Body adornment and interaction aesthetics: a new frontier for assistive wearables

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Abstract
The paper addresses the challenge of balancing the tension between a problem-solving attitude in the design of assistive devices, with an ethical, aesthetic and cultural approach to design for people living with a temporary or permanent impairment. The topic is developed presenting two design cases. The first case addresses a permanent disability. It is a suite of smart jewels tailored for hearing impairment, which sense environmental sounds (e.g. doorbell, someone calling) and notify the wearer of their occurrence through different modalities (light patterns, vibrations, shape changes). The second case addresses a temporary impairment. It is an orthodontic facemask for the correction of malocclusions in children, that has customised aesthetics and ergonomics and is associated with a digital game. The cases illustrate the experience-centred participatory design adopted to mitigate the stigma associated with current wearable assistive devices and promote a cultural shift to transform assistive wearables into beautiful, playful, gender-appropriate accessories.

Keywords: Wearables, Assistive devices, Experience-centred design, Participatory design, Disability, Temporary Impairment, Aesthetics.

1. Introduction
The value of a product lies in the meanings that it has for its users. Sociocultural, psychological and experiential factors should be put at the forefront of design activity so as to fully address the needs, desires, practices and expectations of target groups.

In particular, designing for people with a permanent or temporary impairment implies looking beyond accessibility and functionality, and aiming to experience and participation.

Until the eighties, the *International Classification of Impairments, Disabilities and Handicaps* (ICIDH) introduced by the World Health Organisation defined disability as a “personal health condition”, a limitation or lack of ability to perform an activity in the way considered “normal” for a human being. That perspective changed in 2001, when a new *International Classification of Functioning, Disability and Health* (ICF) was launched. In the revised version, disability is described as “mismatched human interactions” (WHO, 2001), in effect marking a fundamental shift from disability as a personal attribute to disability as context-dependent. This means that the way we design the spaces we live in and the interactions afforded determines human dis/abilities.

Building on this concept, Microsoft has launched a project called *Inclusive Microsoft Design* (Microsoft, 2016), to support designers in understanding experiences that are not only compliant with standards, but truly open to all. The project delivered a design kit in which disability, and the resulting exclusion, is defined in a more nuanced way: permanent, temporary (e.g. wearing a cast for a limited period of time), and situational (e.g. in a loud crowd, hearing is clearly challenging). To help designers to understand the nature of exclusion, a Persona Spectrum was defined to understand mismatched human interactions across permanent, temporary, and situational scenarios. This way of framing exclusion is useful for stimulating a broader attitude to the nuanced and articulated concept of disability/impairment, addressing the needs of the widest possible audience, regardless of their ability or age.

In the last decade, the increasing interest in defining design guidelines to provide equal opportunities for all brought to a proliferation of terms like design for all, universal design, inclusive design, accessibility with a different focus on improving and enriching the experience of use of products, services and environments for people with diverse abilities, ages and cultures (Persson et al., 2015).

For the sake of clarity, we provide in the following some definitions which can help understanding nuanced meanings of the abovementioned terms and position our research with respect to the current literature.

Accessibility defines in a purely functional way the degree in which an environment or artefact is accessible or usable by people of all abilities (Boys, 2014). Whilst the concept is useful from a practical viewpoint, it fails to address the complexity of the lived experience of disabled people. Accessibility is often use in conjunction with inclusive design. Accessibility is an attribute (a product or service is accessible when it meets all accessibility standards), while inclusive design is a general design approach to ensure that products and services meet the requirements of the widest possible audience regardless their ability, age or culture (Boys, 2014). The term Universal Design has an emphasis on the design of products and services with everyone in mind, including aspects like look&feel and aesthetics usually overlooked in accessible design guidelines, which are purely functional (Stephanidis, 2001).

The European Institute for Design and Disability provided one of the most widely spread definition of Design for All as “design for human diversity, social inclusion and equality” (EIDD, 2004). This definition brought to the adoption of the so called “Stockholm Declaration” which situated the design for all vision within a discourse on sustainability which entails not only economic and environmental aspects but also cultural and social ones. The term was coined by Ronald L. Mace and it is often used as a synonym of Universal Design.

Universal Design defines the user extensively and does not focus only on people with disabilities. The emphasis is on the design of products, services and spaces accessible and usable by people to the greatest extent possible. It does not imply that everything is completely usable by everyone: the term refers more to the methodological attitude than to a rigid dogmatic assumption. It aims to offer solutions which can adapt to people with disabilities as well as to the rest of the population, at low costs compared to technologies for assistance or specialized services. This methodological approach found its definitive structure in 1997 with the definition of 7 design principles developed by the Center for Universal Design at North Carolina State University (Story, 1998). The principles accommodate a wide range of individual preferences and abilities, as well as various usage situations.

Notwithstanding the undoubtable contribution of the abovementioned design approaches and guidelines, some authors believe that «they have also obscured as much as they have revealed» (Boys, 2014, p 169). Classifications and norms have framed the disabled body in a way that casts a shadow over the lived experience. Accessible spaces and artefacts must comply with standards which consider the dis/abled body with respect to its abilities overlooking personal beliefs, culture and attitudes.

