TIDAL N+
Transformative Innovation in the Design of Assisted Living products and services

Repair of Assistive Products in the UK:

Prosthetics & Orthotics

Outcomes of a 1-day workshop exploring this topic from user, community and provision system perspectives

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This report summarises the proceedings of a 1-day workshop held by TIDAL Network + at Salford University on 16th May 2024. The workshop explored the repair of assistive products in the UK, with a particular focus on prosthetics and orthotics.

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Broken prosthetic feet from SLSPO, Ragama, Sri Lanka (Photo: Dr Michael Berthaume and Dr Nicola Bailey, Kings College London)

Table of Contents

Introduction

Massive-scale mass manufacture has brought huge rises in quality of life globally, but the associated throw-away culture has engulfed high-income societies. Driven by the climate crisis, a tipping point has clearly been reached, and although recycling processes are patchy at best, the concept is widely accepted in our economy. However, the recycling of raw materials, while an essential part of a circular economy, also loses the value that is added to products through design and manufacture – at huge cost, both financially and environmentally.

The importance of repair across all products globally has seen a phenomenally rapid rise in attention in recent years, with a range of initiatives, actions and changes in practice occurring. These changes have occurred at the enthusiast and community level, within the larger economy as a whole, and at the policy level, with the Right to Repair being implemented in many countries.

However, assistive products (APs) present industry, commissioners and users face a range of challenging problems when addressing repair. The regulatory environment encourages a risk-averse approach; the devices are often used in the home environment, where observation of use patterns is very difficult, and the clinical services providing the devices are heterogeneous and over-stretched. Users may not know who to contact in the event of a repair and, particularly if the AP is associated with supporting mobility - transport of the broken device to a centre for repair is problematic. This problem of inadequate repair strategies is not only environmental – rather, it represents a huge barrier to the optimisation of assistive product provision.

Products can be, and very often are, disconnected from the system that produced them as soon as they are purchased/provided. Critical to recognise is that repair is intrinsically a system activity. It cannot be separated from the system around it – if it is, it is likely impossible. This makes it a very complex issue to address effectively. No one actor can achieve what is needed, and we need to map the actions needed and the value of repair across different parts of the system.

Before we can theorise on solutions, the current status quo must be better understood, and this was the driver for our workshops. The workshops built on an emerging body of work in this area. For instance, studies from the UK[1] and low resource settings[2] have begun to document the frequency of repairs in prosthetics (and other) services. It is interesting to note that, to date, only one of these publications has come from the UK, perhaps driven by the necessity of focusing on repairs in low-resource settings. The team was unaware of published work from the UK addressing the impact of the need for (frequent) repair and/or access to repair services on users and their carers/families. It is also notable that some manufacturers are emphasising the robustness of their products[3].

[1] Nagaraja V, Cheng R, Slater D, Thompson M, Bergmann J. Upper-Limb Prosthetic Maintenance Data: A Retrospective Analysis Study. J Pros Orth. 2022;34(4):223-32.
[2] Berthaume M, Barnes S, Hettiaratchy S, Clasper J, Kumar A, Sathiadas G, et al. Demographic, medical, and financial statistics from the Jaffna Jaipur Centre for Disability Rehabilitation (JJCDR) database, 1987-2018: a prosthetics, orthotics, and mobility clinic in northern Sri Lanka. J Global Health Rep. 2023;7:1-12 ; Dickinson A, Gates L, Metcalf C, Owen C, Kheng S, Harte C, et al. Learning about the changing needs for prosthetics service provision from routinely collected digital centre management data: An exemplar study across three clinics in Cambodia. J Glob Health. 2022;12:04083 and; Oldfrey B, Holloway C, Walker J, McCormack S, Deere B, Kenney L, et al. Repair strategies for assistive technology in low resource settings. Disability and rehabilitation. 2023:1-11.
[3] Covvi (https://www.covvi.com/); Go Assistive Technology (https://www.goassistivetech.com/)

