new dynamics of ageing
a cross-council research programme

Innovation in envisioning dynamic biomechanical data to inform healthcare and design guidelines and strategy.

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In Brief

This research evaluated an innovative way of communicating and understanding the complexity of older people's mobility problems using visualisations of objective dynamic movement data. In previous research, a prototype software tool was created, which visualises, for non-biomechanical specialists and lay audiences, dynamic biomechanical data captured from older people undertaking activities of daily living. From motion capture data and muscle strength measurements, a 3D animated human 'stick figure' was generated, on which the biomechanical demands of the activities were represented visually at the joints (represented as a percentage of maximum capability, using a continuous colour gradient from green at 0%, amber at 50% through to red at 100%). The potential healthcare and design applications for the visualisations were evaluated through a series of interviews and focus groups with older people, and healthcare and design professionals, and through a specialist workshop for professionals.

Summary of key findings

The method of visualising the dynamic biomechanical data enables those without specialist training – both professional and lay older people – to access and interpret the data.

- **It enables lay people to contribute to discussions about biomechanics.** From both the written responses and the subsequent discussions it was clear that the 'traffic light system' was effective as an indicator of the degree of 'pain' or 'stress' being experienced during certain activities, with green indicating 'ok' and red illustrating the 'peak' point. This intuitive understanding of the dynamic visualisations enabled the participants to effectively contribute to the discussion. This was possible without requiring introductory information. For instance, one of the older people suggested that one of the animations seemed to be 'younger', 'more flexible' and to be experiencing 'less pain' than another. Another participant could identify where problems were occurring, commenting that 'the hips are more painful than the knee', and that 'his knees are sore'.

- **It allows connections with personal experience and knowledge.** Both groups could identify with the movements shown and relate them to either their own personal experience or professional knowledge. For example: one of the older people commented *"I see myself getting up and down from the chair."*; a design professional made reference to mobility issues he recognised personally, comparing animations of two different individuals conducting the same movement, reflecting age-related deterioration in mobility: *"me as a boy… and me as I am now".*

- **It enables new professional insights.** Healthcare professionals were able to recognise and compare levels of how hard the muscles were working and stress on joints during a full movement cycle, identifying normal and abnormal movement patterns, such as compensations made in the speed and quality of movements due to mobility problems. In another example a clinician discussed particular movement patterns as indicative of a pre-existing condition that required the individual to make compensatory adjustments to complete a movement, causing additional strain on the hips: 'they are not using their ankles to bend, and so have to compensate elsewhere'.

- **It offers understandable, objective scientific data.** Both clinical and design professionals indicated that such a tool might avoid the need to rely on subjective judgement, intuitive skill, and trial and error, thereby allowing more accurate diagnosis in a clinical setting on the one hand, and presenting a sound rationale for design approaches on the other.

Older people are empowered to participate in the discussion of the problems and issues affecting their mobility with clinicians and healthcare practitioners, and design professionals and how this impacts on their lifestyle and quality of life.

- **It elicits expression of mobility issues.** Comments from participants in the older people's focus group revealed that the mode of visualisation generated empathetic responses. One person who had had two hip replacements and a knee replacement commented:

"This represents my experience". Others commented: *"that's my knee",* and *"I see myself getting up and down from the chair".* They were able to relate difficulties experienced with day-to-day activities in the built environment such as ascending stairs (requiring handrail support), and difficulties entering and exiting taxis – forward descent from transport could prove problematic, and one participant tactically resorted to descending backwards down aircraft stairs while holding handrails.

- **It improves two-way communication between older adults and health professionals.** One issue identified was the current difficulty older people had in communicating with professionals: *"you can tell a doctor [your condition] but don't always feel they've quite grasped it"… "I've had problems trying to explain to doctors who won't listen".* It was felt the visual and contextual nature of the animations could reduce the need for 'medi-speak' which was recognised as a barrier to communication with clients and other professionals. Older participants thought that the animations would be useful to demonstrate and explain mobility issues and to help address 'the white coat syndrome' to assist in a situation where a patient would otherwise forget or overlook an issue during a consultation. At the same time, some professionals have difficulty in providing explanations in lay terms, and it was felt that the tool 'makes two-way communication very easy', that it 'clearly articulates for the health professional and the older person what is going on in the joints' and that it provides an opportunity to explain and encourage normal movement patterns 'to limit, mitigate or overcome pain'.

