MEDICAL DEVICE OR FASHION ACCESSORY? A CASE STUDY OF A REDESIGNED CHILD'S PROSTHETIC UPPER LIMB APPLYING PRINCIPLES OF PERCEPTION AND SEMANTICS TO REFRAME SOCIAL ACCEPTANCE

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ABSTRACT

This paper explores the value of the visual features of assistive products for a positive psychological impact on users. The research focuses on upper limb prosthetic devices and their aesthetic impact on the user. Within the presented study, these products are identified not only as assistive products but also as fashion accessories. A case study is presented that applies an understanding of human behaviour, motivation, and perception of semantic cues within the cultural context of a given society to deliver a more socially acceptable child's upper limb prosthetic.

Keywords: Emotional design, Requirements, Societal consequences

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1 INTRODUCTION

This presentation explores the value of the visual features of assistive products for a positive psychological impact on users. We focus our attention on upper limb prosthetic devices and their aesthetic impact on the user. Within our study, these products are identified not only as assistive products but also as fashion accessories. Most assistive technology (AT) design systems are the result of an engineering-only vision, where the functionality of the product is the first (and sometimes, only) design goal. Consequently, little research has focused on features of devices that are more aligned with the emotional impact of those products for the device's wearer. In this presentation, we want to highlight a user-centred approach to the field of assistive product design and raise awareness of the emotional need of users of a prosthesis. We will highlight how the visual features of prostheses can influence the perception of social acceptance and stigma, in the rest of society. A case study will be presented that applies an understanding of human behaviour, motivation, and perception of semantic cues within the cultural context of a given society to deliver a more socially acceptable child's upper limb prosthetic.

2 LITERATURE REVIEW

2.1 Prosthetic devices and product desirability

Assistive Technology (AT) is defined by the Regulatory Agency of the UK Government as "products or systems that support and assist individuals with disabilities, restricted mobility or other impairments to perform functions that might otherwise be difficult or impossible". This definition helps to define assistive products where the "determining factor will be whether there is a direct link between the corrective function of the equipment and the individual concerned" (Gov.uk, 2021) Similarly, 'prosthetics' is a term that refers to devices designed to replace a missing part of the body. This definition applies to devices such as artificial arms, legs, or fingers. A review of current academic literature on prosthetic design shows extensive work to date has been focused on technical improvement of the devices, e.g. functionality, materials and patients' mobility in contrast to the limited research around aesthetics. (Cheetham et al., 2011, Dunlop 2005). Upper-limb amputation impairs the physical functioning and mobility of people around the world. In 2017, McDonald et al stated that 57.7 million people were living with limb amputation due to traumatic causes worldwide (McDonald et al 2020:1). Conway (2008) defines a social model of healthcare treatment as considering the whole patient/client, over a symptom-only approach, which is the current medical model. This system does not address the whole patient spectrum of needs, (e.g. for their psychological impact or emotional needs), but focuses only on the physical symptoms. Hughes (2000) was highly critical of the medical model, which also applies to prosthetic design, and associated stigma and product abandonment generated because of this approach. A meta-survey of publications by Biddiss and Chau (2006:1) highlighted that a better understanding was needed of an individual's aspirations and lifestyle as well as functional requirements constrained by the availability of enabling resources for an upper limb prosthetics service. AT is a good example of how well-engineered products, delivering optimum functionality, do not always satisfy the social and cultural function (desirability) of a target user. A medical model approach to assistive product design can result in social stigma associated with the product, as it is often different in shape, colour, form and action to other everyday fashion products used in UK society - this mismatch of aesthetic features may lead to product abandonment. (Verza 2006:88-93). Soares et al (2021:1) highlighted additive manufacturing could support a social model of prosthetics design by enabling personalisation and customisation of a prosthetic device for an individual.

2.2 Prosthetic devices use and stigma

The visual choices currently offered in most of the public UK prosthetic centres for a below-limb device are limited to what is considered essential for the patient's motion needs, and little account is taken of the appearance of the device. These choices often include an uncovered device or a basic foam-covered 'cosmetic' prosthesis. Customised prosthetic designs (know also as 'robotic devices') are usually available from a limited number of private companies and are often difficult to access by most prosthetic users (Sansoni et al., 2016). Sayut and Ahmed-Kristensen (2020) have also explored some of the emotional responses to new materials within new product development.

