Captain Electric and Battery Boy: Prototypes for Wearable Power-Generating Artifacts

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ABSTRACT
"Captain Electric and Battery Boy" refers to an ongoing research project that aims to develop electronic garments and wearable artifacts that harness power from the body and use that energy to actuate co-located electronic components. This paper will discuss two initial stages of the collaborative design process, which led to concepts and prototypes that seamlessly integrate technical constraints within design aesthetics. The first stage took place during a winter 2008 design course where students were presented with a brief to create an artifact for "Human-Powered Illumination." The second consisted of a two-week intensive workshop with a selection of the original students, held in the summer of 2008 at XS Labs. Finally, we will briefly present the final outcome.

Author Keywords
Human-generated power, electronic garments, wearable technology.

ACM Classification Keywords
H.5.2 User Interfaces: Input devices and strategies.

General Terms
Design, Human Factors

INTRODUCTION
The "Captain Electric and Battery Boy" research project was initiated in 2007 to explore the design possibilities for human generated power [3]. The project involved some technical development in improving the efficiency of existing systems, but mainly focused on conceptual explorations and user scenarios.

Many commercially available products that use human-generated power require very specific actions that are conceptually unrelated to the function of the actual product. Examples include pump flashlights and crank radios, which, even though they present the most efficient solution, create a disconnect between the activity of powering the artifact and the artifact itself.

An important aspect of this project was to focus on a seamless integration of form and function with the set of gestures or movements necessary for power generation. Through different collaborative design exercises, we generated a broad range of ideas that emphasized a close conceptual integration between the two. Most importantly, we pursued design directions where the activity necessary to generate power was not decoupled from the usual patterns of use of the artifact.

Figure 1. Concept illustration by Miliana Sesartic.

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Some of the early brainstorming included the development of mood boards that included references to fashion, science, science fiction, and fantasy, as well as sketching and illustration work. In order to start building prototypes, these concepts were brought into two different structured design environments. The first was a winter 2008 design course where students were presented with a brief to create an artifact for "Human-Powered Illumination," with an emphasis on concepts that seamlessly integrate technical constraints within the design. The second consisted of a two-week intensive workshop, with a selection of the original students, held in the summer of 2008 at XS Labs.

The ultimate research goals were to produce electronic garments that harness power from the body and use that energy to transform themselves in response to various internal and external stimuli. The garments both passively harness energy from the body and allow for active power generation by the user. Depending on levels of discomfort and extenuation, as well as the desire to supersede the limitations of the human body, the garments produce varying amounts of energy to fuel themselves and actuate elements on the body.

Figure 2. The final Captain Electric dresses.

MOBILE POWER AND SUSTAINABILITY

Our need to power an increasing number of portable (and stationary) electronic devices is constantly growing. Particularly in the design of mobile and wearable electronic devices, power is, and will continue to be, one of the most difficult restrictions to overcome [5]. The development of energy sources that are independent of our power grids and reside on the body, collocated with the electronic devices they power, offers a possible solution.

We believe that research in this area can be categorized in three different directions: (1) flexible solar panels, printable photovoltaic cells, biobatteries, and dielectric elastomers among others; (2) eco-design, power conservation, and designing for sustainability; and finally (3) human-generated power. Researchers such as Paradiso from the MIT Media Laboratory have explored this third research direction in depth. Paradiso's study of "parasitic power" includes the evaluation of methods to recover power (a) passively, from body heat, arm motion, typing, and walking, and (b) actively through user actions such as winding or pedaling [5].

Unfortunately, current wearable power-harvesting technologies are not efficient enough to satisfy demand, while the process of energy harnessing detrimentally affects the comfort of the body.

