

Using human factors and ergonomics methods to challenge the status quo

Citation for published version (APA):

Read, G. J. M., Madeira-Revell, K. M. A., Parnell, K. J., Lockton, D., & Salmon, P. M. (2022). Using human factors and ergonomics methods to challenge the status quo: Designing for gender equitable research outcomes. *Applied Ergonomics*, 99, Article 103634. <https://doi.org/10.1016/j.apergo.2021.103634>

Document license:

TAVERNE

DOI:

[10.1016/j.apergo.2021.103634](https://doi.org/10.1016/j.apergo.2021.103634)

Document status and date:

Published: 01/02/2022

Document Version:

Publisher's PDF, also known as Version of Record (includes final page, issue and volume numbers)

Please check the document version of this publication:

- A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
- The final author version and the galley proof are versions of the publication after peer review.
- The final published version features the final layout of the paper including the volume, issue and page numbers.

[Link to publication](#)

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license above, please follow below link for the End User Agreement:

www.tue.nl/taverne

Take down policy

If you believe that this document breaches copyright please contact us at:

openaccess@tue.nl

providing details and we will investigate your claim.



Using human factors and ergonomics methods to challenge the status quo: Designing for gender equitable research outcomes

G.J.M. Read^{a,*}, K.M.A. Madeira-Revell^b, K.J. Parnell^b, D. Lockton^c, P.M. Salmon^a

^a Centre for Human Factors and Sociotechnical Systems, University of the Sunshine Coast, Maroochydore, Australia

^b Transportation Research Group, University of Southampton, Southampton, UK

^c Future Everyday, Department of Industrial Design, Eindhoven University of Technology, the Netherlands

ARTICLE INFO

Keywords:

Gender data gap
Gender equity
Sociotechnical systems design toolkit
Causal loop diagram
Abstraction hierarchy
Design with intent toolkit

ABSTRACT

There have been recent calls for Human Factors and Ergonomics (HFE) to expand its reach and focus to address larger scale societal and global issues. An area of growing awareness is the issue of the gender data gap, whereby women are under-represented in research data, leading to inequitable outcomes when research findings are used to design real world technologies, products, environments, processes, and policies. The aim of this paper is to showcase how structured HFE methods can be used to address the gender data gap. We applied the Sociotechnical Systems Design Toolkit which involved using causal loop diagrams and abstraction hierarchy modelling from Cognitive Work Analysis to understand the system in which the issue occurs and key pain points, followed by the application of the Design with Intent Toolkit to generate design ideas. A total of 43 ideas were developed that could be implemented by universities to address the research data gap. The application demonstrates the utility of HFE methods in tackling complex issues and offers an opportunity for the HFE community to reflect upon the importance of gender sensitive research practices and gender equity more broadly.

1. Introduction

Developing, testing and extending Human Factors and Ergonomics (HFE) methods to address significant issues within complex systems has been a key focus of Prof Neville Stanton's career. He has been active in improving the usability and utility of systems methods through his books (e.g. Stanton et al., 2018; Stanton et al., 2013) and software tools (Jenkins et al., 2007). His work has also been pivotal in efforts to close the gap between analysis and design in HFE. Specifically, he has undertaken design work in relation to a wide range of products and systems including adaptive cruise control systems (Stanton et al., 1997), helicopter heads up displays (Stanton et al., 2016), railway level crossings (Read et al., 2021) and automated driving interfaces (Stanton et al., 2021). He has also been a co-creator of new design methods and approaches including the Sociotechnical Systems Design Toolkit (STS-DT; Read et al., 2017, 2018), which incorporates another of his co-created methods, the Design With Intent (DWI) toolkit (Lockton et al., 2010). In developing the STS-DT, Stanton was a proponent of 'putting theory back into practice' in design, by suggesting the synthesis of Cognitive Work Analysis (CWA; Vicente, 1999) with the sociotechnical systems tradition arising from the work of the Tavistock Institute (Read et al.,

2015). Central to this impressive body of work has been an emphasis on both the human experience as well as human health and wellbeing generally.

In recent times there have been strong calls for HFE to expand its reach and focus to larger scale societal and global issues (Salmon et al., 2019, 2021; Thatcher et al., 2017, 2020). One such issue is gender equity. The World Health Organisation defines gender equity as "fairness and justice in the distribution of benefits and responsibilities between women and men" (WHO, 2002, p. 4). The concept of equity acknowledges that there are differences in the needs and power between the genders and that these must be considered in addressing imbalances in outcomes (WHO, 2002). An area of growing awareness in relation to gender equity has been the issue of the gender data gap. This term refers to the under-representation of women in research data, a systemic bias which results in inequitable outcomes when research findings are translated into real world design or policy. Brought to attention in the popular book 'Invisible Women', by Criado Perez (2020), there are many important areas where this systemic bias has resulted in inequities. One of the examples cited by Criado Perez is the design of vehicles, where safety testing traditionally and legislatively relies on crash test dummies based around the north American or European male body, resulting in

* Corresponding author. Centre for Human Factors and Sociotechnical Systems, University of the Sunshine Coast, Maroochydore, Australia.

E-mail address: gread@usc.edu.au (G.J.M. Read).

higher risk of serious injury and death for female drivers (Forman et al., 2019). Another example identified by Criado Perez is the provision of ‘unisex’ Personal Protective Equipment (PPE) designed around the North American/European male. She notes this issue as not only about comfort, but as also affecting task performance and having the potential to represent a safety hazard. For example, Criado Perez highlights a survey finding that only 5% of women reported that their PPE never hampered them while performing their work (TUC, 2017). Further, women reported safety harnesses and body armour to cause problems due to rubbing on the skin or being unable to accommodate different body shapes (TUC, 2017). PPE fit has also been a highly pertinent issue during the COVID-19 pandemic, with the media reporting concerns around contamination risk due to inadequate seals when face masks designed for men are used by female healthcare workers (e.g. Topping, 2020). Criado Perez also highlights how the medical industry historically and currently has a systemic bias in terms of the focus of research undertaken, and the propensity for collecting data on male biased or even ‘male only’ populations. The results are routinely generalised to females without an understanding if the symptoms of illness or disease are the same for women, nor if the procedures are as effective, or have the same side effects when applied to women (Criado Perez, 2020). In relation to technology, Criado Perez notes that voice-recognition is also male biased, with the best software on the market more likely to accurately recognise male speech than female speech due to software being trained on predominately male voices (Tatmen, 2017). This has implications in multiple domains, such as automotive, domestic, medical and beyond. Women operating in these domains will be more frustrated and less effective due to systemic bias in design (Criado Perez, 2020).

The HFE discipline prides itself on being holistic, user focused and inclusive. There has been a strong history of HFE research focused on questions relating to gender, such as women’s working conditions (e.g. Dumais et al., 1993), occupational health and safety (e.g. Messing, 2021), and differing impacts of the COVID-19 pandemic on working women (Gulotta et al., 2020). Further, a recent special issue of this journal focused on the topic of *Considering sex and gender in ergonomics: Exploring the “hows” and “whys”* (Laberge et al., 2020). However, there has been little discussion within our discipline regarding the gender data gap, and indeed whether HFE methods could assist to address it. For example, when conducting HFE research in traditionally male-dominated transport industries (e.g. aviation, maritime), participant sampling is often based on convenience (or representation) rather than balanced across genders. This limits the ability to perform any meaningful gender sensitive analysis and issues or findings specific to women in these domains are likely to become ‘washed out’ in the combined analysis (Madeira-Revell et al., 2021).

To promote gender equitable outcomes through HFE research, we need to take a whole of research lifecycle approach. That is, sex and gender should be considered from research design, through data collection, analysis and dissemination of results (Yellow Window, 2018). Previous work has recommended: the development of research guidelines to support this integration throughout the research lifecycle; identifying opportunities such as collecting data online (or through remote means) where possible to remove barriers faced by women associated with in-person attendance; promoting the need for gender-sensitive data analysis (i.e. at conferences, forums); and creating a culture where gender is considered at every stage of the research process (Madeira-Revell et al., 2021).

The aim of the current paper is to build on this previous work to showcase how structured HFE methods created by Stanton, specifically the STS-DT and DWI toolkit, can be used as part of the response to this critical issue. Throughout this paper, we consider the data gap problem from the lens of gender, however we acknowledge that the issues raised are also relevant to other protected characteristics such as race, first

nations descent, sexual identity and sexuality, age and health status, as well as intersections between these characteristics. We believe that the process undertaken here, and recommendations developed could be equally applicable to improving equity in these other areas. While in this paper we use the words ‘women’ and ‘woman’ in relation to gender, we stress that we include everyone who identifies as a woman, whether or not they were assigned female at birth. As noted, the use of designed interventions to address equity can be relevant to many minoritised or marginalised groups.