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Considering the majority of prosthetic users have access only to basic designs like cosmetic or uncovered devices, we can suggest that the restricted range of aesthetic options on offer to users as an issue. The appearance of these devices generally does not correspond to the visual aspirations of the users for their prostheses nor does anything to reduce social stigma. Stigma is not solely defined by a mismatch in the visual expectations of an external observer - e.g. a person viewing an amputee wearing a prosthetic device not corresponding to his/her expectations of how a human being should look. The stigma is also defined by the user themselves feeling uncomfortable with the aesthetic look of their device. Perceived social stigma is defined as an individual's perception that others hold negative stereotypic attitudes about him or her as a result of a disability (Rybarczyk et al., 1995). This factor has been linked to problems of adjustment towards amputation, and in our opinion also affects amputees' confidence in showing their prostheses and in the choice of devices.

Sansoni et al (2016) describe the use of robotic prostheses as a user-centred design approach in allowing amputees to wear a personalised and attractive 'new part of their body', which presents both prosthesis and wearer in a positive self-body vision; and, for external observers to reframe their perception of disability. By using a unique and artistic robotic replacement of the limb, amputees can perceive themselves and be perceived as 'super-abled' rather than 'bearer of stigma'. The authors also highlight the personal differences in users for their tastes and ideal device, as well as a deeper psychological dynamic of their body vision. It is believed that there is an opportunity to encourage a more mature vision of amputation. A different approach in prosthetic design is needed as the first step towards this goal. The assumption is that a change in the image of disability is needed and that by revising the image of a prosthesis to meet the functional requirements, but also the aspirations of users for their prosthetic to enhance their outward persona.

2.3 Current Industrial design process

Practising Industrial designers influence a consumer's perception of a product through the application of tacit heuristics originating in the arts. In current design education, these are often passed on as experience from master to student or learned through trial and error. Design outcomes and success or failure in a market are often the retrospective validation of a design solution. This high-risk approach to design can be seen most clearly in the working practices of graphic designers within Fast-Moving Consumer Goods (FMCG), where time to delivery is critical. An open-loop approach to design is not efficient in capturing the reasons behind the success or failure. It is critical to provide some means to predict and check a design solution before they go to market where significant investment is being made in each product, such as a prosthesis. Designers do not yet have a body of theory to underpin their decision-making in the same way that mechanical and electronic engineers can predict performance. Unlike the physics of engineering, most of the characteristics around social acceptance are fluid, abstract and are influenced by complex adaptive systems that define a culture. Understanding of culture is subjective and often presented as a narrative interpretation of social cues. This is known as semiotics. Lawes (2020) provides a good example of this approach. However, the mechanisms of perception, semantic attribution and underlying motivations can be quantified through the physiological response as well as qualitative responses.

2.4 Social camouflage for prosthetic design

The case study described in the next section uses the principles of two heuristics: Social camouflage (Torrens et al 2019) and technology footprint (Torrens et al 2019). The heuristics incorporate the underpinning principles of gestalt and a learned understanding of human form. Both heuristics are underpinned by David Marr's description of the mechanism of perception (Marr 1982) as well as the principles of Gestalt. The psychologist Max Wertheimer defined the principles of Gestalt, which are a good practical guide to how the mind interprets the world from vision. (Ellis 1997) The principles applied in these heuristics rely on the understanding of 'Phase One' or 'bottom-up' visual processing within perception. Ware (2012) and Crilly (2004) have produced models of visual processing that lead to object recognition and assignment of meaning, which primarily involves 'Phase One' processing, taking 200-250msec to complete. 'Phase Two' processing, involving accessing memories and consideration to the attribution of meaning, is parallel processed alongside 'Phase One', taking around 400msec to complete. The Gestalt principle applied within social camouflage is the 'law of Pragnanz' or 'law of Simplicity', which is defined as "people will perceive and interpret ambiguous or complex

