DRS2016
Design + Research + Society
Future-Focused Thinking

2016 Design Research Society
50th Anniversary Conference
27-30 June 2016, Brighton, UK

A user centred approach to developing an actionable visualisation for 'balance health'

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Abstract: More than a third of people over the age of 65 fall every year in the UK (Department of Health, 2009). General gait problems and weakness are amongst the most common specific precipitating causes for falls. (Rubenstein, 2006). Qualitative research conducted by the investigators (Jan - May 2014) indicates that people do not consider balance health to be an actionable component of their overall health. This is because they do not have the vocabularies or tools to objectively define it on an everyday basis.

We designed an application which can be used to quantify postural sway in the home setting, and conducted a drawing study to explore visual perceptions of balance. The emerging forms were used as inspiration to develop three categories, which communicate four core attributes in different ways. The aim is to distill an elegant information strategy, which can lead to balance health being considered as actionable rather than unalterable.

Keywords: human centred design; preventative healthcare ; provocation; visual literacy

1. Introduction

How is your balance? Would you say you are a clumsy person or do you have the stability of a ballerina? Can you simply define it as good or bad? If yes, then is it consistently good or consistently bad? Have you noticed it changing in the past few years?, , Pertinent questions such as these rarely feature within conventional health conversations. Balance or the symmetry of muscle control is a separate actionable component of an individual's health. It is also one which gradually "declines with age due to lack of use" (Kate Sheehan, Occupational Therapist, personal communication, October 2013).

Tracking the gradual decline in balance can be achieved through the measurement of 'postural sway' (PS). PS is defined as the phenomenon of constant displacement and correction of the position of the centre of gravity within the base of support during quiet standing. It reflects the interplay between destabilising forces acting on the body, and actions by the postural control system to prevent a loss of balance. Hence, balance impairments caused by altered sensory, motor, or central nervous function related to such factors as older age and pathology (e.g. Parkinson's disease, peripheral neuropathy) are reflected in altered characteristics of postural sway. Two independent factors have been found to explain 92% of the variance in 14 time-and frequency-domain measures across 59,049 simulations of postural sway. One factor is sway amplitude, the other is sway velocity (Pavol, 2005).

Over the course of the past two years, we have designed an iOS application that uses an accelerometer in a smart phone to compute postural sway and give feedback in the form of four attributes which define the Balance Footprint of an individual. This paper presents the background to the field of balance quantification; the journey of the development of this application; introduces the reader to the results of a quantitative study wherein we defined the said attributes; finally the paper concludes by presenting three categories of visualisations, which can lead to balance being considered as an actionable component of health.

2. Background

2.1 The context of balance health

Balance is an essential component of our health, and contributes to the occurrence of falls. According to the Department of Health's (2009) study more than a third of people over the age of 65 fall every year in the UK and those who fall once are two or three times more likely to fall again. Falls represent over half of hospital admissions for accidental injury, particularly hip fracture (Department of Health, 2009). Half of those with hip fracture never regain their former level of function and one in five die within three months. Falling in older age can lead to increased anxiety and depression, reduced activity, mobility and social contact, higher use of medication and greater dependence on medical and social services and other forms of care. Of those older people who enter falls prevention programs, most do so only after they have fallen, by which time they may have suffered serious consequences (AgeUK, 2012). Primary prevention of falls is a neglected research subject in the UK as "a lot of the NHS delivered care currently relates to rehabilitating someone who has already fallen, so there is massive gap around evidence base regarding primary prevention of falls in older people, whether that be young older or oldest old." (Sarah Teague, Clinical Lead for falls and bone health, CLCH NHS, personal communication, October 2013)

2.2 Current balance quantification practices

In the research setting, Force Platforms are validated devices to quantify a person's Postural Sway. Force platforms or force plates are measuring instruments that measure the ground reaction forces generated by a body standing on or moving across them, to quantify balance, gait and other parameters of biomechanics. Advancements in technology have allowed force platforms to take on a new role within the kinetics field. Traditional laboratory-grade force plates cost (usually in the thousands) have made them very impractical for the everyday clinician. However, Nintendo introduced the Wii Balance Board (WBB) in 2007 and changed the structure of what a force plate can be. By 2010, it was found that the WBB is a valid and reliable force plate when directly compared to the "gold-standard" laboratory-grade force plate, while costing less than $100 (Clark, Bryant, Pua, McCrory, Bennell & Hunt, 2010); this has been verified in both healthy and clinical populations. (Holmes, Jenkins, Johnson, Hunt & Clark, 2013) (Hubbard, Pothier, Hughes & Rutka,2012). Force platforms traditionally generate stabilograms, while plot the time-varying coordinates of the Centre of Pressure (COP) (Collins & De Luca, 1993), medial lateral (MP, side to side) and anterior posterior (AP) displacement (forward and backward) is plotted along x and y axis respectively [Figure 1].

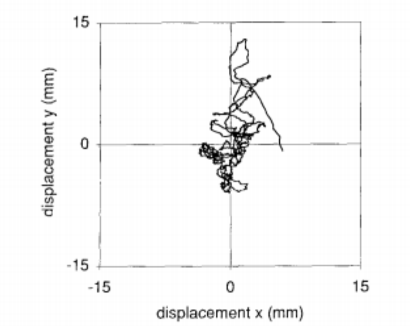


Figure 1: Typical 30-s stabilogram for a healthy young individual during quiet standing

Traditionally, the Wii displays the postural data to the user in the form of "Centre of Balance" results [Figure 2], it also conveys information about their symmetry [Figure 3].