Therefore, it is fundamental to move the design practice from a compliant model of accessibility “on paper” ruled by standards, to a participatory model in which designers and users can learn from each other, with the aim of developing solutions that not only meet the needs of the abilities of the body, but also, and more importantly, the needs of human experience, identity and expression.

In what follows, we first review recent attempts to theorise design and disability studies as two dynamic, interacting disciplines, which can influence and inspire each other. We do this by describing projects with an explicit focus on designing assistive devices beyond a problem-solving mindset.

Later we present two of our design cases: the first addresses the culture around Deafness with a capital D to mean a human condition that is more than just hearing impairment; the second regards the design of a facemask for the correction of maxillofacial disorders in children viewed from a playful perspective.

In the conclusions, we draw some lessons learned and reflections to help designers embrace a broader, socially inspired and participatory culture of design, engaging people who are experts of their disability as active and creative participants.

2. Assistive Technologies

Assistive Technologies (AT) provide a wide range of tools, products and services to support people with permanent/temporary (motor, cognitive, sensory) impairment to live independently, improve well-being and actively participate in educational, work and social activities (Cook and Polgar, 2014).

Though the literal meaning of the term may suggest otherwise, assistive technology is the phrase used to describe supporting equipment for disabled people. Cars are also “assistive” since they compensate for our inability to move fast and cover long distances, but since they are designed for “normal” use, they do not fall into the category of assistive technology.

This example is intriguing. When mobility is intended for normal use, as in the case of cars, design assumes a quintessential role. Brands compete to make the driving experience as comfortable, memorable and valuable as possible. When mobility is intended for use by the disabled, the functional view prevails, the design becomes poor, repetitive and boring in terms of form, materials and colours; the user experience is considered primarily from an ergonomic viewpoint.

Assistive devices rarely reflect the human need for beauty, or a person’s need to express their individual sense of style. One of the few examples, if not the only one, of an assistive device that has evolved from a medical model to a fashionable product is eyewear. Innovative, creative, fancy eyewear styles populate the market, none of which suggest that sight loss is a real impairment.

On the contrary, non-surgically implanted hearing devices are designed to be as discreet, tiny and invisible as possible. This can lead to challenges in interactions. In social situations, hearing people can forget to attend to deaf people’s needs and inadvertently exclude them. Elegant, beautiful, and dignified devices could provide a response to this issue.

We argue that disability, being permanent or temporary, should not be regarded as a problem to solve or a lack to compensate but as a design opportunity. Disability can force some new questions onto the agenda that can actually open up new ways of thinking from a subjective viewpoint, and not just in terms of better accessibility (Pullin, 2002, 2009).

2.1 Assistive wearables

There is a huge potential for innovation in the design of wearables for people with temporary/permanent disability (Moon, Baker and Goughnour, 2019). Wearables are «any device worn or carried on the body capable of receiving input, processing information, and providing output to a user» (Gandy et al., 2008, p.317). Nowadays the spread of tiny sensors and microprocessors with increasing processing capabilities brings wearable computing closer to everyday use. Applications range from mobile communication devices, to physiological data monitoring systems (Majumder et al., 2017), to sensing/perception devices of the surrounding environment (Mateevitsi et al., 2013), to skin interfaces (Liu et al., 2013; Kao et al., 2016) and smart textiles (Pailes-Friedman, 2016).

Unfortunately, many wearable assistive devices remain highly stigmatizing in nature due to their medical-looking, poor aesthetic and no gendered body design (Newell, 2003; Profita, 2016). Furthermore, these devices are usually framed in terms of solving problems of people with impairment. This is of course a valid and important perspective. Yet other more open-minded frames are necessary to address the complexity of the lived experience of wearing assistive devices, which demands for sense of style, self-expression and social acceptance beyond the functional support.

Indeed, socio-cultural influences like stigmatization and negative attitudes often lead the user to modify, conceal or abandon the wearable assistive device (Profita, 2016).

Often assistive wearables do not fit with the self-image: the way we perceive ourselves, the sense of beauty and personal preferences about clothing the body; but also the way in which other people perceive us, the stereotypes, negative attitudes and judgements stimulated by the visibility of the device that makes the disability manifest (Profita, 2016).

Most commercial wearable assistive devices overlook the gendered body and pay little attention to aesthetics, if any. A nuanced choice of materials and forms, chosen by the wearer according to personal preferences and creativity, contexts of usage, and cultural habits are nowadays made almost impossible by the unavailability of alternatives on the market.

People who wear an assistive device to compensate for a temporary or permanent impairment have basically two choices to downplay the negative impact of the device: either giving up accessorising the body with style or adapting the device to suit the desire for style and self-image. More often the device is concealed, selectively used, or completely abandoned.

Therefore, a critical design perspective in the development of assistive wearable technology is necessary to achieve a sustainable convergence of humanistic and technological approaches.

2.2 New trends in AT design

Current assistive technologies are merely designed to address instrumental needs: form and function are not equally relevant (Newell, 2003).

Recently, designers involved in the creation of assistive wearables have started experimenting with new approaches and solutions to counteract the stigma of disability, designing for accessibility and acceptability (Profita, 2016).

