), prototyping is central to design research and the creative practice itself, making a case on the importance of sharing experiences like the making of The Non-myth of the Noble Red with others in the design community.

2 Design of an interactive system: the Non-myth of the Noble Red

For the past five years, my creative practice and research have focused on the intersection of interactive storytelling and tangible interaction, particularly *tangible interactive narratives*. This type of narrative incorporates physical objects and spaces bound to digital content, all of which support the storytelling process. Prototyping tangible narratives involves not only storytelling practices such as planning and writing but also faces the challenges and advantages of working with physical narrative artefacts and exploring their material properties. Tangible narratives are stories facilitated by a computer system, and stories experienced through physical artefacts in the real world. At the same time, generally, a "visual/auditive packaging" ties the entire experience together. Ultimately, all these components behave like a puzzle where software, narrative, and artefact fit together, resulting in a unique storytelling experience that is both interactive and physical.

The Non-myth (Echeverri, 2022) explores emergent social dynamics in a non-linear, multi-perspective, and multi-user storytelling setting. This tangible narrative has two objectives: explore how physical, tangible, computational artefacts can enhance the storytelling process and employ Brechtian-inspired methods to create a sense of alienation in users, prompting them to be more mindful of the implications of their actions within the narrative. With this in mind, *The Non-myth* relies on interactive, hand-worn puppets with multiple sensors to engage with the narrative. These puppets allow users to interact not only with the physical stage of the story (Figure 1, left) but also with other puppets (and users) in a natural manner (Figure 1, right). With these puppets, the users can touch objects, move around the space, make decisions (Figure 2), and ultimately shape the narrative through physical performance (Figure 3). By doing so, users become both performers and observers of others' performances, actively participating in the story's unfolding. The intentional design choice of the puppets as representations without explicit details invites users to interpret and create their understanding of the characters, their actions, and the overall story. Combining the puppets' physical interactivity with the absence of explicit communication of features, *The Non-myth* aims to create an immersive and thought-provoking experience.

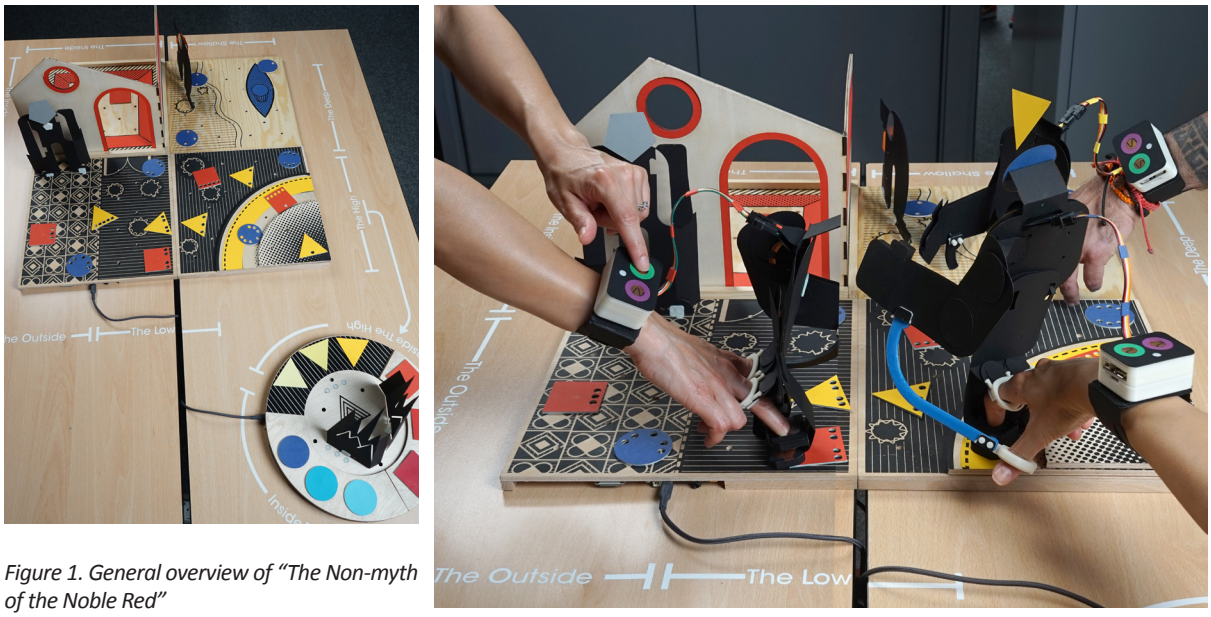


Figure 1. General overview of "The Non-myth of the Noble Red"

Figure 2. Right, wrist controller. It houses a micro-controller, two capacitive surfaces and an LED. It connects to the back of the puppet, also providing stability.

About the Tangible Narrative: *The Non-myth of the Noble Red* tells the story of a community threatened by the Villainous Yellow and the efforts of the Noble Red and the Heroic Blue to save them. The story's progression depends on choices made by users, and the resolution can take different paths. The narrative allows the users to explore options and mutually decide which conclusion best matches their interpretation of the plot. *The Non-myth* uses concepts from performative art, specifically *Brechtian* theatre, to create new and original approaches to interactive storytelling. It explores authoring techniques inspired by Bertolt Brecht's *Epic Theatre* (Brecht, 2019), which creates *distance* between users and the story, allowing them to focus on and consider the social implications of the narrative.