Figure 2 and 3: Screenshots from Wii Balance Board

Physiotherapists who want to create a posturagraphic system based on the balance board prefer the data to be showed in more traditional ways. [Figure 4] shows US patent 20140081177 A1 for a stabilometric system that uses a "balance platform to detect problems in the vestibular system via data capture, data visualisation and mathematical analysis of data." (Patent US20140081177)

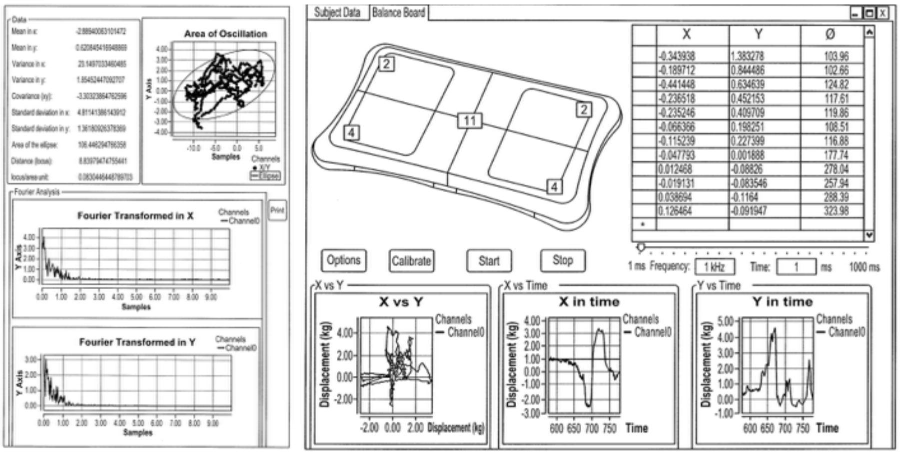
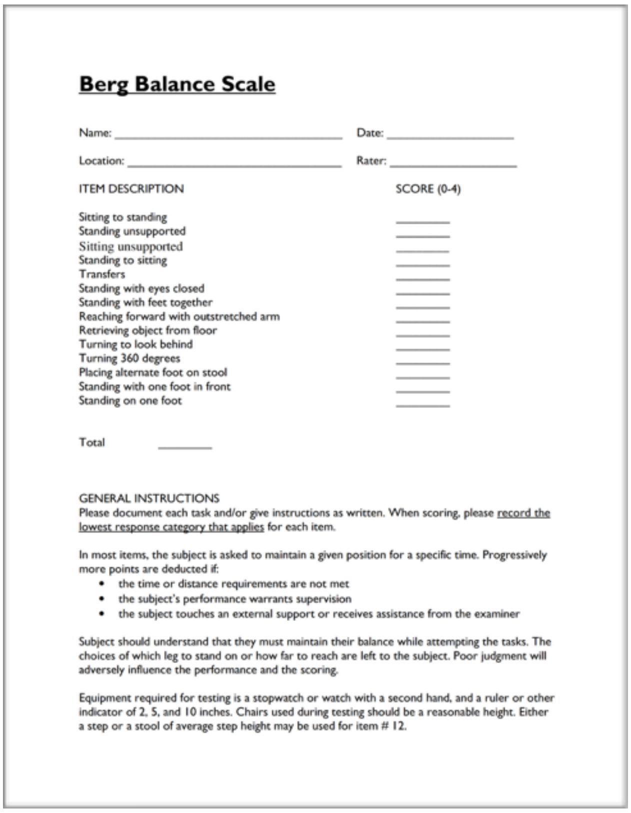


Figure 4: Selected images from Patent submission for US patent 20140081177 A1

In the clinical setting, the Berg Balance Scale [Figure 5] is the most commonly used assessment tool across the continuum from acute care to community-based care (Blum & Korner-Bitensky, 2008). The BBS is a 14-item scale that quantitatively assesses balance and risk for falls in older community-dwelling adults through direct observation of their performance (Berg, Wood-Dauphine´, Williams & Maki, 1992). The scale requires 10 to 20 minutes to complete and measures the patient's ability to maintain balance—either statically or dynamically while performing various functional movements—for a specified duration of time. The items are scored from 0 to 4, with a score of 0 representing an inability to complete the task and a score of 4 representing independent item completion. A global score is calculated out of 56 possible points. Scores of 0 to 20 represent balance impairment, 21 to 40 represent acceptable balance, and 41 to 56 represent good balance.

For an active individual, the BBS is too simple (Blum & Korner-Bitensky, 2008). A systematic review that comments on the absolute reliability of the Berg Balance Scale among people with moderately poor to normal balance concludes, that the Berg Balance Scale has acceptable reliability, although it might not detect modest, clinically important changes in balance in individual subjects (Downs, Marquez, & Chiarelli, 2013) and since is dependent on the visual assessment of the test conductor, it does not provide a granular picture of the distribution of balance along medial lateral and anterior posterior axis.



