

# The Aesthetics of Prosthetic Greaves: Co-Design for Expressing Personal Identity

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## Abstract

We consider the role of co-design in establishing the potential of artisanship in the aesthetics of prosthetics. Limited opportunities exist to accessorise and personalise prosthetics for the aesthetic expression of identity. It has been argued that striving for conformity and similarity would not do justice to the experience and ideals of unique persons and would come at great cost to individuality (Hilhorst, 2004). Furthermore, psychological factors need to be emphasised to a greater extent if the needs of individual prosthesis users are to be appropriately addressed (Schaffalitzky et al. 2011).

We present a project that explored the design of a prosthetic 'greave', a traditional piece of armour worn on the shin, which also fulfilled a decorative purpose (Fortenberry, 1991). The project considered an alternative to existing widely available foam-covers that give prosthesis a limb-shape, thus, transforming the current aesthetics that do not respond adequately to the needs of the wearers (Sansoni et al. 2016). A bespoke wood and tartan greave was designed as an initial exploration of the aesthetic value of the material to personal identity. From this, we established the need for a design process to support artisanship. A design process based upon artefacts that embody the shape of the lower limb, provided a model to craft personalised greaves. The project also explored alternative approaches to templates that support different types of maker in creating bespoke greaves through co-design with amputees. For a woodworker maker, a negative shape template was required, as well as cutting guides, to enable their process of sculpting. For a multi-material model maker, a positive shape template was required. This was to enable their cold-casting process to create a mould, and subsequently apply different casting techniques. Finally, for a willow weaver maker a layered template was required, to guide and position the strands of willow to take shape. The project designed a connector that would allow mounting a decorative greave from different crafts onto a universal section of tube above the prosthesis ankle.

Overall, the process we developed enabled makers and amputees to focus on co-designing elements of the greave in a workshop setting. Furthermore, the workshop provided a platform for the three maker-amputee couples to create a shared understanding of one another's preferences, aspirations, skills and needs. These insights were used to co-design elements of the greave bespoke to the amputee, and also led to changes in the designs that makers proposed. The co-design environment provided a supportive and safe space for sharing experiences related to amputation, identity and craft. It created mutual respect, with confidence for the amputee that the greave would reflect their identity, and for the maker that their work would be meaningful for the wearer.

We conclude by summarising the role of design in a new paradigm for the 'aesthetics of prosthetics'. We identify in greave making the need for co-design between amputees and makers for the true expression of identity. This emerges through a collaborative process, pushing the boundaries beyond the traditionally understood aesthetics of materials from which prosthetic greaves can be made.

Keywords: makers, prosthetics, design, artefact, co-design

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## Introduction

Prostheses are artificial 'body parts' that give back some of the lost functionality when a person suffers limb-loss. When someone loses a limb, or is born without a limb, there is limited opportunity to choose what their prosthesis should look like. Amputation of the lower limb is most common above the knee or below the knee. Above the knee amputation requires the person to wear a prosthesis with a mechanical knee connected to a socket to tightly fit the residual limb. The knee also connects to the prosthetic foot via a piece of tubing to give the prosthesis the preferred length. A below knee prosthesis involves the socket being connected straight onto the piece of tubing and foot. The National Health Service (NHS) in the United Kingdom generally offer two options for the aesthetics: either the bare-pole model (i.e. visible functional components of the prosthesis such as the socket and tubing), or a limb-shaped foam cover that can be pulled around the prosthesis to give it a more natural look when worn under clothing. An additional model in prosthesis design that orthopaedic companies offer, and which is regularly used, is that of a cosmetic cover. These covers are made by skilled prosthetic technicians to mirror the sound limb in shape and colour.