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images as the simplest form(s) possible." (Lidwell et al 2010: 144-5) This principle of Gestalt law or principle is associated with other laws such as ‘continuation’ and ‘closure’, where the mind links visual stimuli together to form something understandable or meaningful. Beyond the physical performance of our sensory organs and human brain neural network, we learn how to interpret these stimuli and signals through our mind and cognitive processing. How we identify a person visually is based on learning what another human being looks like and is closely aligned with child development. We learn from an early age to recognise a face, eyes, nose, and mouth along with the proportions and symmetry of the human form. The social psychology and visual semantics learning of early-stage assignments of meaning carry through into adulthood and how we interpret other people and the wider world. (Roback 2013) Based on the assumption that we prioritise the identification of eyes; then the face; and then the body of a person, we can predict that these sections of an image of a person may be influenced by the profile and sections of the body. Visual perception relies on the identification of a profile in the foreground from the background; the processing of colour and texture, through to an understanding of a three-dimensional form, following Marr’s model for perception. This case study uses the principles of gestalt to deconstruct the image used and to help analyse and explain the outcome of the study. There was a focus on the ‘law of simplicity’, ‘figure-ground relationship’, and social psychology principles of semantics, such as ‘symmetry’, ‘face-ism ratio’, ‘Attractiveness bias’, ‘von Restorff effect’, and ‘Uncanny valley’. (Lidwell et al 2010).

3 CASE STUDY: UPPER LIMB PROSTHESIS FOR CHILDREN

This case study is part of an integrated industrial design final year MSC project to redesign a child’s upper limb prosthetic. The work discusses how improving the appearance of the prosthesis increases social functioning and psychosocial well-being. This study aimed to meet the emotional and social needs of children aged 6-14 years by designing an upper limb prosthesis. The work is also directed at children in developing countries and is designed to be affordable. The research also considered grip within their study. This presentation will focus on the aesthetic design within the case description and discussion. The design process followed by the design research student was provided through initial training and tutoring in a Universal design approach. (Torrens 2011). The project involved a literature review, technology trawl, focus group interview, and survey with eye-tracking evaluation. Ethical approval for the study was obtained, (ref: 2022-8593-10213), before the start of the focus group, interviews and survey. A conventional literature review (ref) and technology trawl approach was used to provide context for the design specification and confirm what had already been produced. The majority of participants where Chinese Masters students on the same programme as the design research student.

3.1 Literature and focus group

The SWOT analysis was completed with four online upper limb prostheses: Hero Arm, Koalaa, Ambiotics and E-Nable as a professional review of performance, price-point, user experience, aesthetics, user and social acceptance. This resulted in the identification of the following market trends: Safety - Aesthetic - Cost-effective - Comfort - Practicality - Interesting. The matrix points were identified to find a combination for effective practicality/value for money and child acceptance/portability (Figure 1a). The 'design points' identified were identified to also included "can add more fun", "adding interaction with children" (i.e. the product user) and "optimise social disguise" (Figure 1b).