Berg Balance Scale

Name: ______________________ Date: ______________

Location: ______________________ Rater: ______________

ITEM DESCRIPTION	SCORE (0-4)
Sitting to standing	_____
Standing unsupported	_____
Sitting unsupported	_____
Standing to sitting	_____
Transfers	_____
Standing with eyes closed	_____
Standing with feet together	_____
Reaching forward with outstretched arm	_____
Retrieving object from floor	_____
Turning to look behind	_____
Turning 360 degrees	_____
Placing alternate foot on stool	_____
Standing with one foot in front	_____
Standing on one foot	_____
Total	_____

GENERAL INSTRUCTIONS
Please document each task and/or give instructions as written. When scoring, please record the lowest response category that applies for each item.

In most items, the subject is asked to maintain a given position for a specific time. Progressively more points are deducted if:

- the time or distance requirements are not met
- the subject's performance warrants supervision
- the subject touches an external support or receives assistance from the examiner

Subject should understand that they must maintain their balance while attempting the tasks. The choices of which leg to stand on or how far to reach are left to the subject. Poor judgment will adversely influence the performance and the scoring.

Equipment required for testing is a stopwatch or watch with a second hand, and a ruler or other indicator of 2, 5, and 10 inches. Chairs used during testing should be a reasonable height. Either a step or a stool of average step height may be used for item # 12.

Figure 5: Sample from Berg balance scale

3. A human centred approach to making balance actionable

3.1 Researching the personal context

Project balance was started in October 2013. In November 2013, we conducted nine expert interviews with Fall Clinicians and Falls Experts in the UK. According to our experts, balance health was an issue under-represented in the public sphere - "Most people don't know about loss of balance unless they have someone who is friend or a family member who takes a fall and suddenly they become aware of the issue" (Patricia Moore, Gerontologist, Industrial Designer, personal communication, October 2013). It is "one those things, which we assume is going to be there, but as soon as you stop using the muscles, you lose them." (Kate Sheehan, Occupational Therapist, personal communication, October 2013).

Along with the lack of public knowledge, there is stigma associated with falling in later life, which leads to an estimated that "70 – 80% of falls going unreported", (Sarah Teague, Gerontologist, Clinical Lead for falls and bone health, Central London Community Healthcare NHS Trust personal communication, October 2013), nevertheless falls account for 40% of UK ambulance call-outs, with the variable proportion being conveyed to hospital accounting for one in ten Accident and Emergency Department (A&E) attendances of the over 75s, a third of whom are admitted, thus comprising about 14% of emergency admissions (Martin, 2009), "often people don't report since it has got a labelling of no longer being able to stay at home or because they no longer want to ask for help” (Sarah Teague, personal communication, October 2013).

In January 2014, we set about the task of researching the personal context for balance for the 51-70 year olds. We focused on women as they are at higher risk for falls and developing a fear of falling (World Health Organisation, 2008). Our research began by conducting a series of ethnographic interviews with members of the ‘Stable and Steady’ exercise classes at Earls Court. These initial interviews lead us to design a quant-qual research methodology (Grover, Atkin, McGinley, 2015) which aimed to understand the participant’s awareness of and attitudes towards ‘Balance Health.’ and how it features in their daily lives. The research process was human centred, with the participants being considered as collaborators and contributors to the process and the outcome.

Our quant-qual research methodology contained two design provocations focused on balance health; a design provocation can be defined as a physical or digital object intended to produce a non scripted, primary and emotive response from a participant. Concepts designed as provocations are not end results but a method of enquiry, which can be used at any stage in the design process. A good provocation increases the capability of the participant to engage in the area of subject inquiry by making it personal and relevant (Helen Hamlyn Centre for Design, 2010).

Our first provocation focused on static balance and getting participants to reflect upon –‘How is my balance?’. We designed an android application and a belt. The phone was strapped on to the ankle of users, who were asked to balance on one leg, while the application took readings of the the standard deviation in angular orientation of the phone and produced a single number or a ‘diagnosis’ [Figure 6]. This result was mapped on to a scale, which contained measurements of all those who had been tested previously.

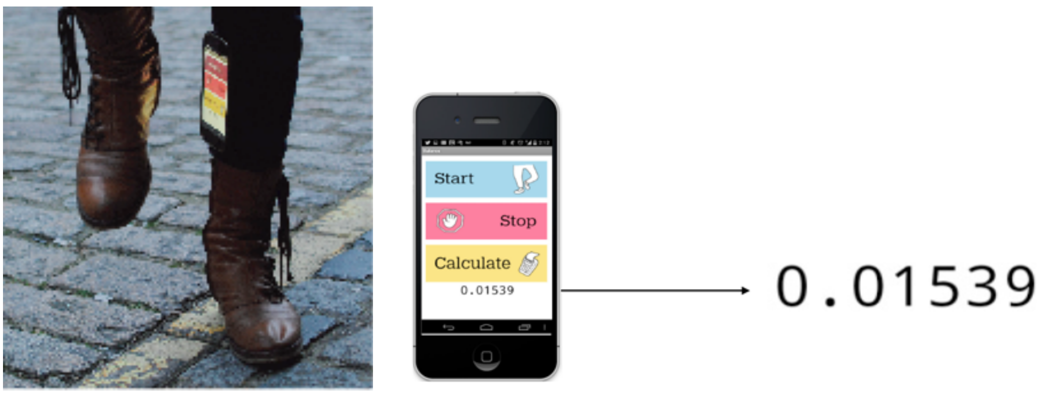


Figure 6: Static balance provocation, getting participants to reflect upon ‘How is my balance?’