## Aesthetics of prosthetics

More than half of the lower limb prosthesis users in the UK, who participated in a study on cosmetic prostheses, reported a neutral or dissatisfied opinion on the cosmetic features (Cairns et al. 2014). The common bare pole model, foam model or silicone cosmetic model only cover a small choice in aesthetic diversity and there are a range of users whose needs are not met (Sansoni et al. 2016). Pullin (2009) examines the traditional goal of medical design to compensate for disability as discreetly as possible, and at the same time questions if flesh-coloured prosthesis actually send out tacit signals that impairment is something to hide. There is a predominant focus on physical functioning that many prosthesis clinics have, which is being challenged by research highlighting the importance of developing a user-based model of service provision (Schaffalitzky et al., 2011). Hall and Orzada (2013) identified three requirements for prosthetic limbs. Firstly, there is an 'operational' need, relating to the body's basic functional abilities. Secondly, there is a 'visible' need, relating to the appearance of embodied completeness. And finally, there is a 'social' need, relating to the user's ability to participate in activities and social events. Sansoni et al. (2016) also explored and prioritised key aspects of prosthesis design: comfort, functionality and aesthetics. All amputees prioritised comfort such as the fitting of the socket. Thus, the first group did not care much for the aesthetic design, the second group prioritised functionality over aesthetic design, and the third group prioritised aesthetic design over some functionality. In addition, Sansoni et al. (2015) report there is a significant group of amputees who prefer a 'robotic' look (i.e. a look designed to be different from a human limb) to a cosmetic or bare-pole look. This does not necessarily mean that they prefer the look of modern mechanical or bare-pole prosthesis that, as Pullin (2009) argues, are not so much designed as they are exposed. It is often the absence of a cosmetic cover that defines them, rather than a designed aesthetic.

## Psychological needs and body image

The importance of aesthetics for prostheses goes beyond the desire for wearing visually pleasing accessories. The appearance of a prosthetic device has an effect on the person's acceptance to wear it, and pleasing aesthetics have the ability to improve psychological wellbeing (Cairns et al. 2014; Pohjolainen et al. 1990). Similarly, the impact of visual aesthetics on user compliance has also shown positive results in other areas of supportive device design, such as hearing aids (Profita et al. 2016) and scoliosis braces (Law et al. 2016). The potential of designing for prosthesis in a way that does not try to imitate the human-limb aesthetic can support the user in promoting their unique identity. As Hall and Orzada found,

by wearing something that highlights the embodied source of stigma, the prosthesis user is reclaiming and redefining the disabled identity by promoting pride and positivity of the non-normative body. Its use celebrates social uniqueness and the inherent worth of the individual, regardless of social labels. (Hall and Orzada, 2013:28)

Previous prosthetics research has highlighted the need for a greater consideration of psychological factors in order to address the needs of users more appropriately towards a more person-centred approach for services (Schaffalitzky et al. 2011). Challenging the preoccupation with physical functioning, Schaffalitzky highlights the impact of physical outcomes on psychological wellbeing, particularly in relation to independence and feelings of self-efficacy and self-esteem. However, it should be noted that psychological benefits such as self-esteem are linked to (small) physical achievements and improvements. The potential effect of the aesthetics of the prosthesis for psychological benefit is not well understood.

In this paper, we present the findings of a project that aimed to explore the role of co-design in the development of personalised, prosthetic greaves that involved collaboration between makers and amputees. The paper will outline the template design and co-design processes, and the respective results in relation to the greaves and value of this approach.

### **Method for template designs**

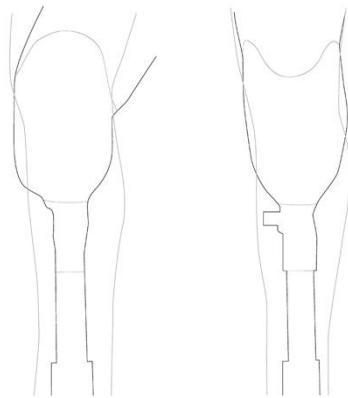
Modelling a limb in an orthopaedic clinic is a skill that technicians develop in their practice. They are guided by rough measurements of the amputee's limb, but modelling the actual shape of a foam cover is done through their acquired skill. A first attempt at recreating a lower limb shape for the pine and tartan greave reached a basic limb-shape but clearly lacked the detail in shape that would create a natural and fluent appearance of a human limb, as shown in figure 1. There was a need to establish a method that would see the natural shape of an individual's limb to be recreated digitally, while at the same time providing appropriate templates that would allow specific craftspeople to use their materials, tools and techniques within the boundaries of a natural limb.