Figure 3. General overview of 'The Non-myth of the Noble Red'. Cardboard puppets: The Noble Red (a) *worn in the user's hand, The Heroic Blue* (b)*, and the Villainous Yellow* (c)*, along with three environments: The Inside* (d)*, The Cave* (e)*, and The Shallow* (f)*.*

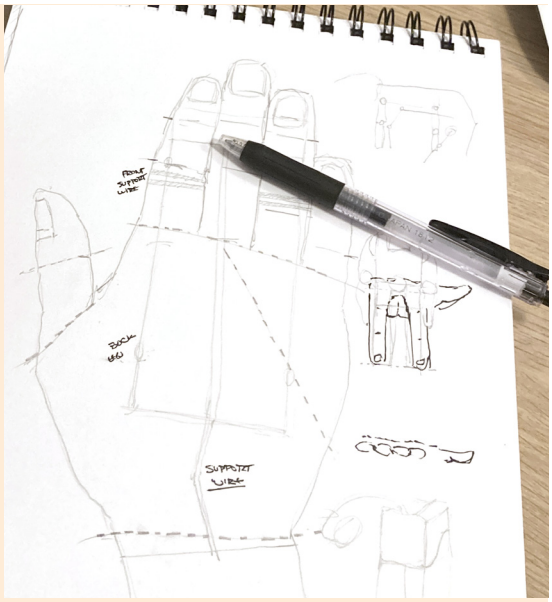
3 Four finished unfinished stories

Prototyping a complex experience like *The Non-myth* was demanding, time-consuming, and sometimes frustrating, but satisfying and enriching. In the following pages of this pictorial, I intend to recount four stories (or better yet, anecdotes) that illustrate the infinite loop of practice and research during the prototyping process. In the first story, *It is an Ergonomic World,* I talk about the journey of creating objects that are worn and depend on how the body moves. In the second story, *Facing the Material Unexpectedness,* I discuss how materiality, at times, can condition the ideation process. In *The Computational Dilemma*, the third story, I argue that sometimes depending on technological tools or technical knowledge can limit the development of the idea. Finally, in *The Never-ending Rabbit Hole of the Many "What-ifs",* I illustrate how non-stop or uncontrolled ideation can hinder the progress of one's creative work.

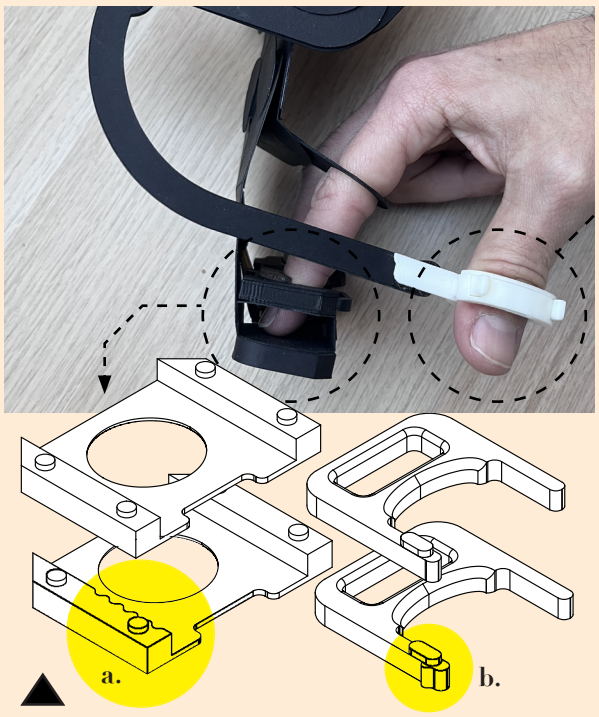
3.1 It is an ergonomic world

Puppetry relies heavily on ergonomic principles, as the subtlety of the puppeteer's movements is critical to their expressiveness.

The Non-myth puppets, for example, not only require the hand to move them but also to keep them stable and secure. These puppets are worn on the user's hand and are connected to a microcontroller housed in the wrist by wiring that links sensors in the puppet's body (Figure 1). The index and middle fingers move the legs of the puppet, while the thumb, attached to a rod, allows the manipulation of the puppet's hand to interact with objects and other puppets. As a result, I needed to design a way of fitting a variety of finger diameters, sizes, and dexterities.



First study of a hand, my hand, to set the dimensions and basic ergonomic structure of the puppet.

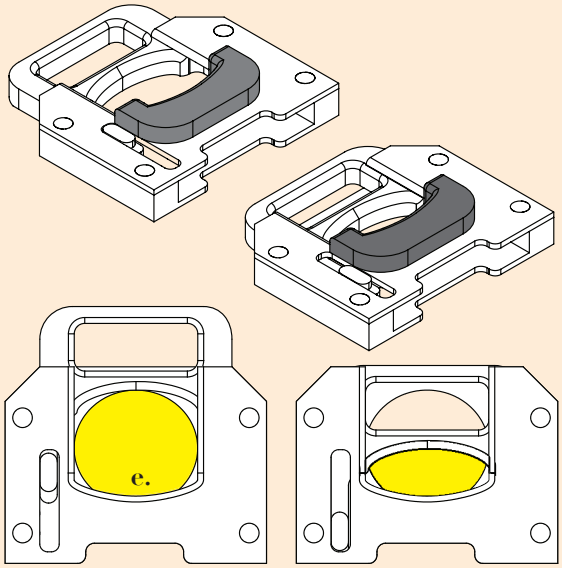


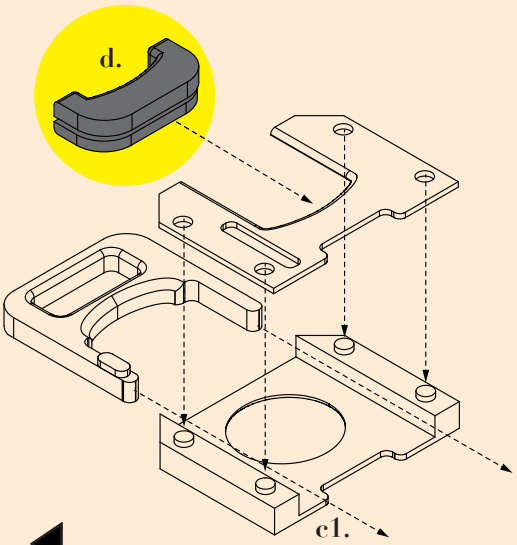
Top, finger clips. Bottom, initial serrated design (highlighted) in the index and middle finger clips.

For the **middle and index fingers**, I considered zip ties, elastic bands, and flaps to fix the fingers directly to the puppet. Still these were uncomfortable to the user and inefficient for their purpose.