DISCOMFORT AND FASHION

One of the driving forces for fashion, spanning history and different cultures, has been to seek a continually evolving concept of beauty through the transformation of the body's natural form. This has been exemplified by practices ranging from subtle adjustments of a body's proportions – through the use of conical brassieres, bustles, crinoline hoops, and exaggerated shoulder pads – to more extreme practices such as deliberate (and sometimes permanent) physical deformation of the body. [4] As such, the field of fashion design could be arguably more receptive to discomfort and inconvenience as a means of power generation on the body. While it is difficult to accept an uncomfortable running shoe or other fitness garment, it is easier to embed the discomfort and the inefficiency of current human-generated power solutions into the culture of fashion and costuming.

At the same time, fashion presents us with a playful and poetic design field. Garments are used to hide, reveal, and distort the self that we present to the world [2]. They also collect and reflect some of our most intimate moments and are marked by our sweat, food stains, and tears [1]. Garments are historically versatile insofar as they are soft and adapt to their context of use and to the shape of the body. Our design methods leveraged this versatility and focused on the development of concepts that integrated the technical constraints of power generation with compelling physical choreographies. The prototypes developed in the two stages of the design process focus on alternate definitions of functionality, such as pleasure, fun, and beauty, so as to allow playful and engaging design concepts.

FIRST DESIGN EXPLORATIONS

The first set of prototypes emerged from a selection of student projects from the winter 2008 Design course "Second Skin and Softwear" at Concordia University. Students were presented with the design brief to create an artifact for "Human-Powered Illumination". They were given a kit that included a variety of generators salvaged from human-powered flashlights and a custom designed circuit board with a rechargeable battery to collect the generated power.

The design brief asked the students to design an illuminating artifact powered through human motion. This could be accomplished in a collocated manner, by moving

the artifact itself, or through a modular system where one can detach the power module, interact with it in a kinetic way, and then reconnect it to the main artifact. The emphasis was placed on the design of poetic, personal, and unexpected choreographies where the motion necessary to generate power could become an integral component of the design concept. As such, students were asked to develop more interesting movements than simply shaking a generator or pulling on a string.

Emphasis was also placed on the reuse of existing electronic objects so as to minimize waste. Students were required to use the casings of the flashlights as a component of their design (structural or aesthetic). Trade or barter economies of scale emerged: some students traded their casings for goods/services if they did not need to reuse them. We encouraged exchanges about sustainable community practices.

The resulting creations varied both in concept and material use. In addition, some students chose to develop soft wearables to house or conceal the solid power-generating components, others chose to use harder materials or to forgo wearables all together and focus their creativity on installation pieces or representative objects.

The power module

We evaluated different ways to generate power from body motion. We experimented with many types of dynamos (from commercially available products) and supplied the students with an assortment of input modalities that included pulling, pushing, and rotation. The pull-cord generators seemed to be the most versatile and efficient but were also the most fragile insofar as the strings tended to break after fewer than 100 pulls.

The students were also given a custom designed PCB with 3 inputs for generators, a rechargeable battery, and one 3V output. The students were asked to stuff the boards as a part of their project work so that they could also master soldering and deepen their knowledge of electronics. The assembled board allowed them to connect up to three dynamo generators concurrently and to use the stored energy to power their illuminating artifact.

Although the brief required the design of an illuminating artifact powered through human motion, the word "illumination" could be interpreted in a more or less literal manner. The fact that most students took the idea of human-powered illumination literally, choosing to integrate lights in their design, was chiefly caused by the power limitations of the circuit. Powering more complex systems proved to be impossible and students were constrained to develop interesting metaphors for light and to build conceptual scenarios that integrate light emitting diodes.

Impact by Catherine Marchand

The theme explored in this project is that of fashion as a frustrating constraint and the false sense of empowerment that garments sometimes provide. Fashion, particularly sports apparel, is presented as a protective physical and psychological shell. The artifact itself is modeled on the bandage-like hand wraps traditionally worn underneath boxing gloves to protect knuckles and thumb joints. The hand wraps are uncomfortably tight and embody themes such as empowerment, frustration, brutality, physicality, force, and domination.