*Figure 1. Basic wooden lower limb, lacking detail in the shape of a sound limb*

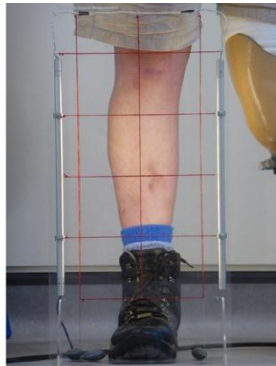
### Modelling a 3D limb

Developments in 3D technologies offer affordable methods not only to create objects through additive manufacturing (3D-printing), but also to scan 3D objects. These objects can be imported into software programs that allow manipulation and creative use in the design process. For a person missing part of one of their lower limbs, the sound limb can be scanned and mirrored so that the designed cover exactly replicates the natural shape of their missing limb. However, there are two problems with this process: firstly, if the person suffered a double limb loss then there is no sound limb to scan and mirror; and secondly, the mirrored model of the sound limb could intersect with the prosthesis of the person, particularly if the person has a below-knee prosthesis and the socket is shaped slightly different from the sound limb. Figure 2 illustrates this problem by showing the mirrored outlines of the sound limb, overlaid on the outlines of the prosthetic limb. In order to solve this problem, the digital model can be manipulated and stretched to completely cover the prosthesis. However, CAD (computer aided design) programs will have difficulty to consider natural relations and constraints of a limb when manually 'stretching' a model. For example, when the top of the mirrored limb from figure 2 is stretched, should the bottom part of the model stretch as well, or would that create a visually blown up ankle? In order to create a limb shape that covers the prosthesis, while approaching the mirrored sound limb as much as possible, we are back to the skill of the designer much like the skill of the technician in the orthopaedic centre.



*Figure 2. View of the front (left) and side (right) of an amputee's mirror image of their sound limb shown as overlay on the prosthetic limb.*

Through analysed 3D scans of lower limb models, we developed a method where the outlines of a limb can be sketched in a front view and side view, and a 3D model is constructed following natural limb contours. This means that when a 2D outline of a limb is sketched in front view and side view, the model will construct a 3D shape that follows the sketched outlines and creates recognisable natural contours of a lower limb. Using this model, the mirrored shape of the sound limb as shown in figure 3 is adjusted to fit the socket as shown by the outlines in figure 4. The new width and depth measurements are used to generate the model shown in figure 5.



*Figure 3A. An amputee's sound limb used to create a mirror image for their prosthetic limb*

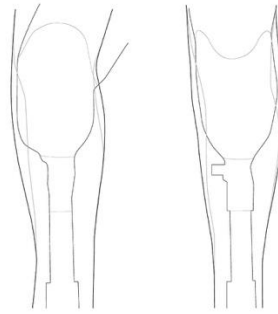


Figure 4. Front and side view of the mirrored sound limb (thin line) as overlay on the prosthetic limb. The thick line shows the adjusted shape to cover the prosthetic limb



Figure 5. CAD generated model of the new limb shape to cover the prosthetic limb

### Craft-specific templates

The project involved collaboration with three makers, each skilled in a different craft. Each maker required a different template that would allow a creative approach to the co-design of limb-shaped Greaves.

#### Wood

Roger Milton from Auldearn Antiques is a trained cabinetmaker and uses a process of sculpting wood. The templates required for this process involved a 1:1 scale outline of the front view and side view to use as cutting guides, and a drilling guide with accurate arrangement to drill four holes for connecting the rear of the Greave. In addition, a negative limb-shape existing of several slices was provided which could be used to position over the wooden sculpture in order to check the shape of the model against the shape of the sculpture.

#### Willow

Karen Collins from Naturally Useful uses traditional methods and locally sourced willow to weave a range of objects such as baskets and coffins. Her weaving process required a template model which would position the vertical strands of willow to follow the contours of the limb, and that would allow her to weave tightly around it.

As figure 6 shows, the template model and weaving in this image were done by the amputee partnered and taught by Karen during the co-design process.



*Figure 6. Template model for weaving willow in a lower limb shape*

White metal and resin

Scott Gleed from Gleed 3D is a multi-material model maker, who specialises in (cold) casting various materials. The process he uses enables him to make replicas of original or sculpted artefacts in different aesthetics. He required a 1:1 scale plain base model, to which he could apply pattern designs and use a single mould to integrate the casting of two different materials.

In addition, each of the resulting greaves needed to be connected to the prosthesis. A standard connector was designed that allowed the amputee to firmly mount the greave onto their prosthesis. The connector and templates were designed prior to the co-design session with makers and amputees, so that this session could focus fully on the creative process, limiting the practical issues as much as possible.