Instead, I developed adjustable clips for the fingers and thumb and prototyped them through several iterations of 3D printing. The initial prototype relied on an interlocking serrated mechanism (**a** and **b**), which limited the clip diameter to specific combinations. This proved to be impractical as fingers vary greatly in diameter. Instead, a final sliding mechanism (**c1** and **c2**) was used to hold the fingers in place.

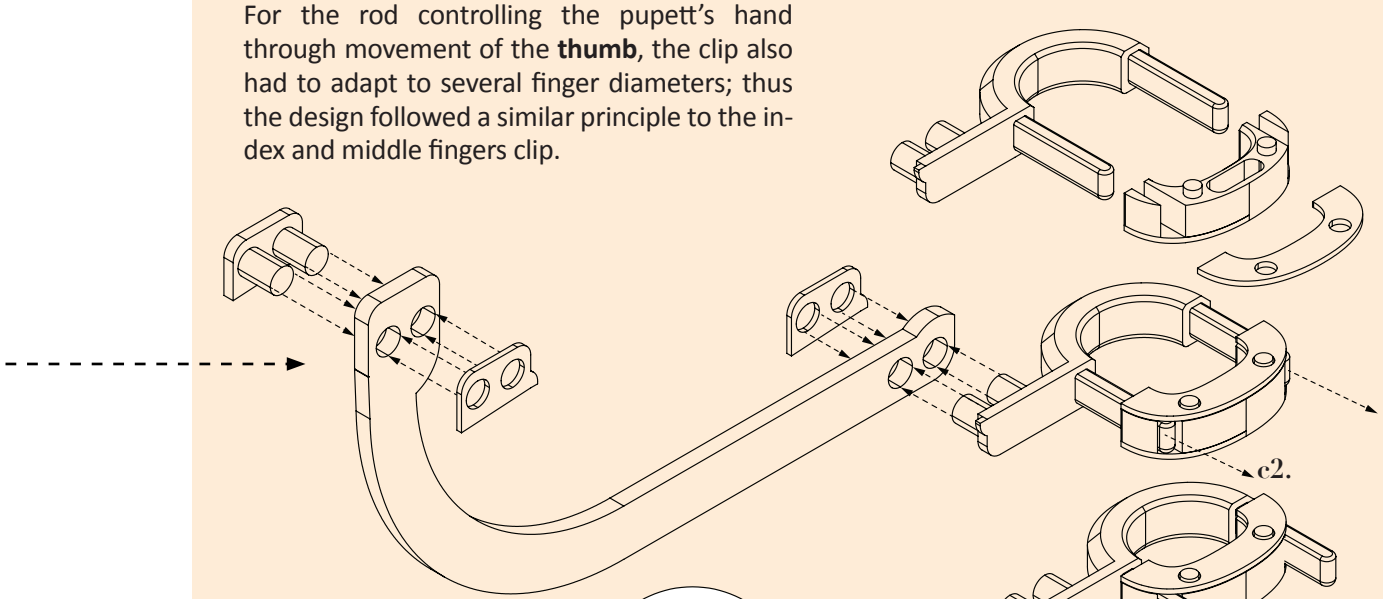
However, during testing, the border of the clip strained the cuticle and proximal nail fold (where the nail grows), causing discomfort and pain. I solved this problem by adding foamy padding around the sliding parts of the clips (**d**).

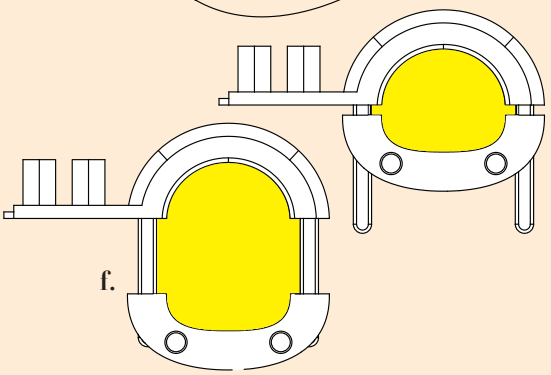




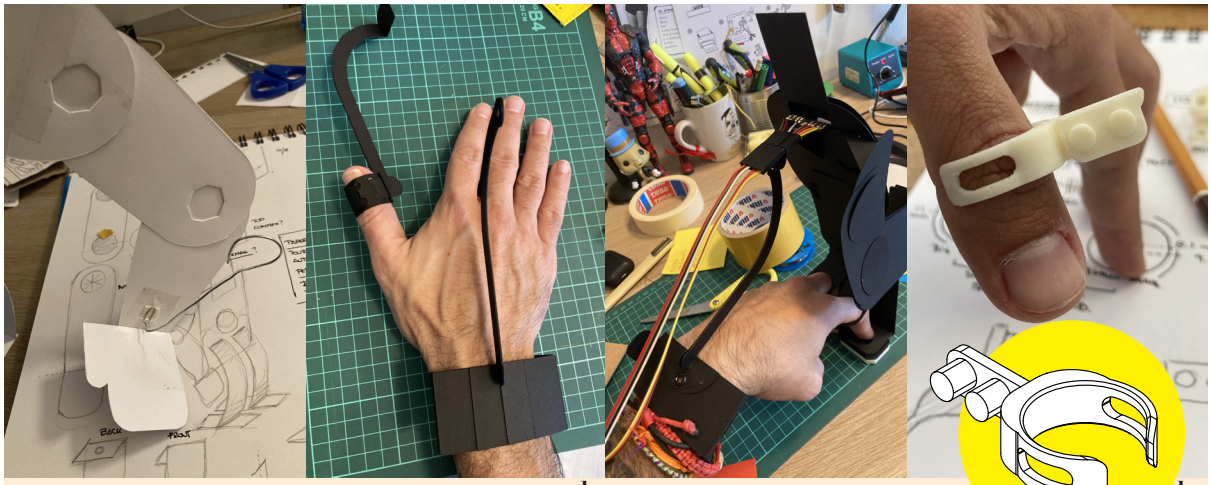
The average adult distal interphalangeal joint circumference of the middle finger (or, in other words, the first joint of the middle finger, closer to the tip) is about 54.1 mm in male adults and 44.7mm in female adults (Garret, 1971). The extended clip (**e**) can fit fingers up to 60 mm in circumference.