Our second provocation focused on dynamic balance and getting participants to reflect causally, ‘What role does balance play in my everyday activities?’

Participants were encouraged to cross the obstacle course by placing alternate feet in step (tandem walk), while answering questions designed to gauge the role of balance as they go about their daily routines [Figure 7]. By engaging their cognition and reducing their base of support, the intent was to recreate daily life movements (like shopping in a supermarket) in a lab setting.

Figure 7: Dynamic balance provocation, getting participants to reflect upon ‘What role does balance play in my everyday activities?’

All our participants had difficulty with our first provocation (i.e. quantified single leg stands). A 60 year old expressed clear surprise at this stating “I’m very shaky, and I used to be very good at this sort of thing, and this is what is bothering me right now. Because I did everything, ballet, yoga and all.” Upon completion of our second provocation, five participants identified compromised balance as impacting their activities of daily living, with crowds and stairs being described major concerns by four out of the cohort of six.

Our primary findings were:

- Balance health is unrelated to activity levels (steps)
- Unless there was a clear culprit like a sprain or a bunion, general balance health was considered an abstract construct in the minds of our cohort
- Balance health was not considered to be an actionable component of overall health
- Participants had a limited vocabulary to describe their balance health using words like “unsteady”, “wobbly”, “clumsy”
- Participants were unaware of tools to objectively define their balance

A literature review indicated that while there is accumulating evidence around structured exercise aiding in independent living by maintaining postural stability (balance), strength, endurance, bone density and functional ability (Skelton, 2001); in rehab scenarios, progress is slow with repetitive exercises required over a sustained period of time. Hence, after a fall, there is no ‘silver bullet’ for improving balance.

3.2 Aim of Project Balance

After the eight week qualitative trial, the focus of our project became to develop a home usage diagnostics-therapeutic device. This would firstly, encourage a better understanding of 'Balance Health,' or the symmetry of muscle control over the lifetime of an individual, by quantifying and tracking changes (diagnosis). Secondly, it would act as a motivation and adherence tool (therapeutic) to keep participants engaged in a long- term exercise program. Our hypothesis being, that tracking would reduce the chances of a sudden fall, and reduce the stigma of impaired balance by making balance an actionable, rather than an unalterable, component of health.

3.3 Co-designing the device

Between April 2014 and May 2014, the team developed three prototypes which could quantify postural sway. Prototypes have been found to support collaborative analysis and collaborative design. While functional, all our devices were designed to be 'blank canvases' to allow for co-design with users. The first a wearable, which could be tied around the thigh, the second a home usage balance platform, and the third was an iteration of our static balance provocation, an application which used the accelerometer in a smart phone [Figure 8].

Figure 8: Balance prototypes L to R; Wearable, the Balance platform and Phone application

We presented these prototypes to our cohort as part of our co-design workshop [Figure 9]. The ease of use and portable nature of a phone application was pointed out as the best medium for our concept by the participants.

Figure 9: Co-design workshop

Post-workshop, we developed a belt, which could keep the prototype stable against the lower back and added audio to give instructions to the user.

When the accelerometer detected that it was stable, it began a countdown to prompt the user to adopt a single-leg and the began to record the phones angular orientation in space, along the x (ML) and z (AP) axis. At the end of a 20 second period, the application calculated the root mean square of the angular displacements from mean of the two axis.

The initial version of the application produced a number, which represented postural sway of the individual. Since our qualitative research had indicated a limited vocabulary for expressing balance health within our cohort, we wanted to convey more than just a number to our participants, Our goal was to develop visual literacy for our participants alongside introducing relevant and jargon-free terminology.

3.4 Exploring visual perceptions of Balance

Inspired by the energy drawings of Bowden, Lockton, Brass, & Gheerawo (2014), we undertook a drawing study “Drawing the Invisible” to explore visual ways of giving feedback to users of the device, to use drawing in order to uncover the current mental models our participants held of their balance. We designed a series of stimulus [Figure 10], and presented this stimulus in a fixed order to our participants in a co-design workshop. The participants were requested to draw their balance, while they were in a single leg stance [Figure 11].

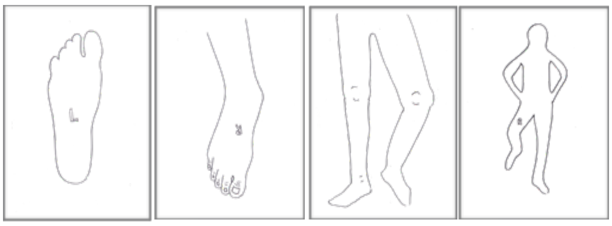


Figure 10: Blank stimuli for “Drawing the invisible”

Figure 11: Participants in a single leg stance while drawing

The idea being to create a sense of heightened awareness of changes or corrections experienced. At the end of the session, the participants were requested to explain their drawings to the group.

