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Enhancing equity in sport: informing the development of an evidence-based standardised starting system in D/deaf and hearing athletics.

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School of Psychology and Sport Science

College of Medicine and Health

Enhancing equity in sport: informing the development of an evidence-based standardised starting system in D/deaf and hearing athletics.

Elizabeth Rosemary Steele

A thesis submitted to

Bangor University

in fulfilment of the requirements of the degree of

Doctor of Philosophy

Supervisors: Dr Vicky Gottwald and Dr Gavin Lawrence

Collaborators: Professor Michael Khan and Dr Eleri Jones

Declaration and Consent

I hereby declare that this thesis is the results of my own investigations, except where otherwise stated. All other sources are acknowledged by bibliographic references. This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree unless, as agreed by the University, for approved dual awards.

Yr wyf drwy hyn yn datgan mai canlyniad fy ymchwil fy hun yw'r thesis hwn, ac eithrio lle nodir yn wahanol. Caiff ffynonellau eraill eu cydnabod gan droednodiadau yn rhoi cyfeiriadau eglur. Nid yw sylwedd y gwaith hwn wedi cael ei dderbyn o'r blaen ar gyfer unrhyw radd, ac nid yw'n cael ei gyflwyno ar yr un pryd mewn ymgeisiaeth am unrhyw radd oni bai ei fod, fel y cytunwyd gan y Brifysgol, am gymwysterau deuol cymeradwy.

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Academic Publications and Conferences

Published Abstracts for Refereed Conference Presentations

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Steele, E., Lawrence, G., Khan, M., Gottwald, V. (2023). Fair starts for all: informing the development of an evidence-based athletics standardised starting system for D/deaf and hearing populations. *Journal of Motor Learning and Development (NASPSPA refereed abstracts repository)*, Toronto.

Conference Proceedings

Steele, E., Lawrence, G., Gottwald, V. (2021). Enhancing equality in sport: informing the development of a standardised starting system for deaf athletes. *Online poster presentation at the Expertise and Skill Acquisition Network conference in May 2021.*

Steele, E., Lawrence, G., Khan, M., Gottwald, V. (2022). Fair starts for all: exploring multisensory reaction times in Deaf and hearing populations to develop a novel athletics standardised starting system. *Poster presentation at the European Congress of Sport Sciences conference in Seville, Spain, August 2022.*

Steele, E., Lawrence, G., Khan, M., Gottwald, V. (2023). Fair starts for all: informing the development of an evidence-based athletics standardised starting system for D/deaf athletes. *Poster presentation at the Expertise and Skill Acquisition Network conference, Manchester, UK, May 2023. Received the ‘Best Poster’ accolade.*

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populations. *Verbal presentation at the Bangor University School of Human and Behavioural Sciences Postgraduate Researcher conference, Bangor, UK, June 2023. Received the ‘Best Verbal Presentation’ accolade.*

Accolades and Awards

Draper's Company Silver Medal

Each academic year, Bangor University and the Draper's Company award two medals (silver and bronze) to outstanding research students in their final year of study. In March 2023, I was awarded the Silver Draper's Company Medal in recognition of my contributions to my academic school and research impact. Below is the supporting nomination for context:

"Libby is already demonstrating competence as an outstanding research-practitioner in her own right and is an excellent ambassador for Bangor University. She has independently established industry collaborations with UK Deaf Sport/England Athletics and her research is having remarkable impact in her field. Libby's lived experience being Deaf provides her with unique insight into the barriers preventing D/deaf athletes progressing in sport and enables her to foster relationships with key stakeholders. The hallmarks of Libby's research are its impressive significance (impact), which is supported by rigour (multi-study/interdisciplinary). Her work is having demonstrable contribution to society, enhancing the accessibility of sport for the D/deaf population. One example of this is a rule change within the sport's National Governing Body, to allow for more flexibility/equity within starting systems. Furthermore, Libby's contribution to the School/College goes above and beyond. Libby demonstrates qualities of great leadership when representing her peers and championing the PGR community."

It was a real honour to be awarded the Silver Draper's company medal for 2023 as is it such an esteemed and well-respected award. Throughout my PhD, I have been a Postgraduate Researcher Representative for the School of Human and Behavioural Sciences (now School of Psychology and Sport Science) which has truly been such a rewarding and fulfilling experience and has added a real richness and overall contentment to my PhD experience. To be recognised for the impact and scope of my research fills me with great pride, I am so passionate about my research and the community that I am serving. A huge thankyou to everyone that was involved in the nomination and application process for this award and to Bangor University and the Draper's company for presenting me with this award.

Expertise and Skill Acquisition Network Conference 2023 – Best Poster

I attended the Expertise and Skill Acquisition Network (ESAN) conference in Manchester, June 2023 and participated in the poster sessions, to which I was awarded with the ‘Best Poster’ accolade. ESAN is a fantastic conference that encompasses interdisciplinary work within the Expertise, High Level Performance, and Skill Learning domains. The theoretical underpinnings of my research focus on reaction time (a tiny part of the ESAN sphere), but the key focus lies within the applied implications and impact in athletics, so it was exciting to be given this award which recognises both the theory and practice of research. A QR code of my poster can be found in the appendices of this thesis.

School of Human and Behavioural Sciences Postgraduate Researcher Conference 2023 – Best 10 Minute Verbal Presentation

As part of the colloquium programme in the School of Human and Behavioural Sciences, I took part in the 10-minute verbal presentation series, presenting one of my quantitative reaction time experiments. I was very grateful to be awarded ‘Best 10 Minute Verbal Presentation’ as it was my final presentation in my PhD, so it felt really good to end on a high, especially around all of my peers and colleagues. The slides for this presentation can be found in the appendices of this thesis.

Additional Research Study not Included in this Thesis

In addition to the studies included in this thesis, I conducted a further study investigating haptic reaction times to an uncertain stimulus location (i.e., no prior knowledge as to where the stimulus was being presented) in D/deaf and hearing populations. The methodology is out of scope of the thesis as the trial order was randomised, thus participants did not know the stimulus location prior to each trial and in a real-world scenario, an athlete is aware of the stimulus (i.e., starting pistol or traffic lights) they are being presented with at the start of a race. This means that the findings would not be generalisable to the intended population and do not address to overall aims of the PhD. Whilst not included in this thesis, the results provide insight into an interesting and largely unexplored research question around explicit stimulus knowledge and reaction times, specifically in D/deaf populations. The manuscript for this study is available upon request.

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Thesis Format

This thesis consists of a general literature review, three empirical chapters, and a general discussion. It is worth noting that the experimental chapters are written in a manuscript format, meaning that there is some degree of repetition across each chapter. Any abbreviations are redefined within each chapter to facilitate readability. This thesis follows the American Psychological Association (APA) Style (7th Ed.) guidelines for formatting and referencing. The references for all chapters are listed at the end of the thesis. Table, figure, and footnote numbering is restarted in each chapter.

Thesis Abstract

Deafness is not a recognised classification under the Paralympic banner, and subsequently, D/deaf athletes¹ are required to compete alongside hearing athletes in the Olympic pathway². This results in arguable competitive advantages for hearing athletes and explains the lack of D/deaf athletes competing at Olympic level. Thus, the primary aim of my thesis was to inform the development of a standardised starting system that ensures fair competition between D/deaf and hearing athletes in mainstream athletics and across all levels of the D/deaf sport pathways. To achieve this, my thesis comprises a General Introduction (Chapter 1), followed by three further Chapters (incorporating three experimental studies and one qualitative study) that each tackle a particular challenge in line with the overall aims, and a General Discussion. To our knowledge, this thesis is the first of its kind to develop a comprehensive evidence-base, rigorously testing factors effecting reaction time (RT) (e.g., stimulus quantity, modality, and location), as well as the sociocultural requirements for an equitable starting system.

More specifically, Chapter 1 provides in-depth contextual information surrounding the history, cultural importance, and barriers experiences by D/deaf people in sport and wider society. It also includes a critical discussion of the complex relationship between RT and hearing level and why it is pertinent to establish equitable RTs in athletics. Both the contextual D/deaf sport background and theoretical underpinnings ascertain the need, rationale, and thesis'

¹ The use of D/deaf is intentional. The 'D' represents those individuals who are part of Deaf culture, use British Sign Language (BSL) and have shared experiences, thus reflecting their identity. The 'd' refers to the medicalised condition of deafness. To be fully inclusive throughout this thesis, the phrasing 'D/deaf' is used.

² D/deaf athletes can also compete in the Deaflympics which creates opportunity for inclusive competition, however it is not recognised by UK performance pathways and receives little funding or formal recognition.

structure to develop an impactful body of research to inform an evidence-based standardised starting system.

Chapter 2 is the first experimental chapter and investigated the relationship between stimulus location and RT in D/deaf and hearing populations. More specifically, we focused on haptic stimulus positioning i.e., high set-level compatible location (hands) versus low set-level compatible location (legs), considering the practical implications of whether it would be more beneficial to RT to position a haptic stimulus directly on the start line (i.e., proximal to the hands) or within the starting blocks (i.e., proximal to the legs). Results demonstrated that haptic RTs were significantly faster at a high-set level compatible location (i.e., the hands) with no significant population difference when presented with a haptic stimulus. These findings were used to inform the methodology, specifically the stimulus positioning, in Chapter 3.

Chapter 3 investigated the influence of stimulus modality (auditory, visual, and haptic), stimulus quantity (unimodal versus bimodal), and hearing level on RTs in D/deaf and hearing populations. Chapter 3 comprises two experiments with similar rationales but different tasks (a more internally valid laboratory target-directed aiming task and a field-based sprint start task), with notable results consistently demonstrating no significant between-group differences for RT when presented with a bimodal visual-haptic stimulus. These findings provide robust evidence and direction for what constitutes an equitable starting system.

The final study, Chapter 4, adopts a more inductive and qualitative approach, encompassing the sociocultural element of this thesis. It explored the experiences, perceptions and opinions of variable starting systems to gain a better understanding of what starting systems have been used at different stages of the participation and performance pathways in D/deaf athletics. It also addresses how and why D/deaf athletes compete in athletics, with focus on access to sport, athlete funding and competitive opportunities. Findings also provided useful insight into what D/deaf athletes, coaches of D/deaf athletes and stakeholders want, and need, from a standardised starting system that will be practical, efficient, and accessible across mainstream and D/deaf sport.

To conclude, Chapter 5 incorporates a general discussion with a particular focus on the applied implications and starting system solution in line with the main objectives and findings of

this thesis. The theoretical implications, practical recommendations, limitations, and future research directions are discussed.

Chapter 1:

General Introduction

Since the London 2012 Olympics and Paralympics, there has been a marked increase in efforts made to promote inclusivity in sport and towards achieving an egalitarian society. However, these efforts have arguably not been paralleled in D/deaf sport, and particularly in athletics. Approximately seven million people participate in athletics each month in the UK (Statista, 2023) and there are over 1650 affiliated athletics clubs in England (England Athletics, 2021). Whilst athletics is the most participated in sporting activity in the D/deaf community, it is estimated that only 10% of the 11 million D/deaf or hard of hearing people regularly partake in physical activity (UK Deaf Sport, 2017), with only a handful of D/deaf athletes reaching elite levels of sport. These statistics are indicative of the inequities faced by the D/deaf community in sport, with one example being the lack of a standardised starting system that promotes fair and inclusive competition for these athletes. This body of work intends to be a catalyst for positive change and legacy in D/deaf sport, increasing access and opportunity by informing the development of a standardised starting system. The implementation of a standardised starting system will increase access for D/deaf people within the participation pathways and ensure equity and consistency within performance pathways.

To be fully inclusive and represent all members of the D/deaf community, the intentional phrasing D/deaf is used throughout this thesis. The ‘D’ represents those individuals who are part of *Deaf culture*, use British Sign Language (BSL) and have shared experiences, thus reflecting their identity (Ammons & Eickman, 2011). The ‘d’ refers to the medicalised condition of *deafness* and those who consider themselves as hearing impaired (Napier, 2002). To be fully inclusive throughout this thesis, the phrasing ‘D/deaf’ is used.

1.1 D/deaf Sport History and Cultural Importance

Within the rich and long history of D/deaf culture, sport, amongst other factors such as education and language, has significantly contributed to the development and growth of the D/deaf community. More specifically, understanding the role and importance of physical education and participation in sport is warranted. In 1933, there were 81 D/deaf-specific schools across the UK (British Association of Teachers of Deaf Children and Young People, 2017), whereby physical education and team sports were a strong component of the bonds made between students and the initial development of organised sport. This has declined to just 22 D/deaf schools in the UK, exacerbated by the continual integration of D/deaf units within

mainstream schools (National D/deaf Children's Society, 2023), arguably reducing the opportunity for inclusive physical education and participation in recreational sport.

Despite this, D/deaf sport does still thrive and holds great cultural significance. Team-based sports such as football, rugby, and basketball are well developed and organised, providing more regular inclusive opportunity for participation and performance. On the contrary, individual sports such as athletics and swimming often involve lone training whereby a D/deaf athlete is responsible for themselves (i.e., coaching, training, competitions) (Kurkova et al., 2011) and has fewer opportunities for inclusive competitions. As things stand, the pinnacle of D/deaf sport and the goal for many D/deaf athletes is to participate and compete in the Deaflympics.

The Deaflympics is an international sporting event that runs on a quadrennial cycle, like the Olympics and Paralympics, and allows only D/deaf athletes with a hearing loss of at least 55dB or more in their better ear to take part. The first Deaflympics was held in Paris, 1924 (Deaflympics, n.d.), 36 years before the first modern Paralympics in 1960 (International Paralympic Committee, n.d.), making it the longest running para-sporting event. The most recent Deaflympics was held in Brazil in 2022, with 20 different sports, 73 different countries and 2412 athletes (Deaflympics, n.d.). However, Team GB did not attend the 2022 games due to a lack of planning, funding, and organisation according to a statement released by UK Deaf Sport (2022), highlighting the current situation in D/deaf sport in the UK.

1.1.2 D/deaf Sport in the UK

UK Deaf Sport is the national governing body responsible for all D/deaf sport in the UK and aims to increase participation and provide opportunities for D/deaf people wanting to get involved in sport (UK Deaf Sport, n.d.). Whilst UK Deaf Sport a national governing body, it receives significantly less funding from the UK Government and organisations such as UK Sport and the National Lottery, with only 0.19% of disability sport funding aimed towards D/deaf sport (UK Deaf Sport, n.d.). Prior to the London 2012 Olympic and Paralympic games, UK Deaf Sport received £134,000 of funding but this was rescinded in 2015 (UK Deaf Sport, 2014). UK Deaf Sport has never recouped or exceeded this amount of funding which presents significant challenges in their aim to support and empower athletes. D/deaf athletes are often required to fund their flights, accommodation, food, and kit when attending international competitions, as its performance pathway is not recognised by the government or UK Sport. At present, it is not

possible to be a professional D/deaf athlete in the UK whereby you receive remuneration for sporting endeavours; whereas in other European countries such as Poland, D/deaf athletes are afforded professional status and receive financial support and subsequently have greater levels of competitive success (Szulc et al., 2021). The lack of funding and recognition for D/deaf athletes is grossly inequitable compared to Olympic and Paralympic athletes who receive significant sums of money each year towards their living costs, training, competitions, and travel.

1.1.3 D/deaf Sport Pathways

Within D/deaf sport, there are two main pathways that allow an athlete to progress: the Olympic and Deaflympic pathways. A common presumption in wider sport is that D/deaf athletes can compete in the Paralympics, but this is not the case. At present, there is no classification system or category in place for D/deaf athletes in the Paralympics and given that many D/deaf athletes do not see themselves as disabled (Kurkova et al., 2011), creating a D/deaf classification would neither empower these athletes, nor resolve these issues³.

The Olympic pathway is hypothetically just as accessible for D/deaf athletes as for hearing, but the realities mean that it is rare for D/deaf athletes to access elite mainstream sport, particularly in athletics, given the many barriers (Kurkova et al., 2011; Atherton, 2007; Stewart, 1991) and absence of a fair, inclusive starting system. Subsequently, the Deaflympic pathway is the most common for D/deaf athletes in the UK and what most D/deaf athletes strive towards. Competing at the Deaflympics and in wider D/deaf sport and physical activity provides a unique and inclusive environment for D/deaf athletes and creates a significant sense of belonging, acceptance, and achievement amongst D/deaf athletes (Atherton, 2009; Solvang & Haualand, 2014). Whilst the Deaflympics do provide the opportunity for D/deaf athletes to represent their country at an elite level, only few athletes in the UK achieve this compared to Olympic and Paralympic athletes, due to the aforementioned systemic challenges and barriers, and even fewer D/deaf athletes reach the elite level in mainstream pathways.

³ If a D/deaf athlete has another classifiable disability, such as cerebral palsy or limb deficiency, they would be able to compete in the Paralympics with their other disability (Foster et al., 2018).

1.1.4 D/deaf Inclusion in the UK

There are deep systemic issues regarding access, opportunity, and recognition within D/deaf sport, resulting in D/deaf athletes withdrawing due to the unsustainability of working full-time, training to elite standard, and self-funding. The lack of elite D/deaf athletes across sport can be attributed to society's lack of acknowledgement and efforts towards active and passive inclusion of D/deaf people in sport (Clark & Mesch, 2018). There is a clear marginalisation and ostracization of the D/deaf community, characterised by lack of effective and inclusive communication, poorer education, and access to employment (Berry, 2017; Mackenzie & Smith, 2009).

Recently, there have been concerted efforts to improve the integration and inclusion of D/deaf people in wider society. The British Sign Language (BSL) Bill was assented in June 2022 by the UK Government after an extensive campaign period and successful implementation in Scotland (UK Parliament, 2022; O'Neill & Wilks, 2021). This bill recognises BSL as a legal language within the UK, meaning that institutes, organisations, and services must provide access to BSL. In sport, this will mean sports organisations, competitions and coaches must ensure sufficient access to BSL, via themselves or an interpreter. The bill will also increase D/deaf awareness within sport to break down prevalent communication and inclusion barriers, supporting the desire within the D/deaf community to participate and compete in integrated environments (eight out of 10 people report that they would enjoy participating in a mixed environment; UK Deaf Sport, 2017).

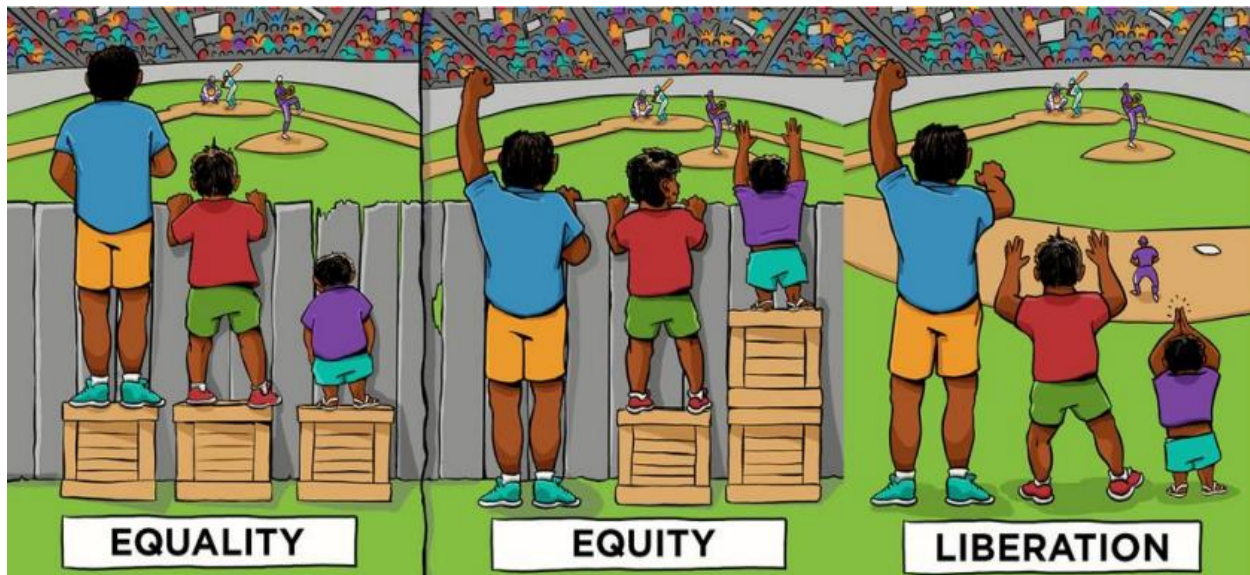
1.2 Equity over Equality

The drive towards an egalitarian society is steeped towards increasing equality in sport but the intention within this thesis is to increase equity in sport. By definition, equality is where everyone has the same status, rights and responsibilities (Collins Dictionary, n.d.) whereas equity is defined as the quality of being fair and reasonable in a way that gives equal treatment to all (Collins Dictionary, n.d.). In sport, providing equal opportunities does not necessarily mean that everyone has the same opportunities, whereas providing equitable opportunities means curating an environment whereby everyone has the same access and inclusion. This is important to consider in the context of this thesis as providing equitable opportunities between D/deaf and

hearing athletes on the start line will create a more profound impact compared to providing equal opportunities (see Figure 1.1).

Figure 1.1

Visual representation of the impact of equity over equality for inclusion in sport (Disability Sport Wales, 2023).



1.3 Models of Disability

A significant factor contributing to the (lack of) integration of D/deaf sport overall is the attitudes and sociocultural assumptions placed on the D/deaf community in sport (Atherton, 2007). These attitudes and sociocultural assumptions can be attributed to two models of disability that are deemed detrimental to the integrity and well-being of the D/deaf community. Firstly, the medical model of disability centres deafness as something that should be ‘cured’ to benefit society and the individual (Power, 2005). The ‘curing’ of deafness stems from the addition of assistive hearing technology such as cochlear implants, hearing aids or bone-anchored hearing aids to encourage verbal communication and access to the hearing world (Woodcock, 2001). Many people in the D/deaf world are against invasive assistive technologies, particularly cochlear implants, as they are often implanted at a young age to preserve spoken language development (Sparrow, 2010), but this can inadvertently result in sociocultural

deprivation in both the hearing and D/deaf worlds due poor integration and language development (Sparrow, 2005). In sport, the medical model of disability is harmful as it reduces the individual to their disability and hinders autonomy and decision-making (Brittain, 2013), resulting in a lack of access and inclusion. Within this body of research, the medical model of deafness/disability is not used nor is it deemed a fit for purpose model. On the contrary, the social model of disability/deafness does contribute to the underpinnings and rationale for this research.

The social model of disability moves away from the drive towards ‘curing’ disability and putting the onus on the individual and contributes issues, barriers and inequities faced by D/deaf people to wider society (Brennan, 2003) via a lack of inclusion and accessibility of services, education, employment (Kushalnagar, 2019) and more relevantly, sport. A lack of D/deaf awareness, poor communication, and inclusion across the sporting sector results in the ostracization of D/deaf individuals meaning that the pathways and opportunities for D/deaf participants and athletes are hindered. In line with this research, the lack of a standardised starting system that provides equitable opportunities for D/deaf athletes is a clear example of how it is wider society that is disabling D/deaf participants. Technically, a D/deaf athlete should have the ability to compete to the same level as their hearing counterparts but the inaccessible starting guns and infrastructure for D/deaf inclusion in sport mean that D/deaf athletes are ostracised and forced to figure alternative starting methods. By developing an equitable starting system, access and opportunities will be afforded to D/deaf athletes and highlight that society should not discriminate against any disability and that it is possible to provide inclusive opportunities. Aside from the medical and social models of disability, it is necessary to consider sport specific and sociocultural models of disability to create a full picture.

Currently in sport, the functional model of disability is commonly accepted as the most comprehensive practice to facilitate inclusive sport (Disability Sport Wales, 2023). The functional model of disability centres around the athlete’s functional ability and what the athlete can do, encouraging a person-centred approach (Bell, 2017). Although this model of disability is becoming more prevalent in disability sport, these sport-wide practices are not as widely observed in D/deaf sport, compared to other groups in disability sport. This is likely a consequence of an overall lack of acceptance and understanding of D/deaf athletes’ abilities and

how they are able to compete, subsequently inhibiting access to participation and performance pathways within athletics.

Whilst it is imperative to consider the functional abilities and requirements of a D/deaf athlete, particularly when considering equity on the start line, it is also important to acknowledge the cultural-linguistic model of D/deafness. The cultural-linguistic model centres around the identity, integration, and self-perception of a D/deaf person in their community (Obasi, 2008) and notes that deafness is not considered as a disability, but it is something that necessitates accommodations and adaptations to ensure inclusivity (Harvey, 2008). It is important to be mindful of the cultural implications and functional ability nuances when establishing D/deaf integration and inclusion, as feelings of respect, awareness, and acknowledgment towards your D/deaf identity can lead to an increased sense of wellbeing and identity (Chapman & Dammeyer, 2017); an important factor for participation and physical activity (Irish et al., 2018) in D/deaf populations.

Understanding of the historical and sociocultural implications of these models of disability in conjunction with the current position of D/deaf sport is paramount within this research. The marginalisation and oppression of the D/deaf world has gone on for too long and it is time for D/deaf people to be prioritised and provided with equitable opportunities and solutions that are not based around ‘curing’ deafness but honour the culture, needs and inclusion of D/deaf people.

1.4 Starting Systems: Inclusive Athletics

The crux of an effective starting system is to minimise reaction time (RT), thus potentially enhancing race outcomes, so ensuring that all athletes have the best opportunity to minimise their RT regardless of their hearing level is critical. At present, auditory starting systems are inequitable for D/deaf athletes, given their inhibited ability to hear the stimulus. Similarly, visual starting systems that are typically used in D/deaf sport would likely inhibit hearing athletes due to the visual facilitation and neuroplastic adaptations often associated with D/deaf populations (Dye & Bavelier, 2013).

To encompass the sociocultural requirements of an equitable starting system, we must consider both D/deaf and mainstream perspectives. For mainstream athletics, auditory based

systems have been used as the primary starting system since 1904 (Hareendran, 2022), meaning that all world records set until now include an auditory start. It would likely be a significant challenge to divert mainstream athletics from using auditory starting systems, and it would present uncertainty around current and future records. It would be less of a significant challenge to incorporate an additional sensory stimulus such as light or vibration that works alongside the current auditory systems whereby D/deaf athletes could be included in the same race start but not be at a sensory disadvantage. With this in mind, it is essential for the future starting system to be both compatible with auditory systems, whilst still ensuring parity with D/deaf athletes, and also be the consistent standardised starting system that D/deaf sport needs.

1.4.1 Current Starting Systems in D/deaf Sport

Within mainstream and Para sport, a starting pistol is used in races regardless of the level of competition (Mitašik et al., 2021). Over the years the starting gun has developed from a pistol-type gun to electronic guns that coincide with speakers situated on each starting block (Hareendran, 2022) to mitigate for sound propagation and lane proximity differences (Brown et al., 2008; Haugen et al., 2013). There is consistency with the starting gun and systems across mainstream and para-sport, but this is not paralleled in D/deaf sport. Historically, there has been a wide range of starting systems used within D/deaf sport such as flags, shoulder taps, visual commands, different light systems and auditory signals and there is no single standardised system that is utilised across all levels of D/deaf sport.

Prior to the commencement of my PhD in 2019, I observed the European Deaf Athletics Championships (EDAC) in Germany to see an elite-level D/deaf competition and to identify the starting system being used. Prior to any races, all sprinters attended a single technical session to familiarise themselves with the starting system before the competition. For context, a newly developed light-based starting system was used at the competition, but there were several issues across the competition. The starting system comprised of a yellow/orange and red traffic light set up (see Figure 1.2) which resulted in several instances whereby athletes could not see the yellow light due to the bright sun. This led to athletes not getting into the ‘on your marks’ and ‘get set’ positions in time, delaying the start of the race. Furthermore, there were several races whereby the individual modules in lanes were faulty, significantly inhibiting the athletes in those lanes ability to start the race effectively and subsequently their race outcome. Figures 1.2 and 1.3

below highlight instances at the European Deaf Athletics Championships whereby either an athlete's individual system did not signal 'set', meaning that the athlete was held in the 'on your marks' position while all other athletes were in the 'set' position or where the 'go' light was not emitted, resulting in delayed or no starts.

Figure 1.2

Sprint Start at the European Deaf Athletics Championships 2019



Note. In this image, all athletes except lane three have been given the signal to go into the 'set' position and you can see the official walking over to lane three. In this instance, the individual module in lane three was not working meaning that the start of the race was delayed whilst this was rectified.

Figure 1.3

Sprint Start at the European Deaf Athletics Championships 2019



Note. This image highlights one instance whereby the ‘go’ light did not emit for certain lanes meaning that athletes (note lanes one and two) were held in the ‘set’ position whilst other athletes initiated their sprint start. This specific instance occurred multiple times, often in the same race and resulted in the athletes (with the faulty modules) responding to the movement of other athletes, rather than the stimulus itself.

1.4.2 Unintended Consequences of Current Starting Systems

Alongside the lack of pre-ascertained information surrounding D/deaf sport starting systems, there are several unintended consequences surrounding ineffective starting systems. From a biomechanical perspective, several starting systems (e.g., flags and visual hand signals), force athletes to adopt a starting position that is sub-optimal for peak sprint start performance due to having to lift the head. To promote peak velocity and power from the sprint start ‘set’ position, an athletes’ head, neck, and shoulders should be in a neutral alignment parallel to the floor, with their eyes towards their central line of vision on the ground (Milanese et al., 2014; Slawinski et al., 2017). Having a poorer, or less than optimal starting position can have negative impacts on force production and velocity (Nagahara et al., 2020), sprint start power (Haugen et al., 2012) and consequently, race outcomes (Coh & Tomazin, 2006).

Further inequity within starting systems arises from utilising a sensory modality that does not promote a fair start. Auditory-based starting systems are used within mainstream and para-athletics, which can ostracise D/deaf athletes who are less likely to process auditory stimuli quickly due to their hearing level. It is not uncommon for D/deaf athletes to also compete in mainstream competitions due to factors such as more organised competitions in their area, a wider athlete and competitor pool, and more opportunity (Foster et al., 2018). However, despite transition into mainstream athletics, D/deaf athletes struggle to progress through the participation and performance pathways because of the lack of access to an equitable starting system. For a starting system to be equitable, there must be no significant discrepancy in RT between D/deaf and hearing so that neither group is disadvantaged based on the stimulus presented and the result of the race is determined by sprinting ability, and not hearing level.

1.5 Reaction Time: The Basics

RT is defined as the length of time between the presentation of a stimulus and the initiation of movement (Schmidt & Lee, 2018), which in the context of sprint starts is when the pressure exerted on the starting blocks by the feet, exceeds a threshold (25kg) thus creating a detectable response, upon presentation of the starting gun or other system (Milloz et al., 2021). Sometimes, an athlete can anticipate the starting stimulus and respond before the stimulus has been presented or respond too quickly resulting in a false start. Specifically, within sprint events,

a false start is determined by the International Association of Athletics Federation (IAAF) as a RT that is quicker than 100ms (Pain & Hibbs, 2007) and can subsequently result in disqualification if the athlete repeatedly activates the starting blocks without their effectors breaking contact with the ground (Milloz et al., 2021).

In sprint events, specifically races like the 60m or 100m, RT is considered a key determinant of race outcome (Piliandis et al., 2012) and contributes to 5% of race make-up (Milloz et al., 2021; Harland & Steele, 1997). This is important as ensuring that all athletes have the greatest opportunities to exhibit fast RTs is imperative for race success. Average sport-specific RTs for simple auditory RT starting systems range from 164ms for men's 100m sprint (Delalija & Babić, 2008) to 170ms for swimming (Benjanuvatra et al., 2004). To my knowledge, there are no publicly available records displaying RTs in D/deaf sport, but existing research-based RT data for visual RTs in athlete populations range from 247ms (Soto-Rey et al., 2012) to 260ms (Tatlici et al., 2018). These values highlight the differences in RT depending on stimulus modality or population which are key elements to focus on when developing a fair starting system that promotes equity across D/deaf and hearing athletes.

