

Balance Disorder Spectrum

Technical Report: January 2018

Professor Andrew Hugill
College of Science and Engineering
University of Leicester
Leicester, UK
andrew.hugill@leicester.ac.uk

Professor Peter Rea
The Leicester Balance Centre
Department of ENT
Leicester Royal Infirmary
Leicester, UK

Abstract—This paper outlines the technical aspects of the first version of a new spectrum of balance disorders. It describes the implementation of the spectrum in an interactive web page and proposes some avenues for future research and development.

Keywords—*balance, disorder, spectrum*

I. INTRODUCTION

This project seeks to create an interactive diagnostic tool for the identification of balance disorders, to be used by clinicians and GPs as well as the wider public. There are three main layers to the project:

- the establishment of the concept of a spectrum of balance disorders;
- the creation of an interactive web page providing access to the spectrum and its underlying medical information;
- the introduction of a symptomatic algorithm that can make an accurate diagnosis.

The first step is a matter of public engagement. The authors are working with trustees of the Ménière's Society and other organisations to develop a media campaign to support the wide adoption of the Spectrum.

The second step may be viewed at <http://andrewhugill.com/balance> This has been developed by Professor Andrew Hugill (an academic, composer and Ménière's Disease patient) and Professor Peter Rea (a consultant otolaryngologist and leading expert on balance disorders). The detailed content of this website is also the substantial part of this technical report.

The third step is in progress and will be further developed by researchers by the Creative Computing Research Group, led by Professor Hugill. The algorithm will deploy AI techniques and knowledge combination to help patients and clinicians navigate the often difficult and unclear field of balance disorders.

II. BALANCE DISORDER SPECTRUM

A. Rationale

Balance disorders are often both unclear and difficult to diagnose, so the notion of a *spectrum* may well prove useful as an introduction to the field. Thanks to existing spectrums (e.g. autism), the general public is now familiar with the idea of a collection of related disorders ranging across a field that might be anything from mild to severe. The importance of balance disorders is generally underestimated. The field has suffered from a fragmented nomenclature and conflicting medical opinions, resulting from a general uncertainty and even confusion about both symptoms and causes. Terms such as: dizzy, light-headed, floating, woozy, giddy, off-balance, feeling faint, helpless, or fuzzy, are used loosely and interchangeably, consolidating the impression that this is a vague collection of ailments. The more accurate medical terms - vertigo, dysequilibrium and presyncope - are poorly understood by the general public.

A significant proportion of the population will experience some kind of dizziness during their lives. 30% of us will see our GP before the age of 65 with dizziness and it is the commonest reason for a GP appointment over the age of 75. Everybody knows someone who has had some kind of balance disorder. While no balance disorder is in itself life-threatening, the consequences on health and well-being can be profound. The embedding of a concept of a Balance Disorder Spectrum in the public mind should help to raise awareness of the range of such disorders. Whether symptoms of some other underlying problem, or recognised conditions in their own right, balance disorders are having a major effect on the health and wellbeing of people, and consequently a negative socio-economic impact. For that reason alone, they deserve to be better understood and more comprehensively researched. It is hoped that this proposed Spectrum will assist in achieving that aim.

B. Organisation

The Balance Disorder Spectrum version 1.0 is organised to reflect three main characteristics:

- The name of the disorder
- The location of the disorder
- The main symptoms, grouped by intensity

Users may select a given disorder name (by clicking or tapping) to bring up a window giving further information about: commonality, additional symptoms, causes and duration.

C. Disorder Names

The nomenclature of balance disorders is an evolving field in its own right and subject to constant updating as new research becomes ever more precise. Thus, a disorder such as Ménière's Disease, which has a history dating back to the 19th Century, is generally understood to be multifactorial and therefore a combination of conditions. PPPD (Persistent Postural Paroxysmal Dizziness), on the other hand, has only recently been identified as a named disorder and research into its characteristic and treatments is therefore at an early stage of development. Nevertheless, it has a quite distinct profile. In between the various named disorders, there are several which do not yet have names or are extremely rare. These do not appear on the current spectrum, but could be added in the future.

D. Disorder Locations

There is a clear diagnostic distinction between inner ear disorders, cardiovascular disorders and disorders of the central nervous system. Even though the symptoms may be similar, the location of the disorder is fundamentally different. There is also a cluster of disorders that do not sit within one of the three main locations and are consequently grouped under "other". Further separation by location (e.g. into psychological, phenomenological, visual, etc.) would be unhelpful, since these often overlap in any case.