Participants made several observations about their strategies to maintain balance and symmetry for example “I have a tendency to lean that way”; or “I did find that my ankles were not that important, maybe it is to do with the fact that I have strong ankles or maybe it is it is more to do with my legs or my feet to get my balance.”

Analysis of the drawings and the explanations lead following findings:

- Clear Visual Forms: An emergence of a clear visual form for times when the participants experienced a large number of changes in their balance- a wobbly line; and when the participants experienced stability-a straight line. Muscles that were used to stabilise the stance were marked with circles. Transfers of stability between muscles were represented with vectors [Figure 12]. “There was a feeling of wobbliness and I could feel it through the centre of the ankle like that. And then there was a solid grounding feeling from my ankle and that was just amazing”; and “red is the muscle pressure and green is the movement of the muscles.”

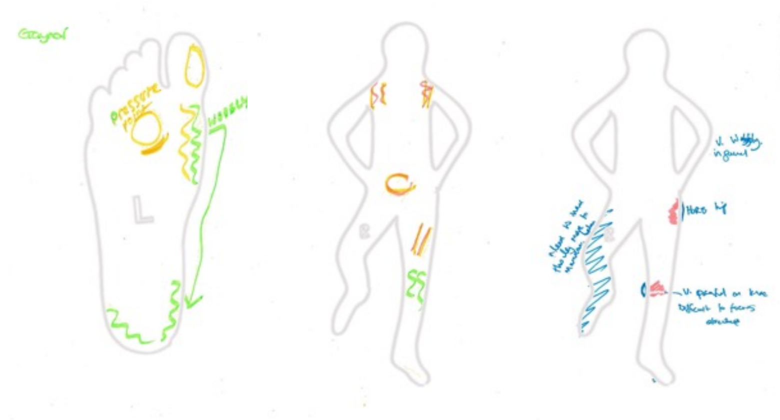


Figure 12: Selected participant drawings from co-design workshop

- Increased Proprioception: The order of the stimulus, starting from a foot, the lower body, the whole body and finally a blank sheet served to remind the participants to being mindful of the role there whole body plays in maintaining balance while in a challenging single leg stance [Figure 13]. More information was received by breaking down the exercise into parts. “Until I saw the sheet with the whole body, I did not think of doing anything in my core, in-spite of all the pilates classes”; and “this one went straight up the heel of my foot and as a line straight to my crown. The nose, navel and knee were in line.”

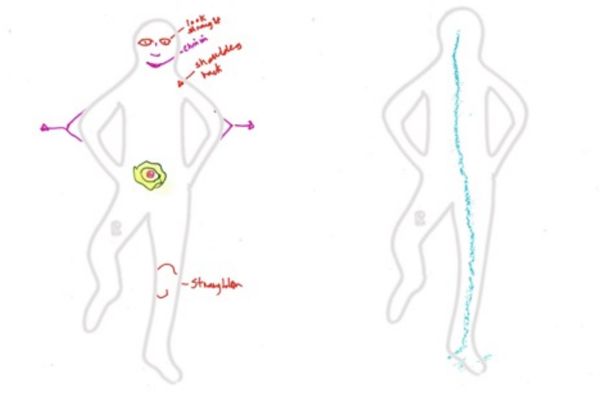


Figure 13: Increased proprioception in participants

These images led to the concept of a balance sparkline [Figure 14]. Sparklines are small, high-resolution graphics embedded in a context of words, numbers, images, they are data-intense, design-simple, word-sized graphics (Tufte, 1991). We concluded the compact size and the density of data of a sparkline would be ideal to convey the varying range of balance experienced by an individual over a long period of time.

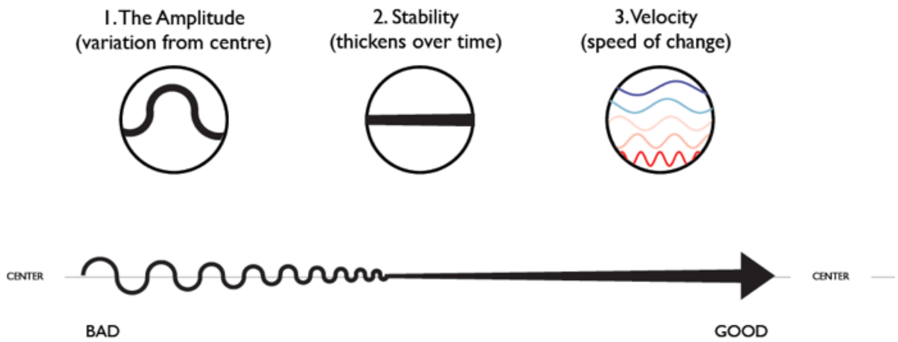


Figure 14: The concept of a balance sparkline

4. Defining and visualising actionable attributes of balance

4.1 Quantifying balance

The balance sparkline was programmed into the application [Figure 15], upon finishing a session, four sparklines were produced: medial lateral (ML, side to side movement) for the left foot and the right foot; anterior posterior (AP, forward and backward) for the left foot and the right foot. In January 2015 we began a period of quantitative testing. We tested our application 340 times with individuals between the ages of 25 and 86. The purpose of the testing was to check whether the application was sensitive to diverse abilities and to identify attributes that define a 'Balance Footprint.' On the initial testing day, we took 10 second long exposure pictures of every participant to get an indication of the accuracy of the device [Figure 16].