1.5.1 Stimulus Modality

The type of stimulus presented, whether that be auditory, visual, or haptic, will either have facilitative or inhibitory effects on RT, complicated further when considering hearing level. Determining the stimulus modality that promotes equitable, but also fast, RTs regardless of hearing level is arguably the most critical element within this thesis. When comparing auditory, visual, and haptic RTs in hearing populations, evidence suggests that auditory stimuli typically promote the fastest RTs due to a shorter neurological processing latency (8-10ms), which is faster than visual stimuli (20-40ms) (Kosinski, 2008). For visual stimuli in hearing populations, RTs are typically slower than auditory RTs, especially when compared to D/deaf visual RTs which theoretically should be their fastest RTs, given neuroplastic adaptations and cortical hypertrophy. Haptic stimuli (e.g., vibrations to the skin) typically promote slower RTs but interestingly, data suggests that there are no significant differences in haptic RTs regardless of hearing level (Heimler & Pavani, 2014). Stimulus modality and hearing level clearly influence RT, but it is also pertinent to consider other variables, such as stimulus quantity, that provide better opportunity for equitable RTs.

1.5.2 Stimulus Quantity

Increasing the number of stimuli presented to induce faster RTs is a widely reported and substantiated phenomenon. Extensive literature, primarily focused within hearing populations, has demonstrated the benefits of adopting a bimodal stimulus to facilitate RT (Diedrich & Colonius, 2004; Forster et al., 2002; Harrison et al., 2010; Shaw et al., 2020), Diedrich and Colonius (2004) noted that presentation of a bimodal auditory and visual stimulus results in RTs approximately 10% faster compared to unimodal auditory (132-150ms dependent on decibel level which included 70, 80 and 90dB), visual (163ms), and tactile conditions (218ms). They also tested the effects of trimodal stimuli on RTs and whilst there was a difference compared to bimodal stimuli, the overall difference between unimodal and bimodal was greater than bimodal and trimodal stimuli. Based on this, it may be more practical to consider a bimodal starting system (as opposed to a trimodal system) given logistical practicalities, whilst still promoting facilitative effects on RT across athletes.

Most of the stimulus quantity and RT literature focuses on hearing populations, and it is likely that we will see differences in the facilitative effects of bimodal stimuli (particularly auditory containing combinations) in D/deaf populations due to an inhibition or reduction in the quantity of relevant stimuli available due to hearing deficits. Whilst literature is limited surrounding bimodal RTs in D/deaf populations, evidence posits that congenital and early deafness sometimes results in poorer auditory-haptic bimodal integration and subsequent slower bimodal RTs than late deafened groups (Nava et al., 2014), explained by impaired multisensory functions from an inhibited critical development period (Schorr et al., 2005). This notion will need to be taken into consideration when dissecting this thesis' empirical data and that any variations in the D/deaf population data could plausibly be explained by the level and onset of deafness i.e., a profoundly D/deaf from birth participant may display poorer cross-modal facilitation than a moderate-severe late deafened (e.g., via illness) D/deaf participant. There is significantly more existing literature focusing on bimodal RTs in blind populations and due to the proximity of the auditory and visual cortices in the brain and the specific processes within neuroplastic adaptations, evidence suggests that the cortical adaptations displayed in blind populations is somewhat mirrored in D/deaf populations, with facilitative effects seen in the intact sense (Bell et al., 2019).

1.5.3 Stimulus Location

The position, or effector, in which a stimulus is located on the body can either have a facilitative or debilitating influence on RT. More specifically in a practical setting such when an athlete is in the crouch start position during a sprint start, there is physical contact with the floor via the hands and fingertips but also on the starting blocks via the feet meaning that it is pertinent to ascertain whether implementing a haptic stimulus will be more beneficial to RT when placed on the upper versus lower extremities (i.e., start line versus blocks). There is a body of literature, specific to haptic stimuli that addresses how the stimulus location and positioning on the body and different effectors influences RT either with facilitative or detrimental effects (Harrar & Harris, 2005). It is worth noting that there is limited evidence that focuses on the relationship between haptic stimulus location and RT in D/deaf populations, but there is consistent evidence that demonstrates no significant difference in haptic RTs between D/deaf and hearing populations (Heimler & Pavani, 2014; Heimler et al., 2017).

Ho and Spence (2014) investigated the relationship between different effector locations (foot and hand) and homologous cues (shin and wrist) on haptic RTs in hearing populations. Their findings demonstrated that RTs were faster when stimulation and the homologous cue occurred at a high set-level compatible location (i.e., hand and wrist), compared to a low set-level compatible location (i.e., shin and foot). Haptic RTs were significantly slower at the lower extremities which can be explained via longer conduction latencies and distance between the stimuli and the brain (Harrar & Harris, 2005) as well as a decreased sensitivity comparative to the hands (Weinstein, 1968). Furthermore, Forster et al., (2002) highlighted faster haptic RTs when a unimodal bilateral stimulation was initiated. Given the fundamentals of an equitable but fast starting system, it may be suitable to adopt a bilateral haptic stimulus at the hands or wrists as this will provide the optimal opportunity for fair RTs between D/deaf and hearing populations.

1.6 Neuroplasticity and Sensory Integration

It has been established that there are differences in RTs between D/deaf and hearing populations depending on the sensory stimulus presented and understanding the underpinning mechanisms explaining these differences in RT. In D/deaf populations, there are several theories and models that explain how the deficit of one sense such as hearing leads to a facilitation of

another sense, most typically vision. These visual adaptations span wider peripheral visions (Loke & Song, 1990), faster visual stimulus location and detection (Bottari et al., 2010; Shiell et al., 2014), and most importantly for the context of this thesis, faster visual RTs (Codina et al., 2017; Bottari et al., 2011). These adaptations are characterised by a reorganisation of the auditory cortices with a hypertrophy of the visual cortices, with the visual cortices becoming the predominant sensory cortical area in the brain (Scott et al., 2014; Dye & Bavelier, 2013). This visual hypertrophy results in a larger activation network and stronger pathways between visual input and processing. D/deafness is a spectrum and there are many causes of D/deafness that can occur at any stage of life such as gestational development issues, illnesses such as meningitis or mumps, genetic and hereditary conditions, or sudden onset deafness to name a few (Nance, 2003; Yung et al., 2011; Dye & Bavelier, 2013; Na et al., 2014). Due to many causes of deafness and the spectrum within deafness, this means that the neuroplastic adaptations may yield similarities between similar types of deafness but the extent of neuroplasticity across the entire population is largely individualised. Research suggests that neuroplastic adaptations that take place during ‘critical’ growth periods during development and once these sensitive periods for multisensory integration have passed, there is a more significant impairment of multisensory processing (Putzar et al., 2007).

Several theories have been presented to explain why and how neuroplasticity occurs and often take a compensatory or deficit approach. One deficit theory is the hypothesis of the division of labour (Mitchell, 1996), which suggests that due to a deficit in hearing, the visual system has a higher recruitment of other functions, resulting in a division of labour between visual and auditory functions, resulting in visual deficits. A more commonly accepted, and observed theory is Parasnis’ (1983) perceptual compensation framework whereby the deficit of one sense, such as hearing, results in a facilitation of another sense e.g., vision. It is plausible that the individual neuroplastic differences could result in differing levels of sensory facilitation following sensory deprivation. Overall, loss of hearing leads to neuroplastic adaptations, and subsequently, varying RTs, reinforcing the need to establish the sensory modality that promotes equity between D/deaf and hearing populations to mitigate for these differences.

1.7 Thesis Rationale and Aim

This thesis has significant applied implications and has potential to generate tangible impact in athletics. Within this thesis, I have identified a major barrier across D/deaf and mainstream athletics and have developed a body of work that provides an evidence-based solution to a real-world problem. Previous attempts to address the lack of a standardised starting system in D/deaf athletics have been supported with limited evidence and subsequently have not had great levels of success in relation to consistency of implementation and utilisation. To my knowledge, this is the most comprehensive body of research that addresses several critical components of an effective and equitable starting system (i.e., stimulus location, stimulus modality and stimulus quantity across populations) with a strong focus on the practical implementation of the starting system across mainstream and D/deaf sporting environments. The practical nature and outcomes of this thesis heavily drives the rationale and justification for this research.

The paramount aim and intention of this thesis is to inform the development of an evidence-based standardised starting system that ensures equitable starts between D/deaf and hearing athletes. This will ensure parity, access, and opportunity for D/deaf athletes to enhance grassroots participation and access to the Olympic performance pathways, via access to a consistent, standardised starting system in D/deaf athletics at all levels of competition (e.g., community level competition and elite international sport such as the Deaflympics). Successful implementation of a standardised starting system will catalyse access, opportunity and provision for D/deaf athletes and allow talented D/deaf athletes to have a better chance of reaching elite-level athletics, regardless of their ability to hear. The development of a standardised starting will create positive legacy in D/deaf sport, but it is pertinent to acknowledge that this is only one piece of the jigsaw, and it will take extensive efforts to dispel the dichotomies and inequities faced by D/deaf athletes to create a truly inclusive environment in athletics and wider sporting environments.

1.8 Theoretical and Philosophical Standpoint

I have adopted a mixed methods approach to this thesis, with both quantitative and qualitative methodologies, resulting in a multifaceted philosophic standpoint. From a quantitative

perspective, I have largely adopted a pragmatist research philosophy as I believe that the current problem, and solution, of the lack of a standardised starting system in athletes, needs to inherently be driven by evidence and empirical data in order to be robust and sound in its foundations (Morgan, 2013). In addition to this, due to my lived experience of being Deaf, I am hugely driven by the experiences of my upbringing and those around me in the D/deaf sporting community, resulting in an interpretivist research philosophy (Denzin & Lincoln, 2005). Due to the nature of this research and its significant potential impact on a worldwide scale, a combination of my personal drive and passions with ensuring a sound evidence-based solution has allowed this research to thrive and realise its true impact both within wider sport and society and the wider academic field.

Within the qualitative elements of this thesis and research, the constructivist epistemological standpoint is more prominent due to the sociocultural implications and perceptions of the research questions and aims (Andrew et al., 2019). Furthermore, due to the individual experiences of, and perceptions expressed, by each participant means there is subjectivity within the qualitative element to this thesis as the findings are largely deductive and exploratory due to the novelty in the research questions. Overall, the theoretical and philosophical standpoint of this thesis create a sound underpinning for an evidence-based, robust, and passion-driven thesis and body of research that has the potential for huge real-world and applied impact.

1.9 Thesis Structure

This thesis is presented as a series of manuscripts aimed to develop a holistic and thorough body of work in line with the project aims. Chapter 2 examines the importance of haptic stimulus location on RT in D/deaf and hearing populations. This informs the development of the studies in Chapter 3 and provides key knowledge regarding the benefits of positioning a haptic stimulus on the start line compared to within the starting blocks. Chapter 3 builds on the previous chapter and explores the influence of stimulus modality (auditory, visual, and haptic) and stimulus quantity (unimodal vs. bimodal) in both an internally valid environment (Experiment One) and an ecologically valid environment (Experiment Two). The experiments in Chapter 3 identify the optimal stimulus modality that promotes equitable RTs between D/deaf and hearing populations to inform the development of a standardised starting system. Chapter 4

presents a qualitative exploration into the experiences of D/deaf sprinters, the coaches/team managers of D/deaf sprinters and stakeholders with focus on the starting systems used retrospectively, experiences in athletics and recommendations for the future starting system. Chapter 5 provides a general discussion of the theoretical and applied implications and recommendations based on the evidence presented in this thesis to establish the key requirements for an equitable and practical standardised starting system.

Chapter 2:

Haptic stimulus location and hearing level: the importance of high set-level compatibility for equitable reaction time across D/deaf and hearing populations.

2.1 Abstract

Scan the QR code below to access a British Sign Language version of this abstract.



Introduction: Within D/deaf sport, haptic-based starting systems such as vibrating armbands have been used as a method for providing more equitable opportunities and accessible communication in team-based D/deaf sport such as football. For athletics-based systems, we wanted to determine whether it would be more beneficial to present a vibration to the hands (i.e., on the start line) or to the feet (i.e., within the starting blocks) when considering equitable reaction times (RTs) between D/deaf and hearing populations. Literature suggests that whilst haptic RTs are typically slower than visual and auditory RTs, there is no significant difference between haptic RTs across D/deaf and hearing populations. Research suggests that adopting a higher set-level compatible stimulus location e.g., hands/wrists, promotes faster RTs compared to lower set-level stimulus locations such as the shins/feet. The overarching aim of the present chapter is to identify the haptic stimulus location that promotes the most equitable RTs between D/deaf and hearing populations to inform the development of future research studies (Chapter Two). This will contribute to the development of a standardised starting system that creates equitable opportunities for all athletes on the starting line. Methods: Four stimulus effector locations were tested: right hand (RH), left hand (LH), both hands (BH) and both legs (BL). Each stimuli required participants to perform a rapid target-directed aiming movement via an upper limb manipulandum. Participants (D/deaf n=16; hearing n=14) had three practice trials of each stimulus location followed by four counterbalanced blocks of 20 experimental trials, with one

stimulus condition per block. Results: Findings showed a significant main effect for Stimulus Location, and no significant main effect for Group or interaction between Stimulus Location \times Group. The significantly slowest RTs were displayed by BL (compared to all hand conditions). Results showed a non-significant RT difference between the RH, LH and BH. Discussion: RTs were faster when a haptic stimulus was presented to the hands compared to the legs. Furthermore, the current dataset demonstrated no significant differences in haptic RTs between D/deaf and hearing populations. This provides sound empirical evidence and direction for future study development (Chapter 3), and scope for the inclusion of haptic stimuli when considering the sensory composition of a starting system that ensures equity across D/deaf and hearing populations.

2.2 Introduction

Endeavours to enhance inclusivity and equality in both mainstream and para-sport populations have not been extended to D/deaf athletics. The primary route for D/deaf athletes to participate and compete is via the Olympic (and not Paralympic) pathway, wherein D/deaf athletes are required to compete alongside their hearing counterparts using auditory starting systems⁴. Subsequently, the prevalence of D/deaf athletes competing in mainstream events is minimal, with considerable barriers in place for these individuals (Kurkova et al., 2011). One contributory factor here is likely the absence of an evidence-based standardised starting system, a critical part of ensuring inclusion in an ever-growing egalitarian society. This has implications for athlete's reaction times (RTs) and can subsequently influence race outcomes. Based on the notion that haptic RTs show little variability across D/deaf and hearing populations (Heimler & Pavani, 2014), this seems a worthy avenue to pursue, especially given that haptic-based armband systems have already been trialled in athletics (Shitara et al., 2018) as well as other sports such as football. However, these systems have been developed with limited theoretical rationale, and neglect to consider integration of alternative sensory configurations via uni- and bi-modal sensory stimuli (i.e., how these systems might be integrated alongside other auditory or visual-based systems). Whilst evidence supports negligible differences in haptic RT between D/deaf and hearing populations (Heimler & Pavani, 2014), there is evidence to suggest that haptic stimulus and effector location does influence RTs in hearing subjects (Ho & Spence, 2014). However, this is yet to be tested in D/deaf populations. Thus, the present chapter aims to provide a more rigorous and comprehensive test of haptic systems, with consideration of set-level compatibility (i.e., to inform whether a stimulus should be located on the upper versus lower extremities) and uni- versus bi-lateral stimuli (i.e., to inform whether stimuli should be placed on single or multi limbs).

Primary mechanisms underpinning RT differences between D/deaf and hearing populations tend to relate to neuroplastic adaptations in the visual cortices (Dye & Bavelier,

⁴ A common performance pathway for D/deaf athletes is the Deaflympics and whilst this provides opportunity for inclusive international competition, due to a lack of funding and awareness, the Deaflympics does not receive the same level of recognition and prestige as competing in the Olympics. D/deaf athletes can only compete in the Paralympics if they have another classifiable disability e.g., limb deficiency or cerebral palsy. There is no set classification for D/deaf athletes in the Paralympics.

2013), typically a consequence of auditory deprivation in D/deaf individuals. For example, enhanced RTs to visual stimuli for D/deaf individuals are widely acknowledged in the literature (Codina et al., 2017; Loke & Song, 1990). However, with evidence supporting limited differences between D/deaf and hearing populations when using haptic stimuli (Heimler & Pavani, 2014; Heimler et al., 2017), research to understand any mechanistic differences has subsequently, often been disregarded. Interestingly, Levänen and Hamdorf (2001) noted that congenitally deaf participants displayed an increased sensitivity to tactile stimuli, characterised by an enhanced ability to detect tactile suprathreshold frequency changes. This facilitation can be explained via cross-modal plasticity of the supratemporal auditory cortical areas, a phenomenon that occurs when there is deprivation in one sensory modality which results in facilitation of other areas of the brain. In a real-world context, the enhanced ability to detect vibrotactile changes in D/deaf populations is highlighted when there are vibrations alongside loud noises, providing important contextual information in lieu of auditory input (Levänen & Hamdorf, 2001). Although this notion may not overtly relate to RT, ensuring that no population has a sensory advantage over the other on the starting blocks is integral to an equitable starting system.

Similarly, different stimulus effectors and locations can influence haptic RT (Forster et al., 2002; Ho & Spence, 2014). Findings from Ho and Spence (2014) revealed significantly faster RTs when haptic stimuli were presented to the wrist compared to the shin, in a series of spatial discrimination tasks utilising thumb-pressing and foot-peddalling as the response action. Moreover, findings showed consistently faster RTs at the wrist stimulus and effector location compared to when the target response involved the feet, which is known as spatial discrimination. Collectively this evidence suggests haptic stimulus detection, discrimination, and RTs are typically faster at the wrists compared to the lower extremities. This is important when considering the mechanics of an effective starting system where the aim is to optimise the stimulus location i.e., on the starting line or on the starting blocks, as to minimise RTs will maximise performance.

Ensuring the optimal stimulus location is pivotal for a starting system and distinguishing the ideal set-level compatibility between the stimulus and response is crucial. When the stimulus-response pair are of the same effector location, responses can ensue without interference (Halvorson & Hazeltine, 2019). In a starting system, this could be integrating the stimulus

location with the key biomechanical elements of a sprint start to optimise set-level compatibility, for example, hands on the starting line. The significance of set-level compatibility is highlighted when there is homology between haptic stimuli positioning and corresponding effector compared to non-homologous stimulus position and effector (Ho & Spence, 2014). Neurological mechanisms have been used to account for set-level compatibility findings. For example, faster RTs to homologous higher set-level compatible pairs can be explained by shorter neural conduction latencies, meaning the closer the vibrotactile cue and response location are to the brain, the faster the RT (Campbell et al., 1981). In support of this, Ho and Spence (2014) observed that haptic stimuli located more distally to the brain, such as the feet, produced slower RTs than stimuli located proximal to the brain. Additional evidence suggests that haptic RTs increase linearly in latency with increasing distance between the site of stimulation and the somatosensory cortex in the brain (Harrar & Harris, 2005). As well as considering set-level compatibility when developing an effective starting system, it is also important to consider the spatial compatibility of the stimulus and response to maximise sprint start performances.

When an athlete is in the crouch sprint start position, they have physical contact with the start line (via their hands) and the starting blocks (via their feet), and it is important to ensure that the positioning of the stimulus does not inhibit fast RTs due to incompatible locations. More specifically, spatial compatibility is associated with faster RTs when the stimulus and response occur on the same (compatible) side (Ho & Spence, 2014) e.g., via the Simon effect. Wherein RTs are faster when the stimulus and response occur at the same location as opposed to opposite sides. This effect even occurs when the stimulus location is irrelevant to the task (Leuthold & Schroter, 2006).

Importantly, stimulus location (e.g., upper versus lower proximities), can also influence stimulus sensitivity and subsequently intensity. Ackerley et al., (2014) noted that palms are more sensitive to the presentation of a haptic stimulus than other parts of the body such as the shin, thus suggesting that haptic stimulus thresholds and sensitivity may vary across effector locations. In the case of a sprint start, stimuli located on one or more hands should thus, result in faster haptic RTs. Not surprisingly, the presentation of multiple simultaneous stimuli also consistently promotes faster RTs (Diederich & Colonius, 2004). Forster et al., (2002) found haptic RTs are

facilitated when presented with a double unimodal stimulus, i.e., both hands, compared to a single unimodal stimulus i.e., one hand.

Similarly, when stimulus intensity and set-level compatibility are considered in the context of one another, RTs are faster when stimulus intensity is increased at a compatible stimulus-response location. Hasbroucq and Guiard (1989) tested the relationship between stimulus intensity (strong versus weak), compatibility (compatible versus incompatible) and RT in a finger and thumb tapping task. Their findings noted that when haptic stimulus intensity was increased, specifically at a compatible location (between-hands), RTs were faster compared to an increased intensity at an incompatible location (within-hands). In line with the current aims, it is pertinent to ensure that the haptic stimulus is of an appropriate intensity (as to not inhibit RTs) and has high compatibility with the response (i.e., the sprint start). Overall, these findings provide further insight into the optimal set-up of a starting system, notably the presentation of a bilateral unimodal haptic stimulus.

In line with this, a large proportion of the haptic RT and stimulus compatibility research methodology adopts the hands, fingertips, and wrists (Forster et al., 2002; Hanson et al., 2009; Hecht et al., 2008; Levänen & Hamdorf, 2001; Ho & Spence, 2014). Ho and Spence's (2014) fastened vibrating tactors to the back of participant's wrists and their shins using Velcro, with the primary response task being a manual finger key response and a foot pedal. Whilst this research is helpful in better understanding some important complexities underpinning the RT literature, it is arguably limited in the extent to which studies have adopted ecologically valid tasks and environments to test these phenomena. Thus, the current study will utilise a larger movement-based task to reflect the explosive nature of a sprint start. Similarly, testing these effects with D/deaf participants is warranted, due to limited existing evidence including D/deaf populations. This will best inform the development of a standardised starting system, and ultimately ensure equity between D/deaf and hearing athletes.

The aims for this chapter were threefold: to (1) investigate haptic RT differences between D/deaf and hearing populations; (2) identify any differences between different set-level compatibilities (i.e., hands versus legs) between D/deaf and hearing populations; and (3) investigate differences between unimodal unilateral and bilateral stimulus locations i.e., singular hands versus both hands. Findings will be used to inform optimal effector location of haptic

stimuli when comparing to alternative stimulus modalities e.g., auditory, and visual stimuli, in Chapter 3. We hypothesised that there would be no significant difference in RTs between D/deaf and hearing groups regardless of stimulus location and quantity, but faster RTs when participants were presented with a hand-specific double unimodal haptic stimulus compared to a leg-specific haptic stimulus.

2.3 Methods

Participants

Thirty participants (hearing $n = 14$, M age = 25.6 years, six males; D/deaf $n = 16$, M age = 33.9 years, eight males) volunteered to participate in the current experiment. Hearing participants were required to not have a medically diagnosed or known hearing loss, and D/deaf participants were required to have a medically diagnosed hearing loss of at least 55dB in their better hearing ear. This threshold is in line with the International Committee for Deaf Sport (ICDS) policy for competition (International Committee for Deaf Sport, 2018). G*Power 3 (G*Power 3; Faul et al., 2007) sample size estimation deemed 16 participants necessary to provide power = .95 for the interaction between stimulus modality and hearing level when $\alpha = .05$ and $\eta_p^2 = .33$. All participants gave their full informed consent prior to taking part in the current study and were provided with an in-depth participant information sheet. The experiment was conducted in accordance with the academic institution's ethical guidelines for research involving human participants.

Task and Apparatus

Participants were seated in front of a purpose-built upper limb aiming manipulandum (see Figure 2.1) and interacted with the manipulandum in the horizontal plane at shoulder height. The manipulandum consisted of an arched target display, a two-dimensional free moving axis situated under the elbow of the moving limb, and an arm support that extended from the elbow to the hand. Participants placed their right arm onto the manipulandum with their elbow located directly over the free moving axis. The arm was then secured using Velcro straps positioned over the wrist and forearm. An aiming marker at the end of the arm frame (designed to represent a pointing index finger) finished approximately 2 mm from the manipulandum's target display. The target display consisted of a start position and a target region. The start position was

indicated by a green light (10 mm in diameter) that was located on the right of the target display directly in line with a neutral position of the right arm (when the arm was bent at 90°). The target region was positioned 50° to the left of the start location and consisted of a red light (10 mm in diameter) with a 10° bandwidth. At the start of each trial, once participants positioned the aiming marking in line with the start location, the trial was started via the computer software, followed by a variable foreperiod (500-1500ms), upon which participants were required to respond as fast and accurately as possible by moving from the start location to the target as fast and accurately as possible. Participants were fitted with four 16 ohm Dayton Audio TT25-19 circular haptic tactors (8.55 × 2.55 cm) that emitted a frequency of 50Hz that were secured with a Velcro strap. Tactors were positioned on each palm and each shin (see Figure 2.2).

Figure 2.1

Laboratory Set-Up: Manipulandum and Haptic Tactors

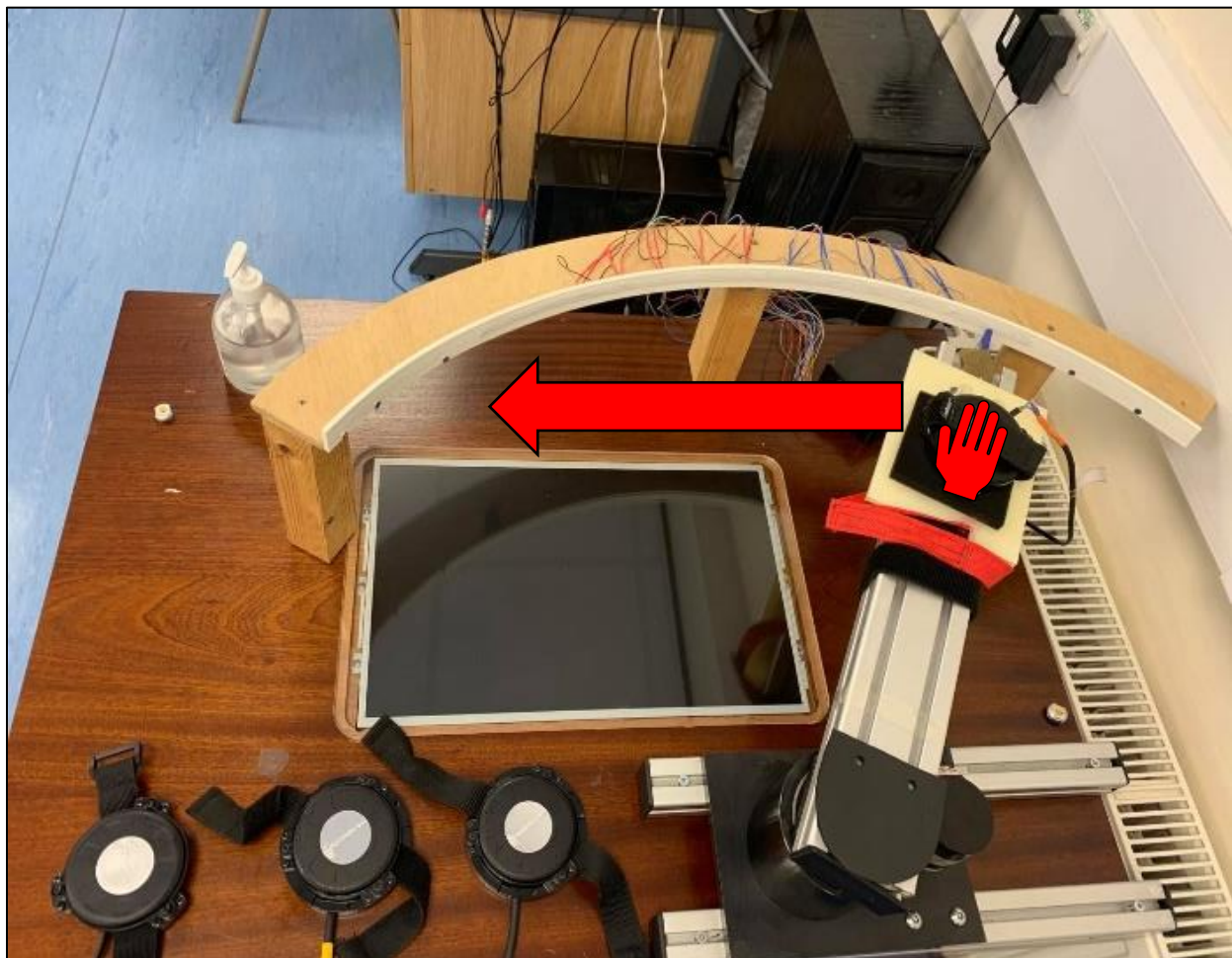
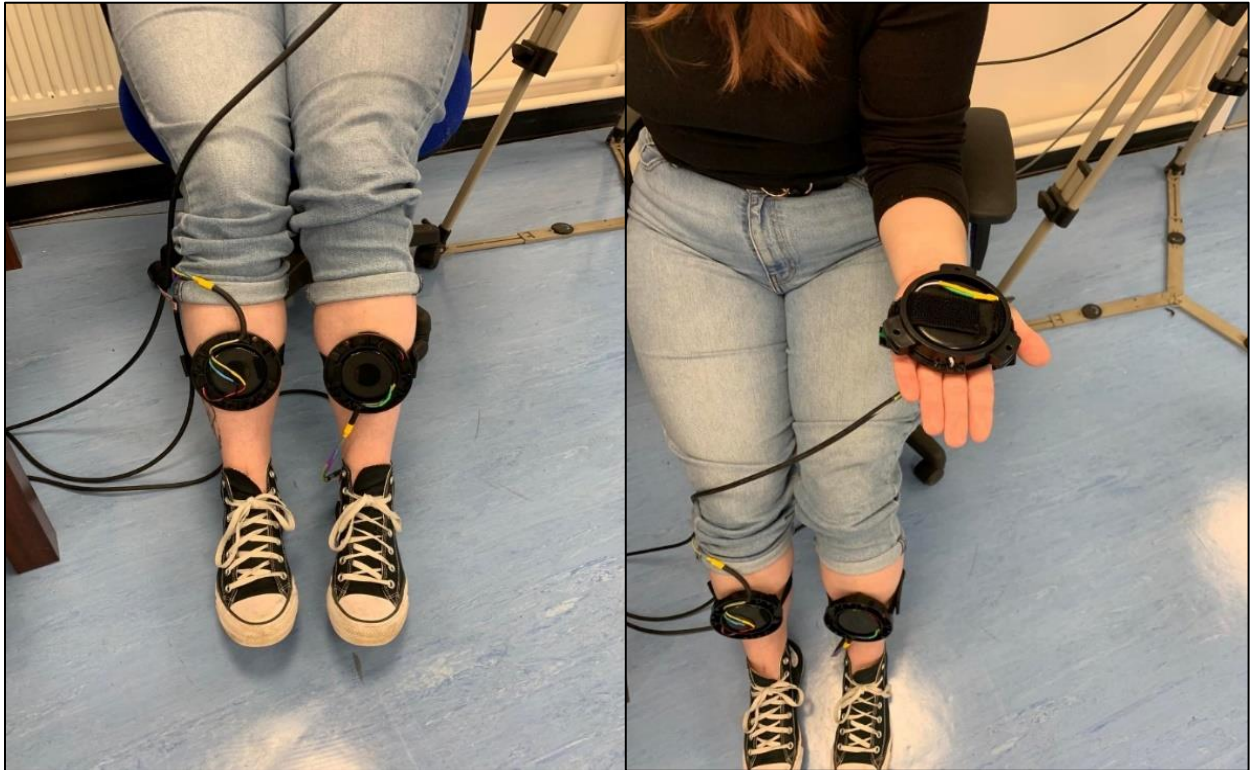


Figure 2.2

Haptic Tactor Positioning



Note. The above images display the haptic tactor positioning for the current study. The image on the left displays the tactors positioned on the legs and the image on the right displays the tactor positioned on the left hand. The tactor for the right hand was located on the manipulandum arm and participants positioned their hand on top of the tactor.