Short Talks Session

We began with short talks from a range of perspectives on this topic – we wanted to understand what repair meant to different people. We wanted to collaboratively build a clearer picture of how these perspectives intersect and what the value of repair is to each stakeholder. We also wanted to identify what future directions could be taken to improve its place in the system with a range of stakeholders and invited:

- Users of assistive technology
- Clinicians, health professionals and other service providers
- Manufacturers
- Designers / Engineers
- Start-Ups interesting in incorporating repair-focused strategies

The talks are summarised below:

Mark Miodownik (UCL Institute of Making) began the workshop with a talk on *"The Big Repair Project"*. This citizen science initiative aimed to gather data on public opinions and behaviours towards maintaining and repairing household appliances and electronics in the UK. ~6000 survey responses were captured, and ~470 home repair activities were analysed. A key finding from the work was that repairing things is viewed as a positive activity (it makes you 'feel good'!), and a move towards more repair-focused production and regulatory environments can stimulate local economies.

Pranay Kumar (Royal Melbourne Institute of Technology) then presented on *"The environmental imperative for medical device design"*. He proposed that there are two approaches to reducing environmental impact in the medical device sector, both of which are needed:

1. Regulate the impacts from manufacturers (top-down)

2. Disruptive innovation in technology and design of product-service systems (bottom-up)

He highlighted the challenges to addressing the environmental impact of AT devices, including prosthetics, but also showed the important role that designers can play in enabling regenerative value cycles and educating the user on available opportunities.

The next talk was given by Lesley Davidson (University of Salford) on *"Why do walking aids get lost in the system?"*. Huge numbers of walking aids are given out or purchased within the UK health system, but few of these are refurbished or repaired. The presentation reported on interviews with clinicians and manufacturers to better understand the challenges of implementing better repair services. The themes which emerged from the study were uncertainty, responsibility and complexity, as well as cost. This presentation clearly illustrated the complexity of the systems-based approach that needs to be addressed if repair is to be an integral part of walking aid service provision.

Sam Simpson (Exceed Research Network), in "Repair of prosthetic devices—the Cambodia experience," discussed the very extensive dataset on prosthetics repairs captured from 1992 to 2019. Preliminary analysis of this data with the team from the University of Southampton has highlighted the value of such data for service optimisation, including stock control.

Sam's talk was followed by Promise Maduako (Legs4Africa) talking on "*Legs4Africa (STAND), Our ATs Repair Journey."* This presentation reported lessons learnt by a charity providing second-hand prostheses (and other devices) to services in Africa. The varying degrees of damage they see in returned prostheses highlight a significant untapped potential for repair. Many components can be refurbished and reused with relatively minor interventions. By addressing these neglected repair

opportunities, they can make a substantial difference in reducing environmental impact and optimising AT provision.

Vikranth Nagaraja (University of Salford) presented his study entitled *"Comparing repair practices of upper-limb prosthetics in the United Kingdom and India".* Vikranth and colleagues published one of the first studies on repairing and maintaining upper limb prosthetics at one UK limb fitting centre (Oxford). He pointed out that rejection rates in upper limb prosthesis users remain high, and it is currently unknown whether access to repair and maintenance services may play a role in this. The presentation reported on the comparison between the UK data set and a similar study carried out with Mobility India (Bangalore). It was clear that neither centre prioritised recording of repair nor maintenance data, making extracting useful data from clinical records time-consuming. Out-of-pocket expenses represented major hurdles to accessing repair for many in India. Future work should aim to set up a more structured approach to capturing repair and maintenance data, which could be used across multiple centres.

Lesley Davidson (University of Salford) followed Vikranth with a talk on her PhD work, *"Only if the User Complies' - Repair & Maintenance in Myoelectric User Manuals".* Medical device regulations require manufacturers of myoelectric prostheses to supply the user with instructions on use. These documents represent an intention to influence the user's behaviour but have not previously been analysed. The analysis of 36 documents relating to 23 devices revealed three themes:

1. Contrasting device durability and fragility narratives: Confusion, uncertainty, unmet expectations?
2. Lifestyle and behavioural adjustments: Under-use, over-use, abandonment, care burdens?