Profita, Roseway and Czerwinski (2016) developed *Lightwear*, a series of gender-oriented garment designed to administer light therapy for on-the-go treatment of Seasonal Affective

Disorder. The project explores the integration of light into fashion-forward wearable textiles combining style and aesthetics with efficacy, usability, and convenience.
A similar approach was adopted in *Flutter*, a fashionable smart garment for sensory enrichment of individuals with hearing impairments (Profita, Farrow and Correll, 2015); and *Swarm*, a fashion-driven actuated scarf aimed at mediating affect for individuals with difficulty in recognizing and regulating emotions (Williams et al., 2015).
Hyungsoo Kim funded *Eone* with the mission to create accessible fashionable products, like a stylish tactile watch for blind people (www.eone-time.com).
Wear Sustain (*Wearable technologists Engage with Artists for Responsible innovation*) is a network funded by the European Commission Horizon 2020 Research and Innovation initiative, operating in 2017-2018 (EC, 2017). The network promoted collaborations between technologists and designers/artists to develop sustainable and ethical wearables. The network funded 46 projects in wearable technology design: 7 projects out of 46 specifically addressed disability and impairment with a focus on ethics, aesthetics and sustainability.
More in detail, 5 projects developed assistive wearables for people with physical, cognitive or sensory disability and 2 projects promoted wearable designs for supporting rehabilitation (Table 1).

Quietude Interactive jewels for enriching the experience of sound of deaf people.	**Sensewear** Smart garments for autistic people to reduce anxiety, stress, and panic attacks.
Beneficial Works Haptic navigation device targeted to blind and visually impaired people.	**Flexability** Kit to create made-to-measure e-textile for people with physical disabilities.
Future Jewels Responsive, wearable objects that create playful interactions with people with sensory impairments.	**Zishi** Garment designed to support posture monitoring for the purposes of rehabilitation training.
Constructing Connectivity Stroke rehabilitation method based on textile making.	

Table 1: Assistive wearables developed within the EU Programme Wear Sustain

Fashion-driven assistive wearables have also been developed following a consumer-driven endeavor in the beautification of assistive devices.

Sophie de Oliveira Barata promoted the *Alternative Limb Project* (2011) where she created highly stylised prostheses as art pieces, involving clients in brainstorming sessions and fine-tuning prototypes throughout the design process.
Similarly, ALLELES Design Studio offers covers to transform the prosthetic to appear less like plastic and more like a textile (alleles.ca/leg-covers/). In this way, the prosthetic becomes a fashionable clothing rather than just a medical device.
A number of maker-focused initiatives have been emerging also from the do-it-yourself (DIY) practice of developing or modifying artefacts: e-NABLE "Enabling The Future" (2015), DIYAbility (2016) and Hackability (2016) are notable instances.
The books *Design Meets Disability* (Pullin, 2009) and *Rhetorical Accessability* (Meloncon, 2014) offer theoretical lenses to think about the complex and dynamic relationship between disability, design and accessibility. Both scholars envision a future where assistive devices are de-medicalized and de-stigmatized as it happened to eyeglasses transformed from medical aids into fashion accessories. However, they develop this argument from different theoretical viewpoints.
Pullin (2009) uses critical theory as a framework to make designers think as opposed to design that solves problems or finds answers, and calls for a new approach to design in the context of disability based on a «richer balance between problem solving and a more playful exploration» (p. 121).
Meloncon (2014) uses phenomenology to connect theory to practice as a way of underlining the ethical need to better consider disability and to reframe, repurpose or remake both technology and the human body. By using the term Accessability she means «to emphasize the need to meet the abilities of users and audiences, no matter what those abilities are, while understanding the need to promote inclusive access for those same abilities» (p. 10).
All projects and theoretical approaches described above promote a cultural shift through a change in discursive and design practices associated with disability. Some of them emphasize person over product approach grounded in disability studies; some others take a product-centred view grounded in design research and practice.

3. Research objectives and methodologies

In what follows we present two design cases developed at the University of Siena (Italy) in partnership with other public and private organisations. The projects explore human-centred design from the lens of an experience-centred participatory design. This way the dichotomy person-centred vs product-centred design is overcome by practising participatory design with end users who are not just consulted but actively engaged in the creative process. Both cases regard the design of assistive wearables for permanent or temporary disability, and highlight the importance of putting the lived experience of people with impairment at the forefront of the design process.
The research question behind the two design cases is related to how to turn a merely pragmatic/instrumental view of current assistive technologies in a rich experience-centred design approach in which aesthetics, personal preferences, comfort, self-image, gendered body considerations, personal meanings associated to clothing and accessorising the body are at the forefront of the design process.

In the following chapters, we address this research question presenting and discussing the participatory methodology adopted to ideate and prototype assistive devices in collaboration with target users and stakeholders. The methodology develops through iterative and incremental thinking-through-making activities which set the scene for a more empathic and emotional approach to the problem. Thinking-through-making is also a way to engage stakeholders in ideating and prototyping solutions together. Intermediate prototypes are used to critically analyse the user experience and let needs, desires and aspirations emerge all along the process.