For the rod controlling the pupett's hand through movement of the **thumb**, the clip also had to adapt to several finger diameters; thus the design followed a similar principle to the index and middle fingers clip.





Top (left) and isometric view (up) of the thumb clip and the hand rod. The average adult interphalangeal joint circumference of the thumb (the first joint of the thumb) is about 67.8 mm in male adults and 56.1 mm in female adults (Garret, 1971). The extended clip (**f**) allows thumbs up to 84 mm in circumference.

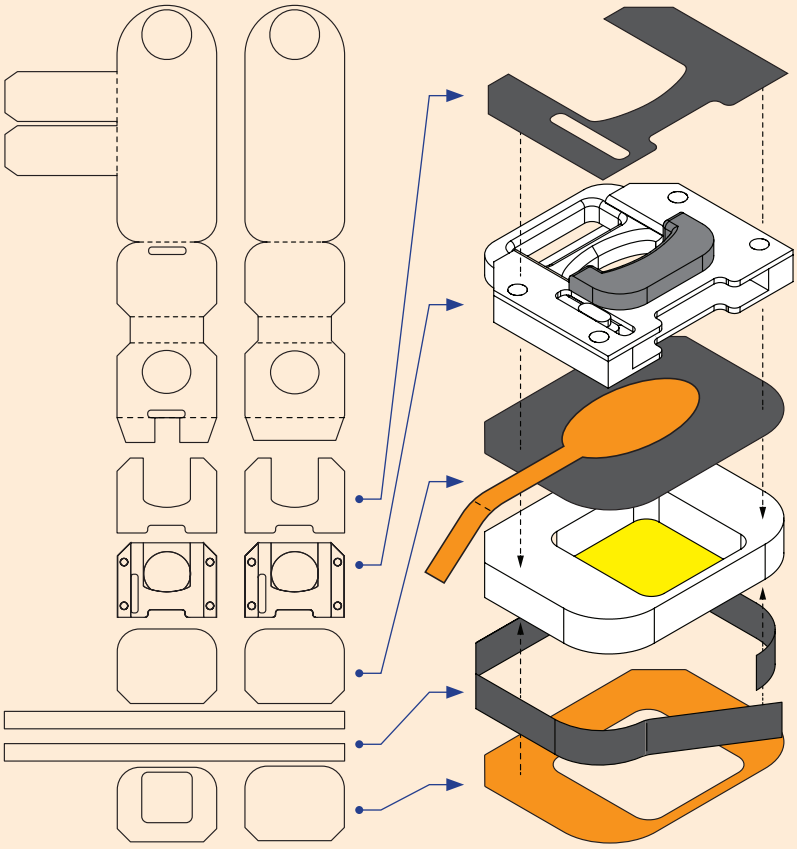


a. b. c. d.

Evolution of the finger clips and wrist support: (a) initial wire prototype and sketch, (b) second prototype with wrist support, finger clip and rod, (c) testing the stability of the puppet with the support of the wrist and thumb, (d) first iteration of thumb clip based on a ring design.

The takeaway from this first unfinished story concerns understanding how the body behaves and moves, accounting for the endless types of bodies, and considering ergonomic aspects to plan comfortable and natural interactions with a prototype.

Model of the puppet's legs and detail of how the bottom part is assembled and integrated with the finger clips and other conducive components.



Cardboard cover.

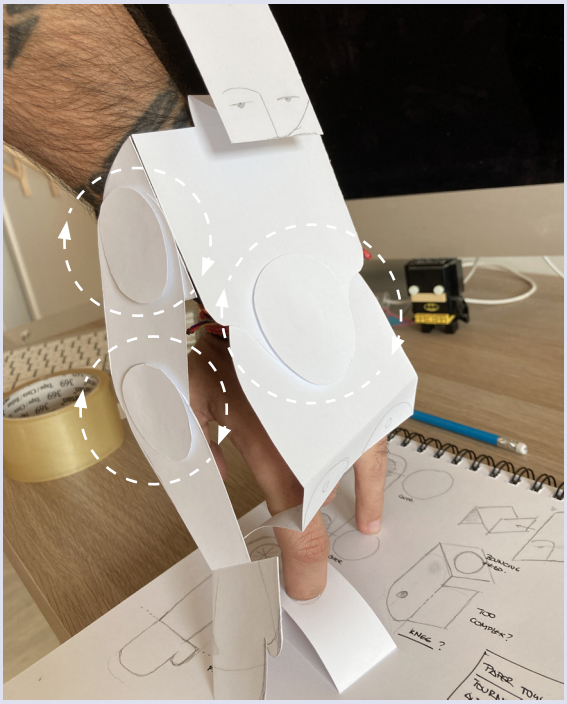
ABS-printed finger clip.

Cardboard layer. It has a copper patch that connects to the bottom layer. It improves response from the capacitive surfaces in the environments.

ABS housing for the colour sensor. The sensor reads the colours of each capacitive surface.

Cardboard ribbon. Wraps around the ABS housing.

Copper surface. It improves response from the capacitive surfaces.