3. Manufacturer as the repair authority: User agency, ownership, attitude towards limb or manufacturer, future device choices?

Myoelectric prostheses are complex devices that also occupy a uniquely personal position for the user—their upper limb. Manufacturer instructions prescribe behaviours, possibly with the aim of reducing incidences of repair: activity, care, maintenance, and use warranty to encourage compliance.

The next talk was from Angus Clarke (Imperial College), *"Designing for repairability: Novel LMIC prosthesis suspension systems"*. Suspension systems provide a stable connection between the prosthesis and the residual limb. Many options exist, but few have been designed for repair or with the needs of LMICs in mind. Design requirements for a suspension system suitable for LMICs were presented and included:low price (<$50); repairable/replaceable; ability to disassemble after integration; no automated or calibrated machining; and designed for the local environment and extended use (3+ years). Three potential solutions were presented, and a discussion followed.

Ben Oldfrey (UCL) followed with his talk on *"Repair of prosthetic socket liners."* Prosthetic liners are expensive components that sit between the socket and the residual limb. The mechanical loading they experience, coupled with the in-socket environment, means they have a limited lifespan. Ben's talk presented a method for repairing damaged liners using a simple re-moulding jig, which offers the potential to extend the lifespan of these devices.

Samantha Curtin (University of Salford) discussed her recent systematic review entitled *"Priorities when designing a service-focused delivery model for mobility devices".* Many consumer businesses have moved away from a product-focused approach to a service-based approach. However, mobility devices lag behind the

servitisation trend. 29 papers were included in the review spanning a range of devices, including prosthetics, wheeled mobility devices and AFOs. The potential benefits of servitisation include:

To the Device User: Maintenance and servicing, support for faults or when there is a change in need, access to health stats, no upfront costs, and no disposal of the device.

To the Service Provider: Insight into device use, where stresses and faults lie, lifespan and use of the device; remote support = broader clientele; ongoing business throughout a device lifespan.

To the clinician: Treating remote communities; objective data about user needs and the device; and automation of repetitive tasks.

Finally, Runbei Cheng (University of Oxford) presented on *"A Consensus Survey for a Free-access Prosthetic Provision and Repair Registry"*. The goal of the work is to produce a registry that clinical centres can use to record device provision, repair and maintenance data in an efficient manner. A short survey was presented to the participants, to inform the development of the registry.

The talks highlighted the breadth of ongoing research on this topic across multiple institutions in the UK and elsewhere. It is interesting to note that there several of the talks linked to experiences in LMICs, suggesting widespread emerging interest in the topic, globally. Following a lunch break, participants were allocated to discussion groups, and a summary of these is provided below.

Topical Session Outcomes

1. Data and Repair

The group's discussion quickly moved towards identifying the challenge of identifying what data is needed. Data at the governmental level might be limited to certain boundaries, for example, during adverse events. For businesses, the cost of repairs is likely only captured in terms of direct costs to companies, i.e., not including the costs to users or third parties, and there is no incentive for companies to share even this sparse repair data.

A different challenge is what data collection methods may be possible, for example, clinic-led or directly with users, with each bringing different privacy issues. There were concerns about what level of honesty could be expected from patients if data was collected directly from them on self-repair practices and third-party repair, with a fear of the consequences for their warranty, if the provider/manufacturer was aware of it, or simply a fear of misuse of data. The recent work on data analysis collected and published from Cambodia P&O services represents a shining example of where rich datasets have been compiled, where other examples of quantitative information are low in number, if not completely absent.

Some examples of potential data fields seen as important were:

- Relative robustness of devices;
- Planning of services;
- How long repairs take and hence the associated cost;

- Factors impacting on the durability of the device and hence inform device prescription.

This could benefit both service providers and users and help with the scheduling of repair services. It could also give users trust through predictability of services, even if they are still not as fast as desired, so they are confident that they will get a well-functioning device after repair.