### **Co-design process**

The co-design process began with a workshop designed to support empathic collaboration between the three makers and three amputees. Each amputee was consulted prior to the workshop and matched with a maker depending on the material aesthetics they preferred. A researcher facilitated the workshop for each maker-amputee team, and guided them through sessions to share their background, experiences, interests and personal values. This led to conversations around elements of the greave that could be designed to reflect the identity and needs of the amputee, as well as the material knowledge and skills of the maker. There was no actual making planned as part of the co-design activities of the workshop. Whether there would be continued collaboration, and the shape and frequency this would take was left open for the maker and amputee to decide.

### **Resulting Greaves and key unique elements**

Figure 7 shows the final greave designs. Each one is briefly discussed below to explain the choices made in the process and how the final design reflects the identity of the amputee.



*Figure 7. Final greave designs, left to right: White metal and resin, willow, wood*

#### White metal and resin

The amputee had a strong preference to not have the greave be differently shaped from a common leg. While the front has the shape of a common limb, the rear is designed to be different, in a more angular shape as shown in figure 8. Another key element is the pattern displayed on the front. The maker originally was planning to explore a figurative design coming in from the edge of the front cover. Through the conversation with the amputee this design was adjusted to now reflect the pattern of a pair of stockings, connecting better to the fashion style of the amputee. Finally, the rear (figure 8) shows the integration of white metal and clear resin. The shape of this intersection is reflecting the seam of a pair of stockings, again to match the style of the amputee. The intersection line runs through one of the logos on the rear, to highlight the making process that involves casting two materials in a single mould, rather than connecting two shapes after being created individually.





*Figure 8. Angular shape of the rear of the greave, executed in crystal clear resin and white metal and final greave design*

### Willow

The strands of willow were sorted by the amputee and based on size and colour. The amputee also chose which strands to use, and the gradient in the colour. The rear of the greave is a 3D-printed part that is painted based on the colour request of the amputee. However, the reflection of the amputee's identity in this particular greave is not limited to the appearance of the artefact. The amputee was invited by the maker to get involved with the weaving process, albeit of a different object than the final greave. As will be discussed in the findings of this paper, the participation in the weaving process was experienced to have a significant impact on the perception of the final greave. The greave thereby not only represents the amputee's identity through the design choices, but also embodies this shared experience (figure 9).



*Figure 9. Final greave design, willow*

### Wood

The key choice that was made in the process evolved around the selection of timber. Through the conversation during the co-design workshop, the amputee highlighted the request for a 'raw' looking piece of timber that was not made to be 'nice and shiny'. The maker sourced a piece of timber that has burls (the twists in the timber in figure 7). These burls appear when a tree is damaged, for example by fungus. The burls resonate with the amputee in a way that it shows an 'imperfection' in a beautiful way, a characteristic that shows both the timber and amputee have been through a journey. In addition, the timber was shaped so that areas of bark are still showing, amplifying the natural appearance of the greave (figure 10).



Figure 10. Final greave design, wood

## Findings

Interviews with all the participants (amputees and makers) were analysed thematically by coding, clustering and synthesising interview transcripts into themes. Participants were interviewed after the initial co-design workshop (amputees only) and the end of the project (amputees and makers) once the final greave design was revealed to all. Questions were centred on the experience of participating in the project, including the collaboration and involvement in the making process, and the resulting outcome of the greave. Insights centred around two key themes: the value of the co-design process, and the relationship between body image, identity and the resulting artefact.

Interview transcripts highlighted the value of the co-design process in supporting collaboration between makers and amputees. The following themes emerged: building a relationship between maker and amputee, openness and flexibility, and challenge, investment and personal (artisanal) development.

### Building a relationship between maker and amputee

Both makers and amputees emphasised the importance of their relationship in the design and development of the greave. The initial co-design workshop supported the sharing of experiences and stories that informed the making process and the design of the greave, enabling the identity of the amputee to be captured in the design. Understanding the experience of the amputee enabled a connection that would start to shape the collaborative relationship. As one amputee described:

having the opportunity to share ... my background and all the things I have been going through. And I think that helped [maker] to understand me and my situation a bit more and [maker] knew what kind of thing [maker] was looking for after that meeting, stuff – materials or specific things to create that cover.

Beginning the project as a group also created the feeling of being part of a 'team' and the initial workshop had further benefit in supporting the amputees to feel comfortable with each other in sharing their experiences:

And when I met the group of people for the first time and had a kind of slow introduction and then you start feeling more comfortable and then you start sharing, yes, we are just normal people with different experiences. And then I start feeling more comfortable with them and sharing my life experiences and all of that.