E. Main Symptoms

It is very unusual for a balance disorder to consist of a single symptom. Nevertheless, there is always a major symptom that gives rise to the classification as a *balance* disorder in the first place. In the spectrum chart, these are grouped by intensity, but it should be noted that the divisions between groups are not necessarily fixed and the idea of intensity is itself quite malleable. Anyone experiencing one of these disorders may well consider that their symptoms are quite intense!

- Vertigo Vertigo is "an hallucination of movement" often experienced as the the sensation of spinning or having the room spin about you. Most people find vertigo very disturbing and report associated nausea and vomiting.

- Dysequilibrium is the sensation of being off balance, and may be accompanied by falls in a specific direction.
- Lightheadedness is the feeling that may precede fainting or, more simply: feeling faint.

The main symptoms are indicated along the y-axis of the spectrum via the red column and the various disorders are grouped by location along the x-axis within the three symptom bands.

F. Interactivity

The interactivity of the Balance Disorder Spectrum 1.0 comprises dismissable pop-up windows that appear in response to a tap or a mouse-click. The site is realised in html5 using the genial.ly environment.

III. THE DISORDERS

A. Inner Ear Disorders (Yellow Column)

1) Main Symptom: Vertigo

- Benign Paroxysmal Positional Vertigo (BPPV)
How common is it?: Common, about 1% of people will experience it.
Additional Symptoms: nausea, visual disturbance, spinning on looking up, rolling over, or lying down.
Cause: Misplaced calcium crystals (otoconia) in the inner ear.
Duration: Episodes are brief (seconds to a minute or so) and intense. Clusters of attacks may last weeks or years but often recur.
- Ménière's Disease
How common is it?: Uncommon. About 1 in 1,000 will experience it.
Additional Symptoms: severe vertigo with nausea, aural fullness, hearing loss, tinnitus, brain fog (usually temporary after an episode). May affect one (unilateral) or both (bilateral) ears to varying degrees. Not all symptoms may be present early in the disease process.
Cause: inner ear fluid imbalance (endolymphatic hydrops), but the underlying cause is probably multifactorial.
Duration: Attacks last 20 minutes - 12 hours. Clusters of attacks may recur over years or decades, or burn out.
- Vestibular Neuronitis (or neuritis)
How common is it?: Common.
Additional Symptoms: dizziness, but no change in hearing
Cause: viral inflammation of the nerves in the inner ear balance system (the vestibular nerve)

Duration: vertigo lasts days, but imbalance may last months

- **Labyrinthitis**
How common is it?: Uncommon (but vestibular neuronitis is often mistakenly called labyrinthitis)
Additional Symptoms: hearing loss, nausea, vomiting
Cause: inflammation of the inner ear, but the underlying cause can be unclear. Viral and bacterial infections are most likely.
Duration: the vertigo may last days or weeks, and subsequent imbalance weeks or months. Hearing may not recover.
- **Superior Canal Dehiscence Syndrome (SCDS)**
How common is it?: Probably rare.
Additional Symptoms: aural fullness, tinnitus, aurophony (hearing one's voice in one's head), fatigue, sound and pressure change-induced vertigo.
Cause: a thinning or complete absence of the part of the temporal bone overlying the superior semi-circular canal of the vestibular system. Aging and head injury are often triggers.
Duration: lifelong without treatment, but surgery is generally successful.
- **AIIED (Autoimmune Inner Ear Disease)**
How common is it?: Rare.
Additional Symptoms: very similar to Ménière's Disease but in both ears
Cause: associated with other auto-immune conditions
Duration: varies according to cause. Tends to burn out over a few years. Often especially sensitive to steroid treatment.
- **Perilymph Fistula**
How common is it?: Rare
Additional Symptoms: aural fullness, fluctuating hearing, tinnitus, pressure induced dizziness
Cause: head trauma or sudden changes in ear pressure (e.g. scuba diving, ear slapping)
Duration: lifelong until treatment

2) Main Symptom: Dysequilibrium

- **Unilateral or bilateral vestibular hypofunction**
How common is it?: Common
Additional Symptoms: imbalance, fatigue, neck ache, anxiety, cotton wool in head
Cause: damage to in-ear balance organ most commonly from vestibular neuronitis, but also from physical trauma, or other ear diseases (e.g. Ménière's)
Duration: highly variable depending on treatment, but underlying cause is lifelong. Most people will

recover in weeks. Those who do not may benefit from 3-18 months of vestibular physiotherapy