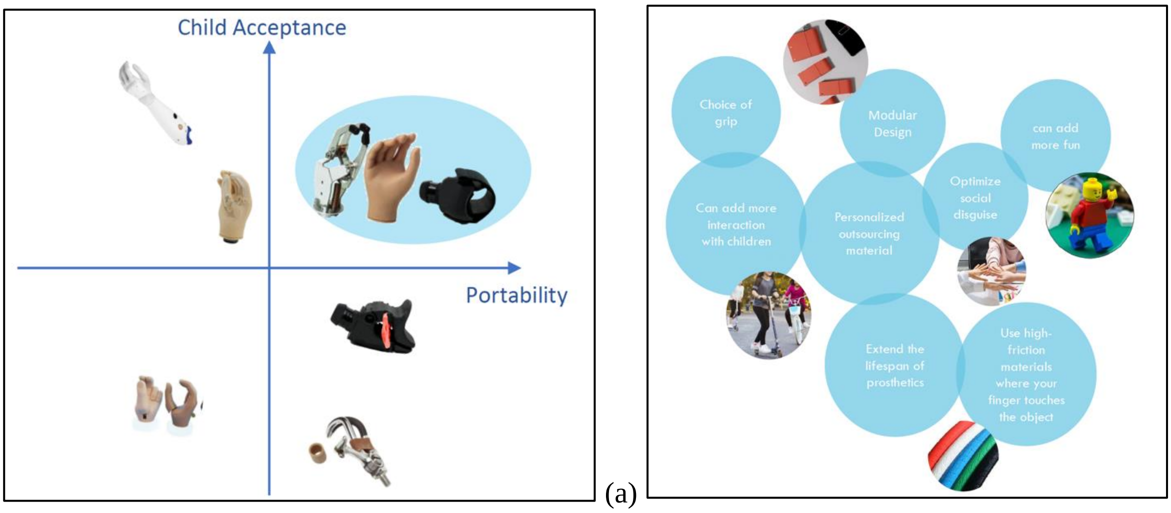

Figure 1. (a) Matrix points and (b) Design points identified in the competitors' overview

A KWHLAQ group map, Know, What, How, Learn, Actions, Questions, (Barell 2010), was also described in the analysis of the process. The first step of Primary Research consisted of Focus Group data collection with eight postgraduate students. The eight participants were shown multiple prosthetic devices and asked questions on the design aesthetics of the devices and their preferences of suitability for children. The participants were positively selected due to having younger siblings and therefore better understanding more about their preferences and behaviours.

The main results of the focus group were:

- Prosthetic limbs resembling human skin were not popular.
- Hooked hands are considered "cold" and "inappropriate" in appearance.
- Fashionable elements e.g. colours were preferred.
- Everyone had different aesthetic tastes, leading to opt for personalised choices.

3.2 Semi-structured interview

An online semi-structured interview (Usability-NET 2023) with three participants was completed who were parents of children who were amputees. The parents were Chinese nationals based in China and recruited through personal contacts of the design research student. The objectives of the interviews were to evaluate design concepts and to gain additional insights into real-life problems and experiences of children with disabilities. The recruitment process followed that authorised via ethics committee, as highlighted at the start of this case description. The participants were given an information sheet about the aim of the study and what they would be asked to discuss. The aim was to verify preferences relating to the shape of the prosthesis, based on the opinions of the adult family members of children who were amputees.

3.2.1 Interview structure

The interview questions were as follows:

1. How old is the child? Which part was lost? What was the cause? At what age did the child start wearing the prosthesis?
2. What are the most frequent problems with prostheses for child users?
3. What are the main concerns of parents for children users?
4. What are the biggest differences between child users and adult users facing prosthetic products?
5. What are you most concerned about when it comes to prosthetic shell products?
6. Which of the following types of shapes would children most like to see on a prosthetic shell?

(showing: Robot, animal, Lego, toy, monster, sci-fi, minimalist, cartoon, other)

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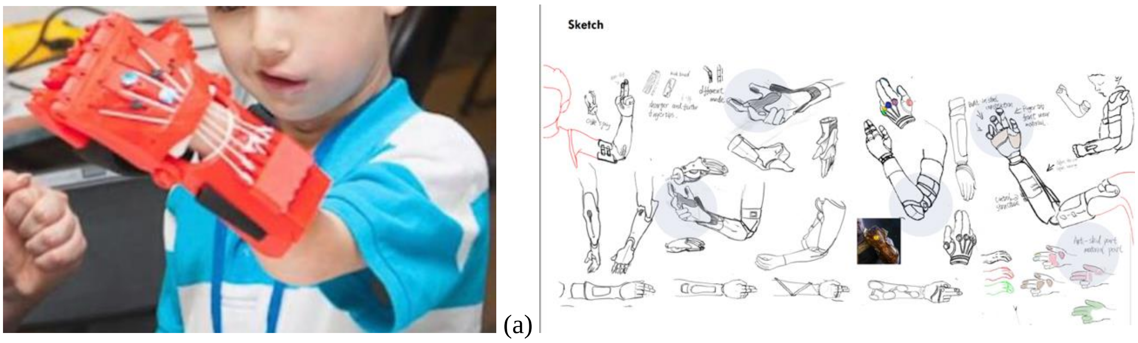
3.2.2 Findings

The main findings were that the prostheses reviewed through the SWOT professional analysis were visually larger and did not fit the proportions of a child's body (Figure 2a). A set of sketches were outlined to better match a child's anatomy, scale and proportions (Figure 2b). The weight of a prosthetic was considered heavier than the child's other arm. This was an opinion and estimate, due to no physical access to product nor user. The insights gained from this exercise and discussion with parents provided enough user requirements for ideation of possible options to be explored.