Healthcare and design professionals can benefit from enhanced communication across disciplines, allowing a more joined-up approach to healthcare and design planning.

- **It facilitates cross-disciplinary insights.** The effective demonstration of sequential movements and immediacy of client feedback were features identified as facilitating the exchange of information. It was felt that viewing the animations together with professionals outside their own disciplines (e.g. between an OT, a physiotherapist, a biomechanist, and a designer) helped provide insights into the other professions: 'a simple animation allowed open dialogue between a few different professionals, again the animation is objective and acted as a focus to discuss mobility. It appealed to everyone in its own particular way and wasn't a tool that in any way isolated the viewer'.

- **It helps overcome problems of terminology.** In particular, the tool helped to overcome barriers that result from variance in terminology used by different disciplines and the need for specialist knowledge to interpret traditional data sets. One example was the

need for arms on chairs. The animations of an older adult sitting-to-standing-to-sitting immediately illustrated the differences in stress on hips and knees when comparing the use of armrests with not using armrests. A bioengineer could discuss this in terms of functional demand, a physiotherapist in terms of movement and rehabilitation strategies, a designer in terms of seat and armrest height, and an older person in terms of stiffness, pain or achievement. All of these perspectives are crucial to improve understanding and aid effective communication, and the tool facilitated the exchange of this essential information. As a result, a broad and objective understanding of issues, and facilitation of cross-disciplinary dialogue was felt likely to reduce the likelihood of conflicting approaches to patient issues.

The visualisations allow a deeper understanding of the issues within professions, both in healthcare and in design.

- **It is superior to existing techniques.** Clinical practitioners suggested that in their current practice it can be difficult to locate stress and strain, which can be disguised by clothing, and that they often rely on "intuitive skill" combined with subjective comment from the patient or other third parties. The tool was considered superior to video techniques currently used during some physiotherapy approaches. The animations objectively illustrated where stresses occur, reducing dependence on intuitive interpretation and subjective judgement, which can result in misdiagnosis. Professionals also felt that data specific to an individual's needs could be interpreted with more objectivity allowing a more detailed and accurate diagnosis.
- **It has educational value.** Some professionals commented that it had been educational to view the tool, and that they had learned that mobility issues are not restricted to isolated joints: they had not previously considered the sequencing of movements and that as a result of the visualisation this was something they were now more curious about in relation to their practice.
- **It has ergonomic applications.** One proposal made by the design professionals was for the tool to be used for architectural applications and product development to objectively test the ergonomics of seating, interiors, and products rather than relying on trial and error in prototypes.
- **It facilitates an understanding of differences between individuals.** It was suggested that the tool clearly demonstrated the variance in capacity of different individuals conducting the same task e.g. in rising from a chair, bending or climbing stairs, or the same individual conducting a task in different ways, reinforcing, in terms of the design of products and environments, the limitations with standardised approaches.

Implications of the findings

There is potential to improve the uptake and integration of biomechanical expertise and understanding into design and healthcare practice.

The field of biomechanics is well established but it has, until now, failed to make the impact anticipated in the fields of healthcare and design. Currently, biomechanics is firmly locked into the domain of scientists and engineers, its currency is numerical data and graphs. As a field it needs to be able to interface in a way that can talk with clinicians and patients to assist in making treatment choice, and with designers in designing environments, products and services that acknowledge the mobility issues and capabilities of older people. This mode of visualising animated data has demonstrated that biomechanical data can be 'unlocked', shared, aid understanding and inform practice.