4. Case Study 1: Smart jewels for hearing impairment

Hearing aids are highly stigmatising. Size and visibility are the main features associated with the reluctance to use them and with the stigma associated with them. A recent survey showed that the most common stereotypes associated with hearing aids are that they make the wearer look older, less communicatively effective, less sociable/friendly, looking disabled, weak, feeble, embarrassing, lonely, and less confident (David and Werner, 2015). The effect of stigma on self-perception and social identity of people with hearing impairment represent a major threat to social identity and threatens the stability of social interaction.

Quietude is an ongoing project developing aesthetically rich, socially sustaining wearables for deaf people to counteract the social stigma while providing functional support.

The responsive fashionable jewellery system recognises meaningful incoming sounds (e.g. wearer's name, the doorbell, a car horn, an alarm) and expressively notifies them to the wearer through light, vibration and shape change.

The project received funding from the EU H2020 Wear Sustain Programme and was developed by an interdisciplinary team of deaf people, designers, technology experts, psychologists and an expert in ethics from the University of Siena, two private companies Glitch Factory and T4All, and Mason Perkins Deafness Funds Onlus specialised in providing services to the deaf community.

Through a series of participatory design activities, the project team and the deaf participants moved from the discovery phase (to understand barriers, needs and desires of deaf people), to the design of prototypes and the evaluation of the project solutions (Marti and Recupero, 2019).

4.1 Participatory design workshops

Deaf people participated in two participatory design workshops.

The first workshop lasted 6 days and involved 4 deaf people, 1 designer, 2 design researchers, 1 psychologist, 1 ethicist, 6 makers/engineers, and 2 Italian sign language interpreters.

Day 1 focused on feelings deaf participants have about not hearing or being heard; Day 2 focused on creating forms and selecting materials; Day 3 focused on developing concepts; Days 4–5 were devoted to materialising ideas and developing low-fidelity prototypes; Day 6 focused on testing the prototypes, reflecting on the achievements and planning the next steps. These activities disclosed a number of complex needs/requirements of deaf people ranging from functional needs like the awareness about meaningful sounds (e.g. pet, doorbell, name, etc.) and public notifications (e.g. train delay); safety in emergency situations (e.g. alarms, announcements in public spaces, police whistles etc.); to needs related to the possibility to

express individual preferences and sense of style; aesthetics of hearing aids; curiosity about the quality of sounds that could be experienced through other senses, (e.g. sight, touch) or through on-body vibrations.
From this workshop, a series of prototypes were developed to materialise ideas and address emerging requirements.
These included: a shape changing necklace (Figure 1c) and a bobby pin with dynamic elements translating environmental sounds in micromovements (Figure 1a); a ring emitting lights associated to environmental sounds, a brooch (Figure 1b) and an armband providing vibrations on the skin to notify specific sounds.

a)  b) 

c) 

Figure 1: early prototypes of (a) bobby pin with dynamic element, (b) brooch and (c) shape changing necklace

The second workshop involved 5 deaf participants and a group of hearing participants composed of 1 psychologist, 1 designer and 2 design researchers supported by an Italian sign language interpreter. The aim of the workshop was to reflect on the needs and desires emerged during the first workshop, and to engage the participants in evaluating the prototypes developed after the first workshop. The workshop was organised in three parts as described below.

- **Card sorting** to reflect on needs and expectations

16 cards were distributed on a table (Figure 2) which depicted 16 basic human desires roughly inspired by Steven Reiss's theory of motivation (Reiss, 2000). Reiss conducted studies that involved more than 6,000 people which resulted in a list of 16 fundamental needs, values and drives that motivate a person.

Figure 2: Card sorting

Although most people are not used to thinking about human behaviour in terms of fundamental desires, we used the cards to help gain insights about some of the needs and desires discussed during the first workshop.

Surprisingly, even though the need for an aesthetic aspect in hearing aids had been mentioned several times in the first workshop, only after some discussion was it recognised as a fundamental need and included in the top short list together with safety, curiosity and social status.

Deaf people recognised that they are biased by a medical model of disability which forces them to prioritise the functionality of hearing aids to the detriment of other aspects of the user experience, such as aesthetics, wearability, personal style, social stigma, etc. Card sorting proved to be an efficient means of stimulating discussion (Robin and Warren, 2019), but the abstract nature of the 16 basic desires sometimes resulted in an unproductive theoretical exercise for some of the Deaf participants.

- **Thinking through making**

After the card sorting activity, all participants were involved in a making activity based on a desire selected from the previous phase. The activity was prompted by the use of various materials including textiles, paper, cardboard, tape, pens, glue and hooks which were put on the table. Participants were encouraged to fabricate their own personal accessory, give it a name, present it to the others and reflect together (Luck, 2018).

Five probes were developed by the deaf participants and two from by the hearing participants to underline equality in the participatory process. These included a brooch, a necklace, an armband and a belt whose properties reflected sensation of self-realisation, need for aesthetics, awareness of the surrounding environment, playfulness.