Procedure

The simple RT task began when participants were presented with a haptic stimulus from one of the four effector locations: the right hand; left hand; both hands; and both legs, with conditions counterbalanced (see Figure 2.3). Participants were given three practice trials of each stimulus location to ensure that they were familiarised with the task and could successfully perform the inwards arm movement on the manipulandum. The experiment was comprised of four stimulus effector location conditions, which were right hand, left hand, both hands and both legs. The experimental testing took place over one session which lasted for approximately one hour. After the practice trials, participants completed four counterbalanced blocks of 20

experimental trials. Participants were given the option of a short break in between blocks to minimise fatigue and familiarisation of stimuli.

Figure 2.3

Haptic Stimulus Effector Locations and Experimental Blocks

D/deaf			
Right Hand × 20 trials	Left Hand × 20 trials	Both Hands × 20 trials	Both Legs × 20 trials
Hearing			
Right Hand × 20 trials	Left Hand × 20 trials	Both Hands × 20 trials	Both Legs × 20 trials

Counterbalanced Block Order

Note. Participants were given three practice trials of each stimulus location.

Dependent Measures and Analyses

Individual trials whereby RTs deviated by >2SD from the given participant's trial overall mean for that stimulus location were removed from the dataset prior to analysis.⁵ The primary dependent measure was RT (ms). Post outlier removal, a 2 (Group: D/deaf, hearing) × 4 (Stimulus Location: right hand, left hand, both hands, and both legs) ANOVA was performed on all RT data. Subsequent to the initial 2-way ANOVA (Group × Stimulus Location) analysis, any significant between-subject effects were broken down using Tukey's HSD post hoc tests, whilst significant within-subject effects were broken down into their simple main effects.

⁵ For the D/deaf participant dataset, 129 out of 1280 RT values were highlighted as outliers, accounting for approximately 5% of trials. For the hearing participant dataset, 120 out of 1120 trials were highlighted as outliers, accounting for approximately 5% of trials.

2.4 Results

Thirty participants (D/deaf: n=16, hearing: n=14) completed the experiment, with no participants removed from the analysis. The separate group mean RTs and standard deviations for all stimulus locations are displayed in Table 2.1.

In line with experimental hypotheses, there was no significant main effect for Group ($F_{1,29} = 4.060, p < .054, \eta^2 = .127$), indicating no difference in haptic RTs between D/deaf and hearing populations. Furthermore, results revealed a significant main effect for Stimulus Location ($F_{1,29} = 5.392, p < .002, \eta^2 = .16$) whereby, both groups responded significantly slower to haptic stimulation at both legs compared to the right hand ($p < .034$), left hand ($p < .021$), and both hands ($p < .009$) (see Figure 4). There was no significant difference in haptic RTs between right hand, left hand, and both hands ($p < 1.000$). Finally, there was no significant Stimulus Location \times Group interaction ($F_{1,29} = .799, p < .498, \eta^2 = .028$) with both groups following a similar trend in RT patterns as shown in Figure 2.4.

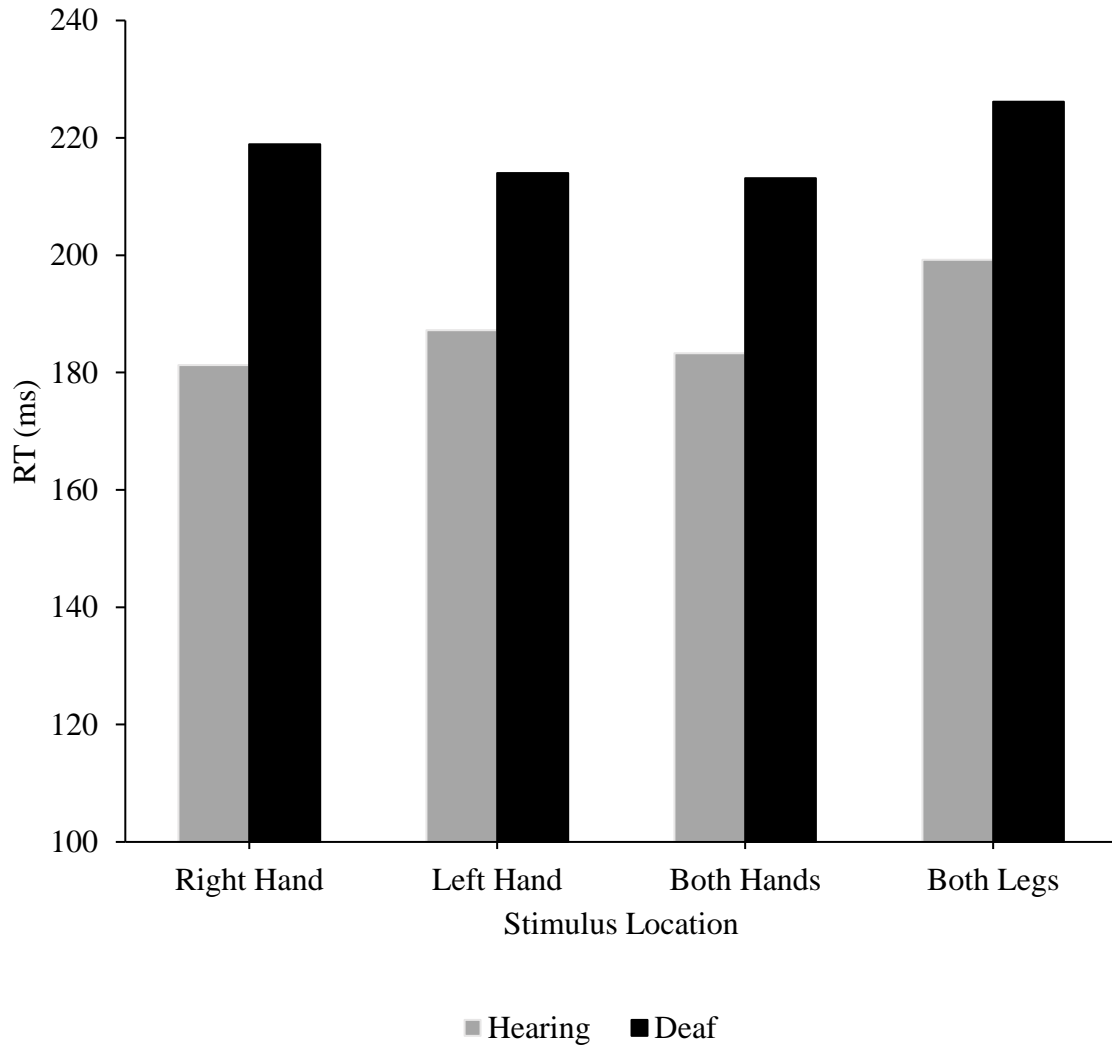
Table 2.1

Mean Reaction Times and Standard Deviations of all Haptic Stimulus Locations for D/deaf and Hearing Groups.

	D/deaf (n=16)	Hearing (n=14)
Stimulus Modality	RT (ms) and <i>SD</i>	RT (ms) and <i>SD</i>
Right Hand	218.9 (48.48)	181.27 (21.41)
Left Hand	214.02 (55.25)	187.22 (30.72)
Both Hands	213.13 (57.42)	183.27 (30.56)
Both Legs	226.14 (51.46)	199.22 (26.12)

Figure 2.4

Mean Reaction Times for All Haptic Stimulus Locations for D/deaf and Hearing Groups



2.5 Discussion

The present study formed an integral part of identifying the appropriate location for a haptic stimulus, if selected as part of the wider project goals to inform a standardised starting system that promotes equity between D/deaf and hearing athletes. The aim was to identify the stimulus location that promoted the most equitable RTs between D/deaf and hearing populations, whilst also considering RT speed, so as not to impede typical simple RTs observed in a sprint

start. For context, in a sprint start position, there are four primary points of contact between the start line (i.e., hands / fingertips) and the starting blocks (i.e., the feet). When considering the mechanical make up of a standardised starting system *if* (based on evidence collected across this thesis) the system was to contain a haptic stimulus, we wanted to ensure that the stimulus was in the optimal position to promote equitable and fast RTs without unintentionally impeding the effectiveness of the sprint start system. To determine this, we adopted a three-pronged approach: firstly, we wanted to compare haptic RT differences across D/deaf and hearing populations; secondly, to investigate any differences as a function of varying set-level compatibilities (i.e., hands versus legs) between D/deaf and hearing populations; and finally, we wanted to determine whether there were differences between unimodal unilateral and bilateral stimulus locations i.e., singular hands versus both hands. By addressing these questions, we can determine the optimal haptic stimulus location that can be implemented into an equitable starting system that ensures parity between D/deaf and hearing athletes.

In line with these objectives, we tested RTs between D/deaf and hearing populations across four stimulus locations: the right hand, left hand, both hands, and both legs. Based on existing evidence regarding set-level compatibility (Ho & Spence, 2014) the Simon effect (Leuthold & Schroter, 2006) and multi-stimulus facilitation (Diederich & Colonius, 2004), we hypothesised that the fastest RTs would be produced by both hands, regardless of group. We also predicted that there would be no significant difference in haptic RTs across groups, as noted by Heimler and Pavani (2014), which was supported in the current findings. Both of these hypotheses were largely supported by the current findings as there was no significant difference in haptic RTs between groups and overall, RTs were faster at the hands compared to the legs, with some theoretical nuances between the right hand, left hand, and both hands condition, which will be discussed. More specifically, results demonstrated no significant difference in RT across the right hand, left hand, and both hands condition, and whilst this does not wholly support the original hypothesis, it does provide important practical information as the non-significant RT discrepancy between the unimodal hand locations and bimodal stimuli highlights that on the starting line, RT would not be negatively impacted regardless of whether the stimulus is presented under the left, right or both hands.

Furthermore, regardless of group, haptic RTs to both legs were consistently significantly slower than haptic RTs at the hands (unimodal and bimodal). This provides support for the relationship between set-level stimulus-response compatibility and faster RTs. Existing evidence consistently notes faster RTs when stimuli are presented at a compatible response location (Aglioti & Tomaiuolo, 2000; Wright et al., 2019). It was expected that the ‘both hands’ condition would promote significantly faster haptic RTs than all other conditions due to the facilitative effect of an increased stimulus quantity and the wealth of existing literature supporting this notion (Diederich & Colonius, 2004; Miller & Ulrich, 2003; Rach et al., 2010). However, we did not find this and found that there was a negligible difference between the bimodal and unimodal high set-level effector conditions. This could be explained by several notions. Firstly, there was a high stimulus-response compatibility within the right-hand condition as the task required a right-arm movement; stimulus-response compatibility has shown to decrease RTs (Hasbroucq et al., 1989) compared to when there is a low, or incongruent stimulus-response compatibility (Proctor & Vu, 2006). Furthermore, Gupta et al., (2022) noted that when presented with an incongruent tactile stimulus-response pairing at a low set-level compatibility, RTs were slower and less accurate than when the tactile stimulus-response pairing was congruent. In line with the current findings, this provides support for the disparity between hand-specific and leg-specific RTs and could also provide an explanation for the negligible RT difference between the hand-specific conditions.

A further explanation for the negligible RT differences between the hand-specific conditions could be unintentional effects of tactile gating. Tactile gating can also influence tactile sensitivity and subsequently haptic RT. This is a concept whereby the presence of vision facilitates haptic RT (Tipper et al., 2001), due to integration of the sensory axons in cortical multisensory areas (Colino et al., 2017). However, this finding is more prevalent in tasks where subjects are ‘reaching’ or ‘grasping’ a haptic stimulus as opposed to singular movement-based RT tasks. With this in mind, it is important to account for the potential influence of visual availability on haptic RT, particularly as the arm and manipulandum were not occluded during the experiment so despite being instructed to focus ahead and to not look at their arm, participants may have had some visual availability of their arm, inducing similar RTs in the unimodal and bimodal hand conditions.

In line with the overall aim of this PhD which is to inform the development of a standardised starting system that promotes equity and consistency between D/deaf and hearing athletes, the findings from this chapter provide sound evidence and scope for implementing a haptic stimulus within the starting system. The findings from this chapter demonstrate that haptic RTs to the hand are significantly faster than haptic RTs to the legs, thus we can confidently say that a starting line haptic stimulus presentation would be more practical and promote faster haptic RTs compared to a starting block haptic stimulus presentation and would not impede athletes' sprint start performance. Furthermore, there was no significant difference between D/deaf and hearing groups, thus providing further good support and direction for the eventual starting system and suggests scope for inclusion of a haptic stimulus within the starting system. The original discussion and development of the current study questioned whether it would be more practical and effective to include a haptic stimulus on the start line with fingertip stimulation or within the starting blocks and stimulus via the feet, as incorporating a new stimulus into the existing starting blocks may be a more feasible option for widespread implementation. However, in line with the current findings, it would be more practical and equitable to incorporate the haptic stimulus on the start line to optimise RTs between D/deaf and hearing athletes.

It is worth noting that whilst the current evidence provides strong support for the use of a haptic-containing starting system due to the parity between populations, haptic RTs are typically slower than auditory RTs (Hernandez et al., 2005; Ng & Chan, 2012) starting pistols and auditory stimuli are consistently used in mainstream athletics, with all world records being set with an auditory stimulus. This is pertinent as implementation of a haptic-containing starting system would promote equity and create a level-playing field between D/deaf and hearing athletes, it could potentially create a decline or plateau in new world records due to the delay in RTs. However, the aims of this study (and PhD) were to identify the haptic stimulus location that promotes the fairest RTs, the question of identifying a fair *and* fast stimulus modality will be considered in the subsequent chapters and in future research.

Little existing comparative evidence between D/deaf and hearing populations, specifically related to haptic RTs which yielded a more exploratory nature to the hypotheses. Whilst we know about the facilitative effects of increased stimulus quantity (Diederich &

Colonus, 2004) and utilising a higher set-level compatible stimulus on RT (Ho & Spence, 2014), there is little empirical research that actively includes D/deaf populations and provides a comparison between D/deaf and hearing populations. To our knowledge, this is the first comprehensive empirical evidence that compares the influence of haptic stimulus location on RT across D/deaf and hearing populations. However, the current evidence does support the existing literature which notes that typically, there are no overall RT differences between D/deaf and hearing populations (Heimler & Pavani, 2014) and provides interesting insight into the relationship between haptic stimulus location and RT.

To conclude, haptic stimulation to the hands, regardless of whether it is a unilateral or bilateral stimulus promotes fast and fair RTs between D/deaf and hearing groups. This provides sound support and direction for haptic stimulus placement for future studies and good justification for adopting a haptic-based starting system to promote equitable starts between D/deaf and hearing athletes.

Chapter 3:

Fair starts for all: understanding multisensory reaction time differences between D/deaf and hearing populations to inform the development of an evidence-based standardised athletics starting system.

3.1 Abstract

Scan the QR code below to access a British Sign Language version of this abstract.



Introduction: Current starting systems in D/deaf and mainstream athletics are predominantly visual and auditory based. A D/deaf athlete who wants to access the mainstream pathways of competition does not have equal opportunity for a fair start due to the inclusion of auditory stimuli (e.g., the starting pistol). Within D/deaf sport, there is no evidence-based starting system that is consistently used across every level of D/deaf sport. In addition, RTs vary across D/deaf and hearing populations due to stimulus modality, stimulus quantity and hearing level, exacerbating the need to develop a system that results in RT parity across populations. Furthermore, little existing research has compared multi-sensory RTs between D/deaf and hearing populations. The aim of this chapter is to identify the sensory modality that consistently promotes equitable RTs between D/deaf and hearing populations. Findings will inform the development of an evidence-based standardised starting system that will provide consistency across all levels of D/deaf sport and offer equal access for D/deaf athletes in mainstream athletics. *Methods:* Both experiments included unimodal auditory (hearing group only), visual, haptic, and bimodal auditory-visual, auditory-haptic, and visual-haptic stimulus conditions. D/deaf participants did not complete the unimodal auditory stimulus condition in either experiment one or experiment two. *Experiment One:* For Experiment One, upon presentation of the sensory stimulus, participants (hearing: n=22, D/deaf: n=17) completed a rapid arm movement along a manipulandum. Stimulus conditions were presented in counterbalanced

blocks of 20 trials. *Experiment Two:* For Experiment Two, participants (hearing: $n=7$; D/deaf: $n=7$) completed an athletics-style sprint start upon presentation of the sensory stimulus with stimulus conditions presented in counterbalanced blocks of six trials. *Results: Experiment One:* Results showed a significant main effect for stimulus modality, group, and a significant Stimulus Modality \times Group interaction. In line with literature, bimodal RTs were significantly faster than unimodal RTs. Whilst visual and haptic stimuli conditions revealed non-significant statistical differences, RTs in the visual-haptic condition produced the fastest non-significant difference in RT. *Experiment Two:* Results revealed a significant main effect for stimulus modality and a significant Stimulus Modality \times Group interaction. Specifically, bimodal RTs were faster than unimodal RTs, and only the unimodal visual stimulus condition revealed significantly faster RTs for D/deaf participants. Importantly, as in Experiment One, there were no significant differences in RT between the D/deaf and hearing groups when presented with a bimodal visual-haptic stimulus. *Discussion:* Overall, the current findings provide scope and direction for the development of an equitable standardised starting system. Both experiments identified non-significant RTs between D/deaf and hearing participants in the bimodal visual-haptic condition. These data provide robust evidence that this is the optimal sensory modality from which to design an equitable athletics-based starting system.

3.2 Introduction

In D/deaf sport, no single standardised starting system exists to provide equitable starts between D/deaf and hearing athletes. The current starting systems include the separate and/or combined use of flags, haptic vibration bands, and visual light systems. However, these are not empirically tested and do not consider differential effects on RT - the critical component of *fast starts* (which are influenced by stimulus modality) and an important component of sprinting success. In line with this, literature demonstrates a disparity between RTs to different starting stimuli for D/deaf and hearing athletes (Soto-Rey et al., 2014), leading to inequity. This inequity marginalises and ostracises D/deaf athletes, as the lack of access to a consistent and evidence-based starting system hinders sporting progression through early participation to more streamlined and high-performance pathways. To encompass and challenge these barriers, a comprehensive effort to identify the optimal sensory condition that consistently demonstrates the smallest RT discrepancy across populations and environments (laboratory versus in-the-field) is warranted. Identifying the smallest RT discrepancy is critical, as in a practical sporting environment this will ensure that neither D/deaf or hearing athletes have an unfair advantage or disadvantage over the other group on the start line; the race outcome would then be determined by an athlete's sprint ability, not their hearing level. The current chapter will test sensory stimuli in both laboratory and sprint start environments to understand which stimuli promote equitable RTs. These data will then be used to inform a standardised starting system that ensures equity among D/deaf and hearing athletes.

To develop an evidence-based and equitable starting system, we must consider the relationship between RT, stimulus modality, and subsequently, race outcome. RT is a critical component of a successful sprint and race outcomes are often determined by as little as a hundredth of a second (Brown et al., 2008). RT can be characterised as the length of time between the presentation of a stimulus – in this case, the sensory starting system – and the initiation of movement i.e., when the pressure on the starting blocks exceeds the baseline threshold pressure (Schmidt et al., 2018; Tønnessen et al., 2013). Typical RTs to sensory stimuli vary across research, with auditory RTs in hearing populations ranging from 126.27ms (Solanki et al., 2012) to 284ms (Shelton & Kumar, 2010). Similar variations are observed in responses to visual stimuli, with RTs ranging from 175.12ms (Solanki et al., 2012) to 331ms (Shelton & Kumar, 2010) in hearing populations and 207ms (Bottari et al., 2010) to 247ms (Soto-Rey et al.,

2014) in D/deaf populations. In addition to these stimulus modality effects, RT also varies based on stimulus quantity and location, together with individual neuroplastic adaptations (Diederich & Colonius, 2004).

It is widely reported that when you simultaneously increase the quantity of stimuli presented RT decreases (Diederich & Colonius, 2004). RT facilitation through increased stimulus quantity can be explained via multisensory enhancement of attention. A notion whereby the presence of a bimodal stimulus creates a convergence of cortical activity in the corresponding sensory cortices (Hecht et al., 2008). The stimulus convergence results in an intersensory facilitation effect whereby the two separate sensory signals (e.g., auditory, and visual) interact prior to stimulus detection. This interaction causes stimuli to attain threshold-level (i.e., the minimum intensity required from a stimulus to produce a response) earlier, resulting in faster RTs compared to unimodal stimuli (Shaw et al., 2020). Whilst the notion of stimuli threshold explains why unimodal stimuli produce slower RTs compared to unimodal stimuli, it has also been reported that the combination of auditory-visual bimodal stimuli produces faster RTs than other bimodal sensory combinations such as visual-haptic (Diederich & Colonius, 2004). This is due to different levels of cortical activation within the bimodal stimulus pairings, the close positioning of the auditory and visual cortices facilitates increased recruitment of information and cross-modal activation (Zangenehpour & Zatorre, 2010), whereas the somatosensory (haptic) cortex often processes information independently to other cortices (Eck et al., 2013). This provides an explanation as to why RTs are different with different bimodal pairings. However, it is important to note that most existing evidence regarding bimodal RTs centre around hearing populations with little research examining intersensory facilitation effects in D/deaf populations. With regards to an equitable starting system, we must consider the stimulus availability and processing capacity for D/deaf and hearing populations and the impact that will have on RTs on the starting line. More specifically, if presented with an auditory-visual stimulus, it is plausible that a hearing athlete will have an increased capacity to process both the auditory and visual stimulus, whereas a D/deaf athlete is likely to only process the visual stimulus entirely. This exacerbates the need to establish understanding around the sensory conditions that produce the smallest RT discrepancies whilst also investigating the influences of stimulus quantity and location on RTs across D/deaf and hearing populations.

Stimulus location e.g., auditory positioning (Proctor et al., 2011; Roswarski & Proctor, 2000), visual stimulus positioning (Carreiro et al., 2003), and the anatomical location of haptic stimulation (Ho & Spence, 2014) is reported to influence RT. For example, Ho and Spence (2014) demonstrated that higher set-level haptic stimulation (e.g., placement of the stimulus on the hands or wrists), promotes faster upper limb RTs compared to a lower set-level stimulation (e.g., haptic stimulation on the legs or feet). These findings were explained by shorter neuronal latency periods between the stimulus and response location. Furthermore, RT is facilitated when the stimulus is located at the same site as the primary task (Ho & Spence, 2014). That is, if a task requires you to move your right arm, a stimulus and response located proximally by or on the right arm, will promote faster RTs compared to a stimulus located by or on the left arm. This increased stimulus-response compatibility is known as the Simon effect, and faster RTs occur even when the stimulus location is incongruent to the task (Valeffi et al., 2005). This is particularly beneficial on the starting line, there is typically an equal distribution of pressure exerted between the right and left hand when in the 'set' position and when pushing out of the blocks in order to counterbalance the velocity and kinematic power from the lower body (Bezodis et al., 2019). Thus, any potential RT differences because of incongruency in the stimulus and response pairing will be less distinguishable, therefore reducing the impact on RT and performance. Therefore, it is plausible to suggest that regardless of whether an athlete predominantly feels haptic stimulus on their right or left hand, due to the set-level compatibility between the stimulus location and actual response, there may be little discrepancies in RTs.

Another way to ensure that sprint start RTs are not impeded by stimulus location is the positioning of the stimulus in relation to the lane. It has been an ongoing discussion that the athletes in lane eight (i.e., those furthest away from the gun) will hear the gun later than those in lane one due to sound propagation, creating potential disparities in RTs due to the location of the starting pistol. At elite level sport, individual starting blocks now contain a speaker but only a single starting pistol is fired by lane one. Brown et al. (2008) investigated the RTs of elite sprinters at the 2004 Olympic Games and noted that athletes in lane one had significantly lower (i.e., faster) RTs (average 160ms) compared to every other lane (average 185ms). Therefore, it is important to ensure that a starting system is positioned optimally so that there is no risk of RT being impeded, regardless of hearing level.

To complicate things further, discrepancies between D/deaf and hearing RTs vary depending on the stimulus modality. More specifically, visual RTs in D/deaf and hearing populations demonstrate the biggest differences, with D/deaf populations displaying significantly faster RTs (Codina et al., 2017). This is due to multi-cortical hypertrophy in the visual and auditory cortices in D/deaf populations to compensate for auditory deficits (Scott et al., 2014). This is in line with Parasnis' (1983) sensory compensation framework suggests that when one sense is inhibited, other senses are reorganised and compensated, characterised by a sensory enhancement. For example, under visual stimuli conditions D/deaf populations often display faster stimulus detection mechanisms (Bottari et al., 2010) and faster RTs (Loke & Song, 1991; Soto-Rey et al., 2014) compared to those without hearing loss. On the contrary, haptic RTs do not appear to be significantly different between D/deaf and hearing populations (Heimler & Pavani, 2014) with research reporting minimal and non-significant haptic-centred neuroplastic adaptation in D/deaf populations (Bolognini et al., 2012).

Cortical differences can be explained via neuroplasticity, a principle whereby the organisation and function of brain development is altered because of a major environmental change, such as deafness (Dye & Bavelier, 2013). A systematic review by Simon et al. (2020) highlighted that auditory deprivation largely impacts the structure of the primary and secondary auditory cortex and language areas. Evidence suggests that there are several modulating factors that influence the extent of neuroplastic adaptations including deafness onset, communication method (oral or sign language), and deafness duration (Simon et al., 2020). More specifically, the compensatory mechanisms associated with cerebral changes in D/deaf individuals centre around enhanced visual abilities, specifically wider peripheral attention distribution (Dye et al., 2007), visual localisation (Pavani & Bottari, 2012), and visual motion detection (Shiell et al., 2014). Further to this, cross-modal plasticity in D/deaf populations suggests that there is often an increased activation of the auditory cortex when processing visual information. This increased activation occurs in several areas of the brain, notably the in the primary auditory cortex, temporal lobe posterior, and anterior and lateral to the primary auditory cortex in both total deaf and residual deafness (Lambertz et al., 2005). The neuroplastic and cross-modal differences between D/deaf and hearing populations reaffirm the rationale for developing an equitable standardised starting system to ensure that race outcomes are determined by sprint ability and performance, not hearing level.

Within this chapter, there are two experiments that attempt to comprehensively explore multisensory RTs in D/deaf and hearing populations. The findings will create a robust evidence-base for the development of a standardised starting system that promotes equity between populations. Experiment One was conducted in a laboratory environment, used participants from wider society, and was informed and developed from the findings in Chapter 1 (haptic stimulus positioning). Experiment Two was conducted in an ecologically valid sprint start environment with participants having sprint experience and responding to stimuli via sprint start blocks. The rationale for including both experiments was to ensure levels of internal and external validity whilst simultaneously increasing the scale and scope of this research in line with the overall aims of this thesis. This research strategy creates a comprehensive and robust body of work that will actively inform the development of a standardised starting system to promote equity across D/deaf and hearing athletes.

The aims of the present chapter were threefold: (1) To establish the relationship between unimodal and bimodal stimulus modalities in D/deaf and hearing populations. (2) To identify the most equitable stimulus modality (i.e., the smallest non-significant discrepancy) between D/deaf and hearing populations. (3) To determine the most equitable stimulus modality that is compatible with auditory starting systems. Based on existing evidence and practical outcomes, the current hypotheses are two-fold: (1) Bimodal RTs will be significantly faster than unimodal RTs, regardless of hearing level. (2) Haptic-containing modalities will promote the most equitable RTs.

3.3 Experiment One

3.3.1 Methods

Participants

Thirty-nine participants (hearing $n=22$, M age = 22.7 years, 13 males; D/deaf $n=17$, M age = 35 years, eight males) volunteered to participate in the current study. Hearing participants were required to have no medically diagnosed or known hearing loss. D/deaf participants were required to have a medically diagnosed hearing loss of at least 55dB in their better hearing ear; this threshold is in line with the International Committee for Deaf Sport policy (International Committee of Sport for the Deaf, 2018). G*Power 3 (G*Power 3; Faul et al., 2007) sample size

estimation deemed 16 participants necessary to provide power = .95 for the interaction between stimulus modality and hearing level when $\alpha = .05$ and $\eta_p^2 = .33$. The final sample size met and exceeded the minimum power requirements. All participants gave their full informed consent prior to taking part in the current study. The experiment was conducted in accordance with the academic institution's ethical guidelines for research involving human participants.

Apparatus and Task

Participants were seated in front of a purpose-built upper limb aiming manipulandum (see Figure 3.1) and interacted with the manipulandum in the horizontal plane at shoulder height. The manipulandum consisted of an arched target display, a two-dimensional free moving axis situated under the elbow of the moving limb, and an arm support that extended from the elbow to the hand. Participants placed their right arm onto the manipulandum with their elbow located directly over the free moving axis. The arm was then secured using Velcro straps positioned over the wrist and forearm. An aiming marker at the end of the arm frame (designed to represent a pointing index finger) finished approximately 2 mm from the manipulandum's target display. The target display consisted of a start position and a target region. The start position was indicated by a green light (10 mm in diameter) that was located on the right of the target display and directly in line with a neutral position of the right arm (when the arm was bent at 90°). The target region was positioned 50° to the left of the start location and consisted of a red light (10 mm in diameter) with a 10° bandwidth. At the start of each trial, once participants positioned the aiming marking in line with the start location, the trial was started via the computer software, followed by a variable foreperiod (500-1500ms), upon which participants were required to respond as fast and accurately as possible by moving from the start location to the target as fast and accurately as possible.

There were six different movement stimuli, three separate unimodal (auditory, visual, haptic) and three separate bimodal (auditory-visual, auditory-haptic, visual-haptic). The unimodal auditory stimulus consisted of the sound of a standard athletics starting pistol (with a volume of 55dBA. This was emitted via a speaker positioned 1.5m directly in front of the participant. The unimodal visual stimulus consisted of a white light (14 × 9cm, 1320 lumens, and 5600K colour temperature) located 1.5m directly in front of the participants. The unimodal haptic stimulus consisted of two 16 ohm Dayton Audio TT25-16 circular (8.5 × 2.5 cm)

vibrating tactors connected to an adjustable elastic Velcro strap. Each disc was placed on the participant's palm with the elastic strap over the back of the hand. The left hand was positioned in a neutral position palm upwards, and the right hand was placed onto the manipulandum frame. The haptic tactors emitted a frequency of 50Hz and were connected to the computer equipment via a thin lightweight wire that did not restrict or inhibit movement. The separate bimodal stimuli consisted of the simultaneous presentation of the relevant unimodal stimuli (e.g., auditory and visual together to create the auditory-visual bimodal stimuli).

Figure 3.1

Laboratory Set-Up: Manipulandum



Note. Birdseye view of the manipulandum set up. Participant's right hand was situated in the frame arm and movement followed path of the arrow. The red circle indicates the end target with a 10-degree target zone where participants were instructed to finish their arm movement.

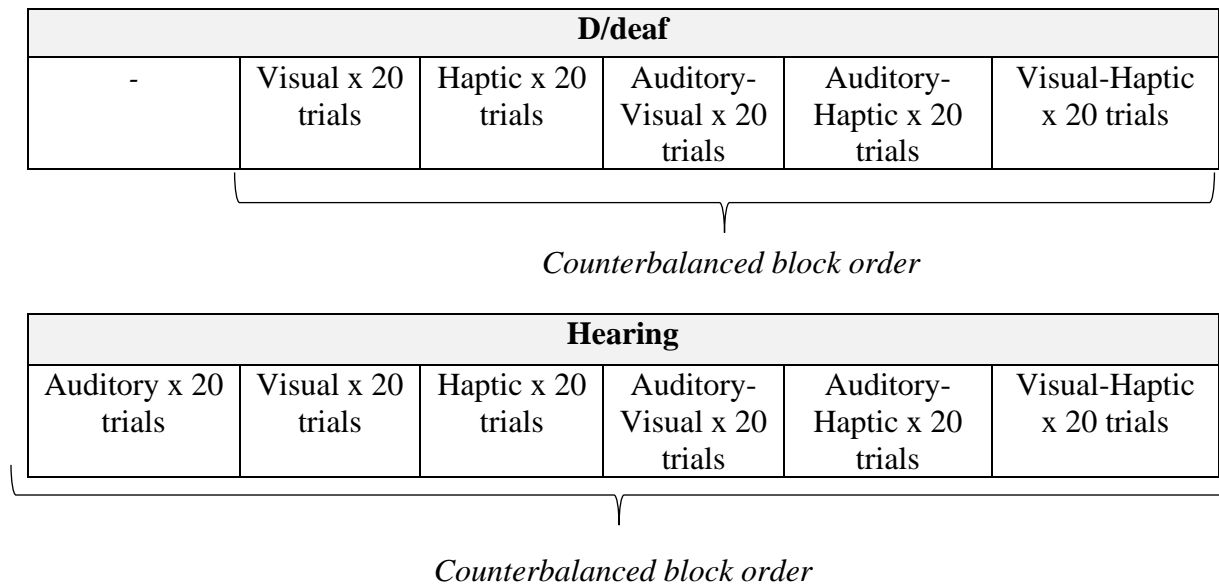
Procedure

Participants completed either five or six (dependent on which group the participant was in) counterbalanced blocks of 20 trials under each stimulus condition (see Figure 3.2).