2. Method

The STS-DT was initially designed to assist in the translation of CWA analyses into design concepts; and later broadened to incorporate other sociotechnical systems analysis approaches (Read et al., 2018). The toolkit guides the user through stages of the analysis and design lifecycle commencing with analysis planning and concluding with testing and verification of implemented design concepts. Depending on the scope of the application, a sub-set of stages can be used. In this case study, we applied the initial stages of the STS-DT, which involved: analysis planning; the analysis process and outputs; design planning and identification of insights; and concept design.

2.1. Analysis planning

The first step in applying the STS-DT is the development of an analysis brief. The analysis brief helps to provide a scope to the activity and define the boundaries of the system for analysis and design phases. Given the breadth of the issue to be explored, we decided to apply two systems-based modelling approaches: causal loop diagrams (CLDs; Sterman, 2002), followed by the first phase of CWA, work domain analysis, using the abstraction hierarchy (AH) tool. The CLD approach took a wider scope, whilst the AH focused on one sub-system.

CLDs provide a means of depicting the complex set of interacting variables across a system which influence an outcome, in this case, gender equitable research outcomes. CLDs comprise variables connected by arrows which depict the causal relationships between them – either reinforcing (denoted by a + symbol) or balancing (denoted by a – symbol). For example, Fig. 1 shows a simple CLD representing the relationship between men in research positions and consideration of gender issues. The model illustrates that as the number of men in leadership positions increases, consideration of gender issues decreases. In turn, as consideration of gender issues increases, the number of men in leadership positions decreases (i.e. more women are supported to

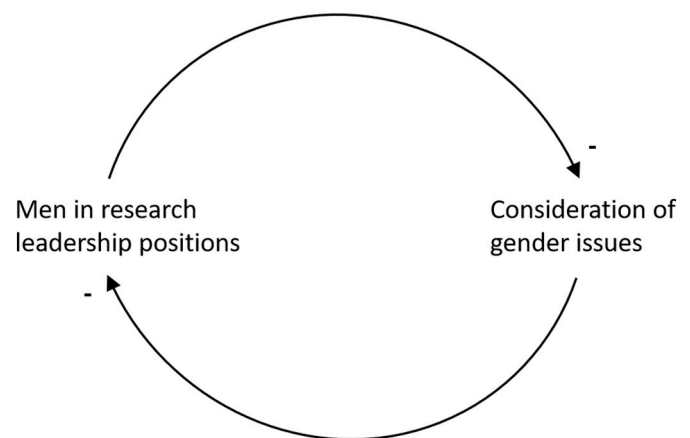


Fig. 1. Simple CLD example.

enter leadership positions).

In addition to the CLD, we selected one sub-system of the overall university system to focus on in more detail using CWA. Specifically, we modelled the role of a research centre or institute. This represents the work domain within which decisions are made regarding the conduct of research and the extent to which it is sensitive to gender issues. Further, universities are commonly conceptualised as a complex system (see Perrow, 1984; Rouse, 2016). Thus, CWA was considered to be an appropriate approach to consider how this system impacts on gender equity and the research data gap.

Previous work has focused on what researchers can do in their role to contribute to gender equity (Madeira-Revell et al., 2021). Therefore, the purpose of the AH analysis was to focus on management decision making within universities and how that might be influenced to support gender equity in research outcomes. While it is acknowledged that wider system changes (i.e. at the university and societal levels) would provide the most benefit, we decided to explore the possibility for innovative interventions within the constraints of the existing system, and could therefore be implemented relatively easily and within a short time horizon.

For this case study, the AH tool was selected to provide a functional analysis of a university research team, as a sub-system of the wider university system. This was chosen based on access to subject matter experts (the authors), and direct relevance to the readership of the journal, and serves as a demonstrative case study for other sub-systems. In other words, the identification of which AH sub-system to focus on did not relate to points identified by the CLD as being prime ‘tipping points’ for wider systemic change. Finally, it should be noted that the AH developed was intended to be generic, with international relevance, rather than focused on a specific university system.

2.2. Analysis process & outputs

The development of CLDs can be either researcher-led (i.e. based on upon peer-reviewed literature and other documentation) or it can be participatory; developed as part of a group model building process with subject matter experts (Bérard, 2010). A hybrid approach was applied in the development of the CLD for this study, following previous applications (e.g. McLean et al., 2021a). The CLD was initially developed by one author (GR), based on a review of the literature, and then reviewed by

the other authors in an online meeting. Refinements were made to the model based upon the feedback gathered and it was distributed via email for final comments prior to finalisation.

AH model development is commonly researcher-led, with review by SMEs (e.g. Naikar, 2013). In this case, the AH was initially developed by one author (PS), and then reviewed and verified in detail by two other authors (GR, KMR) in an online meeting. Other authors were provided an electronic version for review and comment.

The authors all have experience working in academia, with a mean of 12.2 years of experience in research at a postdoctoral level and beyond ($SD = 3.6$). Their experience spans various countries (Australia, UK, the USA and the Netherlands), as well as different disciplinary backgrounds (HFE, systems thinking, design, psychology, sports science and law).

2.2.1. Causal loop diagram

The CLD (Fig. 2) shows reinforcing loops relating to awareness of the problem and the subsequent implementation of gender sensitive research practices, leading to equitable real-world products, systems and outcomes, which can be positively influenced via three key channels. The first is via disciplinary initiatives that raise awareness of the problem. This would include initiatives by professional societies and journal publishers. The second channel involves funding bodies who may positively influence gender sensitive research practices via funding criteria and guidelines or peer review processes. The third channel involves universities who may implement gender equity initiatives to encourage gender sensitive research activities such as guidelines for research practice. Universities may also implement initiatives to support women to attain leadership positions, which in turn supports gender sensitive research practice. Here, it is acknowledged that gender issues may be overlooked not because they are purposefully ignored, but because men, who often dominate leadership positions in academia, are not personally aware of women’s experiences of bias and discrimination. Therefore, it is important that women are represented at senior levels in research centres and academia to provide a voice for these issues. As more equitable products, systems and outcomes become available, this brings awareness to the public who increase their expectations of gender equity in research which in turn supports disciplines to engage in initiatives. It should be noted that many of these reinforcing loops are in an early stage of development and thus may be viewed as representing an ideal situation. For example, while several position papers and

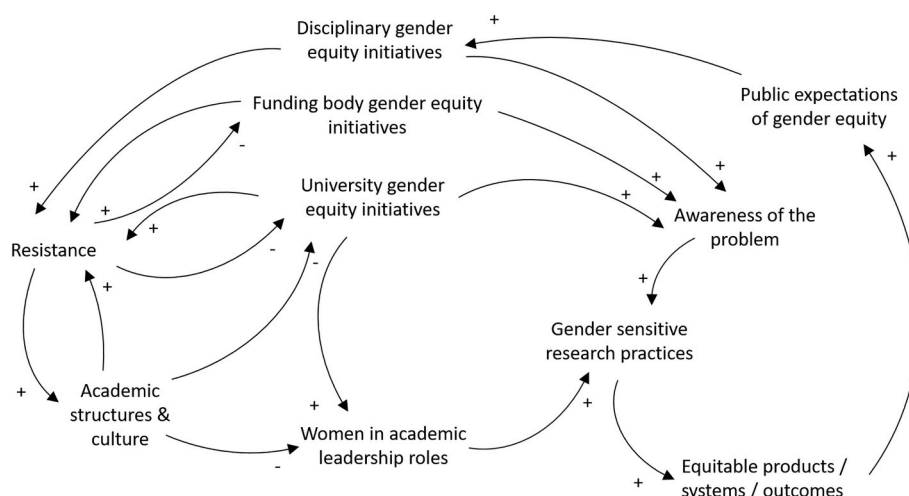


Fig. 2. CLD of research gender data gap.

guidelines are being developed and implemented such as the Sex and Gender Equity in Research (SAGER) guidelines (Heidari et al., 2016), their application is not widespread.