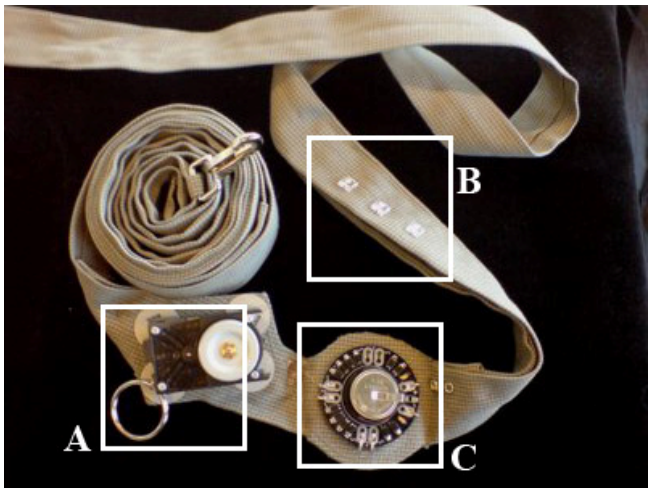

Figure 3. The Impact prototype by Catherine Marchand. Box (A) shows the input pulley generator device, Box (B) shows the output LEDs, and Box (C) shows the PCB with integrated rechargeable battery.

Figure 4. The Impact prototype by Catherine Marchand. As she starts to throw punches in the air, the red LEDs on the knuckles begin to glow.

Referencing fashion's historical relationship with capitalist consumption, the output of this artifact illustrates the triumph of the object in a consumer society: a string of LEDs emits an amber glow after a few punches have been thrown. Placed over the knuckles, the reddish glow is also a symbol of the blood on our hands that results from the punch and further references the brutality of boxing. □□

Figure 5. The Impact prototype by Catherine Marchand.

***LOLLYloop-Lights* by Lois Frankel**

LOLLYloop-lights are wearable jewelry artifacts that magnetically draw friends together for active fun and conversation. They integrate illumination, human-generated power, rechargeable batteries, and traditional materials such as felt, beads, and leather.

When placed together, they replace or complement candles in the centre of a table to create a unique ambiance. Individually, they are distinctive pieces of jewelry that each friend can wear upon parting as a slowly fading memory of companionship. Each loop can be worn in a variety of ways, depending on individual preference. Each LOLLYloop-light is versatile enough to be worn around the neck, wrist, waist, head, arm, leg or any other part of the body as long as the ends come together. Several can be worn together, or they can be worn on their own. The instructions that accompany the artifact state:

1. Remember your special friends every time you wear your LOLLYloop-light. To rekindle your friendship, invite them over and remind them to bring their LOLLYloop-lights!

2. When everyone is gathered, power up the LOLLYlooper.

3. Who needs candles? You can attach everyone's LOLLYloop-lights to make different centerpieces.

4. Don't forget to give a LOLLYloop-light to each friend.

Figure 6. LOLLYloop-lights, with the LEDs turned on.

The LOLLYloop-lights are "parasites" that get their nourishment through a connection to the winding heart when power has been generated by human kinetic energy. The light lasts as long as the charge does, gently fading as the power dies. Without light each LOLLYloop-light remains a special piece of jewelry, reminding its wearer of her special friends and giving her something to look forward to. The next time she gathers with her friends they can recharge their LOLLYloops and so symbolically rekindle the glowing warmth of their friendship.

***Footprint* by Marc Beaulieu**

The sole of each shoe contains a squeeze-triggered, power-generating module sandwiched between sprung blocks. The power accumulated by walking is stored in order to power the lamp. One's steps are constrained by the intentionally cumbersome shoes and alter one's steady walk to resemble a drunken swagger or tired foot-dragging, depending on the physicality and ability of the walker. The choreography created by the shoes references issues pertaining to power conservation, sustainability of resources, and basic personal environmental responsibility. Being aware of every step one takes embodies our concerns with the carbon footprint we leave behind us in our everyday activities.