Figure 15: Quantitative testing version of the application, L to R, phone application and belt, zoomed in view of interface

Figure 16: Long exposure pictures of the participants

Our key finding was that the variation seen between the overall results of the participants (inter-participant scores) was greater than the variation seen within the multiple tests of a single participant (intra-participant scores). This indicated that there was potential for development of the device as an independent instrument through further testing. The raw data collected by the application was analysed to reveal four factors which comprise the unique 'Balance Footprint' of an individual:

- ‘Sway Score’, or How much does the individual sway? This consolidated measure reflects the sway velocity and sway amplitude of an individual. It is calculated by the Root Mean Square of the readings. The higher the sway score, the worst the balance [Figure 17].

Figure 17: Participant on left has Higher ‘Sway Score’ than the participant on the right

- ‘Sway Symmetry’, or How does the left side of the individual compare to their right hand side? Calculated by comparison of strength between the left and the right sides of the body [Figure 18].

Figure 18: ‘Sway Symmetry’, Significant asymmetry between left and right sides balance scores in a participant due to a knee impairment

- ‘Sway Distribution’, or How is the movement distributed along the anterior posterior and media lateral axis? Visualised by plotting the distribution of movement along the media lateral and anterior posterior axis.
- ‘Consistency’, or How much does the individual’s balance vary on a day to day basis?

The long exposure images enforce “comparisons..within the scope of the eye-span” (Tufte,2006), our challenge was to convey these attributes of information in an actionable form.

4.2 Visualising balance

The purpose of redrawing the raw data collected from the quantitative study was to develop a visualisation which:

- encourages a better understanding of current ‘Balance Health’ by facilitating the development of a visual knowledge of attributes. (diagnosis)
- plays a role in selecting contextual goals (therapeutic)
- encourages adherence by removing the noise due to small naturally occurring variances (motivational)

In August 2015, we began the process of identifying a visual schema for communicating the attributes of balance [Table 1].

Table 1: Schema for Balance Footprint

Attributes	*Importance*	*Visual Task*	*Visual Description*
Sway Score	provides a snapshot of balance range of the individual	Conveying a 6 scale range of balance; very stable, stable, average, mild impairment, impaired, very impaired	Size of Mark (smaller the better) Color of Mark (lighter the better)
Symmetry	asymmetry may be a predictor of falls (Skelton, Kennedy,& Rutherford 2002)	3 scale range; symmetrical, moderately asymmetrical, symmetrical.	NA function of sway score
Sway Distribution	reflects where the muscle strength is present or lacking, allowing for specific exercises, changes for every stance.	communicating whether ankle strategy (AP), or hip abductor (ML) strategy is more dominant	Placement of Mark
Variability	our limited study suggests greater variance in balance over short periods of time (10 days) is indicative of poor postural control (Authors 2016)	communicating 3 scale variance range; Low variance,normal variance, high variance	Small multiples of single test measure

Once the schema was defined, we selected datasets from two participants who were a part of the study. The first participant, henceforth referred to as “Participant 1”, is 26 year old, a dancer and has remarkable balance and proprioception. The second participant; henceforth referred to as "Participant 2", is 89 year old, an urban cyclist and a member of the 'Stable and Steady' exercise group at Earls Court. We aim to illustrate two extremes cases which we have come across. Each visualisation illustrates a single session recorded for these participants by the application. Visualisations for participant one are on the left side and participant two on the right hand side. Both participants completed multiple sessions on the application (8 and 52) respectively. The selected sessions are representative of the larger set of data collected.

Three categories have been identified for presenting the attributes. Each category has its strengths and weaknesses and presents attributes in different orders of visual importance. These categories are: movement-based, movement-time, movement-structure.

Movement based visualisations [Figure 19, 20] places the most importance on sway distribution by providing detailed views with all the data. It show the data in its purest form. Instead of "boiling down" (Tufte, 1991) or simplifying the raw data gathered by the accelerometer, these diagrams include all the data points which have been gathered during a single tests on each axis (ML and AP) for each leg.

Figure 19: Scatter plots; Here a small spread indicates low sway score and a big spread indicates high sway score. Each point has a high level of transparency and while they can be identified individually they combine with each other in an additive form to highlight dense data areas. Faint concentric circles help the user get a sense of their balance scaled to others. An additional circle is highlighted to show the user's sway score range.

There are two possible visualisations in this category; Scatter and Hull. Both Scatter and the Hull diagrams offer the advantage of a Macro/Micro display. At the macro level we can see the range. At the micro level we can see the individual data points. Faint concentric circles help the user get a sense of their balance scaled to others. An additional circle is highlighted to show the user's sway score. The user can drill down on a particular test to see the breakdown between each foot. This allows for the user to compare the symmetry of their balance. For Participant 2, it can be seen that the left leg smaller movement as compared to the right. The strength of this visualisation is that the complexity of data here has not been reduced, so the user can see everything captured. The weakness is that this method appears to give a user a "birds eye" view, which might lead to mis-interpreting the acceleration data points as representative of displacement.