Figure 3: Thinking through making

- **Evaluation of prototypes**

The third part of the workshop was devoted to the evaluation of prototypes of jewels realised by the design team after the first workshop including an app developed to record, filter and recognise sounds to be performed by the accessories in visual or haptic modality.

The deaf participants were excited about the possibility to explore the sonic qualities of environmental sounds and experience them through different sensory modalities like the visual (light and shape change) and tactile (vibration) perception. This functionality convincingly addressed the deaf people's curiosity about sound.

The jewels were regarded as an example of universal design which does not stigmatize or define deafness in any negative way and scales the solution to a broader audience than deaf people. The most appreciated design regarded the necklaces and the armbands. The ring emitting lights was criticised since it creates confusion in Sign Language communications. The app was evaluated very positively. One of the deaf participants autonomously started exploring it, setting preferences and explaining the functionality to the other deaf participants. This was regarded as a manifestation of early appropriation of technology.

4.2 Smart jewels

A more advanced and robust release of the jewels was developed after the participatory design sessions. As requested several times by our deaf partners, the new jewels had the ultimate objective to go beyond the functional goal of supporting hearing and fulfilling sociocultural needs such as aesthetics, self-expression and identity of deaf persons.

The resulting system is modular to allow different types of formal configurations and personalisation of use, according to personal preferences and circumstances (Figure 4).

Modules embed sensors to detect specific sounds and actuators to notify sounds through light, vibration, and kinetic modifications (shape change). A video of the system's behaviour can be watched at http://www.quietude.it.

a)  b) 

Figure 4: Necklace realised with (a) regenerated leather and (b) papier-mache

The jewels are dynamic and shape changing interfaces providing a new communication modality (Rasmussen et al., 2012; Kwak et al., 2014; Alexander et al., 2018). While the existing assistive technologies for deaf people rely on visual signals or vibrations, our jewels experiment also with micro-movements to add expressivity and make sound qualities visible. Moreover, micro-movements provide an intriguing opportunity to improve hedonic properties of the wearables, towards aesthetics and pleasure. By setting kinetic parameters of shape change (e.g. speed and frequency, direction, space), a vocabulary of expressive moments can be realised and associated to sounds (Rasmussen et al., 2012).

As anticipated above, the jewels are connected to a smartphone application (Figure 5) that permits customisation of both input (sounds of interest to be filtered and recognised) and output (notification through light, vibration or shape change). The person can create a personal library of sounds of interest by recording meaningful sounds through the microphone embedded in the jewels. The recorded sounds are then labelled and stored in the app, and "translated" into vibrations, light patterns or subtle movements of the accessories to advise the wearer when they occur in the surrounding environment. Preferences related to kinetics, intensity of vibrations and light patterns can be set and fine-tuned through the app for different contexts, moods and bodily sensitivities.

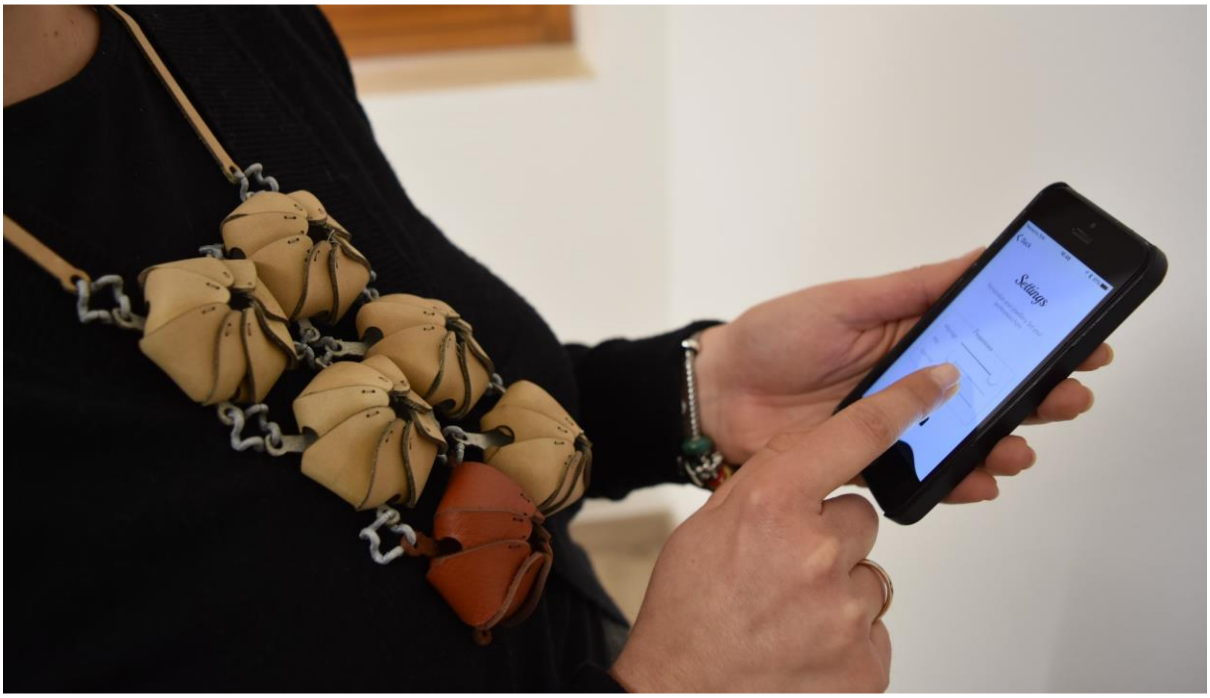

Figure 5: Setting preferences through the app

5. Case Study 2: SuperPowerMe

SuperPowerMe is a research project developed by a multidisciplinary team of orthodontist doctors, designers and technology experts from the University of Siena and the University of Firenze (Italy), with the involvement of children affected by Class III malocclusion and their families (Marti et al, 2020).