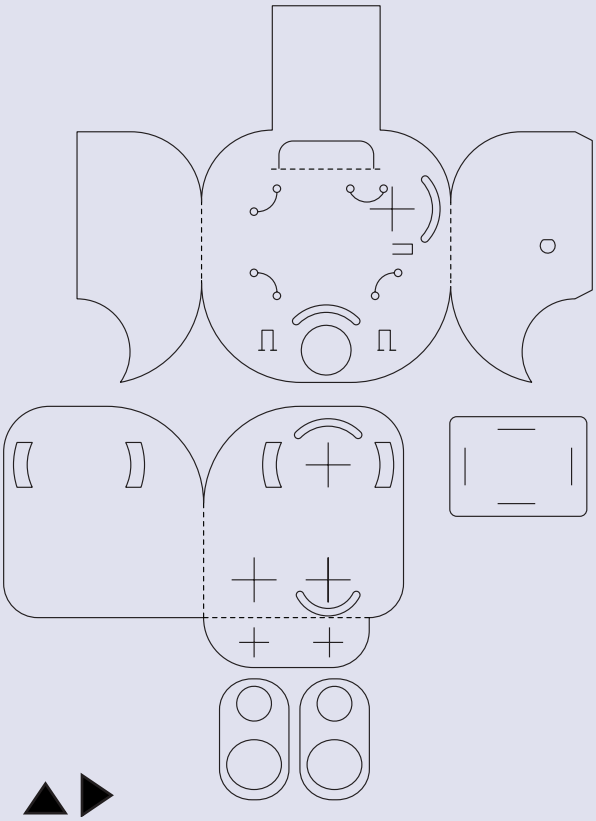


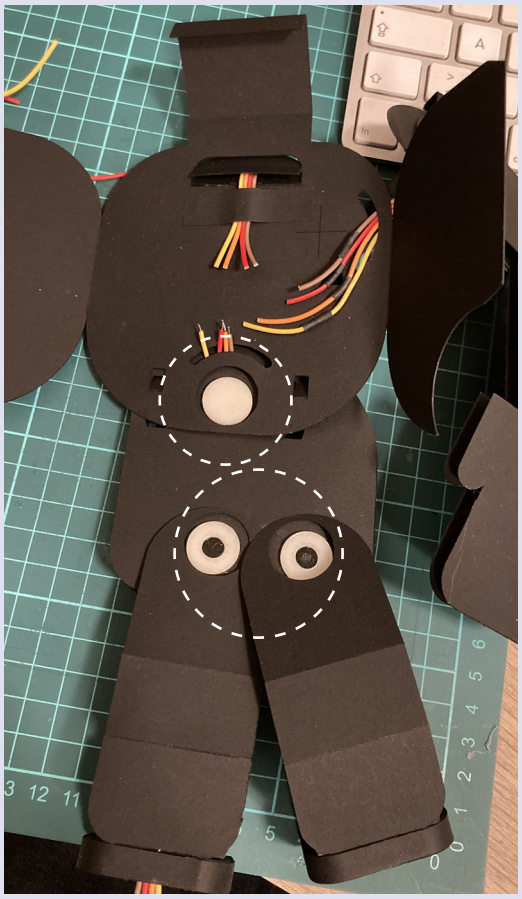
3.2 Facing materiality unexpectedness

Prototyping involves embracing the physical properties of the materials the designer works with to create, in the context of tangible narratives, artefacts that also express narrative aspects. However, executing ideas with materials like paper, foam, or wood can be tricky since unexpected issues like weight, fragility, and unsuitability for specific purposes can arise. For example, in early prototypes of the puppets, friction between rotating paper pieces used as joints constrained their natural movement, while excessive force made the paper rip or crease.

To solve these friction issues, I explored axles of different diameters and thicknesses made of cardboard, MDF wood, and ABS plastic prototypes, allowing pieces to move naturally with little force from the user.

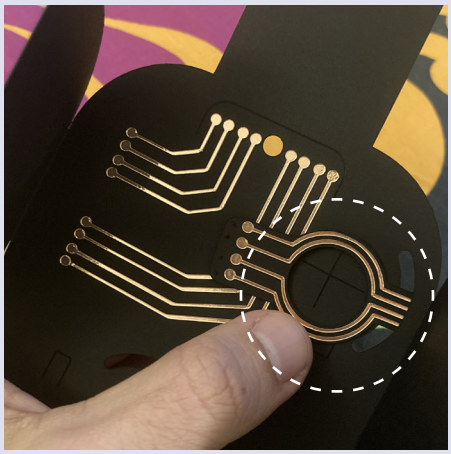
First prototype of the puppet. Highlighted in white, the points of rotation in the joints.

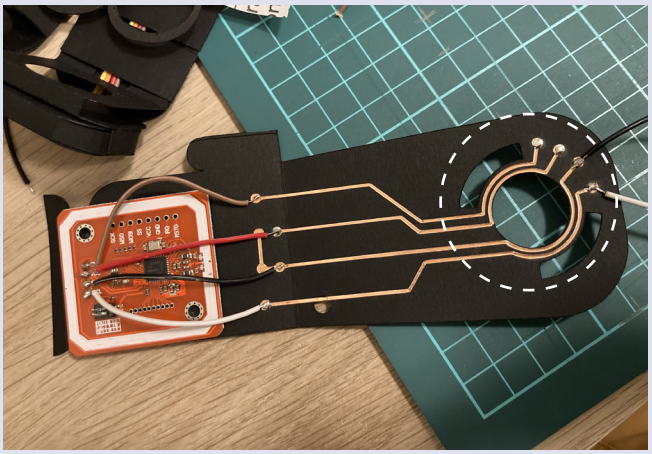




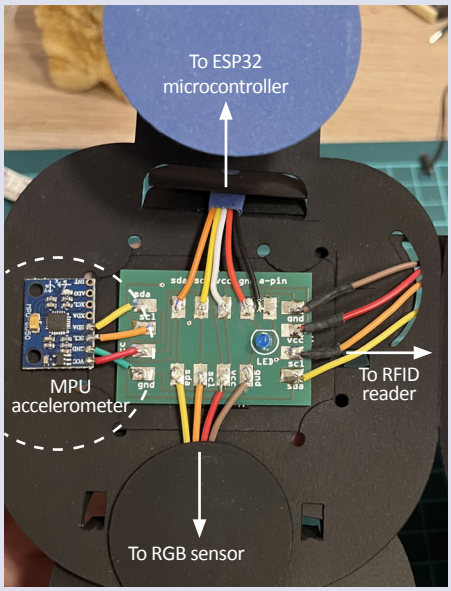
Model of the puppet's torso (top). Crosses mark joints and rotation points. Iteration of the puppet with 3D printed axels; two variations (right): solid versus hollow axels to reduce 3D printing material consumption.

I use paper or cardboard extensively in my creative work. As a Graphic Designer, I have always had a particular interest in this material since it is sustainable, inexpensive, and closely tied to the original orientation of Graphic Design towards printed media. My idea with *The Non-myth* was to create paper circuitry using adhesive copper traces over cardboard, like Printed Circuit Boards (PCB). Although the concept worked initially, the cardboard PCBs' continuous motion and the copper adhesive's limited tolerance to bending and folding with the paper caused the connections to break, rip from the cardboard, or affect the material's resistance.