In some cases, the recorded data simply cannot be accessed in the way that it should. In the case of OPCARE, although clinicians fill in data on jobs, they don't get to see anything other than costs on the clinician dashboard. This concern of data disappearing into an abyss was highlighted as a common problem and a barrier to the motivation to comply with the data systems adequately. One new route out of this could be the growing potential for automation of data collection and AI methods for analysis, but to date, there is no implementation of this in this space.

Potential Solutions Discussed

Future repair strategies will affect how the standards/schemes for recording/using repair data will be set up. Therefore, to gain traction, it is necessary to consider what could be the quickest win for repair data and make it as easy as possible to complete. This could include introducing co-authorship on paper from databases as an incentive or feedback procedures to funders (as in the NGO context).

Ultimately a data collection plan should be implemented. We need more data about repair, such as repair type, reason for repair, and frequency of repairs. The coming research on a repair registry is looking to take these ideas forward and will look at COMBI methods (Communication for Behavioural Impact) which were seen as the main way forward to understand motivation to engage with the registry.

2. Method of Repair

The session highlighted several key points regarding the current landscape of device design and repair, particularly in the context of prosthetics and orthotics. It was noted that manufacturers hold significant decision-making power, often leaving other stakeholders with minimal influence, especially when products are not designed with repairability in mind. Modular design, which could facilitate easier repairs and the use of spare parts, is often overlooked by manufacturers who tend to sell devices as single units. Furthermore, manufacturers typically discourage repairs, as doing so can void warranties, although this is generally justified by safety concerns. The discussion also touched on the financial aspect of repairs, indicating that users may need to bear the costs, whether the repairs are conducted by manufacturers or trained professionals. There may also be a need to expand the definition of repair to accommodate this reality.

As technology has evolved, the skills needed to service devices are changing; many contemporary devices now require electronic interfacing expertise rather than traditional manual repair - complicating efficiently executed repair services. Concerns were raised regarding the reliability of devices compared to 40 years ago, prompting questions about accountability in the event of device failure. The current policies of the NHS were identified as obstacles to the introduction of innovative or repairable designs, as new devices must undergo rigorous testing and standards before acceptance. Additionally, since devices are assigned based on individual mobility scores, the availability of more repairable options may be limited for some users. Lastly, the conversation revealed a lack of clarity surrounding the hierarchy of repair for assistive devices, suggesting that established frameworks, such as the French repairability index, could provide useful guidelines for assessing repair options and

determining whether repairs should be managed by professionals or could be handled by users themselves.

Potential solutions discussed

Modular parts to support repairability was one of the key ideas considered by the group that could underpin solutions. Although we still need to identify what can be modularised, modular and spare parts that could be simply switched via standard tooling should be first approached to investigate. Reference cases from cars for sharable or interchangeable parts or the pyramid adapter could be considered. As well as modularity, further standardisation of component-interfacing would further support this. Creating product attachments by supporting customisation and personalisation could make the products more favourable to users of AT, extending lifespans and motivation to repair rather than replace.

3. Impact of Repair

The impact of repair encompasses design, user experience, and systemic effects, highlighting the short-term and long-term impacts. Accessing repair can be challenging for users, and if devices cannot be repaired, they often will be abandoned. This can create issues such as a lack of trust and impacts positive psychological attachment to devices and embodiment. Variations in repair impact are evident between LMICs and places like the UK, where bringing in more user-centric approaches over technology-driven solutions is crucial to improving the repair system.

Defining repair as a reactive process suggests the need for proactive maintenance strategies to ensure ease of upkeep. Beyond functionality, repairs influence

psychological and identity aspects, particularly when devices like prosthetics, seen as extensions of the body, are taken away. This impacts a person's psychological experience as it can feel that they've lost a part of themselves to repair, and their sense of self and wholeness is affected. Therefore, these prosthetics should be easy to maintain and should apply to both the technology and to the self. Self-repair has its own issues and should be more widely available; participants noted that you can repair your TV or your car, but not your prosthetic, which you rely on every day.