Participants were provided with three practice trials at the start of each block. To avoid fatigue or concentration loss, participants were given the option of a short rest between experimental blocks⁶.

Figure 3.2

Unimodal and Bimodal Stimulus Conditions and Experimental Blocks



Note. Participants were given three practice trials of each stimulus modality.

Dependent Variables and Statistical Analyses

The primary dependent variable for Experiment One was RT, measured in milliseconds. Statistical analyses were conducted using SPSS 27 (IBSM). Separate A two-way (Group: D/deaf, hearing) repeated measures analysis of variance (Stimulus Modality: visual, haptic, auditory-visual, auditory-haptic and visual-haptic) were conducted on RT, MT and Accuracy data. Since our hypotheses centred around RT, MT and accuracy data are presented in the appendices. Any

⁶ This was particularly important for when participants had two consecutive visual-containing blocks i.e., auditory-visual followed by visual-haptic, as the repeated flashing could be deemed as strenuous on the eyes.

significant main effects and interactions ($p < .05$) were broken down into their simple main effects. Individual trials whereby RTs deviated by $>2SD$ from the given participant's overall mean for that specific stimulus modality were removed from the dataset prior to analysis⁷.

3.3.2 Results

Overall, 39 participants (hearing: $n=22$; D/deaf: $n=17$) completed the experiment. Deaf participants did not complete the unimodal auditory condition due to ethical and practical purposes. The overall mean RTs and standard deviations for both groups and all stimulus modalities are included in Table 3.1.

Table 3.1

Mean Reaction Times and Standard Deviations for Unimodal and Bimodal Stimulus Modalities in D/deaf and Hearing Groups.

	D/deaf ($n=17$)	Hearing ($n=22$)
Stimulus Modality	RT (ms) and <i>SD</i>	RT (ms) and <i>SD</i>
Auditory	-	156.76 (18.27)
Visual	207.07 (31.26)	193.93 (26.7)
Haptic	204.16 (28.88)	197.7 (28.93)
Auditory-Visual*	190.08 (31.98)	161.25 (26.81)
Auditory-Haptic*	189.00 (35.09)	152.55 (23.17)
Visual-Haptic	185.94 (25.34)	182.57 (26.99)

Note. Standard deviations are noted in parentheses. * denotes a significant RT group difference.

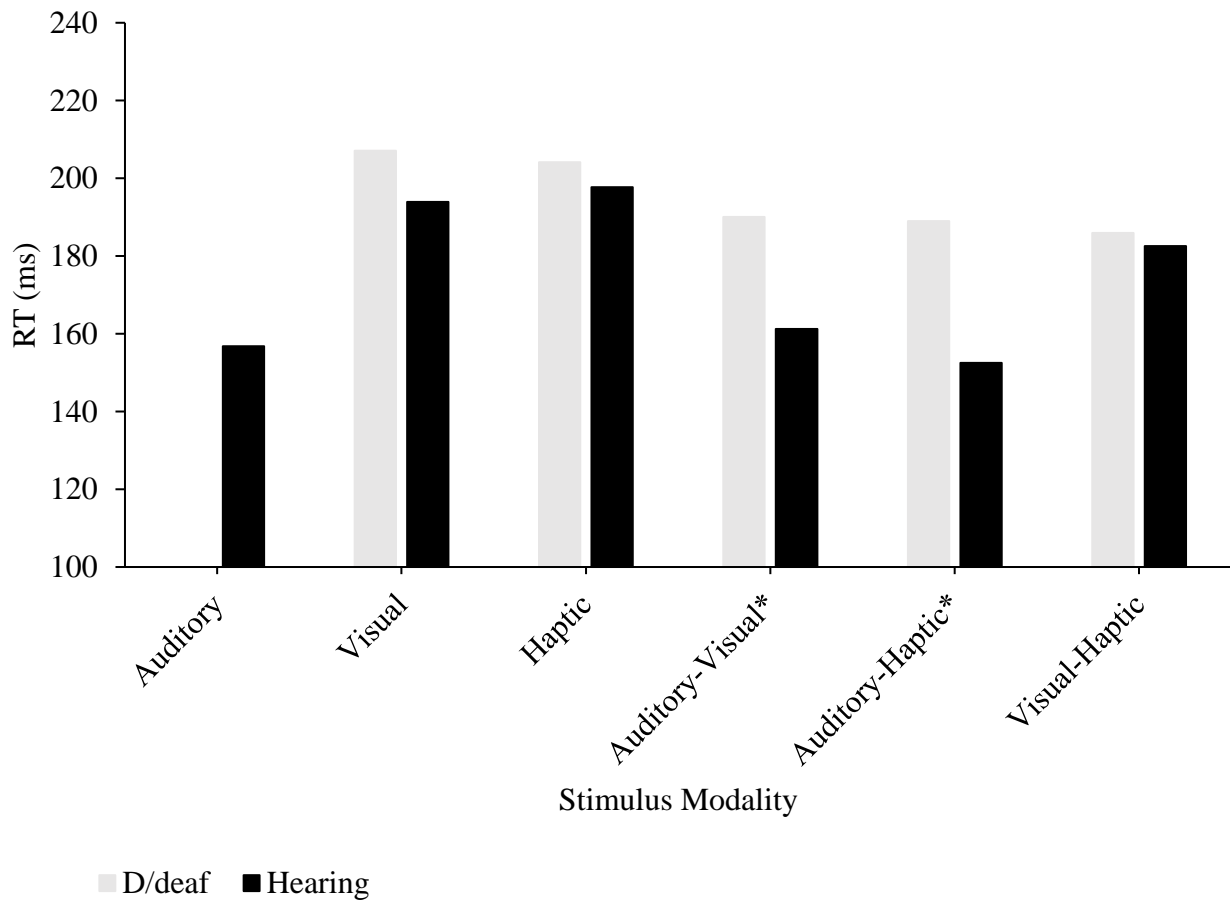
Analysis of variance revealed significant main effects for Stimulus Modality ($F_{2,4} = 38.78, p < .000, \eta^2 = .512$) and Group ($F_{2,4} = 4.560, p < .039, \eta^2 = .110$) together with a significant Stimulus Modality \times Group interaction ($F_{2,4} = 10.375, p < .000, \eta^2 = .219$). Breakdown of the interaction using Tukey's post hoc analysis ($p < .05$) produced a critical t difference of 15.8ms.

⁷ For the D/deaf group, 78 out of 1700 RT trials were identified as outliers, accounting for 4.59% of trials. For the hearing group, 104 out of 2640 trials were identified as outliers, accounting for 3.93% of trials.

This revealed non-significant group differences for only the visual stimuli (13.14ms), haptic stimuli (6.46ms), and visual-haptic stimuli (3.37ms), as highlighted in Figure 3.3.

Figure 3.3

Mean RTs for Unimodal and Bimodal Stimulus Modalities for D/deaf and Hearing Groups.



Note. * denotes a significant group RT difference.

3.3.3 Discussion

The present experiment aimed to identify the stimulus modality that promotes the most equitable RTs between D/deaf and hearing populations in an internally valid environment to inform the development of a standardised starting system. It was postulated that bimodal RTs would be faster than unimodal RTs in both D/deaf and hearing populations and that haptic-

containing modalities would promote the most equitable RTs i.e., the smallest RT discrepancy between groups. The present findings support these hypotheses and provide considerable insight into what constitutes an equitable starting system.

Most notably, out of the non-significantly different conditions (visual, haptic, and visual-haptic), the visual-haptic condition resulted in the smallest RT discrepancy across populations. Furthermore, visual-haptic RTs were the fastest RTs for the D/deaf population whilst also being the closest non-significant stimulus modality to the auditory stimulus in the hearing group (the current starting system used in mainstream athletics). This has important practical implications as it suggests that in addition to a visual-haptic stimulus promoting the most equitable RTs between D/deaf and hearing populations, it will have the least impact on RTs when integrating into mainstream athletics. However, more investigation is warranted due to the strategy of maximising overall validity and sample relevance. Specifically, whilst the laboratory task enabled reduction in confounding variables, it is low in ecological validity. Furthermore, our general population sample lacks generalisability to that of the athletic sprinting population. Therefore, it is necessary to extend the current experiment into an environment with higher ecological validity e.g., sprint start block, and recruit athletes with starting block experience to ascertain whether the current findings can be replicated and solidified further. This will provide a stronger foundation and evidence-base for a standardised starting system that promotes equitable, and fast, RTs between D/deaf and hearing athletes so that race outcome is determined by sprinting ability, not hearing level.

3.4 Experiment Two

Purpose

Experiment Two aimed to replicate the findings of Experiment One and expand these into an athlete specific population. An athletics-specific dataset will help with the aim of collecting data to inform the development of a standardised starting system that promotes equity and consistency amongst D/deaf and hearing athletes. To address this, we collected data using the same explosive movements to that of the sprint start, and in an athlete-specific population, utilising athletes that have starting block experience.

3.4.1 Methods

Participants

Fourteen participants (hearing $n = 7$, M age = 24.4 years, four males; D/deaf $n = 7$, M age = 24.7 years, three males) volunteered to participate in the current study. All participants were required to have some experience of using starting blocks to ensure automaticity of the sprint start movement and minimise any unintentional delays in RT. Hearing participants were required to have no medically diagnosed or known hearing loss. Deaf participants were required to have a medically diagnosed hearing loss of at least 55dB in their better hearing ear; this threshold is in line with the International Committee for Deaf Sport policy (International Committee of Sport for the Deaf, 2018). G*Power 3 (G*Power 3; Faul et al., 2007) sample size estimation deemed seven participants per group necessary to provide power = .95 for the interaction between stimulus modality and hearing level when $\alpha = .05$ and $\eta_p^2 = .14$. The final sample size met the minimum power requirements. All participants gave their full informed consent prior to taking part in the current study. The experiment was conducted in accordance with the academic institution's ethical guidelines for research involving human participants. All participants received a £15 payment for participation.

Task and Apparatus

Participants were required to complete a sprint start upon presentation of the sensory stimulus. As we were only observing RT and not overall sprint performance, participants were not required to complete a full sprint and were instructed to decelerate once they were out of the blocks to minimise fatigue. Participants were given both verbal and visual 'on your marks' and 'get set' instructions with 'go' being the presentation of the sensory stimulus. The visual cues involved displaying one finger for 'on your marks' and two fingers for 'get set' in the participant's direct line of vision to avoid any positional changes in the start.

The starting blocks were standard issue starting blocks, modified with a switch and springs which was connected to the sensory stimuli and computer software. The blocks were altered to incorporate interchangeable rubber studs or spikes underneath so that the blocks were suitable for use on both athletics track and indoor sports facility surfaces. Figure 3.4 displays a typical starting block set up with the rubber studs suitable for an indoor sports facility. Figure 3.5 displays a typical block set up with spikes suitable for an athletics track.

The stimulus modalities and equipment were identical to Experiment One, with the primary difference being in stimulus positioning and trial numbers. The stimulus modalities were

auditory (hearing group only), visual, haptic, auditory-visual, auditory-haptic, and visual-haptic. The auditory stimulus was positioned to the rear of the starting blocks, to replicate the current procedures in athletics, as seen in Figure 3.6. The visual stimulus was positioned on the floor on the starting line, within the participant's central line of vision (see Figure 3.7). Participants were able to adjust the visual stimulus to their preference to avoid any trip-hazards. The haptic tactors were positioned on the start line with participant's hands over the top of the tactors with their fingers and palm in direct contact with the tactor (see Figure 3.8).

Figure 3.4

Starting Block Set-up for Indoor Sports Floor.

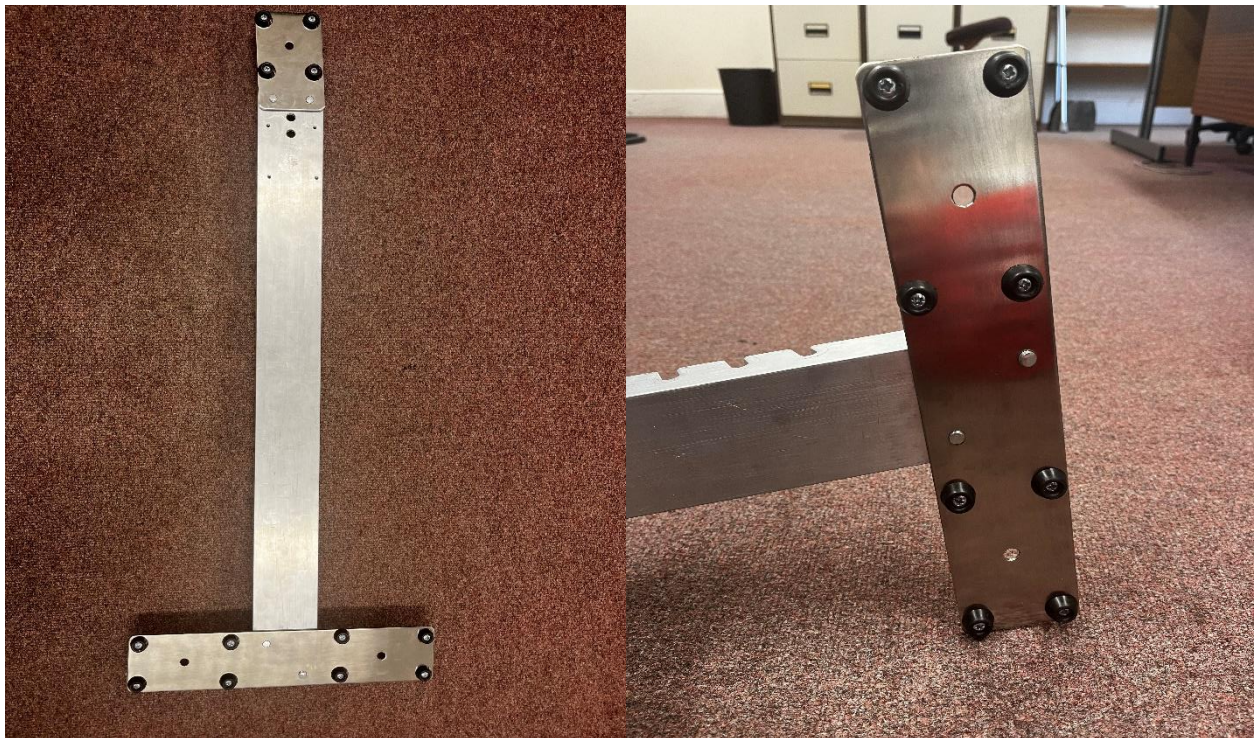


Figure 3.5

Starting Block Set-up Suitable for Indoor Athletics Tracks



Figure 3.6

Auditory Stimulus Positioning for Sprint Starts

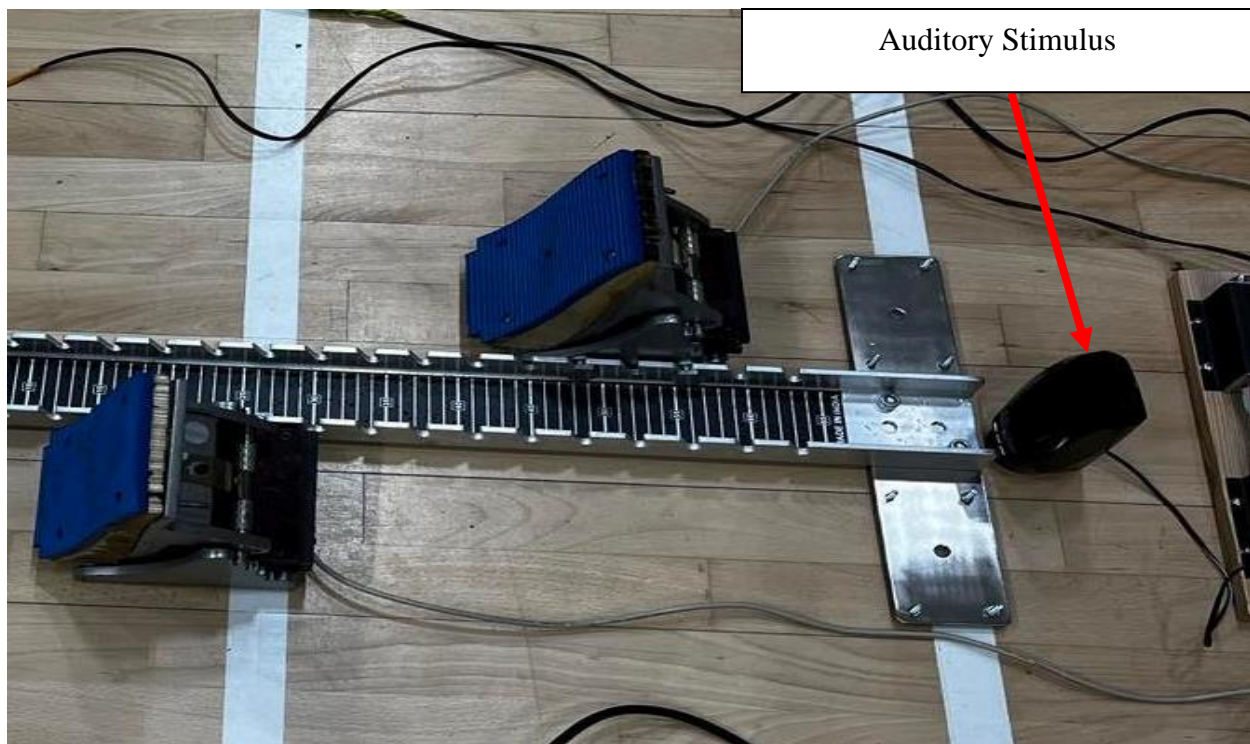


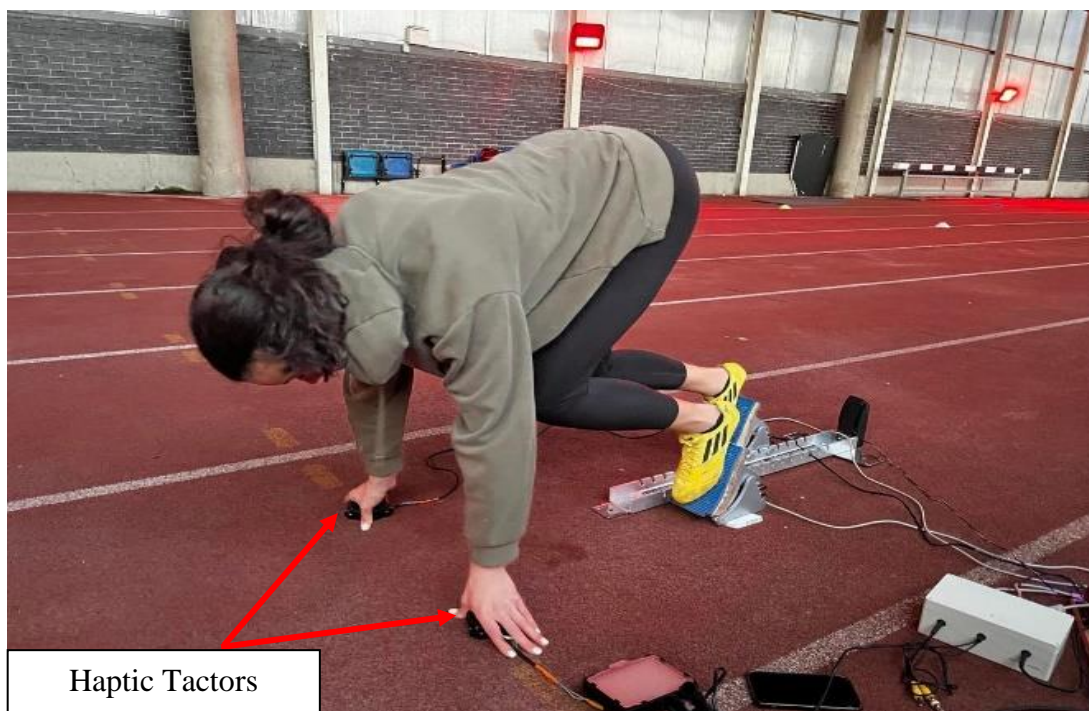
Figure 3.7

Visual Stimulus Presentation on an Indoor Track



Figure 3.8

Haptic Tactor Positioning during a Sprint Start

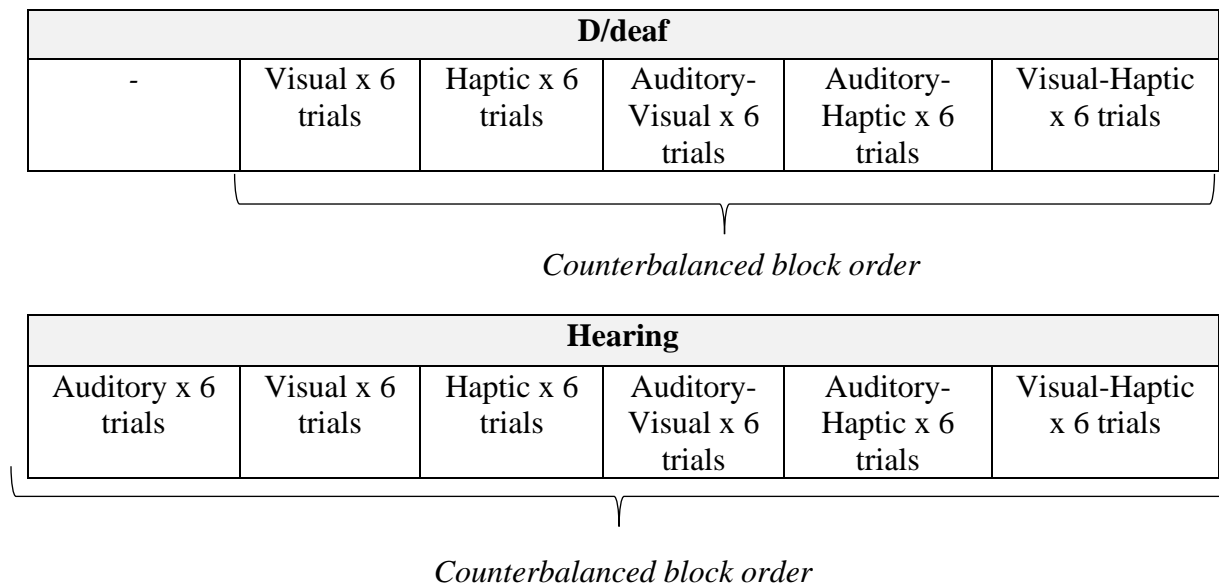


Procedure

Prior to participation, all participants were given time to warm up and adjust the starting blocks to their personal preference. Participants were given two practice trials of each stimulus modality prior to completing experimental blocks of six trials. Hearing participants completed six counterbalanced blocks of six experimental trials and D/deaf participants completed five counterbalanced blocks of six experimental trials. Figure 3.9 displays a schematic of the experimental conditions and order. The stimulus modalities comprised of three unimodal conditions: auditory (hearing group only), visual and haptic and three bimodal conditions: auditory-visual, auditory-haptic and visual-haptic. Testing took place in either an indoor athletics track or an indoor sports hall facility in a light and quiet environment.

Figure 3.9

Sprint Starts: Stimulus Modalities and Experimental Blocks



Note. D/deaf groups did not complete the unimodal auditory condition due to ethical and practical purposes. All participants had two practice trials of each stimulus modality.

Dependent Variables and Analyses

RT (ms) was the primary dependent variable for the current study. Individual trials whereby RTs deviated by $2 > SD$ from the given participant's trial overall mean for that stimulus location were removed the dataset prior to analysis and this resulted in no data points being removed prior to analysis. A two-way analysis of variance was conducted (SPSS 27, IBSM) to identify any main effects or interactions. Any interactions were broken down into their simple main effects.

3.4.2 Results

Overall, 14 participants took part in the study (D/deaf $n=7$, hearing = 7) and no data was removed prior to analysis. The stimulus modalities include auditory (hearing group only), visual, haptic, auditory-visual, auditory-haptic and visual-haptic. The mean RTs and standard deviations for all stimulus modalities are displayed in Table 3.2.

Table 3.2

Mean Reaction Times and Standard Deviations of Sprint Start Unimodal and Bimodal Stimulus Modalities in D/deaf and Hearing Athletes.

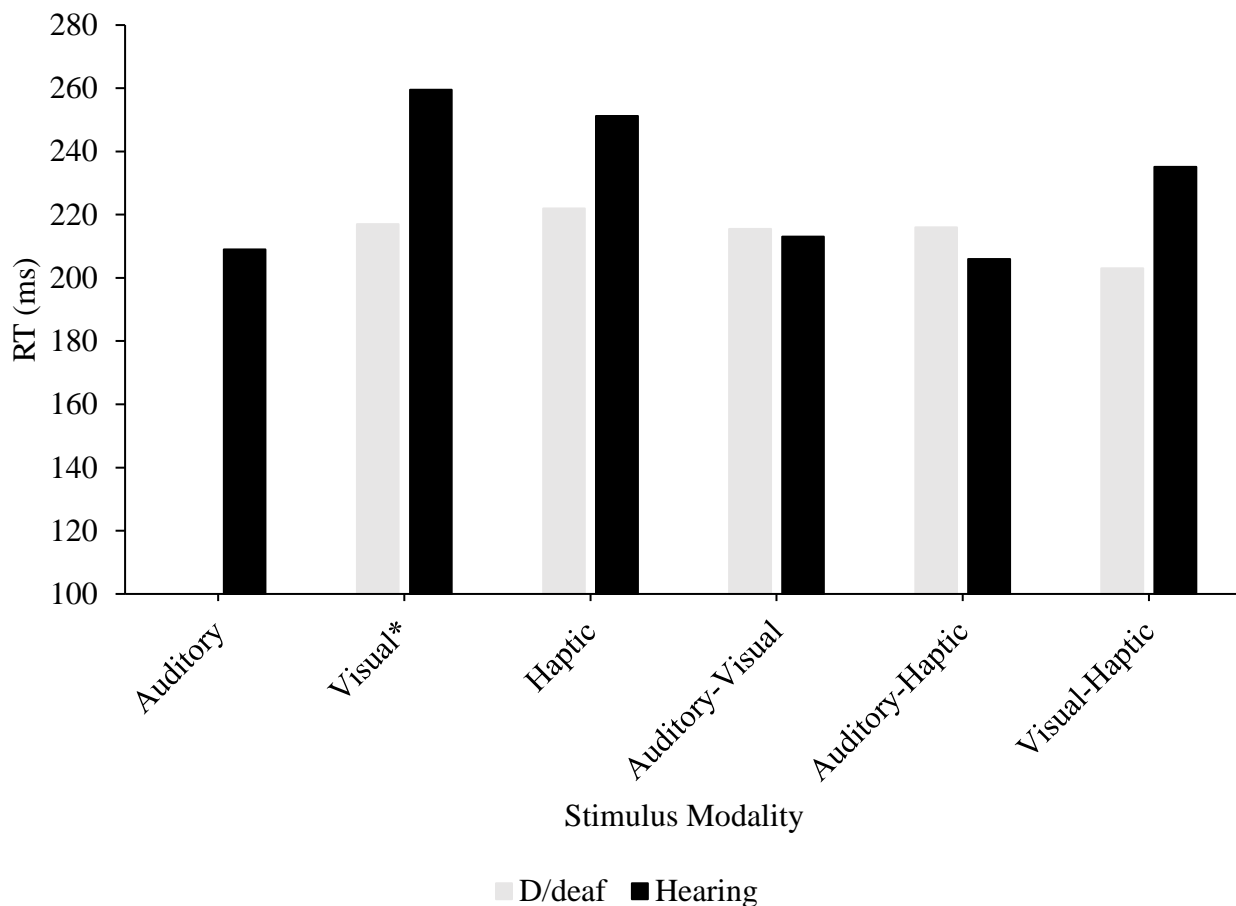
Stimulus Modality	D/deaf ($n=7$)	Hearing ($n=7$)
	X RT (ms) and SD	X RT (ms) and SD
Auditory	-	208.99 (10.70)
Visual	216.99 (53.18)	259.51 (28.90)
Haptic	221.98 (48.33)	251.19 (29.21)
Auditory-Visual	215.48 (63.79)	213.07 (32.92)
Auditory-Haptic	216.01 (56.74)	205.99 (31.17)
Visual-Haptic	203.05 (38.97)	235.10 (29.40)

As shown in Figure 3.10, results demonstrated a significant main effect for stimulus modality ($F_{2,4} = 7.268$, $p < .000$, $\eta^2 = .377$) with bimodal stimulus modalities resulting in

significantly faster RTs compared to unimodal stimuli. Importantly, results also revealed a significant Group \times Stimulus Modality interaction ($F_{2,4} = 5.952, p < .001, \eta^2 = .332$). Breakdown of this interaction using Tukey's post-hoc analysis ($p < .05$) revealed a critical t difference of 35.54ms. This indicted a significant difference between groups only in the unimodal visual stimulus modality (42.54ms difference). All other RTs were non-significantly different between the groups at each of the remaining stimulus modalities (haptic RT difference = 29.2ms, auditory-visual RT difference = 2.41ms, auditory-haptic RT difference = 10.02ms, visual-haptic RT difference = 32.05ms).

Figure 3.10

Sprint Starts: Unimodal and Bimodal Mean Reaction Times for D/deaf and Hearing Athletes



*Note. * denotes a significant group RT difference.*

3.5 General Discussion

The primary aim of this chapter was to identify the stimulus modality that consistently promotes the most equitable RTs between D/deaf and hearing populations. The present findings are intended to be utilised to inform the development of a standardised evidence-based starting system in athletics. To reiterate, the implementation of an equitable standardised starting system will ensure inclusion, parity, and opportunity for D/deaf athletes in mainstream athletics participation and performance pathways. It will also create consistency and standardisation within the D/deaf athletics pathways, forming a catalyst for positive change in D/deaf sport. The present chapter yielded strong and consistent findings, largely in support of the hypotheses, which provides excellent direction and scope for informing the development of a standardised starting system.

The hypotheses for the current chapter were two-fold: we predicted that bimodal RTs would be significantly faster than unimodal RTs and secondly, that haptic-containing modalities would promote the most equitable (i.e., the smallest across-population discrepancy) RTs between D/deaf and hearing populations. The rationale for faster bimodal RTs was postulated from existing literature that demonstrates RT facilitation when stimulus quantity is increased (Diederich & Colonius, 2004; Shaw et al., 2020). In line with this hypothesis, RTs in bimodal conditions were significantly faster than unimodal conditions in both D/deaf and hearing populations across both experiments, thus offering support for the relationship between stimulus quantity and RT, regardless of hearing level. However, one exception to the bimodal RT facilitation effect was observed in the hearing unimodal auditory condition as this was significantly faster than the hearing bimodal conditions. This may be explained by the relevance and familiarity of the unimodal auditory stimulus as evidence suggests that RTs to a familiar auditory stimulus, particularly in a sporting context, can be faster than multimodal RTs (Atan & Akyol, 2014).