The CLD also shows balancing relationships in the form of resistance to change, which can encompass both resistance to change by individuals, as well as more embedded systemic characteristics. At an individual level, some individuals or groups who either benefit from the status quo or fear change, may push back on the initiatives, undermining their reach or sustainability. An example would be male academics whose research has not typically considered gender specifically and who may fear loss of future research funding. Other elements of resistance relate to underpinning assumptions that impact gender equity in the university system, such as the fairness of merit-based systems for selection and promotion. Such assumptions remain even though merit-based systems have been found to fail to account for systemic inequities relating to gender stereotypes, the impact of career interruptions on outputs, and lack of access to social networks (van den Brink and Benschop, 2012). This resistance is likely to be reinforced by traditional academic structures that value metrics such as quantity of publications. Resistance elements in turn support traditional academic structures and cultures of overwork and competition, which act to systematically hinder women from reaching leadership roles, ultimately undermining gender sensitive research practices and equitable real-world outcomes.

2.2.2. Abstraction hierarchy

The AH (Fig. 3) describes a generic university research centre system from five levels of abstraction. The frequency of nodes at each of the abstraction levels are shown in Table 1.

The nodes at each level are linked by means-ends links which can be

interpreted using why-what-how chains. For each node ('what'), nodes linked to in the level above represent 'why' that node is required, and nodes linked to in the level below represent 'how' the node is achieved.

For example, the purpose-related function 'stay up to date with literature' is required to support the value and priority measure of 'number of high quality publications' and is supported by the object-related process of 'provide knowledgebase' which is in turn supported by the physical object 'literature (peer reviewed and grey)'.

2.3. Design planning and identification of insights

The design planning stage of the STS-DT involves the identification of insights from the from the analysis and the development of a design brief.

Insights can take the form of assumptions, metaphors, pain points, leverage points, scenario features and design solutions (Read et al., 2018). For this case study, we focused on identifying pain points in the existing system that suggest areas for intervention and re-design. Pain points refer to problems or issues that are identified during the analysis. They may be points of frustration for system actors, conflicting goals amongst actors or broader problems in the organisational system. Pain points were identified in relation to nodes at the purpose-related function level (middle level) of the AH, which provides a comprehensive set of functions undertaken within a research centre. These functions cover the research lifecycle as well as additional functions which relate to the recruitment and progression of women researchers (e.g. 'recruit staff and students', 'performance planning & management'). Each purpose-related function was reviewed to identify gender equity pain points from both a selection of relevant research literature as well as the authors' own experiences (see Table 2).

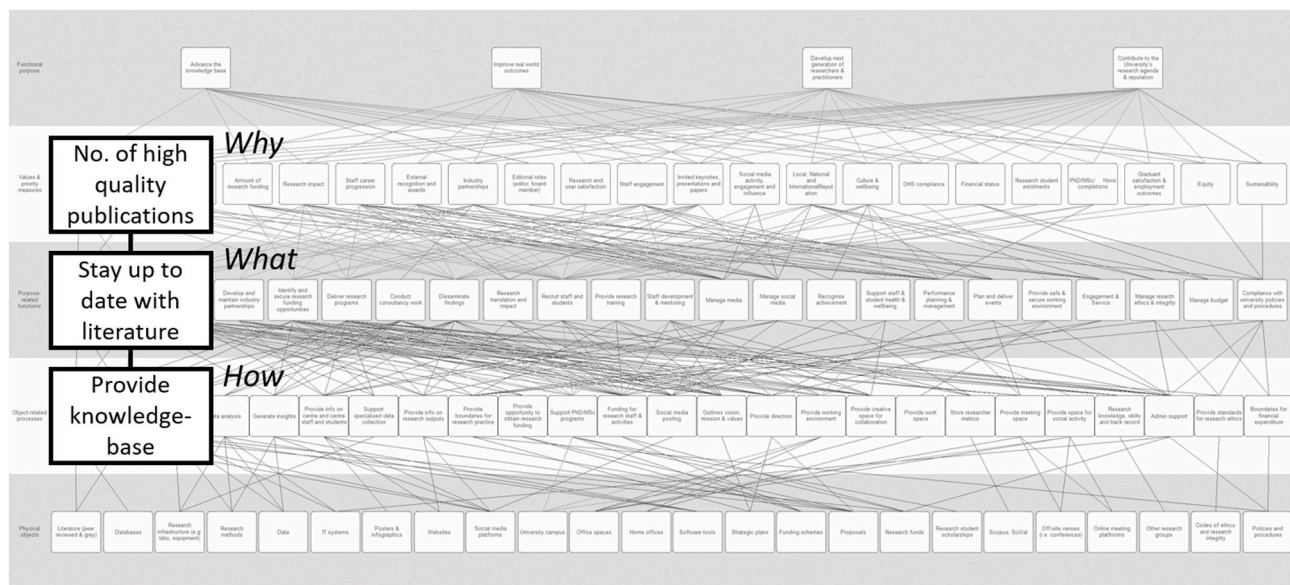


Fig. 3. AH of university research centre. For full model, see the Supplementary Material.

Table 1
Breakdown of abstraction levels.

Abstraction level	Description	No. nodes (n)
Functional purposes	The overall purposes for which a research centre exists	4
Values and purpose	The values used to measure progress of a research centre towards achieving the functional purposes	22
Purpose-related functions	The general functions that need to be undertaken by a research centre to achieve the functional purposes	23
Object related processes	The functional capabilities and affordances of physical objects within a research centre that enable the achievement of the purpose-related functions.	25
Physical objects	The objects used within a research centre	24

Table 2

Gender equity pain points related to the key functions from the AH.

Purpose-related function	Values and priority measures supported by the function	Pain points
Stay up to date with literature	<ul style="list-style-type: none"> - Number of high quality publications - Citations, H Index & FWCI 	<ul style="list-style-type: none"> - Existing literature often biased, need to be cognisant and to note where it is and is not appropriate to generalise (Madeira-Revell et al., 2021). - Often insufficient evidence available that addressing gender is required (thus difficult to influence funders, etc) (Madeira-Revell et al., 2021). - Existing literature base contributes to assumption of generalisability of findings across genders.
Generate significant and innovative research ideas	<ul style="list-style-type: none"> - Number of high quality publications - Citations, H Index & FWCI - Research impact - External recognition and awards - Industry partnerships - Staff engagement - Invited keynotes, presentations and papers 	<ul style="list-style-type: none"> - Lack of prompts and guidance within internal systems to ensure gender equity is considered at the design stage (Madeira-Revell et al., 2021).
Develop and maintain research collaborations	<ul style="list-style-type: none"> - Industry partnerships 	<ul style="list-style-type: none"> - Collaborators may not be aware of gender equity issues.
Develop and maintain industry partnerships	<ul style="list-style-type: none"> - Research impact - Industry partnerships 	<ul style="list-style-type: none"> - May be more difficult for women to develop partnerships in traditionally male-dominated sectors.
Identify and secure research funding opportunities	<ul style="list-style-type: none"> - Amount of research funding - Research impact - Staff career progression - Industry partnerships - Staff engagement - Invited keynotes, presentations and papers 	<ul style="list-style-type: none"> - Funding available for research is often focused on short-term goals and gaining funding is highly competitive – thus it is difficult to pitch for extra funding to support gender equitable research. - Industry partners/potential funders may not be aware of gender equity issues. - Funders have set priorities which may not include gender equity. - Women are less successful in competitive grant outcomes due to systemic disadvantages (Wennerås and Wold, 1997).
Deliver research programs	<ul style="list-style-type: none"> - Number of high quality publications - Research impact - External recognition and awards - Research end user satisfaction - Staff engagement - Invited keynotes, presentations and papers 	<ul style="list-style-type: none"> - Data collection methods may not be designed to identify potentially relevant sex and/or gender differences (Yellow Window, 2018). - Barriers to gaining balanced gender participation (e.g. child caring responsibilities, data collection equipment not designed for women; Madeira-Revell et al., 2021).
Conduct consultancy work	<ul style="list-style-type: none"> - Industry partnerships 	<ul style="list-style-type: none"> - Consultancy activities based on biased research findings could be misleading and potentially damaging.
Disseminate findings	<ul style="list-style-type: none"> - Number of high quality publications - Citations, H Index & FWCI - Almetrics - Research impact - Staff career progression - External recognition and awards - Staff engagement - Invited keynotes, presentations and papers - Local, national and international reputation - Financial status 	<ul style="list-style-type: none"> - Publications do not consistently report gender differences and gender-related findings. Nor is there clear guidance on how to determine where gender directly/indirectly impacts on their findings (Madeira-Revell et al., 2021). - Lack of clarity on how to report on/consider unbalanced samples in qualitative studies (Madeira-Revell et al., 2021). - Gender-related findings are not disseminated to target groups that focus on gender (i.e. institutions, journals, events (Yellow Window, 2018).
Research translation and impact	<ul style="list-style-type: none"> - Staff career progression - External recognition and awards - Invited keynotes, presentations and papers 	<ul style="list-style-type: none"> - Impact or translation activities based on biased research findings could be misleading and potentially damaging.
Recruit staff and students	<ul style="list-style-type: none"> - Number of high quality publications - Citations, H Index & FWCI - Almetrics - Amount of research funding - Research impact - Staff career progression - External recognition and awards - Industry partnerships - Research end user satisfaction - Invited keynotes, presentations and papers - Social media activity, engagement and influence - Local, national and international reputation - Culture & wellbeing - Research student enrolments - PhD/Masters/Honours student completions - Equity 	<ul style="list-style-type: none"> - Project teams are not always gender balanced, or if they are women may not be represented in decision-making positions (Yellow Window, 2018). - Women are disadvantaged in evaluations of academic excellence in hiring decisions (van den Brink and Benschop, 2012). - Women tend to be underrepresented in research positions and overrepresented in teaching and student support positions (Winchester and Browning, 2015).