Two prototypes of cardboard PCB. Top left, overlapping layers of cardboard PCBs. Top right, PN532 RFID module connected to PCB. Highlighted in white rotating points of the PCBs



Final PCB module. On the left of the PCB, highlighted in white, is the MPU 3-axis accelerometer. The bottom connections lead to the RGB sensor in the puppet's foot, and the right connections lead to the PN532 RFID sensor. The top connection leads to ESP32 housed on the wrist of the user.

While prior experiments with paper circuitry have been favourable (Daudén Roquet et al., 2016; Knouf, 2017; Shorter et al., 2014), the changing properties of conductive materials like adhesive copper or carbon- or silver-based conductive ink significantly affect the connection and stability of sensors and other electronics when moved, bent, or folded. However, I could not find a viable solution for the cardboard PCBs I wanted to use. Thus, a custom-ordered PCB was placed in the puppet's chest, connecting sensors to the microcontroller with regular wiring.

The takeaway from this second unfinished story is twofold. First, it highlights the need to conduct preliminary experiments with materials that have similar properties before going all-in with a determined material. Second, the designer/researcher must choose the right battles regarding a material's physical properties. Sometimes is not worth reinventing the wheel.

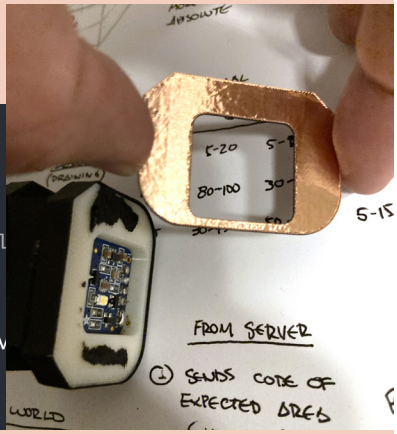
3.3 The computational dilemma

Undoubtedly, designers are increasingly turning to technological tools for their creative work. From graphic design software to 3D modelling tools, technology has made the design process faster, more efficient, and more precise. However, while technology can certainly facilitate a designer's work, good design ultimately depends on the creativity and resourcefulness of the designer to use those tools effectively.

The Non-myth involved several "computational layers" that required a combination of technical skills and creativity.

The first layer (developed in Arduino IDE) involved translating data from various sensors, such as colour temperature and lux values, from the RGB sensor, into a common set of information that could be processed.

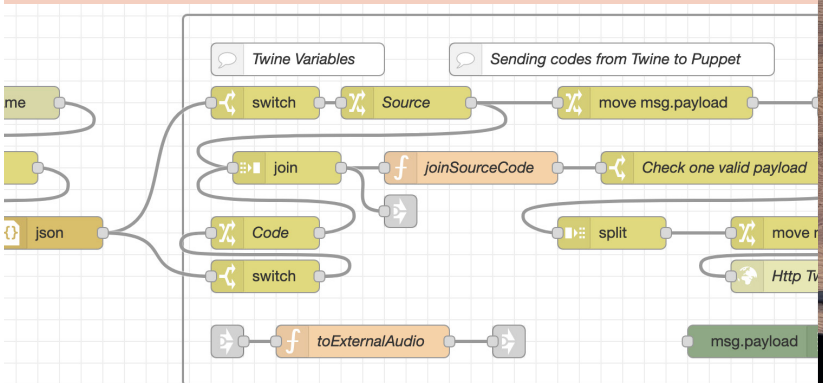
```
colorTemp = tcs.calculateColorTemperature(r, g, b);
lux = tcs.calculateLux(r, g, b);
r = map(r, 0, 65535, 0, 255);
g = map(g, 0, 65535, 0, 255);
b = map(b, 0, 65535, 0, 255);
//Mode 0 looks for a specific color i.e., Yellow looks for Yell
if ( pingMode == 0) {
   if ((( b >= r && b >= g && g >= r && b>=15) && (thisIsMe ==
     (( g >= b && r >= b && r>41) && (thisIsMe == 30)) ||
     (( r >= g && r >= b && g >= b && r>20 && r<40) && (thisIsM
  {
    tcs.setInterrupt(true);  // turn off LED
    locationPinged = true;
```



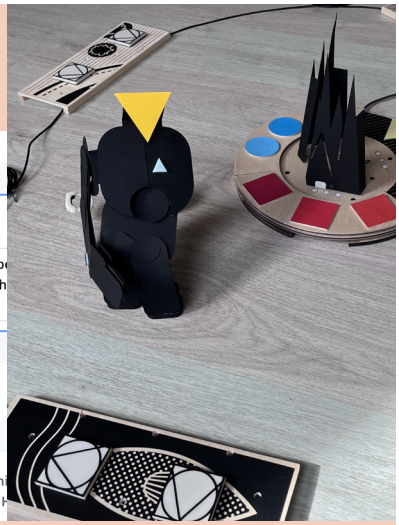
The second layer (made with Twine) mediates between the translated data and the actions the user can take at a particular moment of the story. For example, moving the puppet left or right to choose something or asking the user to place the puppet on top of a particular colour.