- **Ototoxicity**
How common is it?: Rare.
Additional Symptoms: imbalance, oscillopsia (the horizon bobs as you walk), difficulty walking in the dark, hearing loss, tinnitus
Cause: damage to inner ear from systemic drugs (usually injections e.g. gentamicin for severe sepsis). A small number of individuals are super-sensitive to gentamicin
Duration: lifelong (irreversible damage)
- **Trauma**
How common is it?: Common
Additional Symptoms: Symptoms from associated head injury may overlap
Cause: whiplash or head injury
Duration: variable, depending on treatment
- **Visual Preference**
How common is it?: Common
Additional Symptoms: Particular difficulty with dizziness and nausea in complex visual environments such as supermarkets, being a passenger in a car, cross, looking at movement on the TV, or computer
Cause: After any inner ear damage causing vestibular hypofunction. The eyes effectively take over from the injured inner ear.
Duration: whilst exposed to the visual stimulus
- **Acoustic neuroma**
How common is it?: Uncommon
Additional Symptoms: Small tumours may present with vertigo, larger tumours with disequilibrium. However patients will usually have hearing loss and or tinnitus in addition
Duration: vertigo attacks are very variable but the disequilibrium of larger tumours may be persistent

B. Central Nervous System (Green Column)

1) Main Symptom: Vertigo

- **Migrainous Vertigo (Vestibular Migraine)**
How common is it?: Common, about 1% of the population will experience this.
Additional Symptoms: motion intolerance, nausea, visual disturbance, headaches do not always occur, light and sound sensitivity.
Cause: temporary changes in brain activity
Duration: episodic, but occasionally chronic
- **Stroke**
How common is it?: An uncommon but important cause of acute vertigo

Additional Symptoms: include some of: ataxia (loss of co-ordination), hearing loss, weakness, numbness, altered consciousness, slurring of speech
Cause: an embolus or bleeding in the brain

- **Arnold-Chiari malformation**
Additional Symptoms: nausea, tinnitus, hearing loss, neck pain, muscle weakness, insomnia, depression
Cause: structural defects in the base of the skull or cerebellum
Duration: varies according to cause
- **Episodic Ataxia Type II**
How common is it?: Rare.
Additional Symptoms: Symptoms of spinning sometimes with neurological symptoms (ataxia, double vision) and sometimes migraine like headaches, lasting minutes to days. Initially symptom free between attacks but balance can later worsen.
Cause: Caused by a channelopathy - a calcium channel in brain cells which can be tested for with a blood test.
Duration: minutes to days with the disorder often being permanent
Note: This is an important but rare differential diagnosis to Ménière's and vestibular migraine that many doctors will not have heard of, as it can be treated with mountain sickness drugs (acetazolamide)
- **Vestibular Paroxysmia**
How common is it? rare
Additional Symptoms: spontaneous short attacks of vertigo lasting up to a minute but often recurring up to 30 times per day
Cause: probably a loop of blood vessel between the ear and brain compressing the balance nerve
Duration: uncertain. Although attacks very short the disease process may relapse over years
- **Tumour**
How common is it?: Rare
Additional Symptoms: Benign acoustic neuromas are discussed elsewhere. Some tumours can present a slowly increasing headache and imbalance. Malignant tumours are rarely seen in the balance clinic as they often have associated neurological symptoms such as weakness, visual disturbance, severe headache, and ataxia
Duration: progressive until treated
- **Epilepsy**
How common is it?: although epilepsy is common is very rarely seen in the balance clinic
Additional Symptoms: the presentation will be entirely dependent on the area of the brain affected and ranges from "fits" to out of body "Alice in Wonderland" experiences