Part of building the relationship was also important for allowing amputees to feel comfortable in being involved in the making process. There was a mutual understanding between maker and amputee that allowed a positive critical relationship where the amputee felt comfortable to feedback to the maker and ask questions, and the maker was actively seeking feedback in the design decisions. Working in a collaborative way allowed a form of 'knowledge exchange' to happen where maker and amputee were able to learn from each other. The personal nature of the project made all participants feel it was important to work together in order have an effective and positive experience. This was also beneficial in supporting amputees to feel 'part' of the process: 'So I felt part of it and not just the recipient of something that someone is making, it's like you are part of the process'.

The need for frequent interaction between maker and amputee was highlighted as important, partly in making design decisions together, but also to ensure a continued sense of involvement throughout the process that was not just at the start and end of the project. Inviting the amputee to work in the 'maker space' also supported the connection and relationship between maker and amputee. The continuous interaction was also important for makers in understanding what the amputees were looking for. As one maker commented: 'what [they] were looking for, [they] made me aware of that over a period rather than just a couple of sentences'.

The value placed on the collaboration from the makers' perspective was also highlighted in relation to the continuation and future of the project. Makers discussed the impact of the collaborative relationship on the process and reflected that this would be an important part of the process to retain if the project were to continue. As one maker described:

when somebody's being met and somebody's making something specifically for them after a conversation and knowing what kind of person they are. It does have an impact on how you design something and make something ... the fact that you've got a relationship with somebody or building upon a relationship makes a big difference.

The collaboration with the design researcher was also valued and considered a critical element in the process. For one maker this was particularly important in terms of facilitating and curating the relationship and collaborative working between maker and amputee given the sensitive nature of the topic. In relation to this, the importance of empathy and the skills of the maker in being empathetic was seen as important for the relationship in understanding the experience of the amputee. As one amputee explained:

if you don't have the skills to relate using empathy – I mean, I'm talking about the maker, who we guess hasn't got any issues, health issues, well major issues, in [their] life, has to deal with an amputee that has been going through difficult times. So there has to be a set of skills for it to be done in a good way. If not, maybe they need a third person to help them communicate better. It can be very beneficial for both, not just for the amputee, also for the maker to see that happening and see the benefits for the other person; I guess it's very rewarding for the maker as well.

### Openness and flexibility in the making process

Makers were able to adapt to the needs of the amputee through an open and flexible approach to the design and making. The making process in the Wood partnership was heavily influenced by the personal experience of the amputee and therefore required the maker to be flexible and open in terms of how the process happened. The openness of the process meant that the outcome might end up being completely different from what was originally imagined. This is made the maker think about the way collaboration usually happens with clients, where the maker's knowledge about the requested object would influence the design decisions much more.

In the Resin partnership, the maker was planning to experiment with a combination of materials, but the specific design was mainly directed by the amputee. Using materials in a novel way meant that some design ideas were difficult to realize. In the collaborative process, the maker could explain which parts of the mould making and casting process were causing problems with the design, and how an altered design would be more doable. The amputee would consider if this affected the key design elements too much and both would find a solution together.

In the Willow partnership, the maker regularly gives courses teaching how to weave and invite people to the workshop space. The openness of this process and way of working allowed the amputee to become involved in the making process through visiting the studio. The amputee was actively involved in selecting the material for the greave, as well as having the opportunity to weave.

The maker space was seen as a space where amputees felt safe, welcomed, wanted and heard. Spending time in these environments significantly helped the sense of involvement, even without sharing the work on the actual artefact. As one amputee described: 'Then the process of making the piece when I had to say something about how it could be, how it could look, that was good because it made me feel important, in a way, valuable'.

### Challenge and learning for makers

The need for challenge in the making process for the makers had positive benefits for learning and developing their practice. The problem-solving process sparked new ideas, ways in which other materials and methods could be embedded within the greave and opened up the makers' creativity to consider how they might iterate and develop in the future. It also offered the exploration of new ways to work with the material to address problems specific to the greave shape. Through learning about the material, makers could then apply techniques they had tried in other aspects of their work. The novel experience of making a greave required the makers to think creatively in the processes and tools they use. There were practical requirements for the shape, and the design requirements from the collaboration with amputees. This novelty added to the interest in the experience and was a key learning process for the makers, as one commented: 'you don't have the whole history of experience of making a table or something like that I've done a hundred times'.