(a) (b)

Figure 2. Example of mismatched anatomical proportions (a) and sketches for new proposals (b)

3.3 Design outcomes

The aim was to design an upper-arm prosthesis, for children aged 6-14 years, that met their emotional and social needs (Figure 3a). In the first stage, the appearance and internal technical details were designed to be in line with the child's proportions, as well as the functional novelty of modularity in the prosthesis. Using modular parts provided options for customisation, with the product appearance having a variety of different colours such as blue and white, pink, white, and black (Figure 3c).

The selected requirements for application were:

- Safety
- Practicality
- Portability
- Durability
- Aesthetics
- Acceptability to children

The look of the prosthetic and its social acceptance was the primary objective of the design. The innovation of this product was that the detachable module on the back of the hand could be replaced arbitrarily to meet the preferences of children, such as colour, images, text or iconography. A whiteboard version of the panel of the prosthetic arm could be painted or drawn on by the child (Figure 3b). The inside of the palm was controlled with nylon thread. Functionally, the weight of the prosthetic arm had also been reduced to match the weight of a human equivalent.

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Figure 3. (a) Design Mood Board, (b) Design Story Board and (c) Final product design

3.3.1 Product design specification

The PDS covered Basic Operation and functionality, but included:

- Construction
- User experience
- Safety
- Environment impact and recyclability
- Logistics

Within 'user experience', the factors specified included 'Aesthetics' and 'Ergonomic performance'. The main requirement for Aesthetics was the "Visual style with colour blocking in the middle of the arm. Colours specified included brighter shades, such as pastel blue beige, with contrasting black." The purpose was that "it should meet the psychological aesthetic (expectations/aspirations) of the children".

3.4 Questionnaire and eye tracking study

A questionnaire survey combined with eye-tracking was conducted to better understand the social acceptability of prosthetics. The study was conducted with 25 university design staff and students. The protocol for the study followed a modified version of studies by Asghar et al (2020) and Torrens (2019). The test questions were mainly comparing the differences found in the two pictures and the participants' acceptance of the prosthesis, and their preference for different configurations of prosthetics. A computer-generated image of a young girl on an electric skateboard was modified to show her without an arm, wearing a range of prostheses configurations and with two arms. The image was obtained from Humano.com. (https://humano3d.com/). The eye-tracking equipment was an Tracksys supplied screen mounted SMI (SensoMontric Instrument) eye-tracker, 15"/38cm monitor with 1680 x 1050 resolution, Experiment Centre (3.6) in connection with the SMI iView X™ computer program, Data capture with SMI RED at a rate of 120 Hz. Post processing of results was completed using the BeGaze software (Gaze Intelligence 2023) from SMI. The results of the eye-tracking assessment showed that all participants first gazed at the eyes of the girl and then reviewed the proportion of the whole-body profile. All participants noticed the difference in the arms in the picture combinations. The images in Figure 4 (b) highlight the extended time and focus on the 'difference' between the prosthetic and the human arm.

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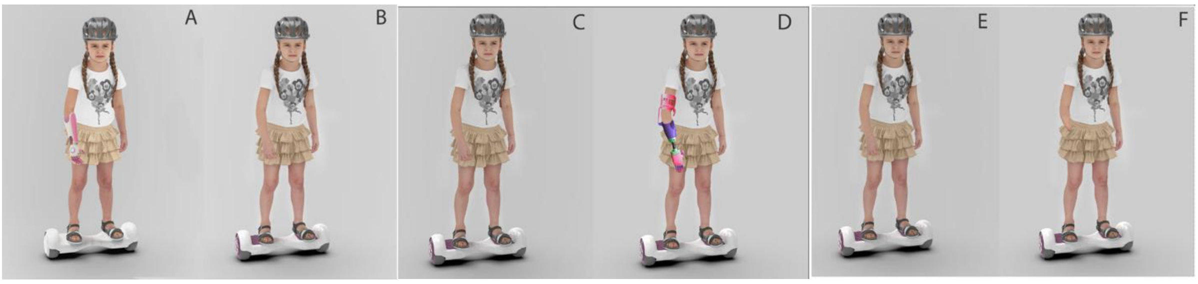