2) *Main Symptom: Dysequilibrium*

- **Migraine**
How common is it?: Migraine is common affecting 10% of the population. Migrainous vertigo affects 1 % of the population
Symptoms: migrainous vertigo presents with disequilibrium or vertigo lasting minutes to days and usually (but not always) associated with headache and light and sound sensitivity. However those with a history of migraine (a "migraineur") may experience disequilibrium between such attacks and worsening of vestibular symptoms.
Duration: One is a migraineur for life if one suffers from migraine, but many go decades between relapses. Others sadly do not.
- **Idiopathic intra-cranial hypertension**
How common is it?: rare
Additional Symptoms: commonest in ladies aged 20-50 and often overweight. Imbalance, headache, pulsatile tinnitus, visual disturbance.
Cause: an increase in pressure within the head of unknown cause
- **MS (Multiple Sclerosis)**
How common is it?: Uncommon, about 1 in 1,000
Additional Symptoms: about 1 in 10 patients with MS experience dizziness initially. Symptoms may also include visual disturbance, numbness, weakness, bladder dysfunction
Cause: Demyelination of the central nervous system
Duration: Very variable
- **Intracranial bleeding**
How common is it?: Uncommon
Additional Symptoms: there are a number of different types of bleeding, in addition to the strokes discussed elsewhere. Chronic sub-dural bleeding should be considered especially in the elderly. Beware of progressive imbalance with headaches.
Cause: Sub-dural bleeding usually follows a bang on the head.
Duration: Symptoms may not arise for days or weeks after the head injury.
- **Traumatic brain injury**
How common is it?: Uncommon
Additional Symptoms: Multiple often "concussion" type symptoms but very variable
Cause: Head injury, most commonly road traffic accidents
Duration: Very variable
- **NPH (Normal Pressure Hydrocephalus)**
How common is it?: Rare

Symptoms: broad based gait, headaches, double vision, incontinence, personality changes, dementia type symptoms

Cause: accumulation of cerebro-spinal fluid in the brain

Duration: lifelong without treatment

- Degenerative (e.g. Parkinson's Disease)
How common is it?: Common in the elderly
Additional Symptoms: Tremor, rigidity, slowness of movement
Cause: loss of dopamine producing cells in the motor part of the brain
Duration: Lifelong

3) Main Symptom: Lightheadedness

- Cerebrovascular Disease
How common is it?: Common with aging
Additional Symptoms: Non-specific imbalance
Cause: Aging, diabetes, high blood pressure, smoking
Duration: Incurable

C. Cardiovascular (Blue Column)

1) Main Symptom: Vertigo

- Irregular heartbeat
How common is it?: Common
Additional Symptoms: Dizziness associated with palpitations. May come and go.
Cause: Irregular heart rhythm
Duration: Episodic

2) Main Symptom: Lightheadedness

- POTS (Postural Tachycardia Syndrome)
How common is it?: Rare
Additional Symptoms: Dizziness and increased pulse on standing. Fainting. Most common in ladies and rare over age 40
Cause: Uncertain. Low blood pressure or low blood volume may be relevant
Duration: Very variable
- Syncopal Syndromes
How common is it?: Common
Additional Symptoms: fainting
Cause: Many different causes. Your doctor will need to investigate if frequent. For many, faints run in the family
Duration: Often life long.
- Postural and Orthostatic Hypotension (Orthostatic Hypotension)
How common is it?: Common

Additional Symptoms: sudden dizziness when standing up from a lying position, or standing still for long periods

Cause: aging, heart disease, family history, medication side-effects

Duration: brief

- Heart Disease
How common is it?: Common
Additional Symptoms: Very variable. Dizziness associated with chest pain requires urgent medical attention.
Cause: Most commonly, hardening of heart arteries.
Duration: Many different causes, so variable.

- Angina
How common is it?: Common
Additional Symptoms: chest pain, shortness of breath
Cause: Most commonly, hardening of heart arteries
Duration: Variable

D. Other (Purple Column)

1) Main Symptom: Vertigo

- Panic Attacks
How common is it?: Common
Additional Symptoms: nausea, palpitations, sweating, shaking, shortness of breath, numbness, fear
Cause: a range of psychological and non-psychological causes
Duration: up to 30 minutes
- Hyperventilation
How common is it?: Common
Additional Symptoms: As per panic attacks. Often tingling of lips and fingers.
Cause: Anxiety or chest disease
Duration: Minutes
- Height vertigo
How common is it?: Common
Additional Symptoms: Nausea, avoidance strategies
Cause: Mismatch of visual and vestibular information
Duration: During exposure

2) Main Symptom: Dysequilibrium

- Persistent Postural-Perceptual Dizziness
How common is it?: Common
Additional Symptoms: persistent sensations of rocking or swaying unsteadiness and/or dizziness without vertigo
Cause: a triggering event, usually an episode of vertigo, associated anxiety
Duration: 3 months or more