(continued on next page)

Table 2 (continued)

Purpose-related function	Values and priority measures supported by the function	Pain points
Provide research training	<ul style="list-style-type: none"> - Culture & wellbeing - PhD/Masters/Honours student completions - Graduant satisfaction & employment outcomes 	<ul style="list-style-type: none"> - Research training does not generally address issues associated with gender sensitivity in research, thus research students and early career researchers are unaware of the issue.
Staff development & mentoring	<ul style="list-style-type: none"> - Staff career progression - Staff engagement - Culture & wellbeing 	<ul style="list-style-type: none"> - Staff training does not generally address issues associated with gender sensitivity in research, staff are unaware of the issue. - Lack of accessibility to female senior mentors, potentially confounded by the fact that providing mentoring is requires time and emotional work; not recognised/valued in terms of career advancement (Blaess et al., 2020).
Manage media	<ul style="list-style-type: none"> - Amount of research funding - Research impact - Staff career progression - External recognition and awards - Industry partnerships - Social media activity, engagement and influence - Local, national and international reputation 	<ul style="list-style-type: none"> - Media may not be aware of gender equity issues, lack of guidelines to support the reporting of research findings in a gender sensitive manner. - Women are underrepresented as experts in media (e.g. Ross et al., 2018). - Deterrents exist for women experts to engage with media (e.g. Shine, 2021).
Manage social media	<ul style="list-style-type: none"> - Amount of research funding - Research impact - External recognition and awards - Industry partnerships - Invited keynotes, presentations and papers - Social media activity, engagement and influence - Local, national and international reputation 	<ul style="list-style-type: none"> - Women researchers may be deterred from social media due to online harassment, leading to negative outcomes such as losing confidence in their work, loss of productivity or reputational damage (Gosse et al., 2021).
Recognise achievement	<ul style="list-style-type: none"> - Staff engagement - Culture & wellbeing 	<ul style="list-style-type: none"> - Lack of awards supporting gender equitable research.
Support staff & student health & wellbeing	<ul style="list-style-type: none"> - Staff engagement - Culture & wellbeing 	<ul style="list-style-type: none"> - Women working in STEM disciplines perceive having their voices devalued (Madeira-Revell et al., 2021).
Performance planning & management	<ul style="list-style-type: none"> - Number of high quality publications - Citations, H Index & FWCI - Amount of research funding - Staff career progression - Staff engagement - Culture & wellbeing - PhD/Masters/Honours student completions 	<ul style="list-style-type: none"> - Gender equity in research not considered in staff performance reviews. - Performance reviews generally based on standards of academic excellence; which are known to disadvantage women (van den Brink and Benschop, 2012).
Plan and deliver events	<ul style="list-style-type: none"> - Research impact - Industry partnerships - Staff engagement - Local, national and international reputation 	<ul style="list-style-type: none"> - Lack of events focused on gender equity in research.
Provide safe & secure working environment	<ul style="list-style-type: none"> - OHS compliance - Staff engagement 	<ul style="list-style-type: none"> - Workplace sexual harassment remains an issue in academia (e.g. National Academies of Sciences, Engineering, and Medicine, 2018).
Engagement & Service	<ul style="list-style-type: none"> - Staff career progression - External recognition and awards - Editorial roles (editor, board member) - Local, national and international reputation 	<ul style="list-style-type: none"> - Lack of university or discipline committees/working groups focused on gender equity in research specifically. - Lack of prompts to consider gender equity in peer review processes.
Manage research ethics & integrity	<ul style="list-style-type: none"> - Local, national and international reputation - Culture & wellbeing 	<ul style="list-style-type: none"> - Gender sensitivity is not routinely raised in research merit reviews (i.e. for ethics approvals).
Manage budget	<ul style="list-style-type: none"> - Local, national and international reputation - Financial status 	<ul style="list-style-type: none"> - Project budgets may not support gender sensitive data collection or analysis, unless designed into project.
Compliance with university policies and procedures	<ul style="list-style-type: none"> - Financial status - Equity - Sustainability 	<ul style="list-style-type: none"> - Universities may not have proactive policies to ensure gender sensitive research.

Based on Table 2, we identified three of the purpose-related functions that had a key influence. Influential purpose-related functions were those that supported all four functional purposes, and had the most links supporting nodes at the values and priority measures level. Those defined as influential functions were: 'disseminate findings', 'recruit staff and students' and 'performance planning & management'.

Next, the design brief was defined. A design brief provides a summary of the background and problem to be solved by the design team. It provides the scope for the design activity. For this case study, a short

design brief (Fig. 4) was developed which was scoped around one pain point relating to each of the three influential purpose-related functions. Given that previous recommendations (Madeira-Revell et al., 2021) focus on what could be achieved from a bottom-up perspective, for this analysis we aimed to consider what recommendations could be gained from the perspective of a university-wide approach, driven by the head of research. We also acknowledge that culture change is difficult to implement and there are often groups who are committed to the status quo and do not see the need for change.

You are the Deputy Vice Chancellor (Research) at your University. A research centre director recently approached you with a report from a working group who have been investigating gender equity in their research. They have identified the following key pain points:

1. Publications do not consistently report gender differences and gender-related findings
2. Project teams are not always gender balanced, or if they are, women may not be represented in decision-making positions.
3. Gender equity in research is not considered in staff performance reviews.

You believe that promoting gender equity in research is a priority but are aware that several senior researchers do not agree and will not be supportive of change to the status quo.

You will use the DWI toolkit (interaction lens and cognitive lens) to identify strategies as part of the University-wide research strategy to address these issues across the university, gaining the support of all senior researchers.

Fig. 4. Design brief.

The design tools selected were the DWI toolkit cards. The DWI toolkit consists of eight design lenses – Architectural, Errorproofing, Persuasive, Visual, Cognitive, Security, Ludic and Machiavellian - which provide a set of patterns that can be applied to influence people's behaviour within a system (Lockton et al., 2014). Two of the lenses, the interaction lens and the cognitive lens were chosen for this design brief given their broad focus (i.e. not on physical design alone). The interaction lens brings together some of the most common patterns used for interface design where users' interactions with the system affect how their behaviour is influenced such as types of feedback, progress bars and previews. The cognitive lens draws on research in behavioural economics and cognitive psychology regarding decision making in terms of heuristics and biases.