The second hypothesis predicted that haptic-containing modalities will result in non-significant RT differences between D/deaf and hearing populations (i.e., promote the most equitable RTs). Here, we observed non-significant differences in the unimodal haptic, and bimodal visual-haptic conditions across Experiment One and Experiment Two. Importantly, whilst data revealed non-significant RT group differences in both the unimodal haptic and

bimodal visual-haptic conditions, the bimodal visual-haptic condition yielded the most equitable (i.e., the smallest discrepancy) and fastest RTs out of the non-significantly different conditions in Experiment One. In Experiment Two, although the visual-haptic condition did not reveal the smallest RT discrepancy compared to the other non-significant group differences, it was the only stimulus modality to present non-significant differences across the two experiments. Overall, we can confidently say that our hypotheses were met and that the most important finding being the consistent non-significant group RT difference in the visual-haptic condition across both experiments. These findings meet the primary aim of this chapter by identifying the stimulus modality that promotes the most equitable RTs between D/deaf and hearing populations. This provides sufficient evidence and scope to inform the development of a standardised starting system that will increase equity, access, and opportunity for D/deaf athletes across athletics.

Whilst we have established that visual-haptic RTs promote equity between D/deaf and hearing populations, it is warranted to understand why this is the case. Within this thesis, we have discussed the neuroplastic adaptations often seen in D/deaf populations due to auditory deficits, however we must also consider the multisensory integrations seen in hearing populations too and why we have seen certain bimodal facilitations. Girad et al., (2010) provides clarity with regards to the spatial principle whereby multisensory interactions are dependent on the overlap between the specific receptive fields that respond to the stimuli. Their evidence highlights that multisensory integration and task responses are facilitated when there is a greater spatial congruence between the stimulus and the receptive field. Furthermore, Sambo and Forster (2009) presented supporting evidence between multisensory integration and the topographical location of the stimuli; their results displayed greater cortical activity when the visual and somatosensory (haptic) stimulus were presented at the same contralateral location. Similarly, increased cross-modal activation has been demonstrated in the somatosensory (Cardini et al., 2011) and occipital cortices (Macaluso et al., 2000) in multisensory integrative tasks involving the availability of vision. This evidence provides an explanation for the findings in this chapter, in both Experiment One and Experiment Two, the positioning of the visual and haptic stimuli were congruent with the task and response meaning that visual-haptic integration was able to occur in both D/deaf and hearing populations. Furthermore, visual-haptic integration has shown to be optimised and facilitated when the tasks involve movement, such as reaching (Serwe et al., 2011), which could be considered as a comparable type of movement to the task in Experiment

One in which the smallest difference in visual-haptic RTs was observed across D/deaf and hearing populations.

As there is no pre-existing evidence regarding the relationship between a visual-haptic stimulus and the sprint start movement. However, the non-significant difference in visual-haptic RTs across both experiments yields excellent practical implications but there are considerations that need to be made for successful implementation and long-term feasibility. More specifically, identifying a way to implement the visual-haptic system in conjunction with current auditory starting systems is necessary to maximise acceptance within mainstream athletics. Similarly, ensuring that the proposed starting system does not promote RTs that are significantly different from auditory RTs is critical, particularly as all records have set using auditory starting systems.

One of the expected challenges associated with the implementation of a visual-haptic starting system is acceptance from the mainstream athletics world with regards to changing the protocol for starting a race and any potential impact on RTs, and subsequent records. Auditory stimuli have been used as the primary starting method in athletics for many years, with evolution from the mechanical starting pistol in 1904 (Hareendan, 2022) to the current Omega Scan 'O' vision electronic starting gun (Haugen et al., 2012) and is widely accepted and utilised across mainstream athletics. The key consideration with implementing a visual-haptic starting system is the level of impact this type of modality will have on start times in comparison to previously recorded sprint start times at an elite level.

Adopting a visual-haptic starting system promotes equity of starts across populations, but not speed of starts for several reasons. Average auditory RTs from the Sydney 2000, Athens 2004 and the Beijing 2008 Olympics ranged from 146ms (men's 100m sprint Beijing 2008) to 207ms (women's 100m sprint Sydney 2000), with RTs becoming shorter across the Olympic games, the exception here being Beijing 2008 which was unexpectedly fast, postulated due to the presence of Usain Bolt, despite Bolt's historically slower RTs (Piliandis et al., 2012). Average 100m sprint RTs at London 2012 were 162ms for men and 156ms for women (Pavlović et al., 2014). The average auditory RT for the current research was 160.69ms which is consistent with elite sprint RTs and whilst the present visual-haptic RTs are different to auditory RTs, RT accounts for approximately 1-2% of overall sprint time (Helmick, 2003), it is plausible that with repeated exposure and training with a visual-haptic system, RTs will become quicker and have

less impact on overall sprint times. When considering the feasibility and societal acceptance of a new starting system in mainstream athletics, it will likely be a significant challenge to transition from the current unimodal auditory system to a visual-haptic starting system if current starting times of hearing athletes are affected.

With these considerations in mind, it is important to consider comparisons of different stimulus modalities across groups to ensure that the starting system is equitable whilst still providing opportunity for fast RTs. More specifically, in Experiment Two, the fastest RT for the D/deaf group was observed in the visual-haptic condition and the fastest RT for the hearing group was observed in the auditory-haptic condition, with a non-significant RT difference of 2.94ms between these two conditions. This provides an alternative solution whereby a visual-haptic system could be implemented alongside auditory systems but the specific stimuli that D/deaf and hearing athletes receive and react to are dependent on their hearing level. This would involve all athletes being presented with a haptic stimulus on the start line (as this will not create an advantage or disadvantage for either group based on existing evidence e.g., Heimler and Pavani (2014), the first empirical chapter of this thesis, and the results of both experiments in the current chapter), D/deaf athletes will be presented with a lane-specific visual stimulus and hearing athletes will be presented with the typical auditory stimulus. This will ensure consistency of a visual-haptic starting system for D/deaf athletes and continuation of an auditory starting system for hearing athletes. To ensure that D/deaf athletes do not inadvertently process the auditory stimulus, it would be within reason to adopt the current rulings and protocols in D/deaf athletics.

In D/deaf athletics, athletes are prohibited from wearing any kind of assistive hearing device such as hearing aids, cochlear implants (CI) or bone anchored hearing aids (BAHA) (Deaflympics, 2009) in attempts to standardise the playing field, however, there does not appear to be any explicit ruling for whether or not a D/deaf athlete can wear their assistive hearing device in mainstream athletics. This ruling could be applied to mainstream athletics, again standardising procedures for D/deaf athletes across all of athletics, as then in this case, hearing athletes would have access to an auditory-haptic system and the D/deaf athletes would have access to a visual-haptic system. The findings from Experiment Two support this solution as hearing athletes had a mean auditory-haptic RT of 205.99ms and D/deaf athletes had an average

visual-haptic RT of 203.05ms, meaning that the difference between these two conditions was only 2.94ms and statistically non-significant. Furthermore, the mean RTs of the Hearing auditory-haptic (205.99ms) and the D/deaf visual–haptic (203.05ms) are the fastest RTs for both groups in Experiment Two, meaning that as well as the RTs being equitable across populations, they are also the most appropriate for each athlete to produce their best potential performance. Due to this it is proposed that in addition to the current auditory starting system, governing bodies implement a haptic stimulus for all athletes together with the integration of a visual system for D/deaf athletes. Given the current results, this will promote equitable and speeded RTs for both D/deaf and hearing athletes and will result in the least impact on overall start times, thus increasing the probability of widespread acceptance in mainstream athletics.

Whilst the implementation of the standardised starting system has been largely discussed with regard to integration within mainstream athletics, we must also consider the D/deaf sport environments. As previously established, there is a lack of a consistent starting system across all levels of D/deaf athletics, often meaning that elite level athletes will not have sufficient experience using the starting system before their race. Based on the evidence presented in this chapter, a visual-haptic system will promote the most consistently fast RTs for D/deaf athletes, and this should be the system developed for D/deaf athletics. It is important to have a level of continuity in the starting systems used across mainstream and D/deaf pathways, as this gives D/deaf athletes the opportunity and flexibility to choose which pathway they want to progress through based on their motivations for sport. If a D/deaf athlete performs in sport to achieve widespread recognition and are relatively integrated in the hearing world (e.g., via work, families, or social circles), it may be more practical and fulfilling for a D/deaf athlete to access the mainstream and Olympic pathways. Alternately, a D/deaf athlete that has a stronger identity and purpose within the D/deaf world may desire to compete in the D/deaf athletics pathways. Ensuring that all D/deaf athletes have the freedom to compete in their preferred pathway via an equitable starting system will increase inclusivity and access to athletics, consolidating sport and society's drive towards equality.

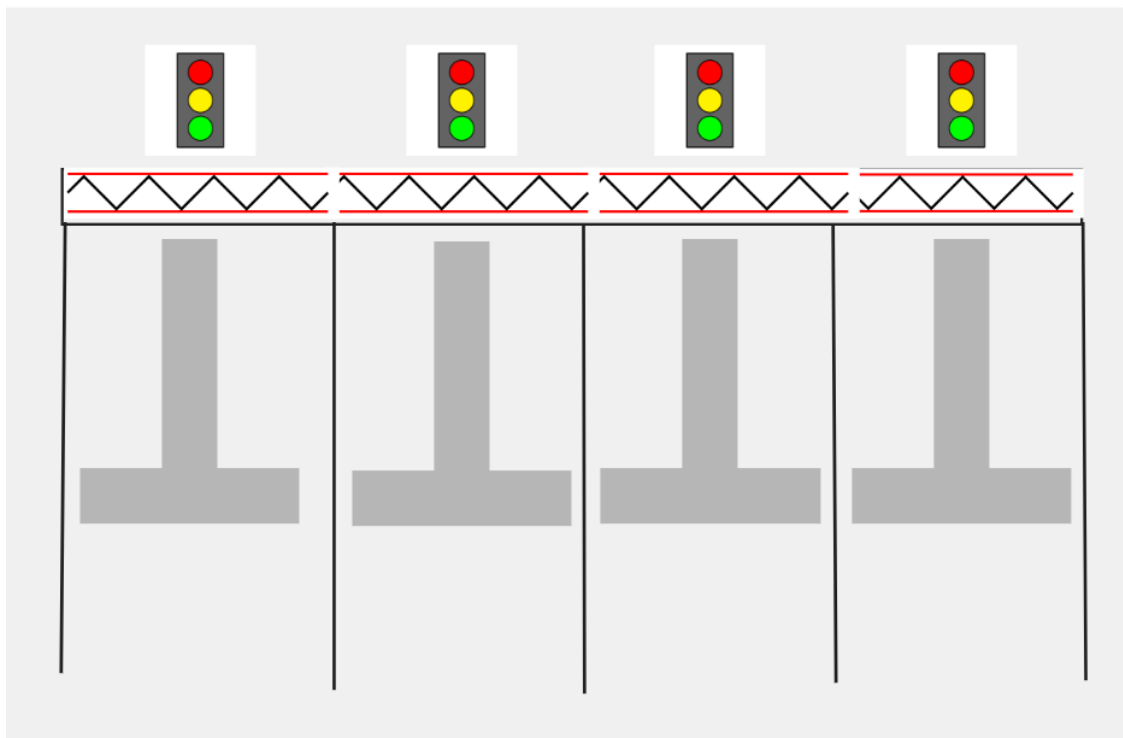
As we have discussed the evidence that will promote equitable and fast RTs for D/deaf and hearing athletes in mainstream and D/deaf athletics, it is useful to create a visual representation of what this starting system will look like. Figure 3.11 below displays the starting

system set up in a D/deaf-specific athletics race and Figure 3.12 displays the starting system set up in a mainstream race whereby one D/deaf athlete is participating. As explained earlier, it is intended that the haptic stimulus will be presented to all athletes (regardless of hearing level) and that hearing athletes will have access to the auditory stimulus e.g., electronic starting pistol and that D/deaf athletes will have access to an individual visual stimulus.

The findings from this chapter and discussed applied implications result in the proposal of a visual-haptic starting system that works in conjunction with auditory starting systems (specifically in mainstream athletics). More specifically, in mainstream settings, hearing athletes will respond to the auditory and haptic stimuli and D/deaf athletes will respond to the visual and haptic stimuli. This ensures that neither group will have a significant advantage or disadvantage on the start line based on their level of hearing, fulfilling the aims and rationale of this thesis. Lastly, implementation of a visual-haptic starting system in D/deaf athletics pathways will provide the much-needed consistency and standardisation to improve the experiences of D/deaf athletes throughout the athletics participation and performance pathways.

Figure 3.11

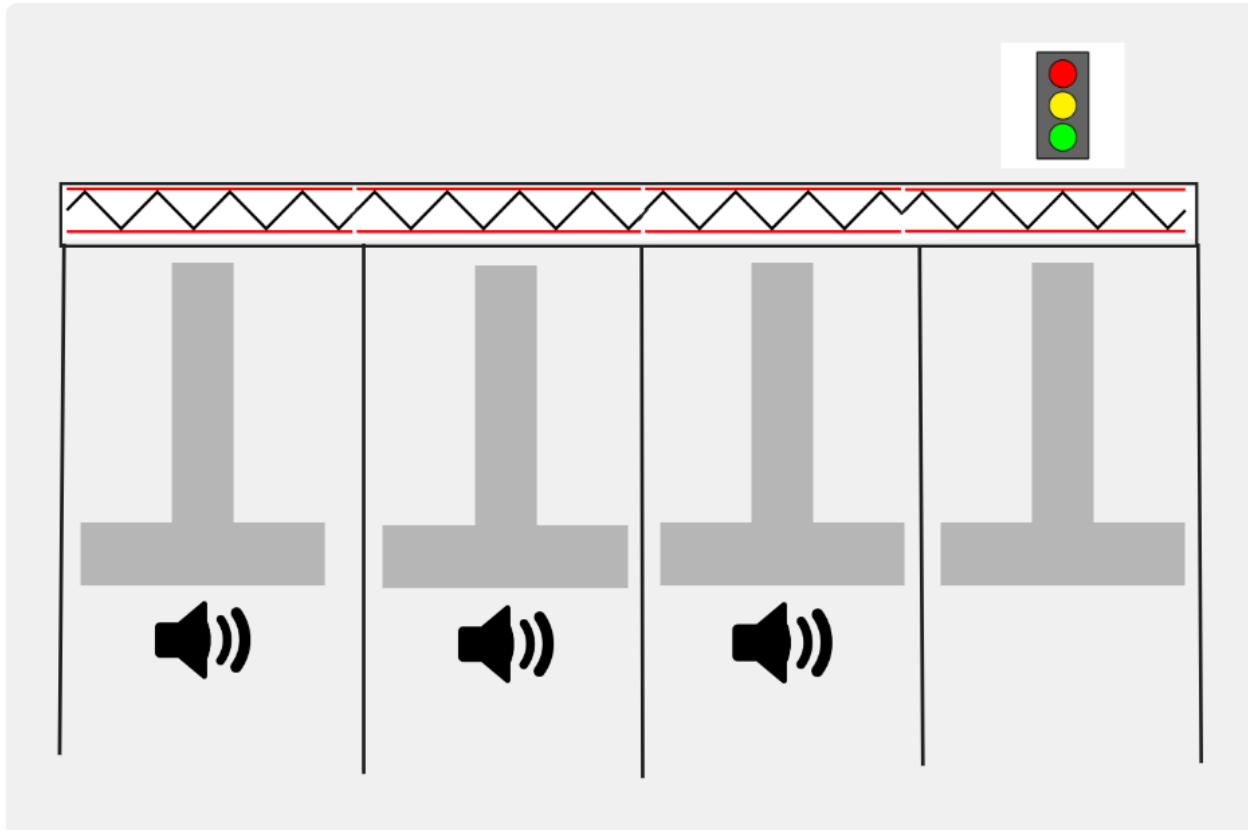
D/deaf Athletics Proposed Starting System



Note. The haptic stimulus will be presented via the hands and fingertips on the start line and the visual stimulus will be presented via an individual hooded light in the athlete's central line of vision when in the 'set' position.

Figure 3.12

Mainstream Athletics Proposed Starting System



Note. The haptic stimulus will be presented via the hands and fingertips on the start line. Hearing athletes will be presented with the auditory stimulus as standard with the sound being emitted from behind the athlete in the starting blocks alongside the actual starting pistol. D/deaf athletes will be presented with the visual stimulus via an individual hooded light in the athlete's central line of vision when in the 'set' position.

Chapter 4:

On your marks, get set, g-...: exploring the experiences and outcomes of variable starting systems in D/deaf athletics.

4.1 Abstract

Scan the QR code below to access a British Sign Language version of this abstract.



Introduction: In D/deaf sport, there are several sociocultural barriers that impact participation and performance such as ineffective communication, lack of inclusivity and D/deaf awareness (Atherton, 2007). At a practical level, a significant barrier for D/deaf athletes is the lack of access to a fair starting system that allows all athletes to respond to the stimulus at the same time. This inconsistency and variability in the starting systems used in D/deaf and mainstream athletics creates an uncertain environment and does not provide the same competitive experience and opportunity as hearing or para- athletes. There is currently no comprehensive qualitative research that explicitly explores the impact of variable starting systems used in D/deaf athletics on the experiences of D/deaf athletes, which is what this chapter primarily aims to explore. *Methods:* Eight participants from three groups (Deaf sprinters n=3, coach / team manager of a D/deaf sprinter n=3; stakeholders n=2) completed a semi-structured interview in British Sign Language (BSL) or spoken English to discuss and explore the experiences of variable starting systems in D/deaf athletics and wider sport. Interviews conducted in BSL were supported with an interpreter. Interviews were transcribed, triangulated, and thematically analysed for common themes. *Results and Discussion:* Three key themes were established which were: Starting System Experiences, Sport Experiences and Recommendations with sub-factors for each identified. The

current findings highlight that in mainstream races, D/deaf sprinters often rely on the other athlete's movement to respond to auditory stimuli i.e., looking under their armpit in the start position, and that various traffic light and multicoloured light-based systems are commonly used and preferred in D/deaf athletics. Common issues within the participation and performance pathways included the lack of consistency and access to a light-based system in training that paralleled the starting systems used at competitions. There was a high prevalence of faulty equipment in competitions which often led to delayed race / false starts which created anxiety and frustration for athletes and coaches. The technical and practical recommendations for a new standardised starting system were also discussed, with four critical considerations identified which were to utilise a traffic-light style light system, which must be connected to the starting pistol (especially in mainstream races). The starting system must also have protection from the sun and unwanted glare via a 'hood' over the lights. Lastly, the positioning of the traffic-lights must not force athletes to move or lift their head and disrupt their start position. Strategies for effective widespread implementation of the starting system are discussed with particular focus on identifying the groups of people (e.g., elite D/deaf athletes and key technical officials) and venues that should have priority access to the starting system. Extensive efforts need to be shown by sporting organisations and governing bodies to support D/deaf athletics to reduce organisational stressors (e.g., increase sport-wide funding), to facilitate inclusion of D/deaf athletes within mainstream pathways and to support the implementation of a standardised starting system.

4.2 Introduction

Considerable effort towards promoting equality and inclusivity in sport in the UK has been observed since the London 2012 Paralympics but this has not been paralleled in D/deaf sport. D/deaf sport is currently not recognised as a performance pathway in the UK, meaning that D/deaf athletes cannot compete with the same recognition as their hearing and Para-athlete counterparts. D/deaf athletes are presented with many systemic societal barriers, such as a lack of funding, access to effective communication, and inaccessible participation and performance pathways (Atherton, 2007; Foster et al., 2018). All of which, will take a significant amount of work and dedication to eradicate, and is beyond the scope of this thesis. However, there are other inequities within D/deaf sport that can be addressed to create significant positive impact and change. More specifically, the lack of a standardised starting system results in inaccessible and inequitable sprint starts for D/deaf athletes, due to the predominant use of auditory starting systems in athletics. Developing and implementing an equitable starting system will ensure inclusive competition alongside hearing athletes (e.g., in mainstream races) and consistency across all levels of D/deaf athletics. Thus, the aim of the present chapter was to explore the different types of starting systems experienced by D/deaf athletes across different competitions, and to understand their overall experiences in D/deaf sport. Furthermore, it was deemed important that to ensure that the development and implementation of a standardised starting system is effective, we must consider the technological requirements and practical recommendations to facilitate this. We can capture this information from D/deaf athletes, their coaches / team managers, and key stakeholders, which will provide a triangulated insight from the individuals who directly experience and use the starting systems. Adopting this approach will provide a greater understanding of the experiences, perceptions and needs surrounding the development of a standardised starting system that is accessible and equitable for D/deaf athletes, regardless of whether it is a mainstream or D/deaf athletics pathway.

To be able to understand the problem and provide solutions, it is important to acknowledge the underlying barriers that have contributed to the marginalisation and discrimination of D/deaf athletes. One area of sport that highlights the inequities faced by D/deaf athletes is funding. Since the Sydney 2000 Olympic Games, Team GB Olympic athletics funding has increased from £6,248,571 to £22,416,808 and Team GB Paralympic athletics funding has

increased from £1,136,298 to £8,469,600 (UK Sport, 2023). Prior to London 2012, UK Deaf Sport (UKDS) received approximately £134,000 from the government and Lottery funding but this funding was removed and channelled into Paralympic pathways (UK Deaf Sport, 2014); this funding has never been fully recuperated. Furthermore, prior to Rio 2016, UKDS as a whole received only 0.19% of disability talent funding (UK Deaf Sport, n.d.) compared to Paralympic funding. In efforts to balance this statistic, UKDS has recently acquired over £1million across five years from Sport England as part of its ten-year Uniting the Movement Strategy (UK Deaf Sport, 2022), which will support various provisions and opportunities within D/deaf sport in the UK. Whilst funding is a large piece of the D/deaf sport puzzle, particularly across elite sport and performance pathways, there are other aspects of sport that significantly contribute to its overall success such as the sociocultural importance of sport and starting technologies.

Within the D/deaf community and culture, sport holds a special status as it provides a protected and inclusive space to communicate freely, build relationships and skills (Stewart & Ellis, 2005). Quite often, D/deaf people are marginalised due to a lack of accommodations and effort to engage and include by wider society; this leads to D/deaf people creating their own inclusive environments such as D/deaf sports teams, local D/deaf clubs, and pubs to facilitate socialisation (Stewart & Ellis, 2005). D/deaf participation in sport is said to be motivated by three factors: sociability, emotional rewards, and self- and group-identity and is driven by the desire to maintain and strengthen relationships and create a mutually appreciated environment (Atherton et al., 2001). These motivations are also seen in elite D/deaf athletes whereby a preference to compete in D/deaf only competitions because of the socialisation and communication benefits. Similarly, it was acknowledged D/deaf athletes do appreciate and value competition with hearing athletes as it provides more regular competitions, often a higher standard of athleticism and increased athletic recognition (Kurková et al., 2011). D/deaf sport yields significant benefits for both the participation and performance of D/deaf athletes across D/deaf and mainstream pathways (Šešum et al., 2023) but these benefits do not extend to widespread inclusion.

The dissonance between D/deaf and hearing worlds is exacerbated in sport. Historically D/deaf people have struggled to fully participate in hearing sport across all levels due to barriers such as lack of effective communication (Clark & Mesch, 2018), a lack of D/deaf awareness, and

ignorance towards accommodating additional needs which led to the development of D/deaf sport to create an environment that has no barriers (Atherton, 2007). Many D/deaf people communicate via visual methods, whether that be sign language, and/or lip-reading, and whilst these methods facilitate the cohesion and communication between D/deaf team-mates and athletes (Kurková et al., 2011), it does not eliminate the social anxiety, frustration, and isolation that the D/deaf community experiences in mainstream settings when communication is not cohesive (Karademir, 2015). This is why many D/deaf athletes prefer to compete in D/deaf sporting competitions - despite the lack of external and organisational recognition associated with D/deaf competitions – as the inclusive environment, effective communication and strong cultural identity is more important to D/deaf athletes (Foster et al., 2018).

As mentioned earlier in this thesis, the Deaflympics is seen as the pinnacle of D/deaf sport and competition. The Deaflympics is a quadrennial international competition with both Summer and Winter events first launched in 1924 (then called the International Silent Games), in Paris with nine European nations taking part (Ogoura, 2018). The most recent Deaflympics was held in Caxias do Sul Brazil in 2022 and 73 countries and 2412 athletes took part (Deaflympics, 2022). Unfortunately, Team GB did not attend the Brazil Deaflympics in 2022 due to preparation issues as a result of the Covid-19 pandemic and funding limitations (UK Deaf Sport, 2022). In order to be eligible to compete in the Deaflympics, athletes must have a hearing loss of at least 55dB in their ‘better’ ear and the use of assistive hearing devices e.g., cochlear implants, is prohibited during competition to create standardisation across athletes (Deaflympics, 2009).

If a D/deaf athlete progresses from the participation to performance pathways, they can compete under mainstream/Olympic pathways or via the Deaflympics. There is no classifiable category for D/deaf athletes in the Paralympics and D/deaf athletes can only compete in the Paralympics if they have another classifiable disability such as limb deficiency (Harrison, 2014). Whilst at surface level it may appear that there are direct and accessible routes to progressing through performance pathways for D/deaf athletes, this is not the reality. Since the start of the modern Olympic Games, there have only been 18 D/deaf athletes that have represented their country at Olympic level across all sports, with only three track and field athletes (Wikipedia, 2022), therefore, whilst D/deaf athletes can technically compete via Olympic pathways, it is highly uncommon.

In mainstream and para-athletics, auditory-based starting systems such as the starting pistol has been used in major events since 1904 with the most currently used systems being an electronic starting pistol that is standardised to play a recording of a gunshot, deploy a flash of light and send a pulse to the electronic starting device (Hareendran, 2022). Currently, the Omega Scan 'O' Vision photo-finish timing system is considered as the gold standard starting system and can capture up to 2000 images per second and estimate the race finish time to within ± 0.0005 seconds, making it highly accurate (Haugen et al., 2012). In D/deaf sport, visual-based starting systems are used with varying effectiveness and empirical justification. In grassroots and lower-level sport and competitions, variable systems such as flags and shoulder taps to signal the start of the race are often used due to the ease of access and cost but these can cause unintentional consequences for D/deaf athletes. In higher-level and international D/deaf competitions, it is more common to see a light-based starting system either in addition to, or instead of the starting gun. However, there is a lack of consistency and standardisation across competitions with different systems being used at each competition. Several efforts have been taken to develop a technologically sound starting system that is inclusive for D/deaf athletes. For example, Zulkifli et al., (2019) developed a visual signal device that works alongside SEIKO technology and has recently been used at the Malaysian National Deaf Games but is not commercialised. In addition to visual-based starting systems, there is evidence of haptic-based systems being developed for use in D/deaf sport. Shitara et al., (2018) developed a visual-haptic system positioned by the start line but a small dataset (three trials per participant) and issues regarding haptic vibration intensity mean that this system is not fully developed and implementable for wider environments. A more comprehensive and evidence-based visual starting system was developed by Rocandio and Cid (2012) and has been used at multiple Spanish D/deaf sports events and D/deaf European competitions, but it is unclear whether this system is still being produced and implemented consistently at different competitions. It is clear from the existing evidence and technology regarding D/deaf accessible starting systems that a more comprehensive, holistic and empirical-focus approach needs to be taken in order to develop a system that does not create any unintentional consequences and is suitable for commercialisation and implementation across all levels of D/deaf sport and competition.

The mechanical and biomechanical challenges created by commonly used starting systems in D/deaf sport can be explained through several unintentional consequences. For example, a visual

starting system such as a flag or light system that is positioned in front of the athlete i.e., not in the athlete's eyeline, requires the D/deaf athlete to lift their head up in the 'set' position in order to see the starting system. Lifting the head disrupts the optimal neutral alignment needed between the head, neck, shoulders, and hips to produce the necessary force required for an effective sprint start (Slawinski et al., 2017). Evidence suggests that not adopting a neutral spinal alignment has a detrimental impact on sprint start performance and subsequently, race outcome (Coh & Tomazin, 2006; Haugen et al., 2012). Furthermore, the use of systems that require an extra level of communication such as flags positioned further down the track could delay RT and result in athletes responding significantly slower to the stimulus. An example of this would be if there is an integrated race i.e., D/deaf and hearing athletes in the same race, and the hearing athletes are using a typical auditory start gun and a flag has been implemented to provide an accessible start for the D/deaf athletes but the flag is only moved once the starter has fired the gun meaning that the D/deaf athletes will either respond to the other athletes moving or respond to the flag which has been presented after the starting gun. Both of these outcomes will significantly reduce the D/deaf athletes' opportunity for an equitable start and race.

Study Rationale and Aims

The existing research surrounding the development of a standardised starting system is largely quantitative in nature, but to ensure that the sociocultural requirements and technical needs are established, a qualitative investigation that encompasses this is warranted. Currently, there is not a comprehensive summary of existing starting systems used at different levels of the D/deaf participation and performance pathways, and how these starting systems impact the overall athletic experiences of D/deaf athletes, which the current chapter aims to address. Similarly, it is important to acknowledge the role of stakeholders and coaches in developing and nurturing the experiences of D/deaf athletes, thus incorporating the coaches/team managers of D/deaf athletes and stakeholders will facilitate wider insight of starting systems. Based on this and the overall aims of this thesis, the primary aims of this chapter were twofold: (1) to explore the experiences of variable starting systems used across the participation and performance pathways and wider sporting experiences within D/deaf athletics; and (2) to establish key recommendations for: the technical requirements of an equitable standardised starting system and considerations to ensure successful implementation and accessibility of a standardised

starting system. This, alongside the quantitative RT findings highlighted in Chapter 2 and Chapter 3 will provide a comprehensive evidence-base to inform the development of a standardised starting system that is equitable and accessible across all athletics pathways.

4.3 Methods

Philosophical Standpoint

The present chapter was grounded by an interpretivist paradigm, underpinned by a constructivist epistemology and relativist ontology. The foundations of an interpretivist paradigm state that reality is subjective and influenced by the perceptions of individuals (Nickerson, 2023) which aligns particularly well with the rationale of the current study and population. The associated impact and scope of this research within D/deaf athletics, alongside my lived experience of being Deaf guides the subjective nature of this research (Denzin & Lincoln, 2005). Furthermore, to embed a sociological underpinning, a constructivist epistemology ensures that there is a collective generation of meaning and perceptions (Lee, 2012). The personal and different experiences of each participant, whether that be a D/deaf athlete, a coach or a stakeholder, allows us to recognise that there are multiple realities and perceptions present, offering a subjectivity and empowerment of the individual's reality (Levers, 2013) to create a collective understanding of an underexplored area within D/deaf athletics and sport. In conjunction with utilising collective meanings and experiences with personal subjectivity, we must acknowledge relativity of different experiences and within the context of this research, there are many factors and environments that will contribute to a different experience within the same sphere. For example, the varied geographical location of participants means that there likely would have been varied local opportunities and networks for involvement in D/deaf sport/athletics which would result in different experiences and realities across D/deaf athletics. This philosophical standpoint has implications for data interpretation due to the contextual specificity of the findings and the population it considers. Thus, it is accepted that the findings from this research, whilst they provide in-depth and explicit knowledge for the development of D/deaf athletics, are value laden and influenced collectively by the participants' and I's own values, knowledge, and experiences.

Participants

Eight participants from three groups (D/deaf sprinters $n = 3$, M age = 29.3 years; coach/team manager of D/deaf sprinters $n = 3$, M age = 51.3 years; stakeholders $n = 2$, M age = 38.5 years) took part in the interviews. For context, all D/deaf sprinters had competed in at least one international level D/deaf athletics competition, all coaches and team managers had specifically coached or managed elite D/deaf sprinters to at least national standard, and all stakeholders had been involved in D/deaf athletics and sport. The geographical spread of participants resulted in a mixture of online and in-person interviews. Two of the interviews were with British Sign Language (BSL) users so qualified interpreters were present in the interviews to facilitate discussion. The other six interviews were conducted in spoken English. Participants were given the option of a £30 payment for their participation. All interviews were conducted in line with the institution's ethical protocols for research with human participants.