In a design setting, a tool of this nature could be used to improve understanding in designers of the importance of ergonomics of products, and in enhancing space design and standards, particularly in relation to the ergonomic and functional attributes of products and the built environment. While recognised as having limited application as a stand-alone tool, as part of a range of healthcare assessment techniques, such a tool could provide a more holistic approach to clinical assessment, diagnosis and rehabilitation in a number of applications.

For example (Figs 2.1 and 2.2), in rising from a seat without using the arm rests the demands on the lower limb joints are close to their maximum capacity. It can also be seen that even with the use of the arm rests, close to the end of rising from the chair and on the beginning of the sitting movement the demands are high at the hip joints. This indicates that any further deterioration in strength at the hip joints may cause problems for this individual, and may cause risk of falls on rising from chairs. This easy-to-see biomechanical information and understanding is of value to both the physiotherapist, and the designer in determining safer mobility strategies, and safer seating.

There is potential to develop the tool, both in terms of the technologies involved, and the data acquired and used.

The focus groups, specialist workshop and subsequent discussions have led to the identification of a number of possible enhancements and potential applications of the tool. Both clinical and design professionals recognised the potential of the tool within their respective practices: understandably, older people referred only to healthcare applications and not to design considerations.

- **There is a need to increase data acquisition.** Suggested improvements to the tool included extending the dataset to include full body measurements as well as including a wider range of daily tasks.
- **There is a need for more efficient data acquisitions.** To be applicable, particularly in a healthcare setting, data capture has to be quick and accurate and at minimum expense allowing for efficient assessment and patient feedback.
- **Real-time viewing of patient movement is desirable.** A proposed ideal healthcare application of the tool would involve capturing data from a patient during a consultation and by viewing real-time dynamic data on-screen, a two-way dialogue could be achieved between the specialist and the patient. The retention of such data could also be used to track progress in rehabilitation.
- **The tool would benefit from using new portable technology.** The generic approach and method of dynamic data visualisation has the potential to be advanced through a range of technological options, from full motion-capture laboratory set-ups, to portable wearable wireless technologies for use in the home.

In healthcare, there is potential to develop new or improved diagnostic, therapeutic, communication and education procedures.

Although this tool had used data derived from relatively healthy and active older adults, during the specialist workshop it was felt that the tool could have a number of applications other than those that had been explored in this project. For instance, in healthcare it would allow improved aetiology, diagnosis, education, communication, and therapy in a number of specific conditions, e.g., in training for falls prevention, stroke, joint replacement and cerebral palsy. It was felt that this could inform, e.g., surgical teams, patients, and their guardians or parents of the consequences of particular procedures, or help guide patients' recovery or rehabilitation through improved understanding of the causes and goals of certain movements.

- **Assessment and diagnosis.** In clinical assessment and diagnosis, it was felt that the tool would assist in communicating the exact source of pain and allow more accurate diagnosis of the cause of the problem – suggesting that it might help determine the extent of an injury as well as being used to investigate how and why, e.g., deterioration had occurred. The tool offers the opportunity for cross-validation of other assessment techniques.
- **Therapy and rehabilitation.** It has the potential to be used with patients during assessment and rehabilitation to illustrate where mobility issues occur and how to overcome or avoid them; and for functional assessment, e.g., in the use of prosthetics. It also allows the effectiveness of clinical interventions to be evaluated over time to establish the suitability of a particular clinical approach as well as to monitor patient progress. By increasing both patient and professional understanding of mobility issues, patient motivation could be increased.
- **Communication and education.** Within clinical practice, it was felt that this tool could be used to inform teaching and communication, e.g., within the teaching of OTs and physio-therapists, and to enhance patients' understanding thereby forming a therapeutic tool better empowering patients to assist in their own recovery.
- **Prognosis and aetiology.** In the longer term, with the generation of volume data sets, it may be possible to pre-empt degradation and identify signifiers of future conditions to inform healthcare strategies to limit further impairment for patients. In addition, the opportunity to explore the cause of such conditions is presented.