Figure 4. (a) original images and (b) eye-tracking results - source: computer-generated picture via CAD software designed by Fan Yang

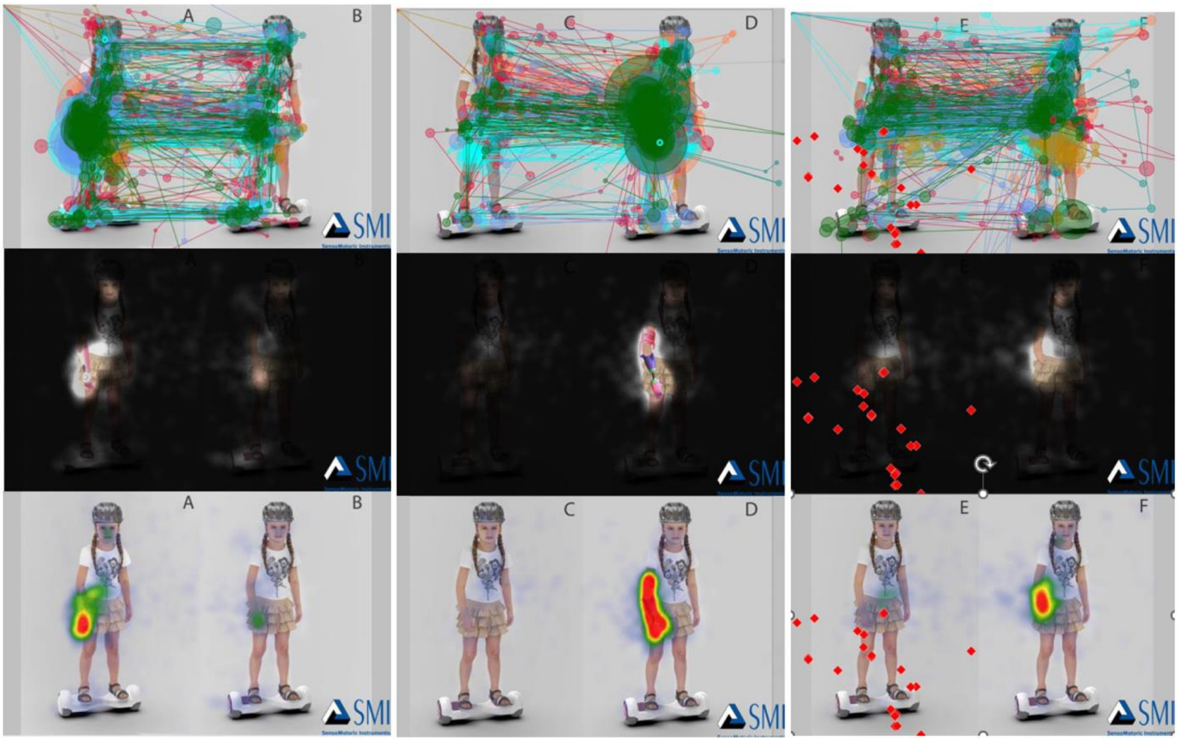

Figure 5. Ten respondents' test data was obtained, to facilitate the viewing and comparison, Test shows the eyeball movement path map, the eyeball main observation area map, and the eyeball main residence time map

As shown in figure 5, most people found the new prosthetic design A. Prosthetic D was considered too brightly coloured and felt they would attract attention, and the proportions did not match the girl in the picture. One comment indicated the proportion of the thumb did not match the appearance of the girl. Four participants did not like the dark purple structure in the middle of the prosthesis D, and thought it looked 'too mechanical' and might not fit the semantics of a prosthetic associated with children. Nine participants disliked prosthetic D. It was considered 'ugly', and 'unrealistic', 'too abstract', and 'conspicuous'. The participants were also asked if the child in the image should wear a prosthesis or not. All participants indicated the child would wear the new design of prosthesis, believing that it would improve a children's self-confidence and make them more 'beautiful' and 'natural looking'. One participant mentioned that seeing the stump made them feel' uncomfortable'. More people choose prosthesis A over prosthesis D, believing that their proportions were more appropriate.