2.4. Concept design

A virtual workshop was held with all authors. In the workshop, the attendees began by reviewing the causal loop diagram and the AH and agreeing on the design brief. Next, a short lateral thinking exercise was undertaken with the intention to prime attendees to shift away from linear, rational mindsets and support divergent and creative thinking about design possibilities in the remainder of the workshop. The exercise involved tackling an 'impossible challenge' (Imber, 2009), whereby attendees were given 5 min to identify three ways that they could "become the President of the United States of America by tomorrow lunchtime". Following this exercise, attendees used Miro, an online collaborative workspace to undertake the ideation process. Fig. 5 shows the Miro Board at the beginning of the ideation process. Attendees were asked to

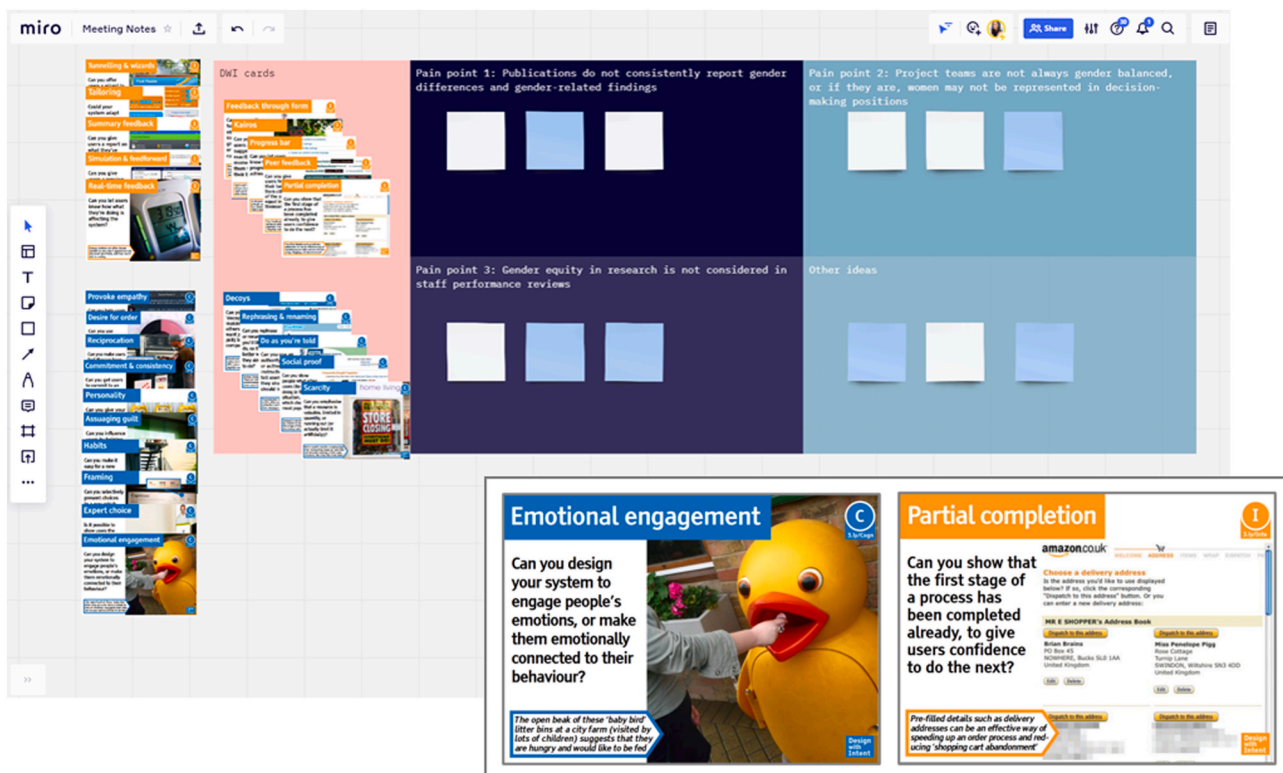


Fig. 5. Miro Board at commencement of ideation session, with enlargement of two DWI cards shown as examples.

Table 3

Description of intervention classifications.

Intervention classification	Description
Awareness raising	Facilitating wider discussion and awareness of the topic of gender equity and the current issues surrounding it.
Process change	Implementing new procedures, or amending those currently in place, to provide more equitable ways of working.
Lobbying	Calling on key individuals, organisations and bodies to enact gender equitable changes.
Research and analysis	Conduct gender equitable research or research that highlights the needs for gender equity.
Reward and recognition	Incentivise gender equitable practises.
Structural change	Large, widespread change to the way the system functions.
Tool provision	Access to equipment that supports gender equitable processes.

work independently for approximately 20 min to consider how the DWI cards could be used to identify interventions to address the three pain points, or to address the gender equity issue more broadly (i.e. 'other ideas'). Attendees were encouraged to move the DWI cards to be positioned adjacent to their design idea, with the ability to 'copy' and 'paste' cards to be associated with multiple design ideas. Following the ideation process, there was a short time for discussion of key themes and ideas from the ideation phase.

The interventions were later transcribed and categorised into short-term (able to be implemented within the next 12 months), medium-term (able to be implemented within 1–5 years) and long-term changes (unlikely to be implemented within the next 5 years). In addition, a small number of ideas were found to overlap and were merged. The interventions were also aggregated and classified on the nature of intervention, see Table 3.

3. Results

In total, 43 ideas were generated during the workshop session. Twelve ideas (27.9%) related to pain point one, 11 (25.6%) to pain point two, 10 (23.3%) to pain point three. An additional 10 intervention ideas (23.3%) were also identified as beneficial outside of the pain points presented. Overall, 46.5% of ideas were focused on a short-term time-scale, 39.5% were medium-term and 7% were long-term. In terms of categories of intervention, most related to awareness raising (30.2%), then process changes (27.9%), followed by lobbying (23.3%), research and analysis (7%), reward and recognition (4.7%), structural changes (4.7%) and tool provision (2.3%).

In relation to the first pain point, *that publications do not consistently report gender differences and gender-related findings*, 12 ideas were generated (see Table 4). Most of the ideas were medium-term, in

addition to some short-term that could be implemented immediately. Those classified as short-term could be implemented internally within the university setting (e.g. 1.4 – require gender equity considerations be considered in ethical review processes). Those classified as medium-term generally involved lobbying and influencing others such as journal editors-in-chief, professional societies and research funding bodies. Thus, it might be suggested that the key opportunities to address this pain point sit outside of the university and may take some time to implement.

In relation to the second pain point, *that project teams are not always gender balanced, or if they are, women may not be represented in decision-making positions*, 11 ideas were generated (see Table 5). In this case, most ideas were thought to be able to be implemented in the short-term as they represented relatively small changes that could be made internally within the university. For example, the university could introduce checklists, develop case study materials of the adverse impacts of having male dominated project teams, or publicly report the gender make-up of their research teams to draw attention to the issue and allow for public scrutiny.

In relation to the third pain point, *that gender equity in research is not considered in staff performance reviews*, 10 ideas were generated (see Table 6). Most could be implemented within the short term due to being within the control of the university and mostly relating to process changes. A few of the ideas, such as 3.3 and 3.8, contrasted academic performance management systems with industry, with the suggestion that academia has fallen behind standards common in other organisations, such as 360° reviews (whereby performance reviews also involve feedback from peers and those reporting to the individual). The long-term intervention, 3.10, was considered to take more than five years to implement due to the somewhat radical suggestion to change the performance review system to support collective negotiation, thus

Table 4Design interventions for pain point 1: *publications do not consistently report gender differences and gender-related findings*.

ID	Intervention	Category	Time horizon
1.1	Call on staff members with journal editorial roles to lobby their journals to encourage gender equitable reporting of research findings.	Lobbying	Short-term
1.2	Call on staff members with journal editorial roles to lobby their journals to consider equitable research as mandatory for 'good research practice' so journals ensure this during the review process. Equity considerations would be incorporated into peer review guidelines.	Lobbying	Short-term
1.3	Call on staff members with journal editorial roles to lobby their journals to create preferred layouts for data presentation (tables/graphs) to incorporate gender comparisons in a balanced, aesthetically pleasing manner.	Lobbying	Short-term
1.4	Build equity considerations into the institutional ethical review approval process. Require applicants to outline how they will consider gender throughout data collection, analysis and reporting.	Process change	Short-term
1.5	Call on staff members with journal editorial roles to lobby their journals to add a gender equity statement or checklist for completion by authors at the paper submission stage (with journals moving gradually to rejecting articles that do not comply).	Lobbying	Short-term to medium-term
1.6	Lobby professional societies to encourage reporting of gender differences.	Lobbying	Medium-term
1.7	Lobby research funding bodies to require gender equity to be addressed in funding submissions.	Lobbying	Medium-term
1.8	Lobby ethics bodies to have reporting of gender-related findings added to national ethics statements	Lobbying	Medium-term
1.9	Lobby companies who publish journal metrics to include metrics relating to gender equity performance of journals – e.g. an equity impact factor equivalent	Lobbying	Medium-term
1.10	Use tools such as causal loop diagrams or simulations to demonstrate how biased research leads to societal inequities and poorer system performance.	Awareness raising	Medium-term
1.11	Develop case studies showing poor outcomes when research team is not gender balanced.	Awareness raising	Medium-term
1.12	Conduct an audit of recent papers across the university for gender sensitivity. Identify and communicate the potential effects if data translated. Would need to be done in a sensitive manner, as a learning opportunity rather than a punitive exercise.	Awareness raising	Medium-term

