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# How and Why We Run: Investigating the Experiences of Blind and Visually-Impaired Runners

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## ABSTRACT

Running offers a convenient and affordable method of keeping fit and maintaining good cardiovascular health. In this paper, we describe the experiences of a group of runners whose practices are rarely profiled: individuals who identify as legally-blind, some of whom run competitively, while others run for purposes of leisure. We specifically focus on planning strategies undertaken, experiences running both with and without sighted guides, the impact of situational and environmental factors, and the ways in which technology is utilized. The study has revealed a set of insights which if capitalized upon could offer considerable promise to support independent running. These include examining ways to reduce levels of uncertainty faced by runners, supporting autonomy, providing greater levels of environmental awareness, and aiding socialization when running. Findings from the work offer promise to interface designers to improve inclusiveness when developing technologies to support runners.

## CCS CONCEPTS

• Human-Centered Computing • Accessibility • Empirical studies in accessibility

## KEYWORDS

Blind Runners, Assistive Technology, Accessibility

## 1 Introduction

There are numerous health benefits to maintaining a physically active lifestyle. Running, for example, is a popular method of exercise, enabling individuals to strengthen muscles and improve levels of cardiovascular fitness [4], in addition to yielding positive

changes in affect [36]. Reasons for its appeal include the need for minimal equipment and that the activity can be conducted at any point in the day in a variety of locations. However, challenges can also be faced during this process. When running outdoors, for example, a variety of situational and environmental conditions (e.g., uneven terrain, inclement weather, presence of static and dynamic obstacles) must be taken into account. An additional challenge currently resulting from the COVID-19 pandemic is the need for social distancing; remaining a specific distance from other runners or pedestrians along the route taken.

While the ability to take corrective action based upon the presence of obstacles, or to find alternative routes when the path ahead is muddy or blocked are taken for granted, these issues are significantly exacerbated for runners who are blind or visually impaired (BVI) requiring additional tools and methods in order to plan accordingly. For example, running outside requires an individual to be cognizant of the running path chosen so that ad hoc adjustments can be made as needed. BVI runners might require a sighted guide to safely identify and navigate their route. This solution requires a significant amount of training and communication with the guide, and can ultimately be successful, but this additional assistance required to run safely can impede independence while running. Technological solutions have been developed which can provide support (e.g., navigation apps and wearable obstacle detectors). However, issues of safety may come into play, as some obstacles may be very difficult to detect particularly if the user is engaged with the activity, performing a secondary task while running (e.g., listening to either music or directions from a navigational app), or if the feedback regarding the obstacle is not presented in an appropriate time frame.

Researchers have investigated various ways that technology might support BVI runners during a running event [11,19,24,28]. While some design ideas supporting BVI runners have been explored [30], or developed but not implemented commercially on a wide scale [16], there has been very little research specifically regarding the BVI running experience. The study described in this paper aims to better understand the challenges that BVI runners encounter, their solutions and workarounds, and how technology might better be designed to support them. The contribution is the development of a set of insights, including examining ways to reduce levels of uncertainty faced by runners, supporting autonomy, providing greater levels of environmental awareness, and aiding socialization when running. The implications identified can be utilized by both interface designers and researchers to better

support BVI runners, with a view to increasing levels of independence when running.

## 2 Related Work

Researchers suggest that a high degree of visual disability can be associated with reduced levels of physical activity [13]. As awareness of the importance of staying fit to reduce health-related challenges increases, similar to their sighted counterparts, individuals who are blind or visually impaired are identifying ways to remain physically active. Organizations such as Achilles International [1] offer support and advice on how to keep fit through adapted sports. While there is greater interest in running among BVI individuals, getting started may be challenging if support is lacking. A range of resources are available to assist existing BVI runners. These include tips for running in both indoor and outdoor environments and handling differing terrains, tools to support running longer distances, and experiences from runners both at the beginner and advanced level such as [9,18,27,38]. However, there remain practical constraints which are described in the section below.

### 2.1 External Support and Safety as Challenges in Physical Activities

Support from other people/devices and safety concerns represent two major categories of challenges identified in prior research [18,20,27,31]. Individuals with visual impairments are heavily reliant on others in order to participate in physical activities [29,31]. In addition to the responsibility of identifying a physical activity and location for that activity, BVI individuals must also determine how and if they will be able to participate. This leads to decreased motivation in physical activities due to the effort required [29].