While the act of walking charges the batteries integrated in the shoes, at the end of a long day, one can remove the shoes and connect them to a lamp using a magnetic connection so as to create artificial illumination for evening relaxation. A causal relationship is thus established between the amount of labor, or steps taken, and the amount of relaxation time earned.

Figure 7. Footprint, by Marc Beaulieu

The shoes are constructed of wood but the lamp, shaped to evoke the branches of a tree, is made of Plexiglas with LEDs at the base. This purposeful conflict in materials echoes the current misuse of resources (both natural and artificial) and points to a future where the depletion of

resources has forced a self-sustaining, off-the-grid existence where people are responsible for their own power creation.

Figure 8. The Footprint Lamp, by Marc Beaulieu

"Being: Seeing" by Emily Paris

Light allows us to explore our physical world in the search for knowledge. Like in Plato's cave, the tangible evidence of knowledge might restrict our minds, ready to believe that physical evidence is indisputable, and prevent our understanding from expanding beyond physical reality.

Figure 9. "Being: Seeing" by Emily Paris.

This project integrates two hand-held silicone spheres attached to the waist with pulleys. The two translucent orbs are illuminated when the battery is charged by the movement of the user's arms. The extension of the arms allows the user to generate light, and metaphorically look beyond the hollow shadows into the intangible.

***Happy Times* by Catherine Cournoyer**

Dance is a form of expression that communicates cultural identity, social concerns, and individual beliefs. Psychologically speaking, dance can express repressed emotions, stimulate the intellect and creativity, while physically it strengthens the body and improves one's health. *Happy Times* aims to promote dance for the individual as a form of celebration and enlightenment.

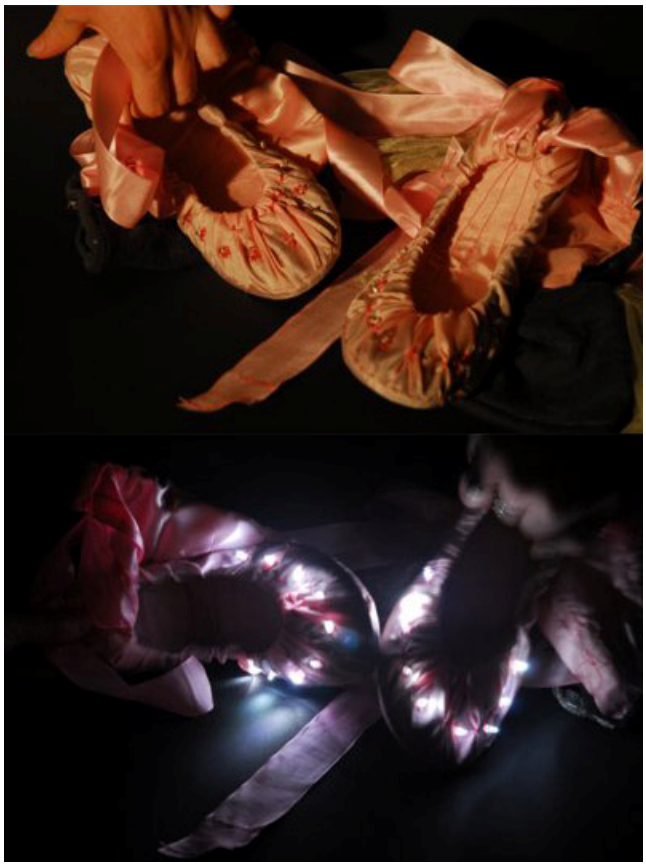

Figure 10. Happy Times by Catherine Cournoyer.

The ballet shoes and accompanying leg-warmers contain LEDs, a soft switch, a power accumulator, and a power generator, all connected through conductive threads. Dancing illuminates the LEDs, creating a sense of satisfaction and wonder. The more the dancer dances, the more joyful light and is generated. The ballerina is given the chance to illuminate herself, if only for a moment, creating a moment of contemplation and surprise.