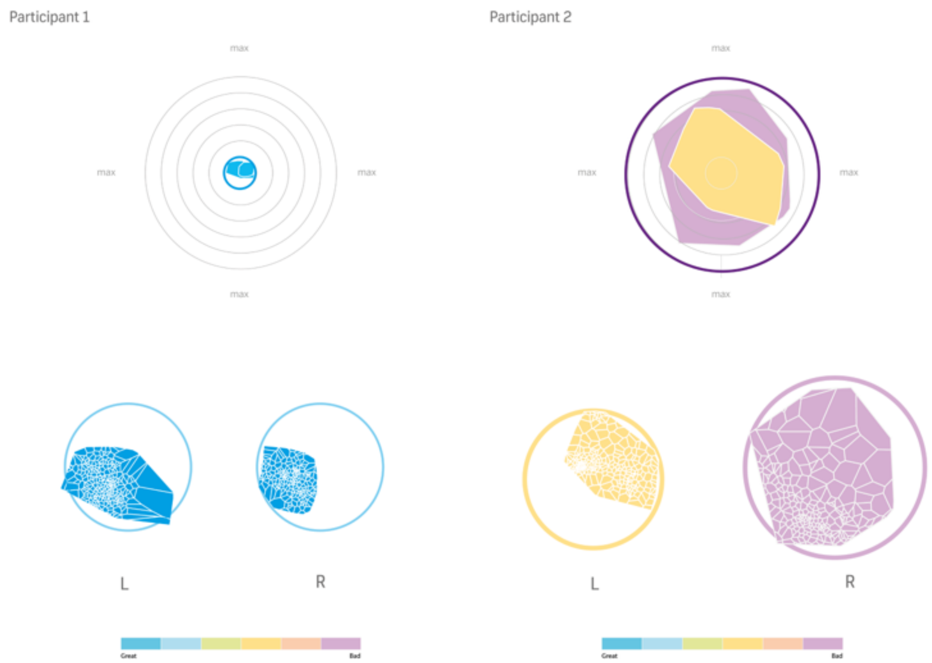


Figure 20: Hulls; The hull diagrams draws a convex hull around the scatter plot with 10% of the outliers removed. The hull provides an easy to interpret way of seeing the breadth the data points covered. A voronoi diagram was constructed with the result being where the lines are densest the data points are densest.

Movement-time based visualisations [Figure 21,Figure 22] respects that the test happens over a period of time and uses the time dimension as part of the visualisation. Bringing this aspect into the diagrams allows the user to gain insights into how their balance varied throughout the test, for example; if there were a lot of corrections in the beginning and good balance in the middle and the end of the test it is representative of good balance, whereas, if there were corrections throughout, with an increase towards the end that is indicative of muscle fatigue. The hope here is that the user will have an easier time matching the data to their experience, identifying when the largest wobbles happened and being able to re-experience their test through the visualisation. This would their increase self awareness of balance.

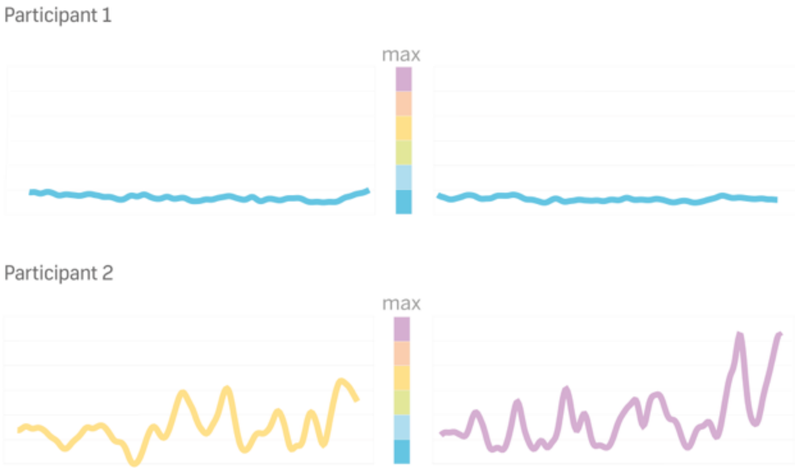


Figure 21: Sparklines; Inspired by the drawing study where many people drew their balance as a wobbly line, it uses smoothing function to create an undulating wave which matches their balance. The diagram makes it easy to pick out when the user’s balance was worst during a test.

Figure 22: Scatter-Time; The scatter time is similar to the scatter plot but the data has been divided into three time segments. Ellipses are drawn around the data from each time segment. This allows the user to view the how their balance varied over the test. It has two levels of drill-down. First splitting into the individual feet and secondly into the the three time segments.

A weakness of the movement time based visualisations is that by bringing in the extra dimension of time some of the key attributes message gets diluted as there is more for the user to interpret. With the spark line the user can no longer see the difference between AP and MP movements. Movement-structure visualisations [Figure 23, Figure 24] aim to transform and aggregate the data into a new abstract object and to not visualise the individual data points.