Procedures

In line with the constructivist relativist perspective, I observed and examined the existing evidence and information surrounding starting systems in D/deaf athletics to inform the rationale of the research questions and interviews. Furthermore, due to the limited existing literature specific to starting systems, the postulated key themes were derived from carefully selected subjective notions (i.e., already established factors influencing participation and performance in D/deaf athletics) from my observations and pre-existing knowledge to ensure cohesion and linearity with the overall aims of this thesis.

Interview Schedule

Due to the novel and exploratory underpinnings of the interviews, the semi-structured interview schedule was developed to encompass the key aims of the research. The semi-structured nature of the interview schedule was important to glean wider information and to facilitate retrospective and prospective discussion across the three participant groups. The interview guide was structured into three sections in line with the key aims and focus of the research: starting system experiences, sport experiences, and recommendations for future starting systems. Prompts and probes were included throughout the interviews to elicit more in-depth information about participant's feelings (e.g., 'How did that make you feel before the start of

your race') and opinions (e.g., What do you think about the integration of D/deaf athletes in mainstream athletics?). Participants were provided with the opportunity to provide further insight into their experiences with starting systems and athletics beyond the interview schedule. The interview schedule can be located in the appendices of this thesis.

Interview Procedure

Prior to the interviews, I had engaged with the majority of D/deaf athletes, coaches/team managers and stakeholders that participated, through my involvement with D/deaf athletics events and across my PhD. This was intentional to facilitate familiarity and rapport with participants to support the discussion between the interviewer and participant. Participants were either directly invited to participate or were recruited via social media and word of mouth. All participants were provided with an overview of the three main themes within the interviews. The online interviews (n=3) took place via Microsoft Teams or Zoom at a mutually agreed time. The in-person interviews (n=5) were conducted in a convenient locations and times to the participant. All interviews commenced by reiterating the key aims and nature of the interview and that all data would be anonymised with all identifiable information removed, and that participants had the right to withdraw at any point. Participants were reminded I was interested in understanding their experiences of different starting systems they had encountered across training and competition, identifying the factors contributing to their sporting journeys and to establish the technical and sociocultural requirements for a future starting system. All interviews started with participants explaining their involvement in D/deaf athletics e.g., number of years involved in athletics, the level of competition and role specificity. The first theme that was addressed in the interviews was the types of, and experiences of different starting systems in relation to their participant group and perspective e.g., stakeholders adopted more organisational insight whereas athletes spoke more anecdotally. Following discussion of different starting systems, the general flow of the interviews comprised questions around broader sporting journeys and factors influencing participation and performance/competitive experience, followed by discussion of the role of sporting organisations and recommendations (technical and sociocultural) of a future starting system. At the end of the interview, all participants were given the opportunity to elaborate, add, or clarify any further information to the interview and were thanked for their time and effort. Once the interviews had been transcribed, all participants were given the opportunity

to read through and check the transcripts for accuracy and credibility prior to formal analysis (Brett & McGannon, 2018). Participants were asked to identify any areas of the transcripts that they felt did not accurately reflect their views and intentions. These areas were amended and resolved in liaison with the participant. The length of the interviews ranged from 39 to 57 minutes. Typically, the BSL interviews were longer due to interpreting.

Data Analysis

The oral English interviews were transcribed verbatim by an external organisation. The BSL interviews were transcribed from BSL to English (using the participant's words, not the interpreter's). All transcripts were read thoroughly prior to analysis. NVivo 12 qualitative data analysis software was used to process and analyse the transcripts. The data was coded across the three main interview themes and then sub-coded for within theme factors. All interviews were coded on a line-by-line basis until entirely coded. Once coded, I examined all of the quotes within the main themes and subsequent sub-factors and adjusted any codes dependent on the data to accurately reflect the theme. Triangulation of the data across the different participant groups was carried out to cross-check the validity of experiences e.g., a specific starting system used at a specific competition and to create a holistic picture of starting system and sport experiences from the different facets of sport. Following this, the sub-themes were developed inductively and used to influence and direct the primary conclusions around starting system experiences, sport experiences and recommendations for a starting system.

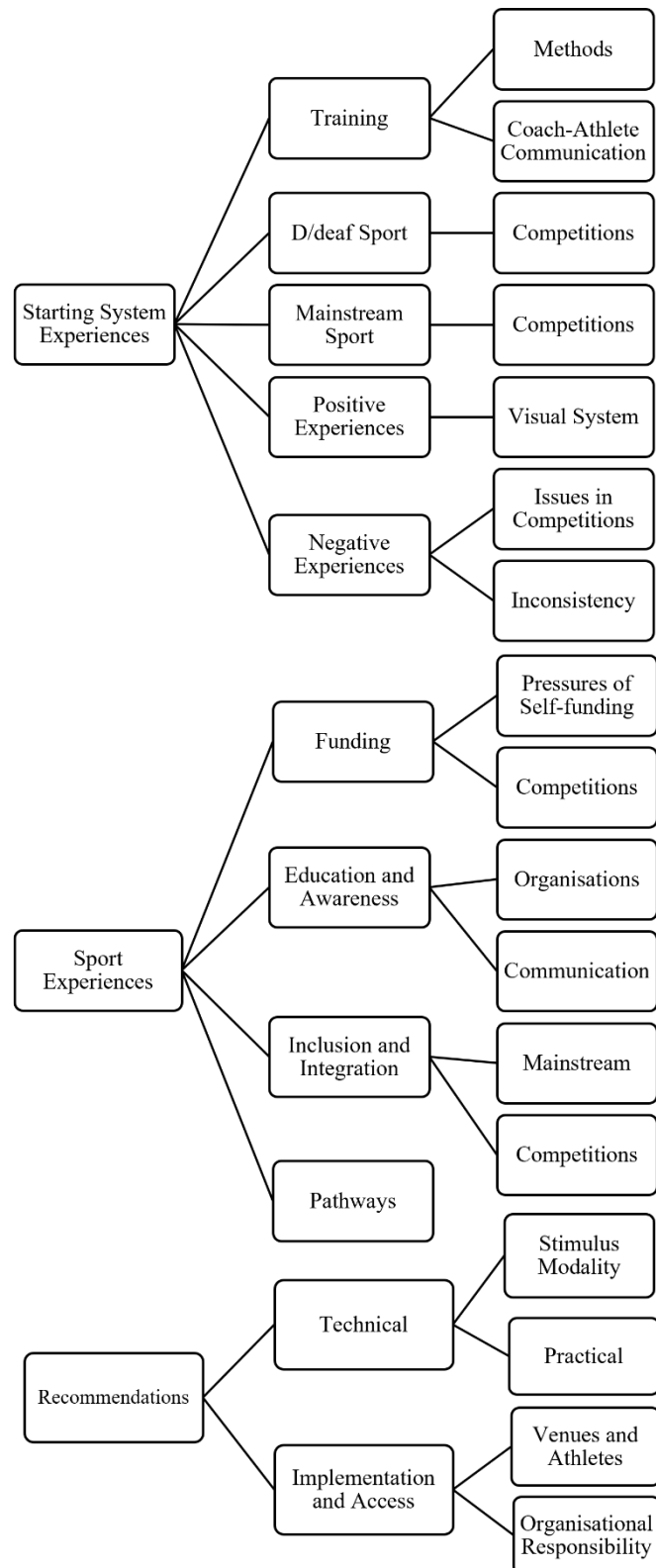
4.4 Results and Discussion

Three key themes in line with the study aims were identified which were: Starting System Experiences, Sport Experiences, and Recommendations. Starting System Experiences encompasses the experiences of D/deaf sprinters, coaches and team managers of D/deaf sprinters and stakeholders with the starting systems used in training, in D/deaf sport competitions, mainstream competitions and then the positive and negative experiences surrounding the different starting systems. Sport Experiences is broader and covers the primary barriers and factors that influence participation and performance in D/deaf athletics such as funding, education and awareness, inclusion and integration and pathways. Lastly, Recommendations discusses the technical recommendations and essentials for a starting system, how to implement

and provide consistent access to a starting system and the importance of reducing organisational stressors for athletes to ensure continued success in D/deaf athletics. Each theme and sub-factor is discussed and substantiated with relevant quotes from D/deaf sprinters, coaches and team managers of D/deaf sprinters, and stakeholders. Figure 4.1 displays each of the three key themes (Starting System Experiences, Sport Experiences and Recommendations) with a breakdown of specific sub-themes. Each sub-theme incorporates quotes and contextual information from the D/deaf athletes, the coaches / team managers, and stakeholders. The three pillars (Starting System Experiences, Sport Experiences, and Recommendations) aim to provide a holistic understanding and breakdown of the interviews with a clear focus on the applied experiences of participants to inform the technicality, practicality, and feasibility of the development of a standardised starting system.

Figure 4.1

Starting System Experiences, Sport Experiences, and Recommendations Themes



Starting System Experiences

Training. All of the D/deaf athletes reported using auditory-based starting systems such as spoken cues, claps, foot stamps, and whistles in training. For example, one D/deaf athlete said, ‘In training, it would just be my coaches voice, on your marks, get set go [claps] like that.’ Interestingly, simultaneous auditory and haptic methods were adopted by one D/deaf athlete whereby ‘my training partner will be next to me, and then when the coach blows a whistle on the other side of the track, they will hit me a bit or I’ll go with them.’ Similarly, in efforts to ensure a quick start post-auditory stimulus, one D/deaf athlete stated that ‘they [coaches] sometimes stand behind me and more or less stamp on my starting block, so I feel it, so I go at the same time as everyone’. Aside from flags and hand gestures, no athletes reported using a physical visual starting system in training. This was corroborated by two coaches/team managers who said:

At home there is only the starting pistol, there are no lights. A flag is used, that’s it’ and ‘In training...I have used touch, possibly used flags, but that would be similar to just using my arms, really. And not light, no.

We can see a strong link between coach-athlete communication with starts in training; it seems that effective and clear communication from the coach is a prevalent method of starting, for example one coach stated:

If [athlete] needs to see when we’re particularly starting, I’ll stand where he can see me, and kind of prepare, and then sort of, you know “On your marks” and then when I say “Set”, I’ll put my hand up, and then for “Go”, I’ll bring my hand down.

Collectively, this highlights that there is a great variety of starting methods used by D/deaf athletes and coaches/team managers in training with verbal cues and physical being the predominant methods.

Deaf Sport. On the contrary to training starting systems, visual systems are the primary and most prevalent starting system method in D/deaf athletics competitions. The most common type of visual starting system used across different European competitions was a traffic light-style system whereby ‘red means “on your marks”, and then amber is “set” and green is “go”.’ Traffic light systems were reported to be used in Germany in 2016:

There were lights on the track like traffic lights, and also higher up. I there were three – red where you came to the line, yellow, to get ready, and green to go. If there was a false start, the other lights flashed’ and at a competition in Belarus where ‘they used the three lights – red, yellow, and green and that was it. If there was a false start, they waved their arms.

However, alternative light systems have also been used at other competitions e.g.:

In Turkey there were two lights, we were told to come to the line, then the first light signalled to “get set” and the second flash meant “go” and other light systems that ‘would just be like white, sometimes go white a sec and then go sort of strobe-y lighting for go.

Specific to indoor competitions, a different visual system has been used whereby ‘on red you went to the line, an orange line meant rise up, and then there were screens either side of the track that flashed (like a camera flash) that meant go’. Stakeholders were aware of the variable systems used at different competitions and had made efforts to source alternative visual and haptic systems for athletes such as:

An off the shelf [visual] system in Australia, which I think is the one that was being used at the Deaflympics, but when we looked into it, they were thousands and thousands of pounds’ and ‘wear an armband...that kind of vibration as the starting, but it didn’t get any further than that...it would have involved the gun going, someone then blowing a whistle in response to the gun, then the armband vibrating.

These statements demonstrate a consensus towards adopting a visual starting system, but it is apparent that there is a significant lack of standardisation and consistency across competitions, particularly in higher-level European based competitions.

Mainstream Sport. In order to build their competitive experience and performance, D/deaf athletes often compete alongside hearing athletes in mainstream competitions which use auditory starting pistols as standard (Mitašík et al., 2021). Despite the obvious limitations with not being able to hear the gun itself, the D/deaf athletes raised other circumstances whereby their start could be impeded. More specifically, the assigned lane position can cause further issues for D/deaf sprinters as when a D/deaf sprinter is ‘in lane one, [they’re] close to the pistol, I can hear it. If I’m in lane eight, I have to look behind’, with this being corroborated by their coach who

noted ‘if [they’re] unfortunate enough to get an outside lane draw, if [they’re] more on the inside, [they’ll] have more visual cues, [they] can see- closer to the starter’. This suggests that when a D/deaf sprinter is assigned an outer lane e.g., lanes six to eight, they are even more less likely to hear the actual starting gun and also feel the vibrations emitted from the gun. Similarly, due to not being positioned close to the starting gun and to avoid lifting their heads to see a flag or hand signal (which impedes the starting position and velocity output (Coh & Tomazin, 2006; Nagahara et al., 2020). D/deaf athletes’ resort to looking under their arm to the athlete next to them and watching when the other athletes move. One D/deaf athlete said:

You have to rely on watching others and when they say, “on your marks”, you move to the line, “get set” means move into position. I must look behind me and watch, I take my cochlear implant off, and then when they fire the gun you run. I am always a little bit late out of the blocks because I’m watching’, with another athlete stating, ‘I will get in the blocks, and I watch the people either side of me.

This demonstrates the inequities and adaptations that D/deaf athletes must use in order to have a fast start. As RT can account for up to 5% of overall performance (Englert & Bertams, 2014) it is unfair that D/deaf athletes must resort to responding to the movement of other athletes to start their race, this will undoubtedly increase their race time and reduce their chances of medalling. However, considering these issues, some D/deaf athletes reported a positive perception of starting pistols as ‘it’s easier to be focused’ when there is one familiar stimulus and due to the increased regularity and exposure to starting guns, D/deaf athletes have ‘trained [themselves] to run out to guns.’ Overall, D/deaf athletes must adapt their starting position (i.e., look under their arm) and accept that they are likely to be slower out of the blocks due to not hearing the starting gun and responding to other secondary stimuli such as other athletes moving. This highlights the need for an equitable starting system that ensures that D/deaf athletes can respond to the stimuli authentically.

Positive Experiences. All participants were given the opportunity to highlight the starting methods that they felt were positive / successful and responses covered mainstream and D/deaf competitions. In a mainstream setting, whilst looking under their arm to respond to their opponent’s movement results in leaving the starting blocks slower, one D/deaf sprinter stated, ‘I really like watching people when in the blocks, so I know when to go’. This could be due to the

reliability and assurance that the other athletes will definitely move, whereas trying to rely on hearing the pistol itself is less reliable. In D/deaf settings, D/deaf athletes reported some positive experiences with traffic light visual starting systems as they 'are just smooth sailing, just like red, orange, green' and that the traffics '...are effective, it's very visual'. These statements suggest that when an athlete is confident and reassured by the starting system method, they often have more positive experiences. Cultivating more positive experiences via the implementation of an effective starting system is critical as many participants found it trickier to identify 'positive' experiences. Everyone has the right to enjoy their experiences, particularly as this has been reported as antecedent to participation and performance adherence (Kurková et al., 2011) and if an equitable starting system promotes that, then it is necessitated to strive towards that.

Negative Experiences. On the contrary, the few positive experiences outlined by D/deaf athletes were significantly outweighed by negative or problematic experiences. There were two clear themes that surfaced within the realm of negative experiences which were issues in competitions and the inconsistency of starting systems. The three primary issues in competitions were faulty units leading to delayed starts / lack of efficacy, false starts, and sun glare. It appears to be a common occurrence with visual systems at D/deaf competitions whereby individual lights did not work at the start of races. For example, one coach / team manager stated:

You might have three heats of the 200 metres, and it would seem to work fine in the first and second, and in the third there'd be a problem' with more problems being noted with the 'strobe' style light system as it was difficult to see the lights so 'some people would drive off and other people are like, mine didn't go off!

There is a general feeling that D/deaf athletes are burdened with greater responsibility with starting systems at competitions as commented on by a coach / team manager:

The athletes have to move them, so they have to be careful. Then when in the starting positions you have to be confident if you move them. They can be either on the left or right of your lane. You need to ensure everything is firmly connected and in place.

Similarly, 'sometimes people had to raise their hand to indicate there was a problem with the lights, so they couldn't start the race'. Another example of increased burden and lack of confidence in the visual systems was noted by one D/deaf athlete who felt that 'sometimes the

lights are risky, because I have to pay for everything, I don't want to risk getting there and having a false start because of the lights' so as a result, athletes utilise other ways of starting such as watching for other movement or listening for a gun (which is difficult when D/deaf athletes are prohibited from wearing any assistive hearing device on the track; Deaflympics, 2009).

As with any type of athletics, false starts can happen but are typically caused by the athlete anticipating the starting stimulus and the starting pistol is fired a second time to indicate a false start (Milloz et al., 2021). However, in D/deaf athletics, there are different solutions to indicate a false start which are not always effective. One coach / team manager talked about one particular occasion where 'somebody ran the whole race without realising there'd been a false start, that definitely happens' and particularly in races where there is a staggered start e.g., the 200 metres as 'the problem would be...if they fire the gun again and I'm in lane eight in the 200 and there's no one out in front of me and I'm sprinting around the corner'. Furthermore, a lack of confidence in processing the starting stimulus and worry about false starting due to the equipment results in increased anxiety and disruption of focus for D/deaf athletes, as stated by one D/deaf athlete, 'I'm nervous about it, the race, hearing the gun, I get very nervous and worried about it, and that affects my focus' and a coach / team manager 'mentally it affects you because you cannot focus, you are mentally prepared and then have to stop which results in loss of concentration. That can mean you aren't prepared and leave the blocks late so have to catch up'. This reiterates the need to develop a starting system that instils confidence and reassurance as well as being equitable to ensure that D/deaf athletes are afforded the same opportunities as their hearing counterparts.

The sun and glare are major contributors to poorer starting system experiences and will be a key consideration for a future developed system. Coupled with the variability and lack of exposure to starting systems prior to a competition, the sun creates issues as 'when the sun is bright, it can be difficult to know which colour it is' and specifically 'the whiter lights, the white lights weren't good when you've got the sun on you' which results in having to 'call in officials to sort it out and test the lights to ensure they were working'. This issue is more specific to outdoor events but as the main athletics season is in the summer, it is essential to ensure that athletes can see the lights clearly, even when the sun is bright.

A recurring insight seen from stakeholders was how the lack of consistency and standardisation of starting systems impacted the conscious work towards making athletics more inclusive. One stakeholder noted:

We want it to be standardised that you turn up: “Oh, there is a D/deaf athlete... Great, so we’ll use this bit of equipment” It’s just a brilliant experience for everybody. It’s the same experience. There’s no “Oh, well, you’re D/deaf, so can we have your starting system that you need to have paid for and brought with you?” and then probably tell us how to connect it to things. So yes, that kind of level of inequity was something we wanted to address.

A nuance to this is that people have tried to develop a starting system previously but have not managed to conduct widespread implementation, for example as mentioned by one stakeholder:

The one in Scotland, which I’ve never seen again, because that was made by an official, [they] knew how to connect it to the starting system, which is where we then go on to this project, of trying to embed it into the new electronic starting system.

Again, this reiterates the need to develop an evidence-based starting system that can feasibly be manufactured and implemented on a more widespread scale.

Summary. The variability of starting systems used within, and across mainstream and D/deaf athletics clearly present issues around inconsistency, effectiveness and practicality i.e., sun glare that intend to be rectified by the development of a standardised starting system. This will hopefully result in D/deaf athletes and their coaches / team managers having more confidence and reassurance that the starting system is 100% effective and consistent across training and competitions.

Sport Experiences

Funding. Unlike several other European countries such as Poland and Ukraine, the UK does not provide any funding for D/deaf athletics (Szulc et al., 2021) meaning that athletes, coaches and team managers have to self-fund and fundraise everything from competition entries, kit, flights to accommodation. This results significant challenges for athletes and coaches / team

managers across the sporting pathways but particularly within in the performance pathway. Alongside receiving no funding, one coach / team manager stated, ‘the UK Government doesn’t recognise UK Deaf Sport’ and while ‘British Athletics are funded to support athletes for the Olympic and Paralympic pathways...there was no deaf pathway in the work they did...certainly no funding from the national governing body, and just generally not really a structure or a system’, one stakeholder said.

The pressure of self-funding and fundraising to attend competitions was reported by all D/deaf athletes and coaches / team managers and it was clear that there were frustrations and discontentment surrounding this. One D/deaf athlete commented that they ‘get no support at all, or if we do get some money, everything else, we have to pay out of pocket if we want to represent our country’ with this being supported by a coach / team manager who spoke about their athlete, ‘Well, let me put it like this; when [they’ve] been selected to represent Great Britain, like representing his country, [they’ve] had no funding. He’s had no funding from the governing body’. Having no support from governing bodies and organisations means D/deaf athletes have to lean on personal support systems, particularly with financial support, to support their development and dreams. One D/deaf athlete who has competed for Great Britain several times over the years with minimal funding spoke about what their family had to sacrifice to afford for them to attend competitions:

It was only when I was older that I realised that it was money we weren’t getting. I just didn’t realise what they were doing. In a way I felt bad because of it because they didn’t go ever on holiday, because they’d just spend so much money on the competition price.

Whilst it is often common across sport in general for families to provide financial support for their children (Lindstrom-Bremer, 2012) it is atypical for families to be expected to pay significant amounts of money to support competition attendance as seen in D/deaf athletics, which is unfair and results in marginalisation of D/deaf athletes. As mentioned previously, the Deaflympics are viewed as the pinnacle of sport in the D/deaf community. In 2022 for the first time ever, UK Deaf Sport did not send a team to the Deaflympics. A coach / team manager provided insight into this situation and said:

UK Deaf Sport had a meeting to discuss the situation and consider the health and safety and funding and it was determined that we weren’t ready. Also, all the information

arrived at really short notice, despite repeated requests, so in the end we decided to drop it.

The controversy and upset around this situation reflects the state of D/deaf athletics in the UK and warrants change to ensure that history does not repeat itself for the next Deaflympics.

The poor funding situation of D/deaf athletics in the UK is not seen in other European countries where D/deaf athletes are recognised as athletes and receive funding and financial rewards for competitive success. Due to no funding, D/deaf athletes in the UK must support themselves financially via employment which reduces the volume of time available for training whereas D/deaf athletes in countries such as Poland and Russia can reach paid professional status. One D/deaf athlete reported:

There are D/deaf Russian athletes who won medals, they received funding for training.

The Polish athletes as well, they are funded to train. In Poland they are paid from 9am to 3pm for their running training but I must work.

Another D/deaf athlete corroborated this and stated, ‘...Russia, Ukraine, are able to get government funding and they get money for winning medal, that’s why they always do so well because they are pretty much full-time athletes over there,’ In the last Deaflympics, Ukraine topped the medals table with a total of 153 medals (68 gold medals, 40 silver medals, and 45 bronze medals), which was nearly three times the number of medals as the overall second place (USA: 55 medals total) (Deaflympics, 2022). The volume of medals won by Ukraine compared with the non-attendance of Team GB due to funding demonstrates the success that can be achieved when D/deaf athletes are properly funded, supported, and acknowledged by their governing bodies. The governing bodies and organisations in the UK need to start formally acknowledging and funding D/deaf athletes to the same levels as mainstream and Para- athletes so that D/deaf athletics (and sport) can develop and thrive. Being awarded funding by governing bodies and organisations can be tricky for many sports but as stated by one stakeholder, ‘If we don’t have the research and the evidence...it’s very hard to then challenge or implement things, especially when it comes to funding because evidence-led research sometimes makes the difference from getting funding or not getting funding’ so hopefully the implementation of an

evidence-based standardised starting system will in turn generate more funding for the future generations of D/deaf athletes and competitions.

A substantial and tangible part of competitions and representing your country is wearing a unified kit across the team so that all athletes look the same. However, the experiences of D/deaf athletes at European level and above highlight that unified kits are not guaranteed and can have consequences at competitions. More specifically, at the European Deaf Athletics Championships in 2019 in the relay races, the sprinters did not have a unified kit due to having to ‘beg and borrow some old kit...we either got some kit that was passed down by various athletics organisations i.e., UK Athletics’. This is technically against the competition rules and the attending coach / team manager stated that the competition officials ‘warned us and said:

Look, you’ve got to have identical-” because every other country had relatively smart kit, everybody did. And certainly the larger countries that had funding, they all had fantastic kit, and we were a bit of a ragbag and people had different kit from different tournaments, basically. So we just didn’t have enough money to standardise our kit.

This is poor and a stark difference from the kit provided to mainstream and Para-athletics athletes; funding and providing a standardised and unified kit for D/deaf athletes who are representing their country is an easy fix to improve the experiences and pride of D/deaf athletes.

Education and Awareness. As already touched on, D/deaf athletes are faced with many barriers that stem from sociocultural facets and a lack of awareness around communication, inclusion and education and it is these barriers that led to the development of D/deaf-specific sport (Atherton, 2007). Across the interviews, it was clear that there needs to be an increase in the consistency and volume of education around D/deaf athletics to improve the inclusion and experiences of D/deaf people. The stakeholders provided excellent insight into provisions and wider attitudes towards inclusion and D/deaf awareness such as:

Come and try events, connected with local athletics clubs, so the coaches then also have that exposure to coaching D/deaf people. It builds their confidence, builds their experience. They’ve connected then, so then the local coach can just be saying, “Oh,

well, come down on Tuesday night"... the work we have done around...recreational running was around D/deaf friendly.

Furthermore, ensuring that other governing bodies, officials and coaches have access to regular educational training and resources was a priority for stakeholders. More specifically, creating D/deaf awareness resources so that

instead of having 30 governing bodies doing, like, an athletics version, a football version, a netball version, that there's a generic version, because sports coaches, that's what they should be good at, is then taking that information and interpreting it in the world of athletics.

Sport-wide resources alongside regular training will hopefully minimise situations whereby 'you deliver training in, say February and then by October/November, you may have a whole new set of officials' which will result in a lack of consistency in trained individuals. To mitigate this, one stakeholder suggested:

Lots of guidance and resources so that chances are, if you're a coach and you do your coaching course, you might not coach a D/deaf athlete, ever. You might do it the next week. You might do it in three years' time. How do you make sure that you can go back to that information or get that kind of information?

Increasing the volume and consistency of educational resources and training should increase the confidence, knowledge, and skillset of coaches, officials, and governing bodies (Townsend & Peacham, 2021) to effectively work with D/deaf athletes and positively contribute to their sporting journey.

Communication can be a significant barrier and antecedent to non-participation for many D/deaf people (Foster et al., 2018) and poor communication can result in lesser treatment as noted by one D/deaf athlete, 'It's sad because I'm deaf and lipread. So, it was hard for me to communicate with other people to find the best way to get good quality treatment' but once they had found a D/deaf-friendly coach, this changed and they said, 'my coaches are very deaf-aware. I mean, they learnt it through working with me' highlighting that the athletes can also be pivotal in advocating for their communication needs. Advocating for inclusive and D/deaf aware

communication can be a daunting feeling and stakeholders are aware of the challenges surrounding this, with one stakeholder commenting:

I think it becomes very hard because if you're not very confident and perhaps you haven't always spoken out at school or BSL might be your first language, so actually you don't feel confident in knowing how to ask the questions or knowing what to ask' which can lead to a greater 'chance of them [the D/deaf person] potentially not having a great experience, because people are not communicating with them well or not understanding their needs, or they've got, probably, experiences of discrimination.

Whilst a confident D/deaf person will be more able to advocate for themselves and educate those around them, stakeholders and organisations hold a responsibility to provide an inclusive environment and access to their preferred communication method. For example, stakeholders and governing bodies are technically responsible for their coaches, thus need to provide them with tools for inclusivity and accessibility so that when 'a D/deaf person comes to your club. How do we make sure they've got a great experience? How do we make sure that someone knows how to communicate with them?' and one such initiative to ensure this was, as highlighted by one stakeholder:

D/deaf athletics resource that we had developed with, it was the National Deaf Children's Society at the time...but things like that around understanding top tips, just having a fingerspelling sheet, for example, or tips for working with a sign language interpreter and all of those things.'

It is a multi-faceted approach to facilitating communication to ensure that everyone involved feels confident and included but it is important that the sole responsibility does not fall on to athlete, because as already discussed, D/deaf athletes are often burdened with extra responsibilities and pressure compared to their hearing counterparts, which creates inequity and barriers across their sporting experiences.

Inclusion and Integration. Inclusion is defined as the practice or policy of providing equal access to opportunities and resources for people who might otherwise be excluded or marginalized (Oxford English Dictionary, n.d.) and while 'things have improved in the last sort of 10 to 12 years since London had the Paralympics. Although [London] didn't include deaf

athletes, it did change people's perspectives to people with any sort of impairment' but it is evident that D/deaf athletics is still behind in terms of inclusive practice, both practically (via the lack of a standardised starting system) and societally. A stakeholder provided great insight into the landscape of D/deaf participation post-London 2012 and stated:

From being involved in parasport and athletics for over a decade, what I saw was that the more disabled people we were getting into clubs, then there was this groundswell of people...understanding disabled people train at the athletics club with non-disabled people. There's a pathway for them, and that having more people come in, and ore people contacting clubs, was a real stimulus for change...we didn't see the same thing with D/deaf athletes. I didn't see more requests to join athletics clubs, or more clubs coming to us to say, "Oh, we've had a D/deaf person join. Can we have some support?" So, I guess we haven't seen that change in culture or in adaptations.

One coach / team manager expressed that 'The world needs more deaf awareness in athletics competitions, and greater inclusion of D/deaf athletes. Historically, there have been lots of barriers.' Inclusion and integration of D/deaf athletes in mainstream athletics specifically can be characterised by the implementation of an equitable starting system, as currently there isn't 'a set system to include [D/deaf athletes] in the sport' and an explicit inclusive infrastructure across the participation (and performance) pathway. This infrastructure is important, as outlined by a stakeholder:

If you've just started athletics, you love running, you're doing a competition, it's a long way to competing in just with other D/deaf people. Most scenarios, you'll be with hearing people, so that's why that kind of scenario is more important.

This is particularly relevant while D/deaf athletics is still growing in the UK, integration alongside mainstream athletics will provide the most opportunity and flexibility for competitions and pathway progression.

In the instance whereby a D/deaf athlete progresses from the participation to the performance pathway, depending on whether they are competing in D/deaf or mainstream competitions, the starting system that they use will vary, and ultimately determine whether the athlete has an inclusive and fully integrated experience or not. Within mainstream competitions,

starting pistols are used as standard but as previously discussed, this does not provide equity of starts for D/deaf athletes and governing bodies are aware of this so have started to implement new flexible ruling to allow inclusion of an equitable starting system. One stakeholder provided more insight regarding this, stating:

With British Athletics, so the starting pistols are being phased out of the sport...and replaced with electronic starting systems. British Athletics...were definitely open to and working on ensuring that, as part of that standard electronic starting system, that a lights module...was included as standard.

This provides critical information and reassurance that with the future development of a standardised starting system will be received well by governing bodies. The inclusion of this ruling will mean that D/deaf athletes will have access to an equitable starting system within mainstream pathways. Integration and inclusion within competitions is also attitudinal and steered by perceptions and behaviours, more specifically,

...wherever you go, there is always an ethos or a vision that those environments are positive and friendly. Yes, competitive because they need to be, and it's healthy for that, but at the same time, it's about making sure it's inclusive.

Furthermore, creating an inclusive environment will reduce the potential discomfort surrounding practices (e.g., 'it's just another thing that is different for you, or you've got to go and tell the official, or you've got to bring your own light system') and lead to a greater acceptance and communication between athletes and officials. There is a wealth of work that needs to be implemented before D/deaf athletes are fully included and integrated in athletics, but things are moving in the right direction.

Pathways. As touched on previously, D/deaf sport in the UK is currently not recognised by governing bodies, thus does not have an official performance pathway for D/deaf athletes (Foster et al., 2018). More specifically, the pathway within athletics was outlined by one stakeholder:

British Athletics are funded to support athletes for the Olympic and Paralympic pathways, so for them, there was also no D/deaf pathway in the work that they did. It's not part of the performance pathway, so there's no...although a little funding, certainly

no funding from the national governing body, and just generally not really a structure or a system.