Table 5Design interventions for pain point 2: *project teams are not always gender balanced, or if they are, women may not be represented in decision-making positions.*

ID	Intervention	Category	Time horizon
2.1	Implement an institutional checklist for new projects. Include items such as whether the team is gender balanced.	Process change	Short-term
2.2	Emphasise how a gender balanced team future-proofs a department - so new hires compared to 'maintain status quo' or 'enhance long-term success'.	Awareness raising	Short-term
2.3	Where non-equitable teams are used, highlight the limitations of their outcomes.	Awareness raising	Short-term
2.4	Develop case study materials of the adverse impacts of having male dominated project teams.	Awareness raising	Short-term
2.5	Provide public reports on the gender make-up of research teams at the university.	Awareness raising	Short-term
2.6	Women able to be authentic and succeed is seen as a 'sign of success' that culture supports equity.	Reward & recognition	Short-term
2.7	Build equity considerations into the institutional ethical review approval process. Require gender balanced teams.	Process change	Medium-term
2.8	Lobby research funding bodies to only fund research with gender balanced samples and teams.	Lobbying	Medium-term
2.9	The value of diversity in a workforce needs to be qualified beyond 'fairness' so that women are a sought-after resource.	Research & analysis	Medium-term
2.10	Conduct comparisons to high-performing research organisations that thrive through a diverse workforce. Identify an algorithm of a 'successful' team structure to enable comparisons and provide guidance on recommended next hire.	Research & analysis	Medium-term
2.11	Trial changing 'war metaphor' in academic culture to a metaphor where range of skills and perspectives are needed, and teamwork is emphasised - how would things change if using a team 'sports metaphor' for a research group? Where the goalkeeper is valued as much as a striker.	Structural change	Long-term

Table 6Design interventions for pain point 3: *gender equity in research is not considered in staff performance reviews.*

ID	Intervention	Category	Time horizon
3.1	For each level or research role assign equity objectives appropriate for that level and provide appropriate support and guidance to achieve them.	Process change	Short-term
3.2	Set a norm for what is done by other researchers by collecting and providing data on how often their studies are gender balanced.	Awareness raising	Short-term
3.3	Review guidance from other sectors (i.e. industry) where gender equity is perhaps considered more in staff reviews and use this to improve the system.	Process change	Short-term
3.4	Educate senior academics on the issue in relation to staff performance and career advancement.	Awareness raising	Short-term
3.5	Remove "productivity guilt" and focus on research quality, including gender-sensitive research, in performance reviews.	Process change	Short-term
3.6	Make gender equity commitments part of agreed performance for the year ahead so there is a "commitment" to be held to.	Process change	Short-term
3.7	Build gender equity into performance reviews via formal KPIs.	Process change	Medium-term
3.8	Reframing what a "performance review" involves. Bring in 360-degree type approaches more common in industry. Phase out the Taylorist mindset over time.	Process change	Medium-term to long-term
3.9	Senior management are rewarded in their performance reviews for creating a culture of gender equitable behaviour in the research lifecycle.	Reward & recognition	Medium-term
3.10	Adapt the university system so that it is tailored better to the needs of women. Allow for women to form collectives who together tailor their agreements with the university.	Structural change	Long-term

providing women with more power to negotiate their working arrangements (e.g. flexible or part-time work) and key performance indicators (KPIs).

In addition to the ideas relating to the three pain points, 10 other interventions were identified in the workshop (Table 7). These were a mix of short- and medium-term interventions, which could all be

implemented internally within the university. A number related to awareness raising and education, such as 4.2 (education programs for academic staff) and 4.6 (communicating success stories where gender equity in research is being addressed effectively). The long-term change here would require lobbying of research funding bodies to focus more on collaboration and teamwork rather than the assessment of individual

Table 7

Other interventions.

ID	Intervention	Category	Time horizon
4.1	Conduct general awareness raising focused on inequitable outcomes that are emotive - e.g. traffic deaths.	Awareness raising	Short-term
4.2	Formal education programs for academics at all levels.	Awareness raising	Short-term
4.3	Require research centres to report and be assessed annually on gender equity across projects, with a traffic light system to denote level of performance.	Process change	Short-term
4.4	Require research centres to provide career development support for precariously employed staff (a majority of whom in many countries, are women; Zheng, 2018)).	Process change	Short-term
4.5	Create demonstration experiences when men use products designed based on women's data. Could be turned into case studies/documentaries for further dissemination.	Awareness raising	Short-term to medium-term
4.6	Communicate success stories of disciplines that are dealing effectively with all three pain points.	Awareness raising	Medium-term
4.7	Develop participant sample selection software which ensures balanced samples	Tool provision	Medium-term
4.8	Undertake a major research project which clearly demonstrates the issue and its impacts in a particular area (e.g. road safety)	Research & analysis	Medium-term
4.9	Involve all staff in participatory processes to create guidelines for equity in research to gain their buy-in for implementation.	Process change	Medium-term
4.10	A more team-like reciprocal model for research funding with less emphasis on individual "superstars" and more on collaboration and reciprocation (in a non-transactional way)	Lobbying	Long-term

performance when allocating funding.

4. Discussion

The aim of this paper was to showcase how HFE methods can be used to respond to the critical issue of the gender data gap. The results showed that the use of the STS-DT, incorporating the DWI toolkit, were effective in identifying a relatively large number of interventions within a short workshop context, suggesting that it provides an efficient approach. Further, the DWI cards prompted the consideration of a wide range of ideas, from awareness raising and process changes, to lobbying and wider structural changes to the university system. Thus, demonstrating the power of these approaches.

However, as a demonstration case study, this work was limited to an ideation phase only, with only the research team involved, and with no further refinement and evaluation of the ideas. An important next step would be to prioritise the interventions via an evaluation process, where the impact of the interventions on the wider system are considered. This might be achieved using the AH model, following previous research (e.g. Read et al., 2017; McLean et al., 2021b). Further, many of the interventions suggest the need for a re-consideration of some of the other value and priority measures, such as individually based research metrics (citations, H index and FWCI). In addition, potential unintended consequences of the interventions should be considered, taking account particularly of the ‘resistance’ variable in the CLD (Fig. 1). An example of how the AH could be used to evaluate an intervention for potential unintended consequences on the wider system is shown in Fig. 6. This evaluation relates to the implementation of intervention 2.1 regarding an institutional checklist for new projects. Fig. 6 shows new nodes associated with the intervention in grey boxes, and their impact on existing nodes higher up in the AH. It was assumed that the checklist would create boundaries for the approval of research projects, whereby a project that did not incorporate gender sensitive research practices would not be approved. The assessment shows that this would assist to generate significant and innovative research projects, that in turn would support three values and priority measures (high quality publications, research impact and equity) as well as three of the functional purposes of the system (advancing the knowledge base, improving real world outcomes and contributing to the University’s research agenda and reputation).

reputation). However, it also highlights a possible negative impact in terms of industry partnerships and, subsequently, research end user satisfaction. An example where this may occur would be where an industry partner is unwilling or unable to invest funds in ensuring that research is gender sensitive (i.e. more time available for data collection and analysis) and the research project is declined by the university for not meeting the gender checklist. While this potential negative consequence of the initiative should not be used to avoid implementing the checklist, it suggests that additional initiatives are required to minimise this impact. Additional initiatives might include consulting with industry collaborators and funders in the development of the checklist and process to gain their buy-in for the need for gender sensitive research or creating an institutional funding source to meet the gap between industry funding and funding required by the researchers to conduct gender sensitive research.

The CLD and AH models themselves provide a useful contribution. To our knowledge, this is the first CLD to consider the issue of gender in research, and we hope that it will prompt further thinking and research around this issue. The generic AH model of a research centre may also be useful more broadly to those involved in developing or leading research centres, where it could be used to explore other questions of interest. It represents one of a small number of applications of CWA to organisational functioning (see also Hulme et al., 2019; Durugbo, 2012), indicating that the AH is useful at this level of analysis. Further, in line with Stanton’s advocacy for methods integration (Stanton et al., 2013), the use of these two models to address the gender data gap has provided a richer analysis than use of a single approach alone.