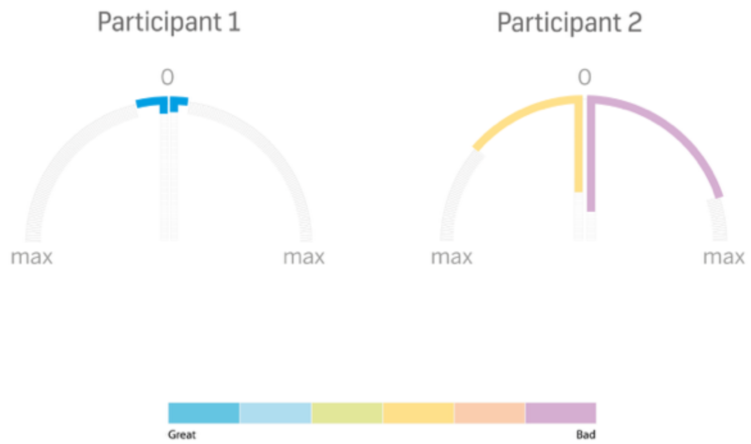


Figure 23: Balance trees; The tree visualisation tries to distill the data into the main attributes we want the user to focus on. MP and AP are given their own axis. The two feet test are placed next each other reducing the need for the drill down. The sway scores are shown by filling up the bars.

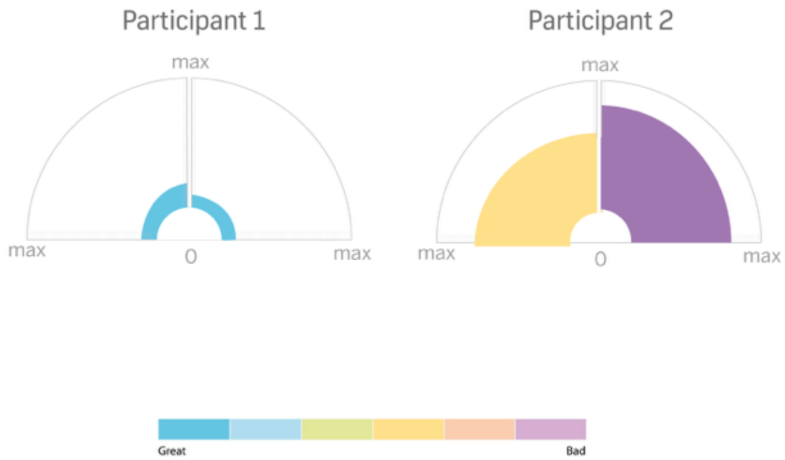


Figure 24: Rainbows; The rainbow visualisation also distills the data focusing on the key attributes. AP and MP are shown by the width of the curve on the appropriate axis. The two tests are close together for comparison and the width of the curve indicates the sway score.

These visualisations bring together the left and right feet tests into one diagram. This allows for very quick comparisons between the tests by having them in close proximity and presenting them in a way that has less variables to compare. By aggregating the data we hope to reduce the mental work the user does to reach the same conclusions. By reducing the complexity the user may have harder time relating what they experienced to what they are seeing in the diagram creating a disconnect between the two.

Table 2: Strengths and Weaknesses of the visualisations (judged by authors)

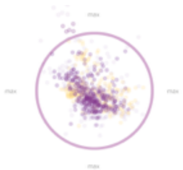
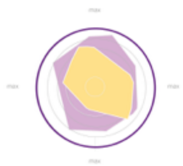
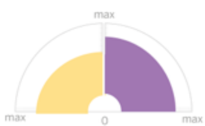
Categories	Type	Visual Hierarchy	Strengths	Weaknesses
movement-based	Scatter Plots 	1. sway score 2. sway distribution	presents actual data	noisy and difficult to set goals
	Hulls 	1. sway score 2. symmetry 3. sway distribution	facilitates comparison between left and right leg	difficult to ascertain whether AP or ML is more dominant
movement-time	Sparklines 	1. sway strategy over time 2. sway score	facilitates accurate mental model of balance test	AP, ML dimension is lost
	Scatter-time 	1. sway score, 2. sway strategy over time	provides actionable basis for improving balance, "I have to concentrate more at the end"	steep learning curve for user
movement-structure	Trees 	sway score symmetry, sway distribution all at same time	provides actionable basis for improving balance, "I have to improve my AP balance"	abstracted from experience
	Rainbows 	symmetry, sway distribution and sway score	provides target to aim for	not as readable as the trees.

Table 2 presents an analysis of strengths and weaknesses of the three categories. One attribute which has not been addressed in this body of work is that of variability. The next step for us is to develop our six concepts as small multiples, so that individuals can see their inter-test variability over time and then present this work to our users and experts in the field to get their feedback.

5. Conclusions

Balance Health, and by extension the attributes of symmetry, sway distribution remain largely unaccessible to the general populace. Equipment that allows individuals to analyse their balance is available in a clinical and research context but not in the preventative home setting. We attempt to frame balance as an attribute of health which can be tracked and shaped. We were motivated by the notion that a clear mental model (of the abstract concept of balance) would lead to possibilities for expression and communication of the current state without stigma and as a call to action. We have created representations with different visual hierarchies. One important attribute our current work has not addressed is 'variability' and the next step is to address this omission by development of small multiples, which would allow tracking of improvements or decline over time. We then aim to conduct a workshop to check the effectiveness and impact of these diagrams with our participants. Selected diagrams will be programmed into the application for longer term testing.

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