Class III malocclusion is a craniofacial deformity characterized by concave profile that results from retrusion of the maxilla and prognathism of the mandible. At the dental level this skeletal relationship reflects into the prominence of the lower arch relative to the upper arch, or the inversion of the anterior bite.

The diagnosis and treatment of Class III malocclusion happens at an early stage so to adjust the skeletal growth. To avoid orthognathic surgical correction, this type of malocclusion is treated using protraction facemask to drive a combination of skeletal and dental changes of the maxilla and mandible. Protraction Petit facemask consists of a frontal pad and a chin-cup made from acrylic, connected by a midline stainless steel rod (Figure 6). In order to apply a forward traction to the maxilla, elastics are attached from an intraoral anchorage system to a cross bar extending in front of the mouth.

The treatment with the protraction facemask is proven to be effective for patients who are growing, until 10 years old, especially in combination with an initial period of expansion (Kim et al., 1999). The effectiveness of facemask therapy depends on patient's compliance with the recommended wear time, possibly ranging between 14 - 24 hours a day, over at least 9 months. In a survey assessing acceptability of orthodontic appliances, facemask was rated as the least acceptable device (Abu and Karajeh, 2013). Indeed, commercial facemasks are unaesthetic, uncomfortable and may cause skin irritations due to uneven pressure by the standard anchorage pads. The facemasks are only available in standardized shapes and in two sizes. There is no gendered body design. Beside poor aesthetics and ergonomics, children often complain about facemask bulkiness and instability, which may compromise the treatment.

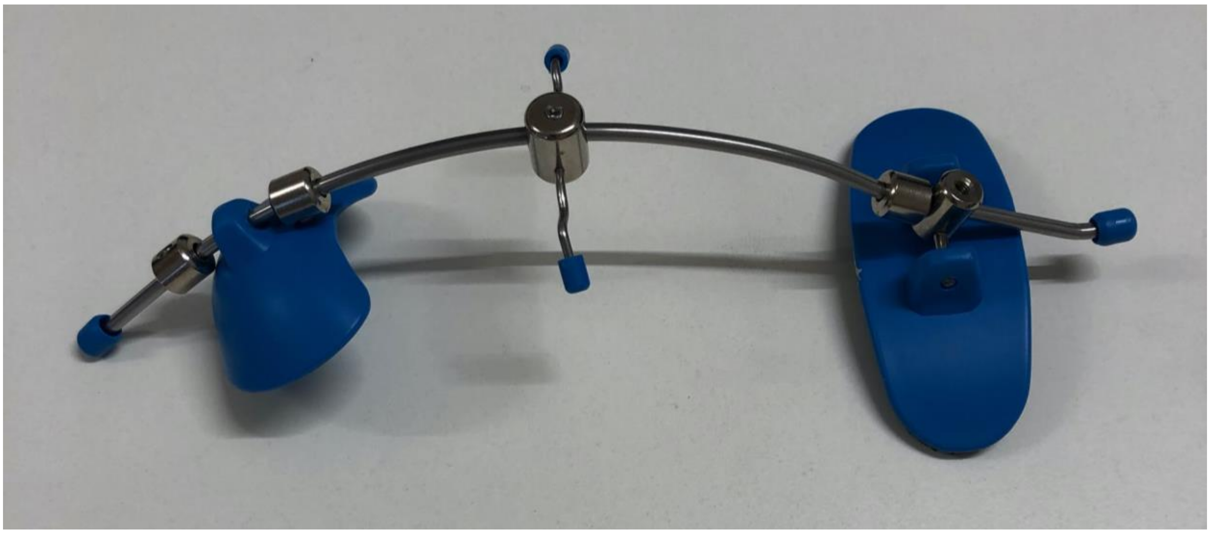

Figure 6: Commercial Petit facemask with a central vertical bar

The design of commercial facemasks is solely focused on the functionality of the device without paying attention to other aspects of the child experience like social acceptance and motivating factors, which are fundamental to make the therapy effective.
SuperPowerMe aims at developing facemasks using 3D printed biocompatible materials and customized design both in the appearance (form and colour are selected according to the child's preferences) and anatomy (the facemask is modelled following the child's face morphology).
The project was developed engaging different stakeholders including children, orthodontists, designers, engineers, psychologists in a participatory design process which evolved along three main phases.

- **Imagination/Ideation**

This was a generative phase of concept development in which the design team defined constraints and related design space.