Safety represents another primary challenge faced by BVI individuals as their need for assistance from others (noted above) leads to an exogenous reliance for the identification of potential safety issues [31]. This introduces the importance of trust between the user and the assistant [17]. The BVI individual must trust the judgement of the assistant to have their safety as a top priority. This reliance can discourage individuals from seeking physical activities [6]. Similar to individual's reliance on others for participation, because they have to rely on others for their personal safety, sometimes the risk does not outweigh the reward [31].

One activity that is a challenge both to independence and safety is running [31]. Because running relies on visual cues for locating the path or sidewalk and any obstacles such as trash cans or steps, individuals with visual impairments must utilize a variety of methods (e.g., running with a guide, using a tether) for participating in this activity which makes running more difficult [16].

### 2.2 Current Solutions

Individuals with visual impairments and researchers have developed various methods and workarounds to address the challenges noted in the prior section. These include assistance from other people, from service animals, and technological support.

*2.2.1 Corporeal Assistance.* One option for accessibility in physical activities is the use of a human guide, who may use either a tether often affixed to the wrist and voice commands to support the process [8]. There are resources and networks available for gaining sighted guides (e.g., [1,38]), blogs and podcasts (e.g., [27]), and social media groups (e.g., [9]), that can also offer advice on tethering and strategies to run with guides, and cater to the gamut of runners. While convenient, personalized, and highly effective, the implementation of a human guide can be time consuming and difficult. Runners expressed many difficulties with scheduling human guides and the lack of reliability of many human guides [17]. To obtain an effective guide, hours of training are required to establish effective communication techniques and trust. There are many other requirements as well such as having a fitness level similar to the visually impaired individual, and the ability to respond within a timely manner to instructions to protect the safety of the BVI runner and guide.

One possible corporeal alternative to a human guide is a service animal (e.g., guide dog). Unlike human guides, guide dog use does not have to rely on coordinating times when the guide and runner are both available, as a guide dog is theoretically on-call 24 hours a day/seven days a week. While not currently commonly used to support running, guide dogs can theoretically be trained to assist BVI individuals during a running event, although one concern for runners is the tactile feedback when handling the dog's harness, as different hand movements can be interpreted as different corrective cues by the dog [17]. Additionally, while dogs were found useful for obstacle avoidance (as opposed to obstacle detection), they may require correction if distracted in crowds [17]. This may in turn impact the runner's momentum, as they may need to slow down or stop to identify ways to address the distraction.

*2.2.2 Technological Assistance.* In addition to human or animal assistance, there have been a variety of technologies designed to assist in independent movement and physical activities. Aira [2], for example, is a mobile application that allows individuals with visual impairments to use their phone camera to connect to sighted assistance to support runners. Microsoft Soundscape [21], uses 3D audio cues to enrich ambient awareness and provide an innovative, audio-based technology to enable a richer awareness of surroundings. Other technologies focus on independent obstacle avoidance. The WeWalk Cane, for example, is an attachment to the typical white cane and provides additional haptic feedback to the user, offering awareness of the environment [39]. Wearable devices, such as the Sunu Band [35] (a sensor located on a wristband) and BuzzClip [14] (a spring-loaded clip that is attached to the front of the user's shirt collar) can be donned to detect objects in proximity to the user. WAYBAND™ is a wearable that is paired with a smartphone and emits haptic signals to guide the runner towards a destination without being obtrusive [32].

Other developments include the introduction of a fixed electromagnetic infrastructure to a standard running racetrack where a BVI runner can run without a guide, wearing just a light/comfortable vibro-tactile sensor unit that allows them to, in effect, run inside an "invisible hallway" [25,26]. Recently, a

machine learning system was developed to help BVI runners run (or walk) independently using a mobile phone, bone conduction headphones, and a painted line on the ground [5]. Also, a trajectory correction system based on an accelerometer, gyroscope, and a haptic actuator was tested to support BVI runners on a 100m sprint [15]. All of these technologies provide increased access to activities, but have similar downfalls regarding their range of obstacle detection [8] or dependence on a fixed location and reduced accuracy at faster speeds [26]. In addition, there is the issue of overload. While these devices offer feedback, depending on the number of obstacles and the speed the user is running at, these devices may be burdensome to employ.