Potential Solutions Discussed

Focusing on the NHS, there needs to be a unified opinion on what's wanted. There should be a greater emphasis on what users need and how to address the diversity in these needs. This then raises its own questions about how much freedom users should be given with these choices. This requires a shift. Currently, there is a lack of user engagement with practice development.

It was noted that there is a lot of fear towards the current system, particularly concerning replacement lead times, which brings about a range of impacts. Users find choosing a time to undertake repairs complex, having to think about when they have the least impact. This has meant some users have had to learn to live with the problem rather than getting it fixed, with knock-on effects across their daily lives. Discussed was the potential solution to utilise local skills for repair locally. One advantage mentioned would be the greater ease of available data in smaller, local hubs as to which parts are available, and clearer wait times, reducing fears about repairs.

4. System Issues and Policy

All participants agree that AT repair in the UK is one of the worst examples of repair systems; however, the repair approach still needs to be seen as a system. Improving access to repair tools, spare parts, and the supply chain needs to be considered to improve the situation. All of these would be supported by AT waste data, both for lobbying and for implementation design, but there is currently no data collection plan in place.

The NHS systems themselves were brought up as the main barrier to AT repair. The fragmentation present within the NHS, does not lend itself to efficient access, and there is a lack of infrastructure to support repair/reuse or recycling. Unfortunately, it is usually more expensive for the NHS to take back devices and repair them, so they are usually lost in the NHS systems. Hopefully, at least some are sold/passed on to other users through private means, eBay or charity shops, but they likely end up in a landfill.

A barrier is that the NHS does not currently formally allow users to use second-hand prosthetics. The idea of normalised deviance on this was discussed, where personnel and decision makers are stuck in extreme safety, avoiding the more complex liability around used prosthetics. It was noted that if used AT is not safe for our country, then why do we pat ourselves on the back for donating it to LMICs?

Finally, the lack of value and ownership arising from the NHS's provision system was mentioned in the fact that users get AT for free. Less ownership means less motivation for users to repair or maintain, with new replacements being more desirable.

Potential Solutions Discussed

Top-down approaches need to start with a change in legislation, which would lead to a change in policy and practice. Financial incentives would make the repair more desirable and can also drive the public will. Education of the public is also considered as another element to drive change. Overall, the Government should sponsor manufacturers to drive change, impacting people at the end of the spectrum. For a system to work, there must be some incentive for each key player. This sort of change needs to be driven, which doesn't happen by accident.

Solutions related to financial incentives could include:

- Extending producer responsibility, as in car industries where the producer has the obligation to cover the disposal cost of vehicles. The cost of repair, and quality control cost for return/repair of AT can be charged back to the producer.
- Introducing tax incentives for repair.
- Making the cost tangible in pounds. We need data to raise awareness and drive behaviour change, showing with invoices that it is not free. Introducing a recycling fee, as in Germany, or charging the cost of waste by weight, as in Finland, could nudge perceptions on this.

Bottom-up approaches must emphasise the consumer as an initiator. Education of the public, such as publicising repair cases from other countries, can set consumers' expectations and put more pressure on politicians to create legislation. The expectation should be that devices are repairable. Studies into the abandonment of devices and tests on how much life is left in them could make visible the extent of the wasted potential of devices in the system. The cases mentioned were mostly related

to car repair, e.g., the practice of repairing the US car in Cuba or the mix-match car parts in Brazil.

Solutions that are not directly related to the change in policy include:

- Change in culture. Currently, repair has become a trendy thing, so we should leverage the use of social media/influencers to drive repair culture. Repair is more embedded in Japanese culture, for example, with the belief that there is a spirit in objects, so more care for objects/repair is prevalent.
- Design-led change (e.g. design for repair) is critical to enable repair processes.
- Change in the NHS process, such as allowing the user to personalise their AT to increase AT value and ownership or encouraging more return-by-text requests to return the unused AT.
- There was also a minor discussion of how to make climate policy actionable, but there was no clear direction on this topic.