4 CONCLUSION

The case study highlights that the conventional wisdom of a prosthetic being only a functional device is incorrect. If a prosthetic user is comfortable with how their device looks and they feel it enhances their social status in with their group and community, it reduces and potentially eliminates the stigma associated with their disability. A prosthetic device is not just 'replacing' a missing limb and its functionality, but also helps restore the user's acceptance in society as well as enhancing their persona and social status in the same way as clothing and fashion accessories are used for this purpose. Social

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camouflage for prosthetics should not be considered a way of hiding a disability, but visually prioritising the person and their values, presenting a device that:
1) Allows the wearer to perform functionally the desired daily living activities.
2) Wearing a device that represents them as a person and their values.
3) Reducing self-consciousness and feeling 'different'.

The demonstration of conventional design practices within this specific market of assistive products, underpinned by principles from social psychology, and validated through associated qualitative and quantitative test methods provides an alternative approach to product design education and practice. Application of a social model of healthcare alongside this form of evidence-based user-centred approach to new product development balances the quality and precision of good engineering practice with quantifiable validation of design. The approach and methods described with associated resources can be incorporated into engineering practice. The mixed methods approach (Creswell 2014) provides methods through which user requirements may be validated within a product design specification.

4.1 Limitations

The study was effectively a pilot case to explore the application of the principles of social camouflage, dialogic design, including participatory or codesign methods, but also combine quantitative and qualitative methods within design practice for a predominantly engineering-led approach to a new product development process for this market. The results from such a small sample group were descriptive. As a pilot there was a limited time to recruit enough participant numbers to statistically validate some of the conclusions. The protocols were applied, but a larger study with more time and participants is required to validate the proposed conclusions.

4.2 Future work

The authors will continue their programme of studies to demonstrate and validate the underlying principles, theories and heuristics associated with the practice of industrial and product design. They welcome further discussion and debate around the topic of social camouflage, user requirements translated into product design specification, and associated methods of validation. The authors welcome collaboration with new partners from both academia and industry.

REFERENCES

Asghar, S., Edward Torrens, G., Iftikhar, H., Welsh, R. and Harland, R., 2020. The influence of social context on the perception of assistive technology: using a semantic differential scale to compare young adults' views from the United Kingdom and Pakistan. Disability and Rehabilitation: Assistive Technology, 15(5), pp.563-576.
Barell, J. (2010). Problem-based learning: The foundation for 21st century skills. 21st century skills: Rethinking how students learn, pp.175-199.
Biddiss, E., & Chau, T. (2007). The roles of predisposing characteristics, established need, and enabling resources on upper extremity prosthesis use and abandonment. Disability and Rehabilitation: Assistive Technology, 2(2), 71-84.
Dunlop, G.R. (2005). Kinematic and Control Design for a Dexterous Mechanical Hand. In DS 35: Proceedings ICED 05, the 15th International Conference on Engineering Design, Melbourne, Australia, 15.-18.08. 2005.
Cheetham, M., Suter, P., & Jäncke, L. (2011). The human likeness dimension of the "uncanny valley hypothesis": behavioral and functional MRI findings. Frontiers in Human Neuroscience, 5, 126.
Conway, M. (2008). Occupational Therapy and Inclusive Design: Principles for Practice. Oxford: Blackwell. pp3–34.
Creswell, J.W. (2014). A concise introduction to mixed methods research. SAGE publications.
Crilly, N., Moultrie, J., & Clarkson, P. J. (2004). Seeing things: consumer response to the visual domain in product design. Design studies, 25(6). pp547-577.
Ellis, D.W. (1997). A source book of Gestalt psychology. (Ed) Ellis. W.D. reprint, The Gestalt Journal Press, Gouldsboro.
Gaze Intelligence. (2023). Online resource. https://gazeintelligence.com/smi-eye-tracking-support. [Accessed: 06/03/2023]
Gov.uk. (2021, October 28). Guidance - Assistive technology: definition and safe use. https://www.gov.uk/government/publications/assistive-technology-definition-and-safe-use/assistive-technology-definition-and-safe-use. [Accessed: 06/03/2023]

https://doi.org/10.1017/pds.2023.262 Published online by Cambridge University Press

Hughes, Hsu, S. H., Chuang, M. C. and Chang, C. C. (2000) ‘A semantic differential study of designers’ and users’ product form perception’, International Journal of Industrial Ergonomics, 25(4), pp. 375–391. https://dx.doi.org/10.1016/S0169-8141(99)00026-8.