Another solution to independently conducting physical activities is the creation of “exergames”, a type of video game that focuses on increasing activity among users [22]. Running solutions have been developed for consoles (e.g., Basic Run [40] and Free Run [41]), and technologies have been used to support running techniques [37]. While there have been initiatives to provide additional auditory and haptic feedback to some exergames [23], challenges with set-up and game accessibility can limit frequency of usage or hinder the ability to exercise without sighted assistance available.

This study seeks to build on the understanding gleaned from, and support developed by, the prior work highlighted in this section and beyond. The research described below aims at arriving at a deeper and more empathetic understanding of the BVI exercise experience by specifically focusing on the challenges and practices associated with the running event, with a view to developing implications to aid interface designers and researchers to better support the needs and abilities of BVI runners.

## 3 Methodology

### 3.1 Study Design and Procedure

The research set out to identify the experiences, perceptions, and strategies of runners identifying as legally-blind. Also, this study aimed to focus on the diversity of the BVI running community, highlighting the experiences of both competitive and non-competitive runners, who run with and without assistance.

Due to its exploratory nature, the study sampled widely, recruiting runners with differing levels of expertise and who run in different environments (e.g., indoor, outdoor etc.). Participants were recruited from a range of venues including social media groups relating to running, the researchers’ personal networks, and snowball sampling.

Once IRB approval was obtained (Protocol #: Y19RK2137), semi-structured 60-minute interviews were conducted. Expanding on the types of questions asked in [31] (e.g., benefits/challenges of exercise, exercise technology background), the probe focused more specifically on various aspects of the participants’ running experience. These included: (1) where participants typically run (e.g., indoors v. outdoors, street v. trail), (2) types of assistance used, including corporeal assistance (e.g., human or service animal), electronic technology (e.g., Fitbit [10], mobile apps such as Strava [34], smart watches, headphones), or other (e.g., tether,

cane), and (3) descriptions of the challenges that might be faced when running (e.g., types of obstacles, course choice limitation, adjusting to variable conditions). Adjustments related to lifestyle changes due to the COVID-19 pandemic, and how BVI runners may be uniquely affected, were also explored. Finally, participants were asked to brainstorm on how technology might be designed to improve their overall running experience in ways that are currently not being served (e.g., type of obstacle notification that would be most useful, optimal timing for obstacle distance/notification timing, preferred feedback modality).

All interviews were conducted remotely by phone or using Cisco WebEx Meetings virtual meeting software, recorded (after obtaining permission from the participants), and automatically transcribed. For each meeting, one researcher conducted the main interview while up to two other researchers took notes. When the main interview was completed, the note-taking researchers were given the opportunity to ask additional or follow-up questions to assure completeness and accuracy of the information obtained.

### 3.2 Study Design and Procedure

A total of 13 participants (7 of whom self-identified as male, 6 who self-identified as female, all US based) were recruited for the study. All self-identified as being over the age of 18 and legally blind. In particular, seven participants had very limited functional vision, three of which described having no functional vision (LNV/TB). The remaining six participants had some functional vision available but were legally blind with varying levels of sight (SVA). Four described themselves as serious runners (e.g., currently train for and compete in competitive events), while the rest presented themselves as casual or intermediate level runners. The average participant age was 38.1 years (STDEV: 12.6). A detailed demographic breakdown appears in Table 1.

### 3.3 Interview Analysis

To analyze the information garnered from the interviews, an inductive thematic analysis was conducted. Each interview transcript was reviewed by two members of the research team who individually generated codes and extracted elements for possible themes. After the first two interviews, recordings/transcripts were separately analyzed, the two researchers met for 90 minutes to assess the raw themes that were gleaned in each separate codebook. Each theme and transcript support for the theme was discussed and agreement was established on an initial set of open codes. Codes that were duplicate or similar were combined or removed. This initial set was then used to code the third interview (also separately) to see how well the developed raw themes were describing the data. The two researchers met a second time to conduct a similar review as in the above-mentioned initial meeting. While some modification to the description of the themes occurred, it was collectively concluded that no new themes emerged in either codebook for the third interview content. Additional interviews would be conducted and coded with each coder reviewing half of the remaining interviews to confirm the existing themes and allow for the development of new themes should they appear. If data

saturation did not occur after the last interview was analyzed, the researchers would have conducted additional interviews.