While our interventions did include some that shaped the wider system around researchers’ behaviour, one insight that was gained from applying the DWI cards to this issue was that many of the cards encode a focus on a particular kind of normative neoliberal structure of individual people’s behaviour being “shaped” from above. The DWI cards were not developed with explicitly inclusive (let alone intersectional) considerations, and some of the examples used are ethically problematic even if intended only to be examples of what exists in the world, rather than what is recommended. Thus, it may be interesting in future updates to the DWI lenses to incorporate some that take a more emancipatory or indeed feminist stance. Indeed, the STS-DT includes a set of prompt questions for the identification of insights from a systems analysis that

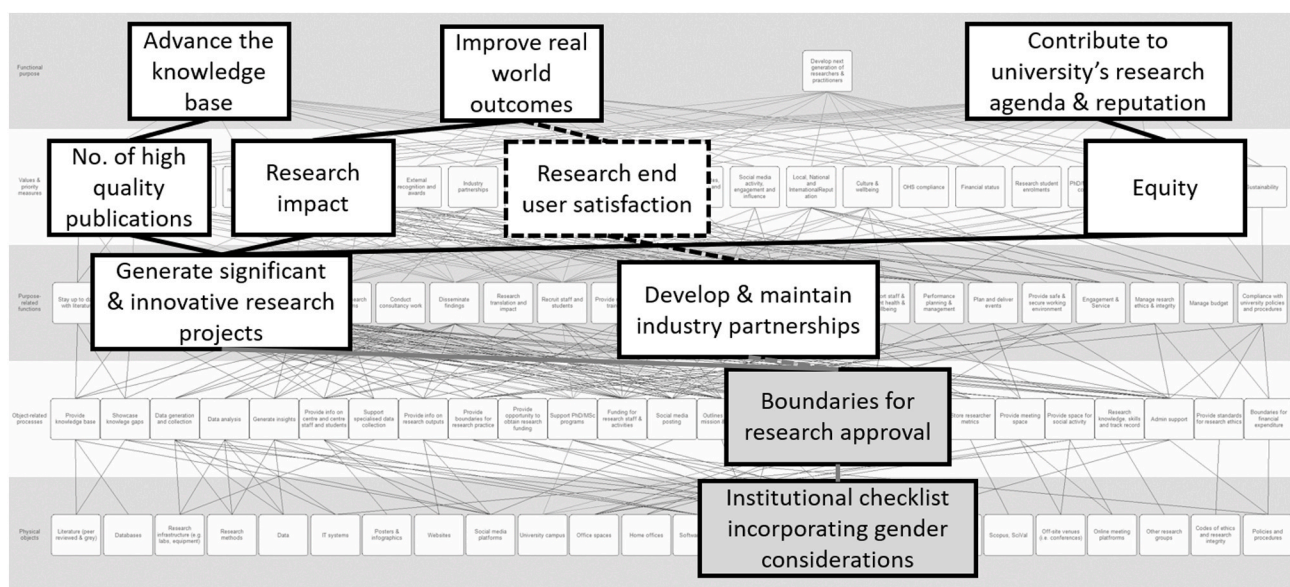


Fig. 6. Evaluation of intervention 2.1 ‘Implement an institutional checklist for new projects. Include items such as whether the team is gender balanced.’ Note, grey boxes = new nodes; white boxes = strengthened existing nodes; grey lines = new means-ends links; black lines = strengthened existing means-ends links; white boxes with dashed outline = weakened existing nodes; dashed lines = weakened existing means-ends links.

relate to different metaphors (Morgan, 1980) including prompts that relate to the metaphors of organisations as ‘psychic prisons’ or ‘instruments of domination’ (Read et al., 2015). Potentially, these metaphors could be translated into design patterns to support the exploration of new angles of consideration in design activities (e.g. Lockton et al., 2019). More broadly, we hope that this paper might prompt reflection on the extent to which HFE methods support inclusivity with reference to both members of the HFE community who apply methods, and end users. There may be scope for more method co-development to ensure that diverse needs are considered.

Overall, this work has highlighted the role that HFE can play in addressing the gender data gap. However, for this case study we chose a somewhat narrow scope in our AH modelling (i.e. an academic research centre). Therefore, there remains significant work to be done to analyse the wider structure, culture and dynamics of the academic system to fully understand the barriers to gender equity in research and how the system could be fundamentally re-designed to improve equitable outcomes.

We believe that the findings and interventions proposed will be of value to academic research groups and centres from any discipline, and for research groups both big and small, although some adaptation to the specific context may be required. In relation to related groups such as industrial research centres, the pain points and subsequent interventions may vary and future research to review what these may be is encouraged. Overall, we hope that this paper raises awareness amongst the HFE, and broader academic, communities of the importance of the gender data gap, and contributes to an increase in the implementation of gender sensitive research practices. We also call for more HFE work addressing gender equity more generally, in line with the discipline’s focus on user-centred and inclusive approaches.

5. Conclusions

This paper has tackled a complex societal problem using socio-technical systems methods. We hope that the recommendations spark more discussions and efforts towards achieving gender equitable research outcomes. We also hope that this demonstration might inspire others to apply similar approaches to promoting equity and diversity in research more generally.

In the context of this Feschrift, it is important to note that Stanton himself has enacted some of the interventions suggested within this paper. He has been a staunch supporter of inclusive design and enabled gender equity to be considered within key ‘research and analysis’. For example, his HI:DAV (Human Interaction: Designing Autonomy in Vehicles) project focused specifically on ensuring that driver-automation interfaces can be personalised for people of various ages and driving experience (Stanton et al., 2021). His input into the development of both the STS-DT and DWI toolkit provide an on-going legacy, with these design approaches being used to improve design in many domains. He has enabled ‘process change’ to support leadership for women with parenting responsibilities, for which he was nominated by his team for a Women in Science, Engineering & Technology (WISSET) award in 2019. His ‘recognition’ for the importance of a family/work balance has resulted in high retention of female staff enabling them to maintain long-term careers and enact further equitable change. Many who have worked with Stanton have gone on to highly successful careers in academia and elsewhere, and who will continue his legacy of pushing the boundaries of HFE.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