Lawes, R., 2020. Using semiotics in marketing: How to achieve consumer insight for brand growth and profits. Kogan Page Publishers.

Lidwell, W., Holden, K., Butler, J., 2010. Universal principles of design: 125 ways to enhance usability, influence perception, increase appeal, make better design decisions, and teach through design, 2nd Ed, Rockport, Gloucester.

Loughborough University, 2018 -Ethical Advisory Committee, Loughborough, Loughborough University. (2020) Internet. Available at: (https://www.lboro.ac.uk/internal/research-ethics-integrity/research-ethics/), Accessed [29/11/2022].

Marr, D. (1982). Vision: A computational investigation into the human representation and processing of visual information. MIT Press. Cambridge, Massachusetts.

McDonald, Osgood, C. E. (1964) ‘Semantic Differential Technique in the Comparative Study of Cultures’, American Anthropologist, 66(3). pp171–200.

Rybarczyk, B., Nyenhuis, D. L., Nicholas, J. J., Cash, S. M., & Kaiser, J. (1995). Body image, perceived social stigma, and the prediction of psychosocial adjustment to leg amputation. Rehabilitation Psychology, 40(2), 95.

Roback, A. A. (2013). The psychology of character: With a survey of personality in general (Vol. 149). Routledge.

Sansoni, S., Speer, L., Wodehouse, A., & Buis, A. (2016). Aesthetic of prosthetic devices: From medical equipment to a work of design. In Emotional Engineering Volume 4 (pp. 73–92). Springer.

Soares, M. M.; J., Pedro Farinha Nunes da Costa, J., Ângelo, P., & Mendes, M. (2021). Expanded Boundaries: Art and Non-human Essence as Playful Inspirations for Children's Prosthetics. In Proceedings of the Fifteenth International Conference on Tangible, Embedded, and Embodied Interaction (pp. 1-8).

Sayuti, A. and Ahmed-Kristensen, S. (2020). Understanding emotional responses and perception within new creative practices of biological materials. In Proceedings of the sixth international conference on design creativity (ICDC 2020) (pp. 144-151).

Torrens, G., Storer, I., Welsh, R., Asghar, S., Hurn, K. (2019). Social camouflage: A survey of 143 students of their preference for assistive technology cutlery and the visual mechanisms being influenced. IN: Charles, R. and Golightly, D. (eds). Contemporary Ergonomics & Human Factors 2019 (EHF 2019), Stratford-upon-Avon, 29th April-1st May. Loughborough University. Conference contribution. https://hdl.handle.net/2134/36645, [Accessed:29/11/2022]

Torrens, George; Storer, Ian; Asghar, Salman; Welsh, Ruth; Hurn, Karl (2019). Persona-Technology footprint: an evaluation of 144 student’s perceptions of a person using assistive technology. IN: Charles, R. and Golightly, D. (eds). Contemporary Ergonomics & Human Factors 2019 (EHF 2019), Stratford-upon-Avon, 29th April-1st May. Loughborough University. Conference contribution. https://hdl.handle.net/2134/36646, [Accessed:29/11/2022]

Torrens, G.E. (2011). Universal Design: empathy and affinity. in Karwowski, W, Soares, M, M, Stanton, A, N, Eds, (ed) Handbook of Human Factors and Ergonomics in Consumer Products, CRC Press. pp233-248.

Verza, R., Carvalho, M. L., Battaglia, M. A., & Uccelli, M. M. (2006). An interdisciplinary approach to evaluating the need for assistive technology reduces equipment abandonment. Multiple Sclerosis Journal, 12(1), pp88-93.

Usability-NET. (2023). Online resource. https://usability-net.lboro.ac.uk/, [Accessed: 06/03/2023]

Ware, C. (2012). Information visualization: perception for design. Elsevier.