This coupled with the fact that ‘D/deaf athletics doesn’t come under the Paralympic pathway’ and there are ‘no pathways for them to the Paralympics, but there is a pathway into the Deaf Olympics...but that’s not a pathway that was formally recognised within our performance pathway’. This creates ambiguity and a lack of clarity for D/deaf athletes as they can technically compete in the mainstream / Olympic pathways but ‘due to the unfair starts and the access barriers, it’s tricky for a D/deaf athlete to get into mainstream sport’. At a participation level, there seems to more acceptance with D/deaf athletes competing alongside hearing athletes as noted by one coach / team manager, ‘...always went to hearing competitions, and they allowed D/deaf athletes to compete to increase confidence’ but this gets much more difficult when reaching higher levels of performance. It appears to be a common theme that D/deaf athletes are unaware of the pathways available to them when entering athletics with two D/deaf athletes stating:

The only reason I found out is because someone recognised I was D/deaf, with my hearing aid and picked me out doing a run. Great Britain Deaf, but I just thought even then that it was normal mainstream athletics, I hadn’t looked at the Paralympics at that point as even then it wasn’t on the telly as much as the Olympics.

I tried to apply to the Paralympics as I thought there might be funding, but I wasn’t allowed because I’m D/deaf and Deaflympics already exists. I just thought it would be a good opportunity...but I couldn’t compete.

This demonstrates that on top of no clear (funded) performance pathway, D/deaf athletes are not provided with enough information and awareness as to what their options are and how they are able to compete. For the next generation of D/deaf athletes to thrive, intentional efforts need to be made to develop and clarify the participation and performance pathways for D/deaf athletes to ensure that athletes do not leave the sport unnecessarily. It is unlikely for a D/deaf-specific classification to be integrated with the Paralympics, which also reflects a wider D/deaf community stance around not wanting to be perceived as disabled (Marti & Recupero, 2019). Thus, D/deaf athletes should be given equal opportunities to progress through the mainstream or D/deaf athletics pathways.

Summary. With regards to the overall sporting experiences and perceptions for D/deaf athletes, coaches / team managers and stakeholders, it appears that while the lack of a standardised starting system does create inequity and performance barriers for athletes, the sociocultural and systemic factors such as the lack of funding and unclear and inaccessible pathways create more significant barriers within D/deaf sport. Whilst resolving these barriers is outside of the current scope of this thesis, it is important to provide insight and understanding to create a holistic and contextual landscape for future research endeavours. It is intended that the implementation of an equitable, standardised starting system will catalyse the dissolution of the systemic barriers by creating greater access for all D/deaf athletes at any stage of the participation and performance pathways and allow for smoother integration within mainstream athletics.

Recommendations for Future Starting System

Technical. The interviews provided a rich insight into the preferences, necessities and considerations for a starting system that is realistic, implementable and practical. Across all three groups of participants (D/deaf athletes, Coach / Team Manager of D/deaf athletes, and Stakeholders), there was a strong preference for a visual traffic light starting system for several reasons as mentioned by one coach / team manager:

A visual system is best, like the traffic lights, so on red you take your marks, orange you get ready, and green you go. That's a perfect system. Previously with just two lights...it was a confusing system. The three lights is perfect as its easier to follow – it's an easy process, ready, set, go.

Similarly, D/deaf athletes also showed support for a traffic light system, 'the three lights, like traffic lights, that is my favourite.' The specification of using a traffic light style system is important as when using two lights, or 'one colour white to white strobing', creates uncertainty and confusion for athletes and has previously contributed to negative / poorer starting experiences. There was uncertainty from D/deaf athletes regarding the incorporation of a vibration, or haptic stimulus. For example, one D/deaf athlete said, 'Vibration, I don't know, maybe your mind could play tricks on you' and another said:

Vibration would be good...for me, I prefer light or vibration. But I think I prefer the light. Because if it's vibration on my block, it can maybe mess up my movement. I think it's a risk where it's touching you.

In line with the quantitative findings earlier in this thesis, it is highly likely that a haptic stimulus will be incorporated in the future starting system so the concern of 'if for example I'm training without lights or vibrations, and then they are used at a competition, I wouldn't know how to respond to them' but as athletes have increased exposure and practice with the starting system, the confidence and familiarity with the starting system will increase. Particularly with mainstream races, there was a general agreement across stakeholders that the new starting system 'has got to connect to the gun. Like, I think it has got to be one system, not a parallel system. It's connected to the gun, so there's no gun goes, someone presses a button, lights start.' which is a critical consideration to ensure that the stimuli are presented at the exact same time and neither D/deaf nor hearing athletes are provided with an unintentional reaction time advantage. Furthermore, to ensure that all athletes, regardless of hearing level, have equal access to relevant stimuli was noted as important by stakeholders:

Having lights as well as a gun, potentially, I would imagine, if you're looking down as you're about to start your race and you've actually got the lights as well as the gun, it's only going to reinforce the start of the race.

By doing this, it will remove D/deaf athletes needing to either look under their arm to other athletes or lift their head to see a flag and allow for a more effective start.

Practical. Other factors that will contribute to the practical efficacy and starting success are the starting system positioning in relation to the athlete, protection from the sun and glare, general portability, and the size of the system. As established, when an athlete is required to lift their head to see a visual stimulus, this disrupts the optimal biomechanical alignment of a sprint start (Milanese et al., 2014) and can have adverse effects on performance and race outcome (Coh & Tomazin, 2006) and as mentioned by one coach / team manager, at a previous competition 'there was one I saw in Poland where they had to almost look up and that's no good'. The ideal positioning of a light-based system was discussed with all participants, with one D/deaf athlete stating the optimal position would be 'on the line of the track, in front of you, where it can't

move. Not on the side, nothing by the side of the tracks flashing, on the ground in your sight line.’ This was supported by a stakeholder who said:

The positioning is important that, when they start, they’re not worried about stepping on something, that their head can be in a natural position to see the lights, which is tricky because, if you think about generally when you go into the start position, your head would be down. Then the set position, your head would not be up, but eyes up a little bit. It’s not going to be looking straight down at your feet, so, yes the ability to position it.

Many of the negative experiences outlined earlier revolved around the sun and glare impacting the ability to see the lights properly, resulting in delayed race starts and interviewees provided some practical suggestions to resolve this issue. One coach / team manager explained, ‘Most [lights] are open – which makes it difficult because of the sun. So if it was like this with a curved surface – indicates shape and size on table in front – it would be easier to see’ so adding a ‘hood’ over the top of the light will protect it from the sunlight and also will provide a solution for situations whereby not all athletes are responding to the light (i.e., in mainstream settings) as outlined by one stakeholder, ‘there has got to be no interference with an athlete in another lane who, perhaps, doesn’t have a light system, who is then saying, “Their lights distracted me” ...it’s something that could arise, couldn’t it, if someone didn’t have lights?’. These practical considerations are important when implementing a system whereby it will be used in integrated and D/deaf athletics settings and in a variety of climates (i.e., the outdoor athletics season is typically held in the summer months when the sun will create more issues). Furthermore, interviewees gave their opinions and preferences for the size of the starting system on the starting line. The general preference displayed by D/deaf athletes and coaches / team managers was ‘just something as long as it’s not very chunky or big, that you could fit in, compact. Cos if it’s chunky I’m thinking “what if my feet clip that”’ because ‘if it was too big and clumsy...I think that could be slightly off-putting. But in reality, something the size of a brick, you wouldn’t trip over it, I don’t think’. Lastly, while the actual system may only be roughly the size of a brick, there are other considerations such as wiring / cables and the portability of the system. More specifically, making sure that it ‘can be transported and how it can be used within the track’ and ‘easy to set up...if you think of, yes, officials who are all volunteers, setting up the starting system, it has got to be dead easy for them to include when they set it up’ is essential

otherwise this may lead to a lack of adherence and confidence setting up the system and result in inequity for D/deaf athletes.

As discussed, there are several factors to consider when designing and developing a starting system that is practical, functional and effective as well as providing equitable reaction times between D/deaf and hearing athletes. Based on the information and perspectives provided by D/deaf athletes, coaches / team managers, and stakeholders, we have a clearer picture of the main priorities and considerations which will substantially support the development of a standardised starting system in athletics.

Implementation and Access. The shortcomings of previously developed starting systems have centred around widespread implementation and access for venues / facilities and for athletes. To have widespread implementation and presence of the starting system across all athletics venues and facilities will provide athletes, coaches, and officials with regular access for training and competitions. However, there needs to be a strategy to successful implementation and as explained by one D/deaf athlete, it is necessary to ‘find out the demand for it, maybe go round athletics clubs and check how many D/deaf athletes they provide for’ and to:

Maybe go to an athletics club that has D/deaf athletes and say, “We’ve got this, which might benefit your athletes” and then the club can have it. And then it could be really good for D/deaf athletes who are at a performing level, when they are still travelling for their athletics club.

It may not be suitable to immediately place a starting system in every stadium for economic purposes but having a targeted approach to implement starting systems in venues with existing D/deaf athletes and then also in ‘the really highly competitive tracks, they should have some blocks for those athletes who travel independently’, as this will ensure already competing D/deaf athletes will have access to a starting system at their local athletics clubs and likely competition venues. In addition to venues and facilities being given their own starting system modules, we could also consider giving key officials, starters and elite D/deaf sprinters their own system as this will:

Give [the athletes] the choice, to an extent it gives them the choice whether they go along and hopefully have the right equipment, or that they have it themselves and make sure that they've got something that they know will be right.

A lack of reassurance about having a light starting system available was highlighted as a concern and source of negative experiences for D/deaf athletes so by having a targeted strategic approach to implementation between venues and athletes will hopefully lead to a smoother roll out and greater confidence for D/deaf athletes. For example, one D/deaf athlete, when discussing starting system implementation and responsibilities, stated:

Make sure the officials know how to set it up, or if it's my responsibility or the other athlete's responsibility, or to take it with them but I don't know if that would be possible to give it to the athlete...but it would be the athlete's responsibility to charge it up or whatever or take it or if you forget it, it's not the officials fault. The thing is, I don't want to be driving to an away thinking "did [the officials] take it out or have they forgotten?"

To facilitate a successful and widespread implementation of the starting system, it seems logical to have a three-pronged sharing of the responsibility of looking after the starting systems via key identified venues, elite D/deaf athletes, and key officials/starters.

Organisational Responsibility. Whilst athlete possession of the future starting system has been discussed and is a plausible avenue within the strategy of widespread implementation, organisations, the government, and national governing bodies have a duty of care and responsibility to provide an equitable and comfortable environment for all athletes, regardless of their hearing level. D/deaf athletes can experience higher levels of stress, frustration, and anxiety as a result of not having an optimal, functional starting system as outlined by one coach / team manager 'Mentally it affects you because you cannot focus, you are mentally prepared and then have to stop which results in loss of concentration'. Ultimately, this is not fair and detracts from the athlete's competitive experience. Organisations, national governing bodies and clubs must hold themselves to account for D/deaf participants experiences and wellbeing and strive towards providing an inclusive and equitable experience. One stakeholder commented 'we want it to be standardised that you turn up: "Oh, there is a deaf athlete. Great, so we'll use this bit of equipment." It's just a brilliant experience for everybody. It's the same experience.' Furthermore, organisations have a responsibility to increase and sustain their awareness and inclusion of

D/deaf athletes and ensure that the starting system is embedded as highlighted by one stakeholder

Continuing to build on that awareness. So, yes, delivering a one-off training session is great, but it needs to be regular. It needs to be almost going back in six months' time, revisiting those officials. Do they fully still understand what the start system is about? So I think training and awareness is key.

By reminding organisations of their responsibility and duty of care towards total inclusion, there should be a stronger and more sustainable implementation and attitude towards D/deaf athletes. It will also hopefully build the D/deaf athletes' confidence and trust around organisations, something that has previously been lacking due to the longstanding barriers and poor experiences.

Summary. Providing consistent access to the starting system via widespread implement will need to be a strategic and focused approach. While the actioning of this is outside of the scope of this thesis, it is beneficial to have the insight and constructive direction from D/deaf athletes, coaches / team managers and stakeholders to inform the essential technical and practical requirements for a starting system. For the starting system to be successful and create its intended impact in athletics, it is critical to incorporate the suggested recommendations as this will result in a user-friendly and effective starting system.

General Conclusion

The present study provided rich insight from D/deaf sprinters, the coaches / team managers of D/deaf sprinters, and key stakeholders with regards to the experiences with variable starting systems, wider sport experiences and recommendations for a future starting system. To reiterate, the aims for the current study were two-fold: (1) to explore the experiences of variable starting systems used across the participation and performance pathways and the contributing factors and barriers across sporting experiences. (2) To establish key recommendations for: the technical requirements of an equitable standardised starting system and considerations to ensure successful implementation and accessibility of a standardised starting system. The findings from this chapter will be utilised in conjunction with the quantitative findings earlier in this thesis to

develop a holistic understanding and sound evidence-based for the technical and sociocultural requirements of an equitable starting system.

With regards to the technical composition of a starting system in line with the experiences, opinions and perceptions expressed by participants, there are four major components to be considered. Firstly, there is a strong preference towards a traffic light style visual starting system as this replicates the classic “on your marks, get set, go” format across athletics and has been used previously at different D/deaf specific competitions. Secondly, the light system must connect with the starting pistol in both mainstream and D/deaf settings, with particular consideration to ensuring that the starting pistol and lights are presented at the same time so that no athlete gets an unintended advantage or disadvantage over other athletes. Thirdly, the traffic-light visual system must be able to be seen in bright and sunny conditions i.e., via the addition of a ‘hood’ over the lights and deflect any unwanted glare from the sun. Lastly, the positioning of the visual starting system is critical; it must not create a trip hazard or worry and must not force the athletes to move their head or neck from the optimal sprint start position by being too far away from the start line. By incorporating these major components, the starting system will provide a reliable and consistent starting experience for D/deaf athletes and allow for smoother integration and implementation with mainstream starting systems.

Whilst developing a technically effective starting system is a significant outcome from this thesis, facilitating a strategic and widespread implementation of the starting system is arguably just as important to ensure that the starting system is accessible and regularly used across the participation and performance pathways. Based on the opinions and suggestions from D/deaf athletes, coaches / team managers, and stakeholders, implementation should be a strategically phased two-pronged approach. A common expression seen across the interviews was that both elite D/deaf sprinters and venues / officials should be given the responsibility of a starting system. The justification for this is D/deaf athletes expressed worry and uncertainty around trusting that a starting system will be available for them to use at competitions and by having their own system, they have flexibility and autonomy over their training. Furthermore, athletes will also have increased exposure and consistency of using the same starting systems across training and different competitions. Whilst this may not be a typical procedure compared to other facets of athletics, it would be an impactful short-term solution for D/deaf athletes

during the anticipated transition and adjustment period of widespread implementation. It is also essential for venues with D/deaf membership, key competitive venues e.g., larger, or commonly used athletics tracks, and key officials / race starters to be provided with access to the traffic-light visual system. Acknowledgement of the responsibility and duty of care held by organisations is also key as it will provide reassurance and confidence to D/deaf athletes and facilitate a sustainable embedding of D/deaf inclusion across athletics. Technical officials and race starters must also be given the opportunity for regular training on using and maintaining the starting systems; this could be provided alongside current national governing body courses for a smoother integration and awareness of the starting system. It is anticipated that the implementation of this starting system will take a substantial amount of time with protected time, effort and financial support needed to facilitate this long-term.

Lastly, it is important to acknowledge the sociocultural barriers expressed by participants across athletics and provide suggestions to erase these barriers and move towards true inclusivity of D/deaf athletics. The disproportionate lack of funding and formal recognition within D/deaf sport is a significant barrier and acknowledgement from sporting organisations and national governing bodies to develop a strategy towards increasing funding and recognition should be a major priority. This will allow D/deaf athletes to participate and represent their country at the same level as mainstream and Para- athletes and create a brighter future for D/deaf athletics.

Chapter 5:
General Discussion

5.1 The Gold Medal Winners: Key Findings

The primary aim of this thesis was to establish the sensory modality that promotes the most equitable RTs across D/deaf and hearing populations to inform the development of a standardised starting system. Implementation of a standardised starting system will both enable D/deaf athletes to compete alongside hearing athletes fairly in mainstream athletics pathways and ensure that D/deaf athletes have access to a consistent starting system, no matter the level of competition, thus increasing the equity, access, and opportunity for a currently marginalised population in athletics. Over three empirical chapters, I have established the empirical and sociocultural requirements of an equitable starting system with significant addition to the limited D/deaf RT literature.

Chapter 2 investigated the importance of haptic stimulus location to establish the optimal positioning of a haptic stimulus within a starting system (i.e., on the start line via the fingers/hand or within the starting blocks via the feet) that promotes equitable RTs between D/deaf and hearing populations, and also to inform the apparatus requirements for the subsequent chapter. Most notably, and in line with previous stimulus location literature (Ho & Spence, 2014), haptic RTs are significantly faster when presented to the hands compared to the legs and there were no significant differences between D/deaf and hearing populations, again support existing evidence (Heimler & Pavani, 2004). Once we had established the optimal haptic stimulus positioning to promote equity and speed, we could then investigate the other key influences on RT such as stimulus quantity and stimulus modality.

Chapter 3 provided a comprehensive insight into the most equitable stimulus modality across D/deaf and hearing populations in controlled and applied environments and utilised a range of unimodal and bimodal stimuli to ensure a complete overview. The overall results from Chapter 3 highlight that a visual-haptic stimulus consistently promotes non-significant group differences (i.e., equitable) in RT. Similarly, results yielded significant practical implications in that when D/deaf athletes would be competing alongside hearing athletes in mainstream athletics, there is negligible difference between hearing auditory-haptic RTs and D/deaf visual-haptic RTs, meaning that the visual-haptic system proposed can be implemented alongside the current auditory systems with no hinderance on athlete RTs.

Chapter 4 addressed the sociocultural and practical demands of an equitable starting system. We took a triangulated approach in our sample to encompass athletes, coaches and stakeholders and explored the experiences, perceptions and opinions of variable starting systems in D/deaf sport via semi-structured interviews to inform future practice. Below, the primary findings of the thesis are presented with particular focus on the practical and applied implications, and impact, of this research.

5.1.1 The Optimal Haptic Stimulus Location for Equitable Reaction Times

Within the haptic RT literature, there is little research that includes D/deaf populations and even less literature that compares D/deaf and hearing haptic RTs under different conditions, such as stimulus location, meaning that Chapter 2 had a somewhat exploratory nature due to the limited existing evidence. The findings from Chapter 2 provide sound direction and justification for the inclusion of a haptic stimuli when considering an equitable starting system. To reiterate, the key aims of this chapter was to identify whether it would be more beneficial to present a haptic stimulus at the hands (i.e., on the starting line) or via the feet (i.e., in the starting blocks) and to establish whether there are any population differences in haptic RTs. The theoretical underpinnings and existing literature in this field postulate that RTs will be fastest when a high set-level bilateral haptic stimulus (Forster et al., 2002; Ho & Spence, 2014) due to the dual benefits of increased stimulus quantity (Diederich & Colonius, 2004) and high compatibility between the stimulus, task, and effector response (Ho & Spence, 2014). Furthermore, existing evidence suggests that there are no significant RT differences between D/deaf and hearing populations (Heimler & Pavani, 2004) when presented with a haptic stimulus. The findings from Chapter 2 supported these underpinnings as there were no significant haptic RT differences between D/deaf and hearing populations, and high set-level stimuli (right hand, left hand, and both hands) produced significantly faster RTs than low set-level stimuli (both legs). Whilst the findings did not demonstrate any significant differences between the right hand, left hand, and both hands (except for that they were all significantly faster than both legs), this is not a major concern for several reasons. Firstly, this provides stronger practical implications to not have differences between the right hand, left hand, and both hands as on the start line, there is typically an equal weight and pressure distribution between the arms (Bezodis et al., 2019), meaning that there is no specific dominant arm in a sprint start. This means that it may not

necessarily matter which hand the athlete primarily ‘feels’ the vibration through as the present evidence suggests that there is no difference between singular or bimodal hand-specific stimuli. Secondly, there were no significant differences in haptic RTs between populations, meaning that presentation of a haptic stimulus does promote equitable RTs and this in conjunction with the significantly faster high set-level stimuli means that we have confidently met the aims of this chapter. In summary, implementing a haptic stimulus on the starting line will promote equitable RTs between D/deaf and hearing athletes but as discussed throughout this thesis, there are other considerations to take such as stimulus modality and stimulus quantity to ensure that the starting system is comprehensively evidence-based.

5.1.2 A Visual-Haptic Starting System is the Solution for Equity in Athletics

Chapter 3 is arguably the most significant chapter in this thesis as it provides robust data across different environments and participant pools which has steered the overall conclusions for the most equitable starting system between D/deaf and hearing athletes. Two of the key practical outcomes of this body of research are to produce a system that allows for equitable competition between D/deaf and hearing athletes and to provide a system that ensures consistency across all levels of competition in D/deaf athletics. The findings from Chapter 3 allow us to meet these outcomes and be hopeful that we can create the impact and legacy needed to provide a sustainable and feasible solution. There are two primary findings from this chapter which yield significant practical importance and direct the overall conclusions of this thesis. Firstly, across Experiment One (laboratory rapid target-directed movement) and Experiment Two (sprint starts), there were no significant RT differences between D/deaf and hearing populations when presented with a visual-haptic stimulus which provides consistent evidence that this is the most equitable sensory combination to meet the aims and outcomes of this thesis. Furthermore, in Experiment Two, there was a non-significant difference between hearing auditory-haptic RTs and D/deaf visual-haptic RTs ($>3\text{ms}$) meaning that in a mainstream setting, the proposed visual-haptic system could be successfully implemented alongside current auditory starting systems, reducing the potential challenges around mainstream acceptance and implementation. As the visual system will likely be an individual module, it is plausible to develop it so that it is lane specific and can only be seen by the athlete in that particular lane meaning any D/deaf athletes competing in a mainstream race will have access to the same system used in D/deaf athletics,

creating the much-needed consistency across pathways. Furthermore, the haptic stimulus will be presented to all athletes on the start line so that hearing athletes will be presented with an auditory and haptic stimulus. This set-up will streamline the overall acceptance, efficiency, and efficacy of the starting system across mainstream and D/deaf athletics pathways.

It is sensible to approach the proposed integrated settings (i.e., D/deaf athletes competing alongside hearing athletes in a mainstream environment) with pragmatism. Athletics is a traditional sport with a long history and culture, so introducing something like an alternative starting system needs to be done strategically and tactfully to avoid pushback and a lack of acceptance within mainstream settings. Similarly, athletics is also one of the most inclusive sports with para-athletics growing exponentially and more frequently being integrated into the same athletics programmes as mainstream events so it is hopeful that the integration of an equitable starting system will be received well across athletics. It is anticipated that there will be a greater challenge regarding acceptance within the elite athletics sphere due to the potential influence on overall race times so extra intention needs to be taken to navigate this and avoid discontentment from mainstream athletes. Due to the wider barriers and current state of D/deaf athletics, it will likely take several seasons and years for a D/deaf sprinter to reach elite level within mainstream pathways which affords time to ensure widespread acceptance and awareness of the starting system.

Another consideration to facilitate the implementation of the visual-haptic starting system pertains to the ruling of D/deaf athletes wearing their assistive hearing devices on the track. Currently, D/deaf athletes are prohibited from wearing any kind of hearing device when on the track (Deaflympics, 2009) but there is no explicit rule in mainstream athletics outlining whether D/deaf athletes can or cannot wear their hearing devices. A plausible suggestion to maintain consistency across mainstream and D/deaf pathways would be to instate this rule in mainstream settings. This would standardise the competitive experience for D/deaf athletes as they would be responding to the same stimuli (visual-haptic) regardless of whether it is a mainstream or D/deaf specific event. If a D/deaf athlete was to wear their hearing device in a mainstream setting, this technically provides them with a trimodal starting system as they are more likely to hear the starting pistol which may inadvertently give D/deaf athletes an advantage. This goes against the ethos for this thesis, which is to promote equity, regardless of hearing level. This warrants further

discussion and consultation with D/deaf athletes and stakeholders and is discussed further in the future research direction section.

5.1.3 Starting Systems in Athletics: What's Next?

Chapter 4 provided significant insight into the preferences and requirements for an effective starting system based on the experiences of D/deaf athletes, coaches / team managers of D/deaf athletes, and stakeholders. To reiterate, the four key considerations for an equitable and effective starting system are that it should be a traffic-light style visual system and must be able to be connected to the starting pistol (especially for in mainstream settings). It must also have protection from the sun via a hood with glare deflection and be positioned where the athlete does not need to move their head/neck to see the light. Once prototypes have been developed and tested, there must be a planned strategy for a phased implementation of the developed starting system. This strategy should be developed with an increased mutual communication and consultation with stakeholders and athletes to ensure a top-down (stakeholders) and bottom-up (athletes) approach and implementation.

To ensure an effective implementation of the starting system, identification of key athletics clubs, technical officials, and elite D/deaf sprinters to be trained on the how to use the system, to test the system and to be given systems is of critical importance. This will allow for the individuals most likely to use the starting system to have access to the starting system in training and competitions. This increased exposure will build confidence and awareness ahead of future situations when the system will be used more regularly. In addition to this, collaborating with stakeholders and high-level sports organisations such as UK Sport will further raise awareness of the starting system and trigger action of the flexible starting system rule change. The starting system will need to also be introduced into mainstream settings with both athletes and competitions with the intention that one day, it will be standard procedure to use the starting system whenever a D/deaf athlete is competing.

Only on successful implementation of the starting system will it be possible to see its full impact in athletics. Within the D/deaf athletics pathways, a standardised starting system that is consistently used across all levels of competition, from local grassroot to Deaflympics competitions will create greater access for any D/deaf person to get involved in athletics. A

consistent starting system should have a facilitative impact on the overall competitive experiences of D/deaf athletes as there will no need to be worried about issues with the starting system, meaning athletes can entirely focus on their competition and performance. This also has the potential to improve the overall sprint times and standard for D/deaf athletes, creating more opportunity for talented D/deaf athletes to progress through the mainstream Olympic pathway.

With regards to the Olympic pathway, it will likely take several years to see an elite D/deaf athlete in mainstream settings but the intentions and aims of this research are not short-term; it is accepted that this will be an ongoing body of work that is regularly being reviewed and developed. The majority of D/deaf athletes struggle and cannot access the mainstream performance pathways but if the implementation of an equitable standardised starting system means that a D/deaf athlete has greater opportunity and chance to reach performance level, then the aims of this research have been fulfilled. There are many ‘blue sky thinking’ aspirations and goals that I have for this starting system, and I am determined to reach these goals and create a lasting positive impact in D/deaf athletics. However, increasing inclusion and equity in D/deaf athletics cannot be achieved by one person, it is a society wide challenge with many other sociocultural facets and barriers that must be addressed.

From a sociocultural and organisation perspective, the factor that has the potential for significant change is to increase funding across D/deaf athletics. It needs to be a key priority for stakeholders to recruit more funding for D/deaf athletics (and sport in general) to develop inclusive initiatives at participation levels and support athletes progressing through the performance pathways. A starting point would be to support athletes and teams travelling to competitions and relieve the burden of self-funding which is a major barrier for performing athletes at present. An increase in funding could also be directed towards providing educational and practical training for coaches, venues, and stakeholders on how to deliver D/deaf inclusive training and competitions. This will encourage more D/deaf people to get involved in athletics if they are reassured that they will be included via effective communication, social engagement, and general D/deaf awareness.

5.2 Putting the Jigsaw Together

The mixed methods nature of this thesis was intentional to develop a holistic evidence-base that encompasses the empirical, technical, and practical needs of an equitable starting

system. The quantitative findings dictate that a visual-haptic starting system that can be used in conjunction with an auditory starting system provides the most equitable solution whereby RTs are fair across D/deaf and hearing populations and fast. As discussed, depending on the type of competition i.e., D/deaf-specific or mainstream, will determine the stimulus modalities presented to athletes. It is important to reflect the quantitative findings with the opinions and perceptions expressed across the starting system experience interviews to ensure that there is harmony across the methodologies. From the interviews, there was a clear preference for using a traffic-light style visual system and D/deaf athletes had been exposed to auditory starting systems in mainstream competitions. Mixed opinions regarding the incorporation of a haptic stimulus were expressed by D/deaf athletes but that was largely due to the unfamiliarity of the stimulus. Thus, if athletes were exposed and able to train with the visual-haptic starting system, this uncertainty may be relieved, as empirically, adopting a visual-haptic system promotes the fastest RTs for D/deaf populations. Similarly, presentation of an auditory-haptic stimulus promoted the fastest RTs for hearing athletes, suggesting that athletes could better their RTs utilising the haptic stimulus.

There is a good consistency across the findings and applications of the quantitative and qualitative elements of thesis which tells a convincing story and provides a strong rationale for the constitution of an equitable starting system that is feasible across D/deaf and mainstream pathways. The implementation of the starting system is the next big challenge but as the findings from this thesis incorporate current starting systems in mainstream and D/deaf athletics (i.e., auditory stimulus for mainstream athletes and visual stimulus for D/deaf athletes), adding an additional stimulus that facilitates RT regardless of hearing level will hopefully provide a convincing proposition for widespread implementation and acceptance.

5.3 Contribution to the Literature

As established throughout this thesis, there is not a wealth of existing RT or athletics/sport research that specifically focuses on D/deaf populations, with even less research providing comparisons between D/deaf and hearing populations. The majority of D/deaf specific research concerns neuroplastic adaptations (Dye & Bavelier, 2013), visual facilitation (Bottari et al., 2011) and cross-modal integration (Scott et al., 2014) which does provide useful insight and the underpinnings of why it is necessary to measure RTs in different populations as it is evident

that there are differences which need to be taken into consideration. The breadth of the existing literature (albeit of which a large portion focused on hearing populations) provided many pieces of the jigsaw to establish the definitive theoretical rationale for this thesis. The heart of this thesis lies with its practical implications, impact, and legacy with every methodological decision (i.e., stimulus positioning, type of auditory stimulus) being driven and informed by pieces of the literature ‘jigsaw’ to develop a substantial evidence-based body of work to address a real-world problem.

There have been previous attempts to address the issue of the lack of a consistent starting system in D/deaf athletics (Forth Valley Athletics Club, 2016; Rocandio & Cid, 2012; Shitara et al., 2018; Zulkiflli et al., 2019) with varying degrees of success, notably in Malaysia, but the primary issue still heavily presents as there is no standardised starting system that is used across all levels of D/deaf athletics and in integrated mainstream settings. The previous attempts to develop a novel starting system have used very small sample sizes and number of trials, raising questions regarding the power and rigour of the research. Furthermore, despite these studies developing starting system prototypes, there is little comparison with other stimulus modalities and populations such as hearing athletes. Due to this, widespread implementation of these systems would likely be met with challenge and difficulty as international governing bodies will need extensive evidence, rationale and high levels of rigour and reliability before commercial production and implementation. This thesis and body of research is arguably the most comprehensive existing comparison of D/deaf and hearing RTs with the intention of developing a real-world solution with high impact; the incorporation of the different influences on RT (stimulus quantity, stimulus modality, and stimulus location) with appropriately powered and sized samples across different methodologies has created an extensive and rigorous body of research.

With regards to the literature that inspired and encouraged the qualitative elements of this thesis, it is fair to say that there is only a small breadth of articles in the UK and Europe that have addressed the sociocultural and sporting experiences of D/deaf athletes at different stages of the participation and performance pathways (e.g., Atherton, 2007; Foster et al., 2018; Kurková et al., 2011). The present body of work adds to this literature and offers perspective from different key groups in athletics such as D/deaf athletes, coaches / team managers of D/deaf athletes, and

stakeholders to provide a triangulated insight to create the best opportunity for positive impact and change. Furthermore, whilst factors affecting participation and performance have been studied, there is currently no published evidence exploring the variable starting systems used in D/deaf athletics and their impact on performance, which this research has addressed.