- Multi-system balance disorders
How common is it?: Common
Additional Symptoms: Commonest in the elderly with associated problems with vision, arthritis, and confidence for example
Cause: Multiple
Duration: Persistent
- Cervico-genic Dizziness
How common is it?: Uncertain
Additional Symptoms: neck pain, headache, imbalance with head movements
Cause: cervical spondylosis, cervical trauma, and cervical arthritis. Whiplash. But our understanding is poor.
Duration: episodes: minutes and on movement
- Physiological dizziness
This is an almost universal experience - but to very varying degrees
Sea sickness results from a conflict of information going to the brain from the eyes versus the information from the ears if you look at the rocking boat floor - your eyes say there is no movement, your ears say there is (hence staring at the horizon helps). Height vertigo has not dissimilar origins. We have all experienced the odd sensation of motion when in a stationary train and the train next to us slowly pulls away: our eyes and ears are again in conflict.
- Mal de Débarquement Syndrome (MdDS)
How common is it?: The true syndrome is rare, although symptoms of MdDS are common after vestibular disorders and need to be clearly distinguished
Additional Symptoms: constant sensation of rocking, vision disorder, anxiety
Cause: often follows exposure to motion
Duration: hard to estimate, but may be self-limiting
- Joint Replacement/Arthritis
How common is it?: Common
Additional Symptoms: Pain, stiffness, falls
Cause: Aging
Duration: Persistent
- Visual Problems/Glasses
How common is it?: Probably common
Additional Symptoms: Balance worse wearing varifocals or after change of glasses
Cause: Visual vestibular mismatch
Duration: During exposure
- Motion Sickness
How common is it?: Common
Additional Symptoms: nausea, fatigue

Cause: a mismatch between visually perceived movement and the vestibular system's sense of movement
Duration: normally ends naturally when motion ceases

- Fear of falling
How common is it?: Common in the elderly
Additional Symptoms: Imbalance, falls, isolation
Cause: Often a previous fall
Duration: Often long lasting

3) Main Symptom: Lightheadedness

- Anxiety
Anxiety is a common primary cause of dizziness and a very common accompaniment to those with dizziness of whatever cause. It may produce symptoms of dysequilibrium and not just lightheadedness.
Additional Symptoms: It may present as short lasting panic attacks with hyperventilation, or chronic imbalance with headache, fear of falling, claustrophobia, and malaise
Cause: may be a result of the dizziness or a cause
Duration: very variable
- Medication
How common is it?: Common
Additional Symptoms: Postural dizziness
Cause: Often diuretics, blood pressure lowering medicines, strong pain killers
Duration: whilst on medication
- Endocrine
How common is it?: Uncommon
Additional Symptoms: Depends on cause, but may include fatigue, low blood pressure, weight loss
Cause: investigation of low blood pressure, blood sugar, thyroid function may be needed
Duration: Until treated
- Anaemia
How common is it?: Common
Additional Symptoms: Fatigue
Cause: heavy periods, other illnesses, diet, hookworm
Duration: Until treated
- Vitamin D Deficiency
How common is it?: Common
Additional Symptoms: Fatigue, aches and pains
Cause: Lack of exposure to sunlight
Duration: Until treated

IV. CREATIVE COMPUTING

The creative components of this first version of the project lie in Hugill's vision of a balance disorder spectrum, and its realization in the form of an interactive web page. The conception of the spectrum itself arises from a computational mindset, as the knowledge combination and delineation of a fluid field reflects digital creativity.

This lays the foundations for future creative computing development as AI is introduced. Accurate diagnosis of balance disorders is immensely challenging, and the consequences of wrong diagnosis can be dire, so the AI needs to respond intelligently to the complexity of a range of input symptoms that may be described quite vaguely and inaccurately. This is where the creative computing comes in: parsing natural language to respond effectively to a multi-faceted condition and combining knowledge to deliver an

accurate diagnosis and, ultimately, treatment recommendations. The spectrum will never replace doctors and consultants, but will, it is hoped, deliver an improvement in the diagnosis and treatment of balance disorders.

V. AUTHORS

Andrew Hugill is Director of the Centre for Creative Computing at Bath Spa University. He is also a composer and musicologist. In 2009, he was diagnosed with Ménière's Disease.

Peter Rea is consultant Otolaryngologist at The Leicester Royal Infirmary and Honorary Professor of Balance Medicine at De Montfort University, Leicester, UK.