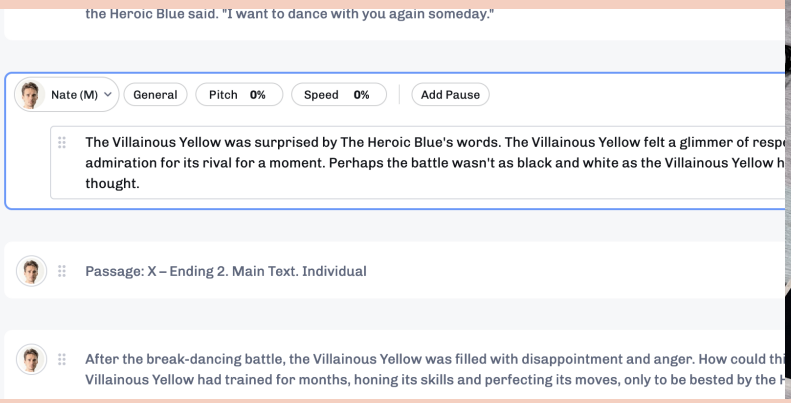
```
        (set: $twineCode to 40)
        (set: $emptyExpression to window.sendHarloweVariable('twi
))
        (set: $emptyExpression to window.sendHarloweVariable('twi
        (set: $emptyExpression to window.sendHarloweVariable())
    ]
]

<!-- MATCH MESSAGE TO COLOUR-->
[(live:)[
(if: $noderedSource is $twineSource)[
    (if:$noderedCode is 404)[
```

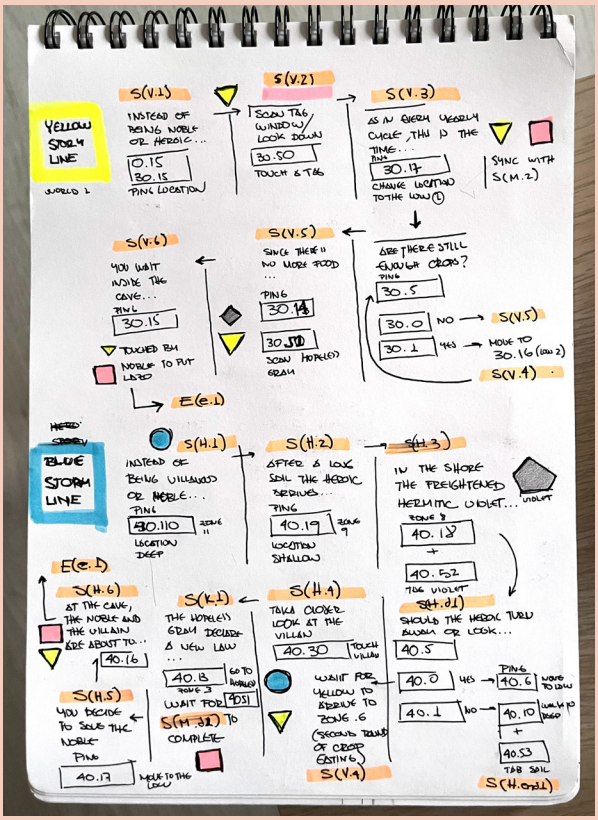
The third layer (in Node-Red (Mee, 2017)) integrated all the puppets and environments, their unique translated data, with the story, unifying the experience and conveying content to each user based on their actions.



Finally, **the fourth layer** (made with AIVA and Murf studio) involved expressing the story through audible music and speech that the users could hear through their headphones.







Sketchbook page. Planning communication codes between the puppet and the system within each storyline.

Given the technical complexity of this project, it was no surprise that it required me to have a steep learning curve on how to use new platforms, tools, and systems. However, after consulting with people working in the IoT field *(as suggested by another of my students)*, I devised a strategy built on existing knowledge. It leveraged resources and tools I created for previous research work and integrated them with new tools. I also made a solution inspired by sequences of two- or three-digit codes, each with a specific significance, like the codes used by police or firefighters to communicate. For example, the code 10-40 for a policeman might mean a fight in progress, while the code 10.40 in *The Non-myth* system means that the yellow puppet (identified with the number 10) will turn on its RGB sensor (40). Ultimately, the script of *The Non-myth* is reduced to a long exchange of identifiers and codes that stream into a server.

The takeaway from this third unfinished story is to leverage existing knowledge with new technical challenges depending on the time available, the skills and the resources of the designer/researcher. Technology cannot condition the creative process or how an idea can be executed or prototyped. A modular prototyping approach allows the designer/researcher to focus on specific needs and tasks. For instance, I ensured I could translate all data from the sensors before creating the system to play audio or even author the entire story.

3.4 The never-ending rabbit hole of the many *what-ifs*

As I inched towards more refined versions of my prototypes, becoming technologically versed in the different tools and having built a stable platform for *The Non-myth* that allowed me to quickly test new ideas, build upon them, and fix bugs and errors, I fell into a rabbit hole. A rabbit hole of *what-ifs*, one that opened and made me very ambitious, feeling almost limitless with what I could do. *What if I do this? What if I do that*—I asked myself over and over. I thought about adding new endings, new ways of interacting, more detailed dialogue, more dynamic outcomes and actions, exploring new materials, reinventing, rebuilding, reinterpreting, reprocessing, and so, I got trapped in it.

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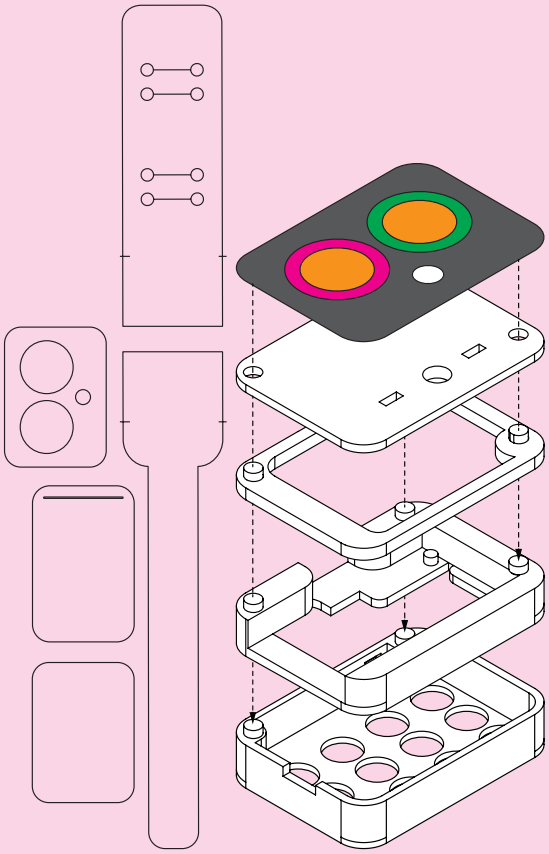
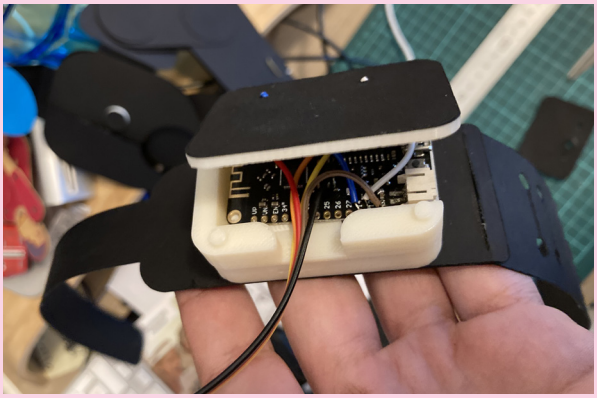
Iterations of the microcontroller housing. Most of these iterations sought to make better use of the space available while keeping the housing small and comfortable to be used from the wrist.