SECOND DESIGN EXPLORATIONS

The second design phase of the project was an intensive two-week workshop during the summer of 2008. Five students from the design course, along with an electronics consultant, were invited to participate. The work included research presentations that spanned fashion design, industrial design, science and technology, as well as performing art. The workshop resulted in a series of brainstorming and bodystorming exercises, as well as some physical prototyping. The ultimate goal of this second

phase was to develop stronger concepts that would allow us to further refine ideas for human-generated powered, ultimately defining a unifying thematic for the final collection of garments.

BRAINSTORMING

Perverse Connections

The initial exercise consisted of printing out three sets of words: a verb, an adverb, and a noun describing a body part. Words from each category were pulled at random, and concepts were sketched based on playful interpretations of the word combinations.

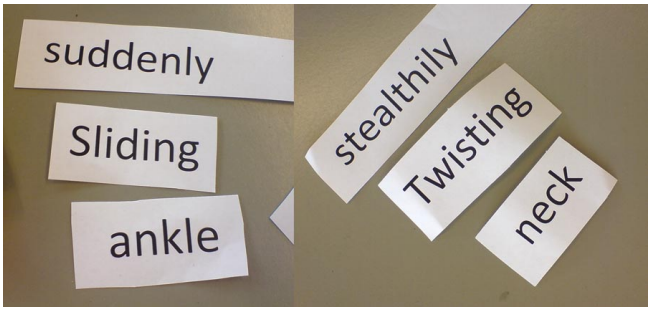

Figure 11. Word combinations for brainstorm exercise.

The group was strongly influenced by the mechanics of specific power generators, such as the pull-cord dynamos, and a theme quickly emerged: body parts fastened together, creating unusual postures, prompting specific body movements. As the body struggles to move, pulling on the strings that drive the dynamos, power is generated. Like a Chinese finger trap, these "perversely connected garments" would compel the individual to fight against the discomfort, while the generated energy reinforced the disruptive behavior.

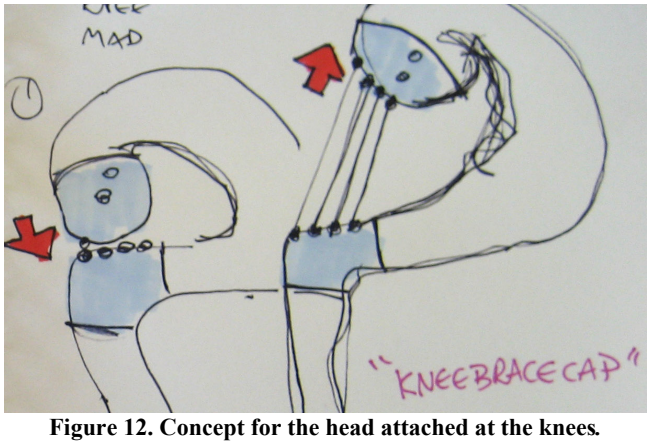

Figure 12. Concept for the head attached at the knees.

The exercise not only produced an interesting array of design possibilities and silhouettes for fashion design, but also produced two potential interaction scenarios: (a) one that focused on the individual adapting to restrictive situations and (b) another that focused on a more parasitic anthropomorphic relationship with the garment. These concepts sketched out garments that connected different parts of the body that would otherwise be apart within a single garment design. The garment concepts pull the body into uncomfortable, convoluted positions and reference choreographies influenced by performing arts such as dance or theatre.

Figure 13. Concept for the head attached to the navel.

In one example, the head was tethered to the knees. As the head pulls away to straighten the torso, energy is generated. In another example, bellows that look like gills or membranes are placed under the arms and connected to dynamo push mechanisms. As the arms squeeze close to your body, the batteries are charged.