- Improved ergonomics: commercial facemasks are heavy, standard in size and uncomfortable. Furthermore, the bulkiness and poor fit of the facemask make it unstable and painful.
- Material design: the plastic material of the forehead and chin cup currently used in commercial facemasks produces skin irritations.
- Child's experience: children complain about the mask's medical appearance and poor aesthetics.
- Aesthetics: commercial facemasks have no gendered body design. The design is boring and purely functional.
- Patient's motivation: the long duration of the treatment generates frustration and poor patient compliance.

Furthermore, the concept of a gamified therapy was developed which was composed of two main elements: 1) a personalised facemask designed according to the anatomy of the child's face and made of biocompatible materials; the mask embeds sensors to measure wear time and pressure exerted by the facemask on the forehead and chin; 2) a digital game designed to be a never-ending story which evolves with increasing levels of difficulty and challenges. Wearing the facemask for a predetermined number of hours per day allows gaining power and progressing in the game challenges. A video concept of the project can be watched at https://vimeo.com/268795652.

- **Exploration**

This phase developed along an iterative and incremental design process in which visions were materialised into prototypes of different levels of fidelity, aesthetics and material. The prototypes were collected in a workbook (Gaver, 2011) and documented with images, 3D models, sketches, and photos. The final design includes a skeleton of facemask (Figure 7) which can be decorated according to the child's preferences (Figure 8) and a simulated adventure game (Figure 9).

Regarding the facemask, several iterations were performed, from low-fidelity prototypes to fine-tuned masks, in order to reach a proper balance between functionality, ergonomics and aesthetics. Indeed, the design of customised medical appliances needs to consider both the requirement for orthopaedic treatment and the patient's need for comfort. For example, the material used for the single midline stainless steel rod is required to be strong enough to support the force for maxillary protraction (Yepes at al., 2014), while the pads need to be soft to the touch so to avoid skin irritation.

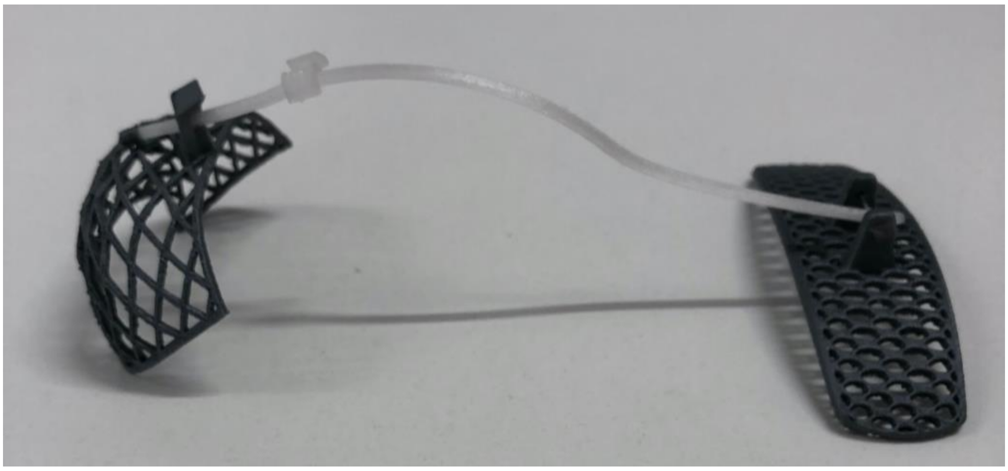

Figure 7: Personalised facemask with biocompatible material

Children affected by Class III malocclusion were involved in the design of decoration and embellishments using different colours and vinyl stickers. The design focused on the children's need for changing the appearance of mask, as for wearing accessories and clothes. Therefore, a catalogue has been created containing different models of pads and forehead decorations which can be applied on the mask (Figure 8).

Figure 8: Examples of decoration and embellishments

The interactive game for smartphone and tablet is connected to the facemask and can be played only when the mask is worn by the child. The game is an adventure game where a superhero avatar wears a facemask akin to the child's one (Figure 9). The more the child wears the facemask, the more the superhero avatar gains power and progress in the adventure. The facemask wear time is monitored by pressure and temperature sensors embedded in the chin and forehead pads. The use of embedded sensors is also useful to provide the orthodontist with metrics about the therapy, to evaluate the efficacy and to adjust the duration of the treatment.