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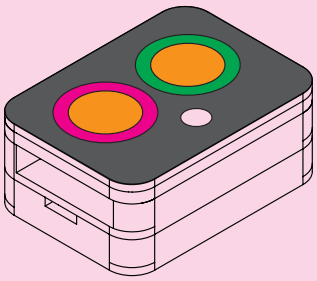
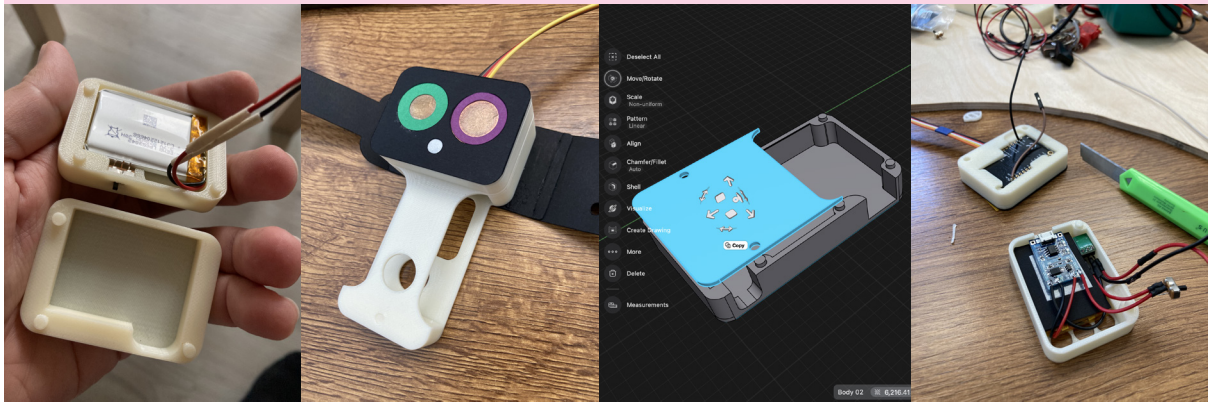
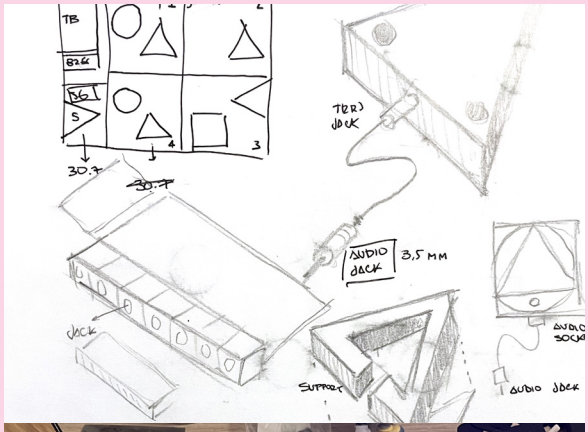
Microcontroller housing. I conducted several iterations of this housing to fit a battery, a charging module, a 5V to 3.3V converter, and an ESP32 microcontroller.





Yes, prototyping allowed open-ended exploration of new ideas, quickly testing hypotheses, and pursuing further research questions. However, it also diverged me from essential objectives and necessary tasks and placed my attention on gimmicks and distractions. As a solution, I started planning priorities and working on concrete goals one at a time. I tried to group these objectives based on the artefact I was working with. For instance, anything related to object tracking: tracking with the puppet, tracking a location in one environment, tracking specific colours, etc.



From sketch to prototype: these rectangular modules are capacitive (react to touch) and emit light to signal where a puppet can stand. These lights are controlled from the story via WiFi by an ESP8266 microcontroller.

The fourth and final takeaway is that by compartmentalising ideas and prioritising them, I could refocus, allowing ideation and prototyping to lead the research while following a well-defined plan. Through this plan, I carefully documented the entire process in my design journal to analyse, evaluate, and seek feedback later. This documentation helped me reflect on the conversations and discussions between myself, the research process, the theory, and the artefacts I created.

4 Conclusions

At the time of writing this pictorial, *The Non-myth* is in its late stages, where a fully working prototype is complete, although I still consider that it is not completely finished. However, each prototype, experiment, test, and iteration has driven me closer to its final form. In this journey, prototyping and prototypes had multiple purposes; they evaluated an idea, proved or disproved a hypothesis, and provided me with a new conceptual perspective to initial underlying questions on interaction and storytelling. And without a doubt, they became arguments in the continuous dialogue between me—the researcher, and the idea. With this pictorial, I hope to inspire peers to overcome the pitfalls and challenges of practice-led research —either becoming overwhelmed by a sea of thoughts, feeling constrained by technical choices, or dealing with tricky materials —and highlight the prototyping process's importance. Ultimately, it is not about the act of making something but about creating knowledge from the reflection of the designer/researcher, both *in-* and *on-action* (Schön, 1983), through this process. The current step in this adventure is to test *The Non-myth* with real users, where they are engaging with the story and playing with my ideas while I try to identify the possible emergent social dynamics, determining what helps towards a positive narrative experience, and in general contribute knowledge towards the maturing the study of interactive storytelling, in particular the small, but growing l field of tangible narratives.

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