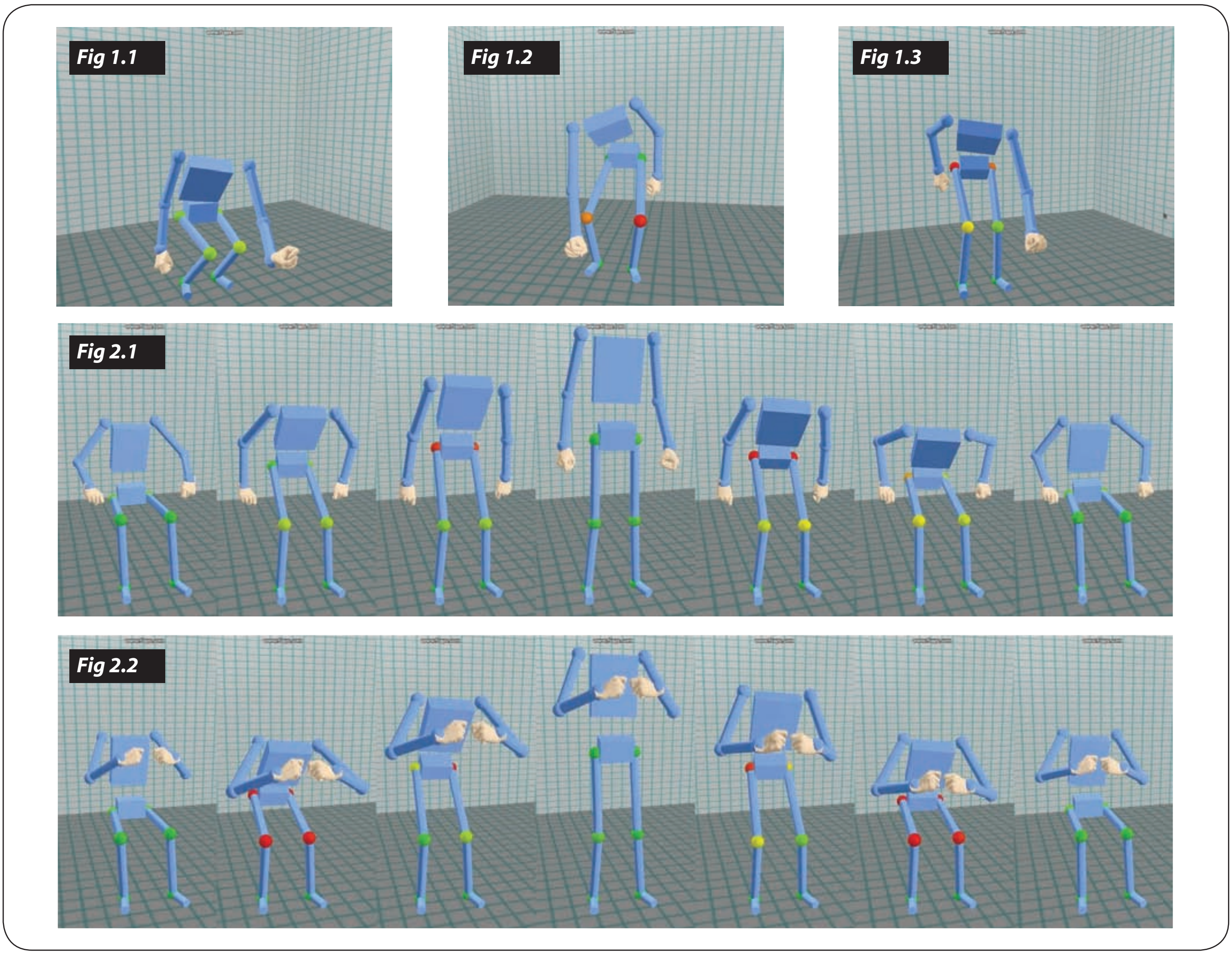
Background

Aim and objectives

The aim of the project was to evaluate the potential applications of visualising dynamic data in this format. The objectives of the research were: a) to gather evidence of how the range of stakeholders (older people, healthcare professionals and design practitioners) interpreted what was being visually represented by the animations; b) to evaluate the potential role of this tool to facilitate cross-disciplinary discourse and deepen professional practitioner understanding; and c) to develop insights about the mobility experience in older adults through empowering them to participate, on an equal basis, in discussions with specialists from a range of clinical and design disciplines. At all stages possible older people were to be involved in the evaluation of the tool.