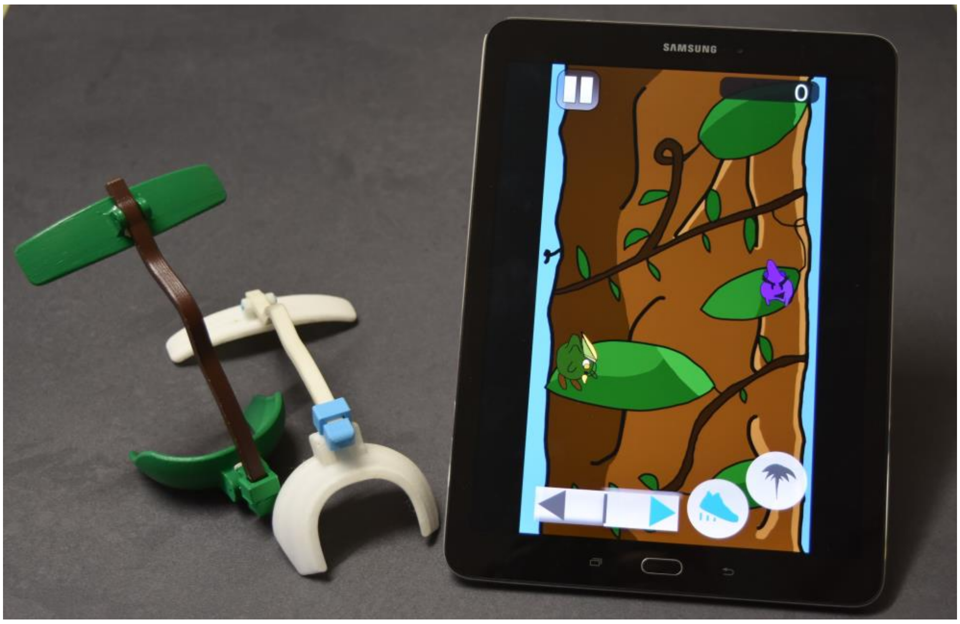

Figure 9: Simulated video game and prototypes of facemasks

- **Acting in the world**

This was an evaluative phase in which designers explicitly confronted prototypes with the real world in all its complexity, by engaging potential users and stakeholders in evaluating the solutions, and analysing opportunities for the real adoption and marketing of the new facemask. A national patent was claimed, while the international patent is still pending, though it has received a positive intermediate evaluation. A series of meetings have also been organised with manufacturers of medical devices to explore market possibilities.

Currently the project has developed custom facemasks that will soon undergo clinical trials at the Careggi Hospital in Firenze, Italy. Embedded electronics and the videogame are still under development.

6. Discussion

The design cases described above represent the extremes of a continuum from permanent to temporary impairment. Notwithstanding the diversity of the cases, they share some important features of the user experience: the stigma associated to hearing aids and orthodontic facemasks currently available on the market considerably alters self-image and self-esteem of people affecting all aspects of life such as emotional and functional well-being, socialization and relationships in general. The design cannot ignore the potential psychological impact and social stigma associated with assistive wearables.

In designing aesthetically rich and socially sustaining solutions, we engaged disabled people as experts of their impairment in co-designing potential solutions, and actively and critically participate in the design process. As Balsamo (2011) argues, design involves not just the making of new products/services but also the creation of new cultural possibilities.

In our cases, people involved in the design of new assistive wearables were somehow also engaged in the process of designing and communicating a new culture of disability based on playfulness, gendered aesthetics, self-esteem and sense of style.

Through several iterative and incremental co-design sessions, cultural beliefs were materially reproduced, identities were negotiated, and social relations were codified (Mainsah and Morrison, 2014). In this process, design made possible the expression of new meanings related to the demand for de-stigmatisation and de-medicalisation of the assistive devices.

In our projects, the co-design process took several forms from observation to interviews, and participatory design workshops.

The design cases highlighted that current assistive wearables are unattractive for both male and female targets. Gender appropriateness was clearly remarked as an issue as well as the emerging social stigma.

In general, the participatory design activities carried out in the two case studies, made desires, uneasiness and disquiet emerge, pervading the entire design process. The activity was grounded in the lived experience of disable people and driven by their aspirations, beliefs and culture.

Results obtained so far show that individuals value participation in the design process and the opportunity of customising and transforming assistive devices. This is an important component to grant individuals' agency, ownership and pride in wearing a device commonly fraught with marginalization. The practice of co-design has the potential to increase confidence in use and hopefully generate greater societal acceptance and awareness toward disability.

7. Conclusions

Although in recent times accessibility and inclusive design have acquired an increasing attention by regulatory bodies – the tendency to focus on instrumental aspects of assistive devices still prevails.

This paper describes two design cases addressing the stigma associated to the use of assistive devices in temporary and permanent impairments. It describes a participatory design approach used to balance an instrumental view of assistive devices with an experience-centred view valuing aesthetics, personal preferences, comfort, creativity in accessorising the body as pivotal for design.

The first design case addresses the complex needs of deaf people living in a sound-oriented world. Through participatory design activities, the project developed a suite of smart jewels which notify the person of the presence of environmental sounds through cross modal feedback (light patterns, vibrations, shape changes). Thanks to the involvement of deaf and hard of hearing people along the design process, we designed a solution that is not only useful and usable, but also desirable.

The second design case addresses the temporary impairment caused by Class III malocclusion in children. The correction of this malocclusion requires the child to wear a protraction facemask that is not well tolerated due to ergonomic and aesthetic issues.

In this case, the project developed a customised facemask focusing on aesthetics and ergonomics, as well as on motivational factors based on a gamification strategy.

The discussion of the design cases highlights the importance of adopting a holistic and experience-centred design approach where end users and stakeholders can participate to the ideation of intermediate solutions. The cases promote a cultural shift in the design of assistive devices to turn a merely instrumental products into beautiful, playful, gender-appropriate accessories.

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