**Table 1: Participant Demographics (SVA = Some Vision Available, LNV/TB = Limited to No Vision/Totally Blind)**

ID	Age	Gen	SVA	LNV/TB	Type of Runner	Type of Support
P01	52	M		X	Serious	Guide/Tether
P02	18	F	x		Serious	Guide/Tether
P03	46	M	x		Serious	Guide/Tether
P04	66	F		X	Casual	Independent
P05	27	F	x		Intermediate	Independent
P06	36	M	x		Serious	Guide/ Voice Guided
P07	26	M		X	Casual	Guide/Tether + Holding on to Guide
P08	42	M		X	Casual	Guide/ Tether
P09	33	F		X	Casual	Guide
P10	35	F		X	Intermediate	Guide/ Tether
P11	36	F	x		Intermediate	Guide/Tether (or Independent)
P12	31	M	x		Casual	Guide/ Tether
P13	47	M		X	Casual	Guide Tether

## 4 Findings

The interviews explored (1) the locations where participants run, (2) the type of assistance they use while running, and (3) the experiences and challenges they face while running. The findings revealed the diversity of abilities, needs and preferences among the BVI running population, not only in terms of the spectrum of their visual abilities, but also the spectrum of motivations for running (from staying healthy to competing in a triathlon). The findings from these interviews are described below. A discussion of implications for design including some actionable suggestions for implementing these are outlined in Section 5.

### 4.1 Where Participants Run

A mixture of preference for street/sidewalk running and trail running was identified among participants. A few occasionally ran on a track, though it was not preferred by any of the participants for anything other than training, or to improve performance. Treadmill running was also universally shunned or viewed as a last resort at best. There was also no clear distinction for running location preference based on amount of functional vision available or the type of runner they were (e.g., competitive vs non-competitive).

Whether participants indicated street/sidewalk or trails, the preference almost universally was for surfaces that were predictable, flatter, smoother, or well-trodden. The predictability that smoothness offers makes it less likely that a runner may stumble or fall compared to surfaces with variations and imperfections. P10 (LNV/TB) prefers smooth trails, “*not hiking trails*” where there may be “*a lot to trip on*”, but “*trails people walk and run on*.” P04 (LNV/TB) likes to run in the safety of her own

driveway, not only because of the certainty of the context, but also because “*it’s pretty smooth*.” P06 who had some functional sight available (SVA) feels safest running down the street shoulder, “*even if it is closer to traffic*” and often along a line of parked cars because, “*it’s a lot flatter*.” P12 (SVA) likes to run on “*paved sort of bike trails*”, or more generally, “*well-trodden, even paved paths*”.

The preference leaned towards avoiding sidewalks if possible. P11 (SVA) and P06 (SVA) eschew sidewalks due to the extra set of “*ill placed obstacles*” and “*gradient changes*” that are perceived to be present in the sidewalk vs. the street. P13 (LNV/TB) was about “*50-50 running in city streets and on trails*”, but the ratio changed to mostly street after March 2020 due to restrictions resulting from the lockdown associated with COVID-19. P06 also discussed methodologies for how he improves the safety and certainty of street running: “*I’ll typically start on my run down the wrong way down a one-way street...because I can sort of see the cars coming at me...and it’s bright enough out because it’s the summer time where I can see well enough*.”

Even though smoothness of surface is important to P10 (LNV/TB), as is noted above, so is certainty which is why she still prefers trail running to sidewalk or street running. P10 highlighted that “*there are a lot more obstacles on sidewalks compared to trails. I think it is more pressure on the guide too...there are more steps to be concerned about like step up, step down, ramp up...more people just standing around looking at their phones not really paying attention to the world...I used to run on the streets all the time ... but you have to stop more because of cars and stuff like that*.”