Although this theme was predominantly linked to makers, one of the amputees also reflected on the learning throughout the process and how this opened up the possibilities for prosthesis:

learning that you can kind of do anything with it [prosthesis] ... That is something that I struggled with a lot becoming an amputee was the NHS prosthetics. I kind of had an idea... I know that there is a lot being made now but it's nice to know... Using these different materials I think has made me realise you can do anything with it and make it anything you want it to be rather than just what you're given.

#### Body image and identity: beyond a personal accessory

Another key theme that emerged was related to the body image and identity of the amputees. The greaves created in the project were designed such that the amputees could wear them and allowed the personal identity of the amputees to be reflected through the design. However, the insights from amputees suggest that the benefits of being involved in the process extend beyond designing the greave as a reflection of personal identity.

While designing the greaves together with the makers, it was crucial to let the amputees express their story and their own take on their amputation, including how they let themselves be perceived. The reason for aesthetic choices in the making process went beyond that of personal taste of materiality, it reflects a deeper relationship that the amputees have with their prosthesis, their missing limb and their journey of amputation. For example, the material chosen by one maker and amputee reflected the unique character after trauma had occurred. The careful selection of materials and design with the makers helped to reflect the story of the amputee who expressed how the amputation shaped their character:

As soon as you see it, you can see that something has happened to me and there has been a journey, that's not like a plain [material], there's something special. So not seeing it as something bad. ... That's the way I related to that; I feel it's very personal. It's like, as soon as you see it, this is talking about the same thing I've been through.

The process also helped to overcome some of the grief of losing a limb. The connection that the greave represented was described as a 'psychological armour' that would protect the stump. The material of the greave also represented a personal connection that made the experience more special:

some of it comes from the west coast which I hope to get to one day, some of it comes from Edinburgh which is where my [relative] comes from and me and my [relative] we got on really good, and some of it was local and it just makes it more special. It's all the bits that mean something mixed up together.

These experiences suggest that the body image that was sought through the design process was not aimed at covering up their prosthesis with a 'nicer looking' thing. The resulting greaves embodied a deeper, richer expression of the individual identity of the amputees in a beautiful and intricate way:

I think it just opens up people's imaginations and what... What's so nice about this project is it's so personal and everyone's been involved in it, then it makes the amputee not just as a designer, let the amputee think about 'What do I want to have?' and it's about them personally rather than it being 'I can get this beautiful thing'. It's like 'This is a part of me and I want to make it mine.

Undergoing amputation has a significant impact on the body and the perception of one's body. The process of coming to terms with the new shape and functioning of one's body is highly dependent on the individual experience and the cause of amputation. One participant expressed that their amputation meant the end of a long-term illness and in fact was perceived as a positive moment that meant their body was now healthy again. The experience of amputation for participants affected how they related to their prosthesis as part of their new identity. All participants expressed they were not afraid to show their prosthesis, which was also reflected by their choice to not wear a cosmetic cover. While there was no particular dissatisfaction with the aesthetics of their prosthesis, there had not been much choice regarding the appearance either. One amputee explained how the process of developing the greave could be beneficial for others:

you could have people like 'it would be nice to have an accessory', but some others, they are struggling with the fact of wearing a prosthesis and they go and choose these foam, fake legs to cover the prosthesis to try to imitate a real leg, which is even worse than wearing just a metal, robotic thing. So for them, there could be an option, an alternative to say 'you could wear this but why not make it more obvious that you have a prosthesis and not try to hide it?' And maybe it could be a good thing for them, emotionally.

This also links to another important aspect that was discussed by participants that the novelty of the greave as an accessory could support a positive image of disability. In order to wear such a personal artefact like a greave the amputee would need a degree of self-confidence; a positive disregard about what other people think of their prosthesis. This experience grew throughout the project, and amputees as well as makers commented that going through the design and making process potentially helps the acceptance of amputation. As one amputee described:

But it just gives me a better connection to nature, to life, to how I feel that people can take it or leave it. If they see my leg, I don't care if they don't like it. I'm really proud to put that on.