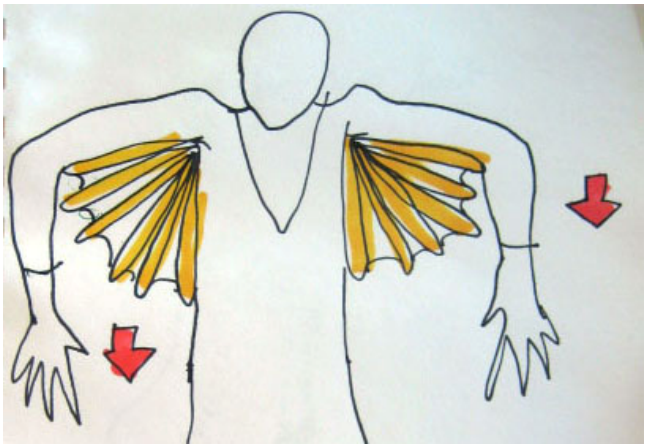

Figure 14. Concept for underarm accordions.

Despite the interesting thematic and conceptual discoveries made from this exercise, the majority of the sketches and the thoughts behind them tended to be limited by the technological requirements of the dynamos. Since the team had been involved in the original design class, their familiarity with the power-generating modules inhibited the more playful mandate of these design exercises.

Emotional States

Based on discussions and informal analysis of the first exercise, a second exercise was developed to encourage more playful and less literal ideas. Instead of using random verbs, adverbs, and body parts, the starting point was to

define specific emotions as well as actions and objects associated with these emotions. The exercise aimed to uncover design possibilities that dealt with more emotive properties of garments: designing garments for a particular emotional state or feeling, rather than the technical considerations of human-powered garments.

Each participant was asked to describe two distinct emotional states. For each one, participants were asked to propose an object and an action related to that emotional state. In order to generate more playful and spontaneous results, the action was then passed to the person sitting to their right, and the object to their left. Sketches were limited to two minutes and were to integrate the three elements.

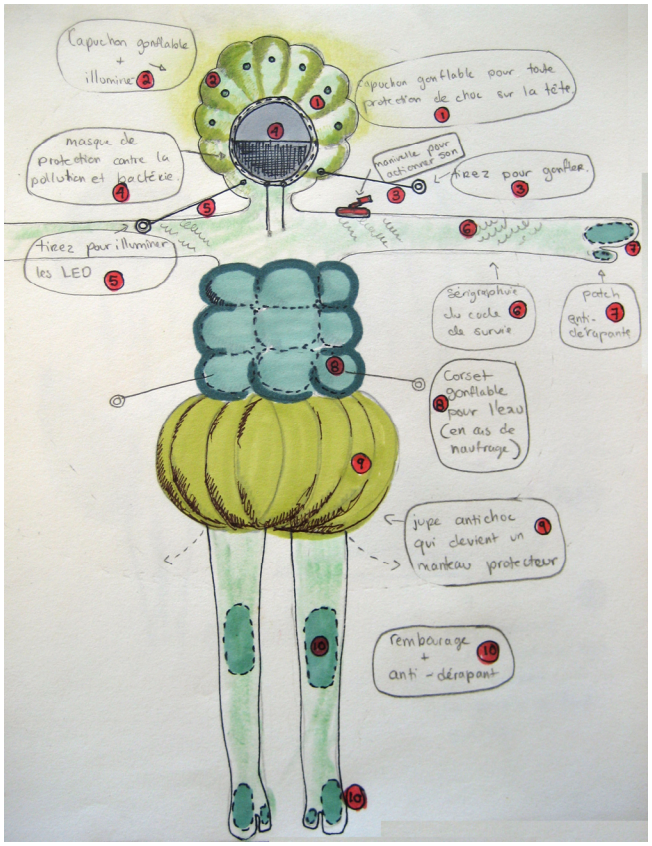

Figure 13. Personal protection, both physical and emotional.