5.4 Implications

5.4.1 Theoretical Implications

There are several theoretical implications to come out of this thesis, specifically regarding the expansion of comparative RTs in D/deaf and hearing populations. Much of the comparative sensory RT literature pertains to hearing populations with little evidence comparing RTs to different stimulus modalities, stimulus locations, and stimulus quantities in D/deaf and hearing populations. Chapter 2 particularly adds to the stimulus location literature and consolidates existing notions surrounding the non-significant differences in haptic RTs (Heimler & Pavani, 2014) with expansion of the influence of stimulus location. Chapter 3 considerably adds to the multisensory RT field and provides evidence across different populations (i.e., general population versus athletes) and tasks (i.e., rapid target-directed movement versus a sprint start). The evidence presented in this thesis has strategically addressed under-researched areas whilst also addressing the real-world underpinnings and implications to develop a practical and impactful solution to increase equity in athletics.

5.4.2 Applied Implications

The potential reach and impact of this body of work is substantial and could change how athletics, specifically the sprint starts, functions from grassroots to international elite level competition. Specifically, within D/deaf sport, inconsistency and lack of access to a standardised starting system have been key areas of focus and notable barriers within participation and performance for D/deaf athletes. The current findings, both quantitative and qualitative, demonstrate a strong rationale for developing a visual-haptic starting system and it is postulated that this will be widely accepted within D/deaf sport. Once prototypes have been developed and tested further and more large-scale production has commenced, it will be possible initiate widespread implementation amongst elite D/deaf sprinters so that they can train and compete with their own starting system, in addition to ensuring that the starting systems are accessible to

key competitive venues, technical officials and starters. This will mean that regardless of position on the participation and performance pathways, D/deaf athletes will have access to the same starting system that will be used at competitions, thus eliminating the barrier of the lack of a standardised starting system. Furthermore, as the visual-haptic system will be compatible with auditory starting systems, this will allow D/deaf athletes equitable access to mainstream athletics pathways, increasing opportunities for competitive experience, integration, and athletic recognition, all previously noted barriers for D/deaf athletes.

Within the mainstream athletics sphere, it is anticipated that there will be a greater challenge regarding effective implementation and acceptance. However, as several key stakeholders are on board and have already starting to make adaptations to implement an equitable starting system, notably the UK Athletics rule amendment to allow for flexibility in the starting systems used when D/deaf athletes are competing, the challenge of higher level (i.e., national governing bodies) acceptance is reduced. Acceptance amongst athletes is likely to be a bigger challenge and will require a shift in attitudes and practice, particularly in the elite sphere. As anticipated with D/deaf athletes, an increased exposure and practice with using an alternative starting system should build acceptance and efficacy over time. In an ideal world, all athletes should be motivated by inclusion and equity and there has been a shift towards this within sport which will hopefully one day, translate into D/deaf athletics.

5.5 Limitations

As with any research, there are limitations within this thesis. The primary limitation is a ‘Catch-22’; recruiting D/deaf participants, particularly sprinters or those with starting block experience, was one of the most challenging aspects of my PhD. I needed as many D/deaf participants as possible, but due to the systemic issues and barriers that I have explained throughout this thesis, there were only a handful of eligible participants across the UK (specifically Experiment Two in Chapter 3). D/deaf sprinters are few and far between in the UK, with only eight sprinters competing in the last two Deaflympic cycles which meant that I had an incredibly small pool of people to recruit from, made even trickier by their spread-out geographical locations e.g., Glasgow, London, Loughborough, and Birmingham. I wonder if I will take the record for the number of miles travelled for a bout of data collection...a 600-mile round trip to Glasgow for one participant is no mean feat, nor is driving through London in rush

hour (I do not recommend this!) but I did it. The niche and incredibly small participant pool was exacerbated by the more ‘remote’ location of Bangor. In several attempts to maximise my recruitment and data collection output, I temporarily moved all my laboratory studies to different locations such as Wrexham, Stoke and Manchester to boost participation, which was successful allowed me to complete my data collection. One key thing I have learnt throughout the course of my PhD is to be adaptable and flexible, particularly when the rules and regulations surrounding the Covid-19 pandemic were everchanging.

The pandemic presented challenges and unavoidable delays with recruitment and data collection. More specifically, I was unable to collect any data for approximately 10 months which was a significant portion of my overall PhD. This meant that I had less time overall to complete the empirical studies, which has affected the overall sample sizes. Whilst we have ensured that each study is appropriately statistically powered, it must be acknowledged that some of the sample sizes are somewhat small (again, exacerbated by the incredibly small pool of potential D/deaf athlete participants). The delay in data collection commencement resulted in an intensive recruitment and data collection period but as previously mentioned, being flexible and adaptable meant that it was possible to complete the data collection in a timely manner. The pandemic also presented challenges when communicating with D/deaf participants and in particular BSL users or those reliant on lip-reading. In line with regulations, face coverings were worn during face-to-face testing, but this made it tricky for both participants to hear me and read my lips and for me to also hear participants. Adjustments were made to facilitate communication, such as increasing the distance between myself and the participant, introducing a Perspex divider and also using face masks with a clear mouth panel. Across the course of my PhD, I have been learning BSL which did facilitate communication, but it was still a challenge as, at that point, I was not fluent and was having to sign technical language. I think that if the strict Covid-19 restrictions were not in place during my data collection, I would have been able to recruit bigger samples in Bangor and other locations. Despite these challenges, I am proud of how I navigated the pandemic.

5.6 Future Research Directions

When this PhD was first proposed, there was meant to be an additional study which involved developing prototypes based on current evidence and testing RTs with the prototype and other

systems in place e.g. flags, shoulder taps, different light system, gun to ensure the consistency and efficacy of the current proposed system. However, due to the Covid-19 pandemic, there was a delay in the initial data collection by 10 months (due to lockdown, local restrictions, and a lengthy return to research process), which resulted in not enough time to conduct this study by the end of my funding. However, this may have been a blessing in disguise and provides opportunity for a series of future research studies to perfect the starting system before the official implementation across venues.

In terms of future empirical studies, it would be worthwhile to test the sprint start trimodal (auditory, visual, and haptic) RTs of D/deaf and hearing athletes, with specific testing of D/deaf RTs with and without their assistive hearing devices. Based on the current picture of the future starting system, auditory, visual, and haptic stimuli will be present but D/deaf and hearing athletes will only respond to two modalities, so it is necessary to ascertain whether either group has an unintended advantage via the presence of a trimodal stimulus. Furthermore, if there is no significant difference in RT between D/deaf and hearing athletes when presented with a trimodal starting system then this could also be an alternative solution that would warrant further investigation.

At present, we only have the evidence-base for an equitable starting system and not a tangible product. Thus, a future research project would be to develop a prototype based on the data from this thesis and conduct testing in a variety of environments such as indoor, outdoor, different weather conditions (i.e., sun and rain) and different lane formats (i.e., side-by-side on a 100m start and staggered like a 200m start). It is pertinent to conduct this testing with a bigger pool of D/deaf and hearing athletes across different stages of the participation and performance pathways to establish the optimal design etc., for future implementation.

5.7 Thesis Conclusions

This thesis has considerably added to the sensory RT literature by investigating the influence of stimulus location, stimulus modality, and stimulus quantity on RT between D/deaf and hearing populations. Similarly, this thesis has provided significant insight and perspective into variable starting system experiences, recommendations for a future starting system, and sport experiences which is an unexplored and novel area in the D/deaf athletics literature. The

mixed methods approach across this thesis aimed to produce a comprehensive evidence-base to inform the development of a standardised starting system whereby the technical and sociocultural requirements were addressed in-depth. I am confident that this has been achieved across the three empirical chapters and there is now a clear direction as to what constitutes an equitable starting system and how it can be implemented across athletics. To serve both the mainstream and D/deaf athletics pathways was a key focus for this thesis as they both provide opportunity for elite level performance and recognition in their respective ways.

Now that there is a strong evidence-base for what constitutes an equitable starting system across D/deaf and mainstream athletics, concentrated efforts need to be taken to further extend this data to address specific nuances to ensure the starting system is robust and fit for purpose, ahead of prototype development and testing, widespread production, and implementation. To see the fruition of an equitable starting system and positive change in D/deaf athletics as a result of this thesis would be profound and highly impactful. It would be a great legacy and testament to this body of work for any D/deaf athlete to have the freedom and opportunity to fairly access and progress through the participation and performance pathways the same as their hearing counterparts, with race outcomes being determined by sprinting ability, not hearing level.

5.8 PhD Reflections

When I first arrived at Bangor through clearing in 2015, slightly unsure and apprehensive of the world and my future, I never would have imagined that I would stay at Bangor for eight years and end up doing a PhD. It's funny how life turns out and I could not be more grateful for the journey I have had at Bangor. It was during the second year of my undergraduate when we had to develop our project proposal, which was essentially a baby version of my PhD, when we realised this project had the potential to really make an impact in athletics and then we nurtured and developed it into what it is now. I have always known that I want to have a career in sport which streamlined into disability sport, and now D/deaf athletics, and I genuinely feel that this research and trajectory is my purpose, and my PhD has given me purpose.

When this PhD was first proposed to the ESRC, it was titled 'Enhancing **equality** in sport:...' but after education, greater understanding and consideration of the societal and sporting implications of what equality actually means, I changed this to 'Enhancing **equity** in sport:...'. It

is intended that this demonstrates depth and internalisation of the needs and impact of this research. Taking this approach was influenced by understanding the representational needs of the D/deaf community in sport, as well as considering the different models of disability and how they can inform practice. Throughout the course of my PhD, I have realized that we do not live in an equal society, and things that are often termed as ‘equal’ do not actually mean equality whereas equity is more conceptually profound and goes one step further than equality. I pride myself on being accessible, equitable and pragmatic so the change in title better reflects my morals and motivations.

I was only five months into my PhD when the Covid-19 pandemic broke out and changed everything. I was just getting into the swing of how to do a PhD and trying to fill my days with useful and productive tasks (not always successfully!) but suddenly I was unable to collect any data and did not know when I would be able to resume (it took 10 months...). This was a really frustrating time during my PhD because as I had previously done a smaller version of this project during my undergraduate and Master’s degrees, I had already read a lot of the key papers that formed the theoretical underpinnings of this thesis. This resulted in me really struggling in what to do on a day-to-day basis which only really changed once I was able to start the arduous ‘Return to Research’ process. However, it was not all doom and gloom. One of the positives about this time is that I realised that I am quite good at (and somewhat enjoy) writing ethics forms, risk assessments and other often tedious documents. I’m not sure what this says about my personality, but it did make me realise that sports policy is a plausible career avenue, as I would be able to combine my passion for creating positive change, legacy, and impact for marginalised and underrepresented groups with the skills of writing documents and policies.

Whilst it may not be directly related to my PhD, I wholeheartedly believe that putting in the effort to learn British Sign Language (BSL) has catalysed and solidified my determination to immerse myself in my rich and beautiful D/deaf community. Learning BSL to a ‘fluent’ level has allowed me to communicate with all of my participants and has enabled me to independently collect my data (with the exception of two BSL interpreters who supported two interviews in Chapter 4) which has genuinely been really rewarding and has boosted my confidence and own identity as a Deaf person. On a more personal note, I have been Deaf my entire life but only now recognise my privilege and atypical ‘D/deaf’ upbringing. I am incredibly lucky to have had an

excellent support system formed of my family, friends, audiology department, support workers and teachers who have always encouraged me to achieve the highest heights and get the best education that I can. I know that for many young D/deaf people, they are not afforded the same education or support network, which is the stark reality of the marginalisation and ostracization of D/deaf people in UK society. I really hope that the UK continues its increase in D/deaf awareness, acceptance and understanding and provides all D/deaf children with access to a fruitful and whole education to nurture and develop the next generation.

To finish, as with every PhD, it has been a rollercoaster with many highs and lows. I've made sure to celebrate the small wins and learn from lows. Doing a PhD was definitely the right decision for me personally and professionally and I am excited to see what the future holds. I have recently started a new job at Welsh Athletics as an Inclusion and Engagement Coordinator where I will be continuing some research and initiative development with underrepresented groups in athletics which has been really rewarding and fulfilling so far. I am grateful for everything that Bangor University and my School have given me over the last eight years, and it will forever hold a special piece of my heart. Diolch Bangor!

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Appendix A: Expertise and Skill Acquisition Network Conference 2023 – ‘Best Poster’



Fair starts for all: informing the development of an evidence-based athletics standardised starting system for D/deaf athletics.

Libby Steele¹, Dr. Vicky Gottwald¹, Dr Gavin Lawrence¹, Professor Michael Khan²
Bangor University¹, Trent University²

Introduction

Deaf Sport

- D/deaf athletes currently compete in the *Deaflympic* and *Olympic* (not *Paralympic*) pathways, with variable starting systems (e.g., visual, haptic, auditory).
- Reaction times vary between D/deaf and hearing individuals when reacting to different uni- and bi-modal stimuli.
- No current equitable starting system available for D/deaf and hearing athletes to compete fairly alongside each other.
- Subsequently, no D/deaf athlete has ever medalled at the Olympics in a sprint event.
- Need for evidence-based system that promotes equity between all athletes.

Reaction Time (RT)

- Stimulus Modality:** RT varies depending on stimulus modality. Differences in auditory and visual RTs across pops. but no difference in haptic RTs.
- Stimulus Quantity:** RT is faster with increased stimulus quantity.
- Stimulus Location:** High set-level compatible locations e.g. hands = faster RTs than low set-level compatible locations e.g. feet.
- Hearing Level:** Due to neuroplasticity, D/deaf pops. likely to have faster visual RTs than hearing pops.

Aims and Hypotheses

Aim: To identify the stimulus modality that results in the most equitable RTs between D/deaf and hearing populations. This data will inform the development of a standardised starting system across D/deaf and mainstream athletics.

Hypotheses: 1) Visual-haptic RTs will yield the smallest discrepancies between populations.

2) Bi-modal RTs will be significantly faster than uni-modal RTs across populations.

Experiment 1

Participants: D/deaf $n=17$, hearing $n=22$.
Task: Simple target-directed aiming task.
Measures: RT, MT, error.
Procedure: Participants completed the task across several stimulus conditions (see Table 1).



Figure 1. Manipulandum. Participants completed a rapid inward arm movement on presentation of the stimulus from A to B.

Methods

Stimulus	Exp. 1	Exp. 2
Auditory	x20 trials (hearing only)	x6 trials (hearing only)
Visual	x20 trials	x6 trials
Haptic	x20 trials	x6 trials
Auditory-Visual	x20 trials	x6 trials
Auditory-Haptic	x20 trials	x6 trials
Visual-Haptic	x20 trials	x6 trials

Table 1. Stimulus modalities and experimental blocks for Exp. 1 and 2. All blocks were fully counterbalanced.

Experiment 2

Participants: D/deaf $n=7$, hearing $n=7$.
All other aspects were identical to Exp. 1, except for the task (see Fig. 2).

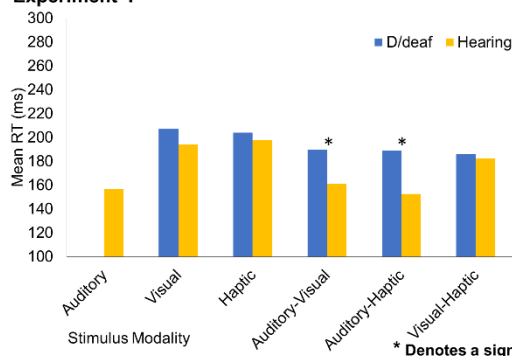


Figure 2. Sprint starting block set-up. 1-auditory stimulus, 2-visual stimulus, 3-haptic stimuli.

Exp. 1 & 2 Statistical Analysis: 2 (Group) \times 5 (Stimulus Modality) ANOVA
Post-hoc: Tukey's HSD for breakdown of simple main effects

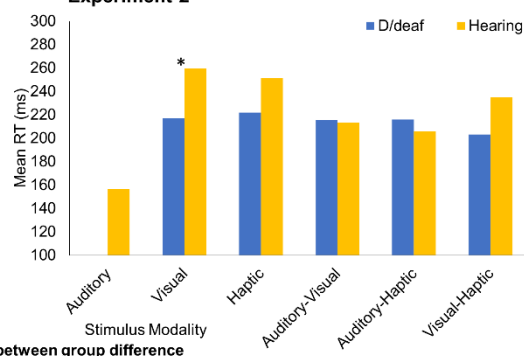
Results

Experiment 1



* Denotes a significant between group difference

Experiment 2



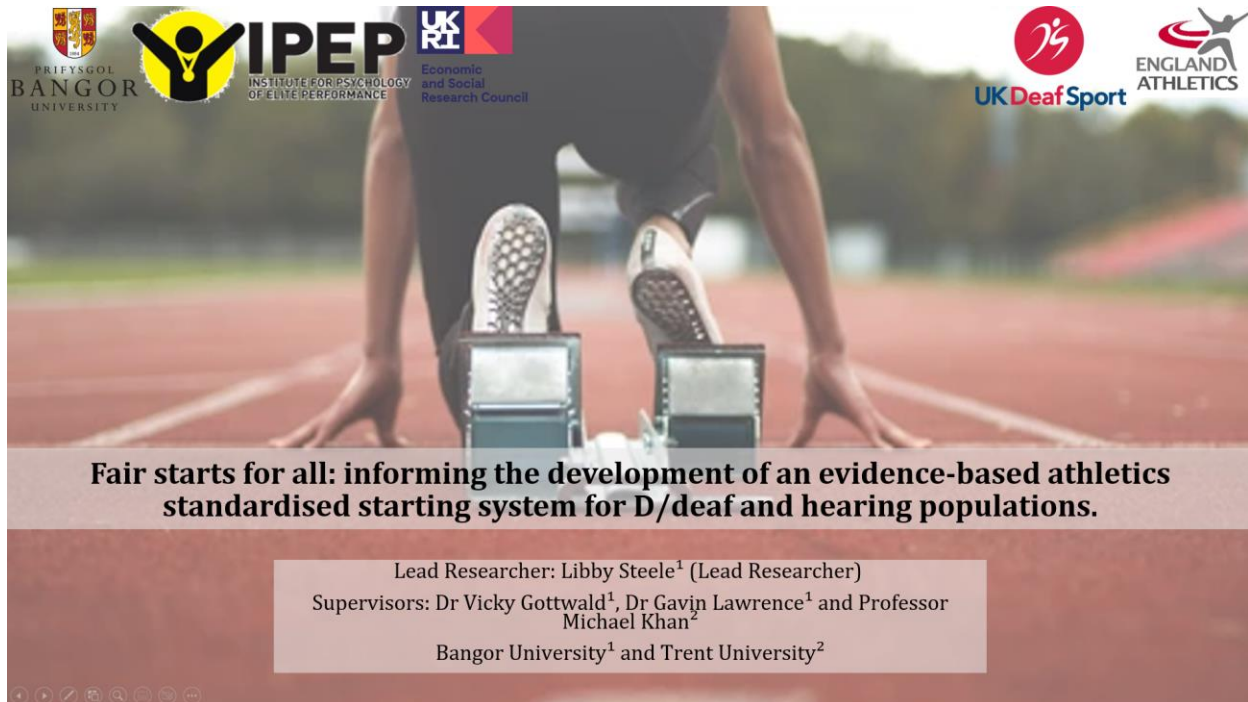
Discussion

- Visual-haptic stimuli consistently promote fair and fast non-significantly different RTs between D/deaf and hearing populations.
- Sound evidence and direction to inform the development of a standardised starting system that ensures equity across all athletes, regardless of hearing level.
- Interestingly, this would result in the least significant change for current start times and records.

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Appendix B: School of Human and Behavioural Sciences Postgraduate Researcher Conference 2023 – ‘Best 10 Minute Verbal Presentation’



PRIFYSGOL BANGOR UNIVERSITY **IPEP** **INSTITUTE FOR PSYCHOLOGY OF ELITE PERFORMANCE** **Economic and Social Research Council** **UK Deaf Sport** **ENGLAND ATHLETICS**

Fair starts for all: informing the development of an evidence-based athletics standardised starting system for D/deaf and hearing populations.

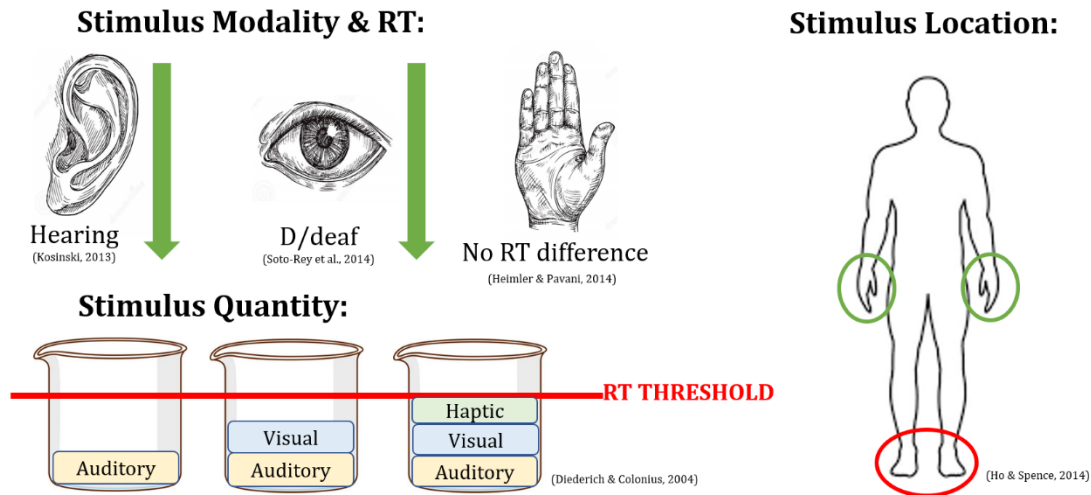
Lead Researcher: Libby Steele¹ (Lead Researcher)
Supervisors: Dr Vicky Gottwald¹, Dr Gavin Lawrence¹ and Professor Michael Khan²
Bangor University¹ and Trent University²

D/deaf Sport



Foster et al., (2019)

Factors Influencing Reaction Time



Aims and Hypotheses

Study Aim:

Identify the stimulus modality/ies that produce fairest RTs between D/deaf and hearing populations.

Hypotheses:

- 1) Deaf populations will have slower RTs than hearing populations.*
- 2) Bimodal RTs will be significantly faster than unimodal RTs across populations.*
- 3) Haptic-containing modalities will promote the smallest discrepancy in RTs than other stimulus modalities.*

Methods

Task: Simple target-directed aiming movement



Deaf (n=17)	Hearing (n=22)
-	Auditory
Visual	Visual
Haptic	Haptic
Auditory-Visual	Auditory-Visual
Auditory-Haptic	Auditory-Haptic
Visual-Haptic	Visual-Haptic
x3 practice trials of each condition Randomised counterbalanced block order with 20 trials per condition.	

Navigation icons: back, forward, search, etc.

Results

	\bar{x} Deaf RT (ms)	\bar{x} Hearing RT (ms)	Group Difference
Auditory	-	156.76 (18.27)	
Visual	207.07 (31.26)	193.93 (26.7)	13.14ms
Haptic	204.16 (28.88)	197.7 (28.93)	6.46ms
Auditory-Visual	190.08 (31.98)	161.25 (26.81)	28.83ms*
Auditory-Haptic	189 (35.09)	152.55 (23.17)	37.44ms*
Visual-Haptic	185.94 (25.34)	182.57 (26.99)	3.37ms

1. Overall, D/deaf group had slower RTs.
2. Bimodal faster than unimodal regardless of hearing level (thresholds).
3. No group differences between visual, haptic, and visual-haptic BUT visual-haptic = smallest discrepancy (3.37ms) = **fairest and fastest**.

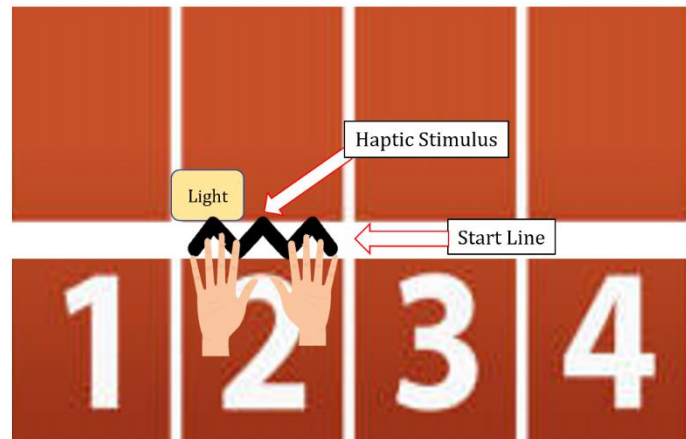
Stimulus Location: MAIN EFFECT $p < .001$
 Group: MAIN EFFECT $p < .05$
 Stimulus Modality \times Group: INTERACTION $p < .001$

Navigation icons: back, forward, search, etc.

Discussion

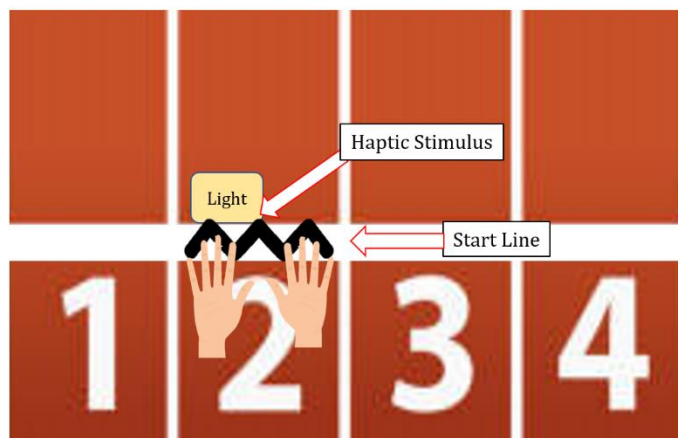
- Visual-haptic RTs = FAIR
 - Smallest discrepancy in RT between groups
 - Fastest non-significant RT
- Visual-haptic = smallest impact on current start times for mainstream athletics e.g., auditory start gun

- Next steps...




Discussion

The challenge...
Implementation
Acceptance from stakeholders



Thank you for listening! Questions?

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 - [@libby_steele](https://twitter.com/libby_steele)

Appendix C – Starting Systems Interview Guide

Pre-interview Brief: The goal of this interview is to explore the experiences, thoughts and opinions of different starting systems in D/deaf athletics which will help inform the development of a standardised starting system that will a) provide a consistent starting system across all levels of D/deaf sport and b) allow opportunity for fair competition between D/deaf and hearing athletes on the start line.

Introduction:

- Welcome participant and introduce myself
- The general purpose of this interview is to discuss and explore your experiences, thoughts and opinions on different starting systems from the perspective of a D/deaf sprinter, coach / team manager, stakeholder.
- This interview is being conducted in-person / online and will be audio and video recorded / recorded. By consenting to taking part in this interview, you consent to recording of the interview.
- You are free to end the interview at any time you wish, and you do not have to answer any questions that you do not want to.
- This interview should take around 45 minutes give or take. If you need a break during the interview, you are more than welcome to.
- Your information will be kept confidential. Only the research team (me, my two supervisors and one other colleague involved in this study), and transcribers will have access to the full information. Upon publication of this research, you will not be identifiable by name and will be kept anonymous. If you decide to withdraw from the study after the interview, any standing or involvement you have in D/deaf sport/my research will not be affected.

Interview Guidelines:

- This interview will consist of a series of structured questions. During the interview, I may ask you additional questions to further clarify or elaborate your answer. You may choose not to answer a particular question, you can also ask to take a break or end the interview

at any time. Your answers and any information identifying you as a participant will be kept confidential and non-identifiable.

- I would like to record this interview / online interview for data analysis and to ensure that the responses to questions and discussion were captured and transcribed accurately. No one other than the research team mentioned, and the transcriber will have access to the interview ,and they will be stored on a password protected file and computer and stored securely in line with Bangor University protocol.
- Do you have any questions for me before we begin the interview and recording?

Starting System Interview Topic Guide – D/deaf sprinter

- 1) Tell me about yourself and your sporting experience
- 2) Throughout your respective sporting and competitive journeys, what starting systems have you experienced and what were your thoughts on them?
 - *Prompts: Was it easy to use? Challenges/difficulties when using the starting system? Most consistent system that you have experienced? Favourite type of starting system?*
- 3) What qualities/features would you want out of a future starting system?
 - *Prompts: portability, size, positioning, link to other systems, type of stimulus*
- 4) What has been the biggest challenge surrounding your experiences with starting systems and what would minimise this challenge?
 - *Prompts: standardisation, ease of use, access to starting system, consistency across competitions, level playing field*
- 5) Is there anything you think that could be done by national governing bodies etc. to improve the starting systems used in sport at the moment?
 - *Prompts: funding, provision, product development, integration*

Debrief:

- Is there anything else that you would like to say about anything we have discussed today?
- Thank you so much for your time, it is really appreciated. If at any point you would like to revisit your participation in this study, please don't hesitate to contact me. Just to confirm, you have agreed/declined that you may be re-contacted at a later date to clarify or further explore some of the responses you provided today. Your insight and perspective has been really helpful and will contribute to some important research and change in D/deaf sport.

Starting System Interview Topic Guide – Coach / Team Manager of D/deaf sprinter/s

- 1) I'd like to begin by asking you to tell me a little bit about yourself and your involvement in D/deaf athletics/sport
 - a. *Number of years, type of sport, how you got involved, your roles, competitions attended, officiating*
- 2) Throughout your experience in athletics, can you talk about what different starting systems you have seen be used in training and competitions and what your thoughts on them are?
 - *Prompts: Was it easy to use/explain to athletes? Challenges/difficulties when using the starting system? Most consistent/reliable system that you have experienced? Preferred type of starting system? Positives/negatives*
- 3) From your experiences at these competitions and seeing/using different starting systems, what would you say are the biggest / most prevalent challenges faced by athletes? Also coaches/managers? How do you think we could reduce these challenges?
 - *Prompts: standardisation, ease of use, access to starting system, consistency across competitions, level playing field*
- 4) One of the aims of this research is to initiate the development of a new starting system in Deaf sport. Could you have a think about what qualities/features you think would be beneficial for a future starting system in deaf sport / integrated sport?
 - *Prompts: portability, size, positioning, link to other systems, type of stimulus*
- 5) For D/deaf athletics, is there anything you think that could be done by national governing bodies etc. to improve the starting systems used in sport at the moment?
 - *Prompts: funding, provision, product development, integration*

Debrief:

- Is there anything else that you would like to say about anything we have discussed today?

- Thank you so much for your time, it is really appreciated. If at any point you would like to revisit your participation in this study, please don't hesitate to contact me. Just to confirm, you have agreed/declined that you may be re-contacted at a later date to clarify or further explore some of the responses you provided today. Your insight and perspective has been really helpful and will contribute to some important research and change in D/deaf sport.

Starting System Interview Topic Guide – Stakeholder

- 1) Tell me about yourself and your involvement / experiences with D/deaf athletics.
- 2) Throughout your involvement in D/deaf athletics, what starting systems are you aware of and what can you tell me about them?
 - *Prompts: Was it easy to use? Challenges/difficulties when using the starting system? Most consistent system that you have experienced? Preferred type of starting system?*
- 3) What qualities/features would you want out of a future starting system?
 - *Prompts: portability, size, positioning, link to other systems, type of stimulus*
- 4) What has been the biggest challenge surrounding your experiences with starting systems and what would minimise this challenge?
 - *Prompts: standardisation, ease of use, access to starting system, consistency across competitions, level playing field*
- 5) Is there anything being done by national governing bodies etc., to improve the starting systems used in sport at the moment?
 - *Prompts: funding, provision, product development, integration, initiatives*

Debrief:

- Is there anything else that you would like to say about anything we have discussed today?
- Thank you so much for your time, it is really appreciated. If at any point you would like to revisit your participation in this study, please don't hesitate to contact me. Just to confirm, you have agreed/declined that you may be re-contacted at a later date to clarify or further explore some of the responses you provided today. Your insight and perspective has been really helpful and will contribute to some important research and change in D/deaf sport.