Methods

The tool was evaluated through a qualitative methodology. For the purposes of evaluating the prototype, two main groups were recruited: 1) older people (N=18); and 2) healthcare and design professionals (N=15). Older participants in the 60+, 70+ and 80+ year old age groups were recruited through the University of Strathclyde's Centre for Lifelong Learning and Age Concern Scotland. The older people were selected to match as closely as possible the cohort of individuals (and their associated age- and health-related conditions) from whom the original data for the visualisations were obtained. The range of professions selected comprised clinical medicine, physiotherapy, occupational therapy, bioengineering, disability consultancy, engineering design, and interior design. The professionals selected combined practitioners who had close experience of working directly with end-users of healthcare or design. These were recruited through existing networks of The Glasgow School of Art and the research consultancy, Journey. The professionals and older people (N=33 total) were interviewed to determine issues and themes of concern to them in regard to the effect of ageing on mobility.



Two different topic guide proforma were created for the interviews, tailored to each of the groups, yet covering the same issues. Data analysis software was used on the recorded and transcribed interviews to identify emergent themes for discussion in the focus groups (FGs).

Figures 1.1, 1.2, and 1.3 (top row, left to right): Stills from animations: comparison of different individuals lifting objects from a high to a low shelf. Figure 1.1 – 74 year old female with no apparent problems; Figure 1.2 – 81 year old male, osteoarthritis of knees; Figure 1.3 – 67 year old male, history of back problems and history of fractures.

Figures 2.1, (middle row) and 2.2 (bottom row): Stills from animations: comparison of a 67 year old male with history of back problems and history of fractures performing an activity in different ways. Figure 2.1 – rising from a chair using arm rests. Figure 2.2 – rising from a chair without using arm rests.

Three focus groups (FG) were held to evaluate responses to the dynamic visualisations: one comprising solely older adults (FG1); the second with a range of healthcare and design professionals (FG2); and a third with a mixture of older adults and professionals (FG3). Each FG was video-ed for later analysis, and participants asked to complete questionnaires to capture additional responses. In FG1 and FG2, the participants were shown a sequence of animations, without prior explanation. The animations were selected to show e.g. comparison of two individuals doing the same ADL task (e.g. lifting an object from a high shelf to a lower one, Fig 1.1, 1.2, 1.3) or the same individual doing the same task in different ways (e.g. rising from sitting to standing with and without using a seat's armrests, Fig 2.1, 2.2).

Methods continued

In order to capture the extent of participants' initial understanding, participants were asked to write down their initial responses to a few simple questions. Following this, a semi-structured discussion was facilitated to explore in more detail: the responses, understanding and interpretation of the visualisations; the insights they provided; potential applications; and how the prototype might be improved. In FG3, the mixed group was shown short video clips of older adults' and professionals' comments from FG1 and FG2, summarising the main findings from each. Following this, the findings from FG1 and FG2 were discussed in more depth, facilitating discussion between the two groups, enabling comparison between the professionals' responses and those of the older adults.

Validating the findings

Initial findings were presented at a national Strategic Promotion of Ageing Research Capacity (SPARC) seminar attended by around 70 delegates, eliciting further feedback. These findings, and a further analysis of the Focus Group videos were also used to structure a specialist workshop with professionals (N=8) to explore: the potential future development and applications of the prototype; next stage technologies; and implications for future practice, predominantly for healthcare applications. These discussions, and others to identify future funding possibilities, together with parallel discussions for design applications are continuing beyond the funded period of the project.

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Published by the NDA Research Programme
Department of Sociological Studies
University of Sheffield
Elmfield
Northumberland Road
Sheffield S10 2TU
www.newdynamics.group.shef.ac.uk
email: nda@sheffield.ac.uk

Design | Print | www.sheffield.ac.uk/cics/uniprint | August 2009