5. International Connections

The discussion highlighted that more and better collaboration is needed at the international level to improve standards and help deliver impact.

International connection creates value for all partners as funding can be used collectively, potentially improving ideation and implementation, connection across workforces and facilities and generating bigger, more impactful/convincing data sets. Bi-lateral agreements between countries could show how low-resource settings can lead the way in progress on repair strategies. For example, in low resource settings,

there isn't the inertia associated with current service models, so new technology (e.g. 3D printing) can fill a gap rather than replace an existing service. Case studies from other countries can be used to challenge/develop services in the UK.

Discussed were ways forward to engage with manufacturers to accommodate local repair. This can be done by moving towards design for repair that is aligned with local skills and materials. Although local manufacture of parts can be a good solution, quality control is a key challenge. Standardisation and component compatibility were even more heavily discussed, albeit in an international context, noting that many manufacturers operate either globally or regionally. Therefore, action needs to be at that level. A barrier to this currently is that the ISO standards are limited in scope, and addressing this may help move standards into standardisation of components. As P&O incorporates both bespoke components and standard components, at least standardising the connectors to facilitate repair services is necessary. Despite no obvious advantages in doing so, there is a potential for more efficient use of resources. It was noted that standardisation could also simplify or accelerate the training needed and, therefore, help with the current situation of a massive shortage of trained P&O technicians.

6. NHS Clinical Challenges

The NHS faces various challenges related to space, funding, and time alongside motivation and liability issues being a healthcare service. The ratio of staff to managers contributes to inefficiencies and creates over-pressure in dealing with existing demands. The centralised structure creates distance between decision-making and implementation, leading to delays in adopting new products and development. Clinicians also have additional overhead from research and Patient

and Public Involvement and Engagement (PPIE) activities. Added to these operational challenges, generational differences in education and training create cultural challenges within the NHS. This is also a highly relevant factor in bringing in new initiatives.

Different models of care were proposed by members of the group. Examples include the potential for local services like the "mom & pop" companies in the US to be supported by GPs, voucher systems for devices, or charities fielding applications for studies to centralise triage and decision-making. Capturing views from a variety of groups would benefit system change, with better outreach to currently poorly engaged sectors of society. For example – sometimes cases of children with congenital limb loss, who could have had better support, will not be known about until attendance at the clinic for some other reason.

As needed, better fostering shared knowledge across the NHS among users and clinicians. This involves distributing knowledge, such as from single centres issuing multi-grip prosthetics, for example, who have developed strong practice knowledge, addressing the challenges in patient recruitment for studies, and enhancing patient education.

The need for greater lobbying tools was discussed - currently, we only have support from the right to repair movement. This could be strengthened by making a sustainable impact in the NHS standard contracts, with alignment to the NHS carbon reduction policy.

Conclusion

This one-day workshop explored the complex significance of repair within the assistive technology landscape, revealing diverse perspectives from various

stakeholders. With a range of perspectives given, we heard a plethora of valuable insights into the meaning and importance of repair and what it means to different people involved.

Agreed upon was that there is a critical need for a systemic shift towards increased repairability and sustainable practices across the sector. We heard of the potential benefits of citizen science initiatives in shaping public perceptions, the necessity for regulatory changes alongside disruptive innovations, and the importance of creating frameworks for efficient repair services. Strategies must stem from the product design stage with further modularity and standardisation, with financial incentives and policy changes to enact change down the value chain and improve service delivery.

Potentially the most critical factor that underpins all of these elements is the current lack of comprehensive data on repair practices and user experiences, which continues to hamper understanding and decision-making at all levels. There is a strong need for transparency and privacy in data collection, with suggestions to implement systems that encourage user engagement without fear of repercussions.

As the conversation continues, it must include the voices of all stakeholders, crucially users themselves, if more interconnected, effective, and reparable systems are to be created. We thank all involved and hope that the efforts put into this event will contribute a small step in the right direction and momentum can be gained.

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