The group developed sketches of garments based on deeper, complex themes such as uncertainty, fear, anxiety, and paranoia. The concept sketches led to a series of prototypes that conceptually referenced personal protection, both physical and emotional, as well as our fears of various states of emergency and other dangers, disasters, personal phobias, and awkward social situations.

PROTOTYPES

To begin prototyping, a small amount of time was allocated to exploring technological considerations. Electronic components were acquired and rapid prototyping during the last week of the workshop was undertaken to further explore the notions of perverse connections, anxiety, and personal protection. Four prototypes were constructed, though not fully completed. Three of these were garments exploring specific output and one was a module aimed at maximizing power input.

Figure 14. The Jellyfish Hat.

The Jellyfish Hat & Frill

The Jellyfish Hat and Frill both use vibrating motors. Jellyfish has three tentacles that fall from the back of the hat onto the neck. Inside the tentacles are vibrating motors controlled by a microcontroller and a piezo switch. The sound and the movements of the tentacles on the back of the neck compels the individual to scratch or touch the neck. In doing so, the piezo switch is triggered, deactivating the vibration for a short amount of time.

Figure 15. The frill.

Frill is a dress that secures one arm to the hip with a pulley dynamo. Around the neckline is a sculptural webbed frill, with embedded vibrating motors. The frill vibrates, tickling the neck and face, prompting a swatting action from the

tethered arm. As the arm moves, it generates additional power, which feeds the dress and the vibrating frill. As in Jellyfish, a piezo flick switch deactivates the irritating vibration for a short time. The frill begins to move again in order to recharge its battery, when its power level drops low enough for the dress to demand another feeding.

Both garments illustrate a perversely antagonistic relationship that is rather parasitic, highlighting notions of dependency and discomfort.

Figure 16. Sketches for the Safety Jacket

Figure 17. The Sticky dress.

Safety Jacket

The Safety Jacket references our fears of natural and unexpected disasters. This garment is constructed out of a modified water safety jacket and augmented with small airbags. One airbag is filled by blowing into a hose and the other by repeatedly pulling on a pulley to actuate a fan. The preserver is covered with a yellow silk-screened fabric, depicting the function of the garment.

These prototypes directly influenced and informed the final stage of the project, entitled simply "Captain Electric," which consisted of three dresses. The final dresses are called Itchy, Sticky, and Stiff [3]. They mirror the themes developed during the workshop insofar as they conceptually reference safety apparel and personal protection.

CONCLUSION

The "Captain Electric and Battery Boy" research project aims to explore the design space for body-worn electronic artifacts that are driven by human-generated power. We have explored different collaborative design methods to develop concepts that integrate technical constraints with poetic and unexpected physical and personal choreographies. Rather than attempting to conceal the generators and their operation, we chose to overtly integrate them into the garment concept and design.

The prototypes developed through this design process focus on alternate definitions of functionality, such as pleasure, fun, and beauty, so as to allow playful and engaging design concepts. Reflecting fashion's historic relationship between discomfort and style, the different prototypes and designs restrict and reshape the body in order to produce energy. These uncomfortable limitations helped to develop a conceptual framework focused on personal protection and our fears of natural disasters and other states of emergency, personal phobias, anxieties, and paranoia.

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REFERENCES

1. Berzowska, J. "Memory Rich Clothing: Second Skins that Communicate Physical Memory", Proceedings of 5th Conference on Creativity & Cognition, ACM Press, New York, 2005, pp. 32 – 40.
2. Berzowska, J. "Electronic Textiles", Textile, Berg, London, 2005, Volume 3, Issue 1, pp. 2–19.
3. Captain Electric website http://www.captain-electric.net
4. Koda, H., Extreme Beauty: The Body Transformed, Metropolitan Museum of Art, New York, 2001.
5. Starner T. and Paradiso J.A., "Human-Generated Power for Mobile Electronics," Low-Power Electronics Design, C. Piguet, ed., CRC Press, 2004, chapter 45, pp. 1-35.