The feeling of being 'heard' in the making process helped the amputee take control of how their identity was expressed in the artefact, which would make it something to be 'showed off', and this included both their prosthesis and amputation. This can be recognised in what Hall and Orzada (2013: 28) describe as "reclaiming and redefining the disabled identity by promoting pride and positivity of the non-normative body". Makers also echoed this by saying their designs might help the amputee on their journey by giving something to help progress and 'go out'.

When discussing how this type of process of developing a prosthetic greave could be integrated within the health and care service, amputees felt that it could be very beneficial for the wellbeing of other amputees. However, it was recognised that taking part in a process such as this one would have to happen at a later stage in the amputee journey as there is a period of adaptation that happens when coming to terms with amputation. As one amputee described:

it's not the best moment to do it just from the start, they have to adapt to a new life and a new process. So it's nice to have something that you can feel is more personal, something that will look good, will look nice to others, to show off. But maybe has to wait until a later stage, maybe a few months later, when they get used to their new life. Obviously it could help but it could be too much to deal with, at the same time. So it's a process and you probably have to wait.

## Discussion

'Prosthetic Greaves' aimed to explore the role of co-design in the development of personalised, prosthetic greaves, supporting collaboration between makers and amputees to offer a new creation of aesthetic expression. The process enabled makers and amputees to create a shared understanding of amputation, identity and craft through the safe space offered through the co-design environment. The outcome of the project led to the design of bespoke greaves that reflected the identity of amputees and offers several lessons about the role of co-design in supporting collaboration.

The findings highlight the critical importance of empathy, openness and relationship building across the process in ensuring a mutual respect between maker and amputee. The emerging themes suggest that involvement in the process has benefits for amputees that extend beyond the expression of identity, supporting confidence and a potential to create a positive image of disability. Although there was a positive impact on body image and identity, it was out of the scope of the current project to research and discuss how the greave could affect this over time. For makers, the process provided the opportunity to explore novel ways of applying their craft and offered a new collaborative experience.

The environment that supported the collaborative relationships to develop was seen to be an important part of the experience and allowed everyone to be equal. Researchers involved in the project facilitated the initial session and stimulated the participants to continue their collaboration in a way that suited their needs. While the resulting collaborations were successful, it was also recognised by researchers and participants that working in such a personal and sensitive subject would require careful recovery of the initial match-making as well as the continued collaboration. The need for this role to curate the design process relates to the proposed role Sansoni et al. (2016) describes as the Visual Prosthetic Designer. This is someone who is outside of the traditional clinical environment and who can bring their experience in design processes and aesthetic choices. Pullin (2009) also refers to the role that design professionals can take in designing for disabilities. The experience in the Prosthetic Greaves project confirms the idea that designers outside of the traditional healthcare environment can contribute in a valuable way to the experience of wellbeing. We would propose to extend the role of the designer in this process to curate collaborations with makers specialising in other materials and crafts. The ability of the designer to bring people together and curate co-design between different parties can open up a new range of aesthetic expressions.

The focus on functional aspects of prostheses clinics as described by Schaffalitzky et al. (2011) was also



recognised by participants in the greaves project. The traditional healthcare context felt as if things were being 'done to them' and limited choice was offered in the process. There might be more potential for a positive collaboration to design accessories outside of the traditional prostheses clinics. However, this would bring other challenges such as the impact on functional aspects of the prosthesis, particularly considering modern bionic knees. More research would be needed to explore how a co-design process with makers would fit with a traditional clinical process.

The value placed on the greave by the amputee was considered beyond economic which made it difficult to estimate a 'cost' for the greave. Participants recognised the time and energy involved in the making process and also the intricacies of the craftsmanship in achieving the final design. From the perspective of the makers, they believed that the value in economic terms would be related to the mindset and aspirations of the amputee. The total value was seen as greater than the cost of materials and time given the personal nature of the greave. Future research could explore the potential for this process among a wider group in order to understand how this approach could be integrated within health and care environments or be pursued as a commercial opportunity.

## **Conclusion**

Overall, the project provides evidence of the value of co-design in supporting collaboration between makers and amputees in the design of the Greave based on a shared understanding of one another's preferences, aspirations, skills and needs. The co-design environment created mutual respect, with confidence for the amputee that the greave would reflect a true expression of their identity, and for the maker that their work would be meaningful for the wearer. The collaborative process has pushed the boundaries and challenges assumptions beyond traditional understanding of the aesthetics of materials used in prosthesis.

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