- Bérard, C., 2010. Group model building using system dynamics: an analysis of methodological frameworks. *Electronic Journal of Business Research Methods* 8 (1), 35–45.
- Blaess, D.A., Santin, C., Bloom, L.K., Hollywood, G., 2020. Mentoring millennial women in academia. *Journal of Education and Culture Studies* 4 (3), 101–121.
- Criado Perez, C., 2020. *Invisible Women: Exposing Data Bias in a World Designed for Men*. Abrams Press.
- Dumais, L., Messing, K., Seifert, A.M., Courville, J., Vézina, N., 1993. Make me a cake as fast as you can: forces for and against change in the sexual division of labour at an industrial bakery. *Work, Employment and Society* 7 (3), 363–382.
- Durugbo, C., 2012. Work domain analysis for enhancing collaborations: a study of the management of microsystems design. *Ergonomics* 55 (6), 603–620.
- Forman, J., Poplin, G.S., Shaw, C.G., McMurry, T.L., Schmidt, K., Ash, J., Sunnevang, C., 2019. Automobile injury trends in the contemporary fleet. Belted occupants in frontal collisions *Traffic Injury Prevention* 20 (6), 607–612. <https://doi.org/10.1080/15389588.2019.1630825>.
- Gosse, C., Veletsianos, G., Hodson, J., Houlden, S., Dousay, T.A., Lowenthal, P.R., Hall, N., 2021. The Hidden Costs of Connectivity: Nature and Effects of Scholars’ Online Harassment. *Learning, Media and Technology*.
- Gulotta, C.J., Madeira-Revell, K., Fendley, M.E., 2020. A heuristic international glimpse at SARS-CoV-2 effects on work-home equilibrium and women. *Human Factors in the Manufacturing and Services Industries* 31 (4), 389–396.
- Heidari, S., Babor, T.F., De Castro, P., et al., 2016. Sex and Gender Equity in Research: rationale for the SAGER guidelines and recommended use. *Research Integrity and Peer Review* 1, 2. <https://doi.org/10.1186/s41073-016-0007-6>.
- Hulme, A., McLean, S., Read, G.J.M., Dallat, C., Bedford, A., Salmon, P.M., 2019. Sports organisations as complex systems: using Cognitive Work Analysis to identify the factors influencing performance in an elite netball organisation. *Frontiers in Sports and Active Living* 56.
- Imber, A., 2009. *The Creativity Formula: 50 Scientifically Proven Creativity Busters for Work and for Life*. Liminal Press, Caulfield.
- Jenkins, D.P., Stanton, N.A., Salmon, P.M., Walker, G.H., Young, M.S., Whitworth, I., Farmilo, A., Hone, G., 2007. The Development of a Cognitive Work Analysis Tool. *International Conference on Engineering Psychology and Cognitive Ergonomics*, Berlin, Heidelberg. https://doi.org/10.1007/978-3-540-73331-7_55.
- Laberge, M., Caroly, S., Riel, J., Messing, K., 2020. Considering sex and gender in ergonomics: Exploring the hows and whys. *Applied Ergonomics* 85, 103039. <https://doi.org/10.1016/j.apergo.2019.103039>.
- Lockton, D., Harrison, D., Stanton, N.A., 2010. The Design with Intent Method: a design tool for influencing user behaviour. *Applied Ergonomics* 41, 382–392.
- Lockton, D., Harrison, D., Stanton, N.A., 2014. Exploring design patterns for sustainable behaviour. *The Design Journal* 17 (1).
- Lockton, D., Singh, S., Sabnis, S., Chou, M., Foley, S., Pantoja, A., 2019. New metaphors: a workshop method for generating ideas and reframing problems in design and beyond. In: *Proceedings of the 2019 Conference on Creativity and Cognition (C&C '19)*. Association for Computing Machinery, New York, NY, USA, pp. 319–332. <https://doi.org/10.1145/3325480.3326570>.
- Madeira-Revell, K., Parnell, K.J., Richardson, J., Pope, K.A., Fay, D.T., Merriman, S.E., Plant, K.L., 2021. How can we close the gender data gap in Transportation Research? *Ergonomics* 54 (1), 19–26.
- McLean, S., Kerhervé, H.A., Stevens, N., Salmon, P.M., 2021a. A systems analysis critique of sport-science research. *International Journal of Sports Physiology and Performance* 16 (10), 1385–1392.
- McLean, S., Read, G.J.M., Ramsay, K., Hogarth, L., Kean, B., 2021b. Designing success: applying cognitive work analysis to optimise a para sport system. *Applied Ergonomics* 93, 1–11.
- Messing, K., 2021. *Bent Out of Shape: Shame, Solidarity and Women’s Bodies at Work. Between the Lines*, Toronto.
- Morgan, G., 1980. Paradigms, metaphors and puzzle solving in organization theory. *Administrative Science Quarterly* 25, 605–622.
- Naikar, N., 2013. *Work Domain Analysis: Concepts, Guidelines and Cases*. Taylor & Francis Group, Boca Raton, FL.
- National Academies of Sciences, 2018. *Engineering, and medicine. Sexual Harassment of Women: Climate, Culture, and Consequences in Academic Sciences, Engineering, and Medicine*. The National Academies Press, Washington, DC.
- Perrow, C., 1984. *Normal Accidents: Living with High-Risk Technologies*. Basic Books, New York.
- Read, G.J.M., Beanland, V., Lenné, M.G., Stanton, N.A., Salmon, P.M., 2017. *Integrating Human Factors Methods and Systems Thinking for Transport Analysis and Design*. Taylor & Francis.
- Read, G.J.M., Beanland, V., Stanton, N.A., Grant, E., Stevens, N., Lenné, M.G., Thomas, Mulvihill, C., Walker, G.H., Salmon, P.M., 2021. From interfaces to infrastructure: extending ecological interface design to re-design rail level crossings. *Cognition, Technology & Work* 23, 3–21.
- Read, G.J.M., Salmon, P.M., Goode, N., Lenné, M.G., 2018. A sociotechnical design toolkit for bridging the gap between systems-based analysis and system design. *Human Factors in the Manufacturing and Services Industries* 28 (6), 327–341.
- Read, G.J.M., Salmon, P.M., Lenné, M.G., Stanton, N.A., 2015. Designing sociotechnical systems with cognitive work analysis: putting theory back into practice. *Ergonomics* 58, 822–851.
- Ross, L., Boyle, K., Carter, C., et al., 2018. Women, men and news. *Journalism Studies* 19 (6), 824–845.

- Rouse, W.B., 2016. Universities as Complex Enterprises: How Academia Works, Why it Works These Ways and where the University Enterprise Is Heading. John Wiley & Sons, Hoboken, NJ.
- Salmon, P.M., Stanton, N.A., Read, G.J.M., et al., 2019. From Systems Ergonomics to Global Ergonomics: the World as a Socio-Ecological-Technical System. Chartered Institute of Ergonomics and Human Factors Annual Meeting, UK.
- Salmon, P.M., Stevens, N.J., McLean, S., Hulme, A., Read, G.J.M., 2021. Human Factors and Ergonomics and the management of existential threats: a work domain analysis of a COVID-19 return from lockdown restrictions system. *Human Factors and Ergonomics in the Manufacturing and Service Industries* 31 (4), 412–424.
- Shine, K., 2021. Willing but Wary: Australian Women Experts' Attitudes to Engaging with the News Media. *Journalism*.
- Stanton, N.A., Plant, K.L., Roberts, A.P., Harvey, C., Thomas, T.G., 2016. Extending helicopter operations to meet future integrated transportation needs. *Applied Ergonomics* 53 (Part B), 364–373.
- Stanton, N.A., Revell, K.M.A., Langdon, P., 2021. *Designing Interaction and Interfaces for Automated Vehicles*. CRC Press.
- Stanton, N.A., Salmon, P.M., Rafferty, L.A., Walker, G.H., Baber, C., Jenkins, D.P., 2013. *Human Factors Methods: A Practical Guide for Engineering and Design*, second ed. Ashgate, Aldershot.
- Stanton, N.A., Salmon, P.M., Walker, G.H., Jenkins, D.P., 2018. *Cognitive Work Analysis: Applications, Extensions and Future Directions*. CRC Press, Boca Raton.
- Stanton, N.A., Young, M., McAulder, B., 1997. Drive-by-wire: the case of driver workload and reclaiming control with adaptive cruise control. *Safety Science* 27 (2–3), 149–159.
- Sterman, J., 2000. *Business Dynamics: Systems Thinking and Modeling for a Complex World*. McGraw-Hill, Boston.
- Tatman, R., 2017. Gender and dialect bias in YouTube's automatic captions. In: *Proceedings of the First Workshop on Ethics in Natural Language Processing*. Association for Computational Linguistics, Valencia, Spain, pp. 53–59.
- Thatcher, A., Waterson, P., Todd, A., Moray, N., 2017. State of science: ergonomics and global issues. *Ergonomics* 61 (2), 1–33.
- Thatcher, A., Nayak, R., Waterson, P., 2020. Human factors and ergonomics systems-based tools for understanding and addressing global problems of the 21st century. *Ergonomics* 63, 367–387.
- Topping, A., April, 2020. Sexism on the COVID-19 frontline: 'PPE is made for a 6ft 3in rugby player'. *Guardian* 24 April 2020. From: <https://www.theguardian.com/world/2020/apr/24/sexism-on-the-covid-19-frontline-ppe-is-made-for-a-6ft-3in-rugby-player>. (Accessed 22 October 2021).
- TUC, 2017. Personal protective equipment and women: guidance for workplace representatives on ensuring it is a safe fit. <https://www.tuc.org.uk/research-analysis/reports/personal-protective-equipment-and-women>. (Accessed 22 October 2021).
- van den Brink, M., Benschop, Y., 2012. Gender practices in the construction of academic excellence: sheep with five legs. *Organization* 19 (4), 507–524.
- Vicente, K.J., 1999. *Cognitive Work Analysis: toward Safe, Productive, and Healthy Computer-Based Work*. Lawrence Erlbaum Associates, Mahwah, NJ.
- Wennerås, C., Wold, A., 1997. Nepotism and sexism in peer-review. *Nature* 387, 341–343.
- WHO, 2002. WHO gender policy: integrating gender perspectives in the work of WHO. <https://www.who.int/gender/mainstreaming/ENGwhole.pdf>. (Accessed 29 June 2021).
- Winchester, H.P.M., Browning, L., 2015. Gender equality in academia: a critical reflection. *Journal of Higher Education Policy and Management* 37 (3), 269–281.
- Yellow Window, 2018. Checklist for gender in research. Retrieved from. https://cca91782-7eea-4c09-8bff-0426867031ff.filesusr.com/ugd/17c073_22d7b327acc8434a91dbceba1898e7d2.pdf. (Accessed 12 February 2020).
- Zheng, R., 2018. Precarity is a feminist issue: gender and contingent labor in the academy. *Hypatia* 33 (2), 235–255.