A few participants did note that on occasion they might venture to more unpredictable/adventurous trails, but not without predefined plans. P02 (SVA) prefers running on trails, but notes it is “*really hard in the winter months*”. If a trail is unfamiliar, she will “*walk the trail first*” together with her guide, as it is easier to commit landmarks or obstacles along the way to memory at an early stage. While the memory burden was found to be a challenge, it was also deemed necessary to achieve independence for successive runs. P12 also expressed concerns if the trail is not a familiar one where landmarks are committed to memory. P08 (LNV/TB) runs on trails, tracks, and if necessary, on a treadmill, but prefers running outside.

Treadmills were not preferred for a variety of reasons, including a commonly reported issue of inaccessibility of treadmills at public gyms (e.g., touch-screen controls). Treadmill use seemed to require the gaining of experience before becoming comfortable enough to use it as an alternative. Finally, some referred to the reduced experience of having to hold on the railing when running to maintain one’s balance and centering. A few had a treadmill in their home and some used treadmills located in the apartment complexes where they lived, but regardless of the location, treadmill running was largely regarded as more of a last resort option or as a necessary evil during bad weather. Other reasons include because participants travel a lot, no one was available to guide, for COVID-19 related concerns, or the general lack of socialization when running on a treadmill when compared to running outside with others. P09

(LNV/TB) finds the treadmill more boring [compared to running outside] and feels “*like a hamster*” when using one. P08 (LNV/TB) perhaps best summarized the frustration of treadmill use for BVI individuals: “*If I go to the gym alone, I will have to go to the front desk and ask someone to show me an empty treadmill and set it up to the settings that I want. My [sighted] spouse sometimes joins me in the gym...and tries to find a treadmill next to me, where [my spouse] can have a site view to my display [and] play a role of a screen reader...[This] can...be very cognitively demanding at the same time that you want to focus on your exercise, your brain has to also focus on other stuff. And also, your other hand is on the handle to keep you safe.*”

Most of the issues that are outlined in the choices of where BVI runners run support the “Uncertainty” theme (discussed in Section 4.4.1).

## 4.2 Types of Assistance

The most common assistance reported was that of another human, either a designated running guide or simply a friend or partner. No one ran with a service animal although some were not averse to the idea in principle. Inorganic support came primarily from make-shift tethers used to connect with guides. Some electronic devices/apps were used, but not to a great degree.

**4.2.1 Human Assistance.** All but two of the participants incorporated a human running guide that accompanies them during a running event and often in planning routes to take. The two exceptions, P04 (LNV/TB) and P05 (SVA) are both non-competitive runners. P04 runs in the driveway of her home or near her home at night seemingly due to the familiarity and the controlled nature of the space. P05, because she has enough functional vision to get by, likes to run “*independently*” and does not like the idea of “*using apps to guide*” her. In addition, P06 who has some functional sight available (SVA) who competes in triathlons and mostly trains independently, described liking the idea of utilizing a guide for the “cycling portion.” Cycling was thought to require additional support, due to worries about encountering turns, bends or obstacles at higher speeds compared to running.

The remaining participants ran with another human and employed some sort of tether to connect with their running partner, as this would help them to maintain appropriate proximity with the guide, and provide the ability if fairly taut, to quickly detect changes in the guide’s running pattern. While tether use was clearly most popular, a one-size fits all option did not seem to suit all participants. P02 (SVA) uses a tether that she purchased from a website, but in many other cases, the tether was fashioned from household material which was thought to be more comfortable and easier to maneuver. P01 (LNV/TB) uses a tether made out of a chopped-up clothesline. P09 (LNV/TB) uses a resistance band for exercising because “*it’s customizable to different heights and weights*”, or “*...whatever I happen to have.*” P10 (LNV/TB) uses a shoelace. P11 (SVA) used a child “*leash*” until it broke and then started using a shoelace. One participant eschewed using a tether, preferring the flexibility of using the guide’s voice for directions, or by placing a hand on their shoulder while running. However, this

also could lead to challenges should communication not be strong between both parties.

**4.2.2 Non-Electronic Equipment/Technology.** Some participants use bright colored vests to indicate to others that they are visually impaired. This allows the runners to avoid slowing down or stopping once pedestrians/other runners were detected, with the hope that approaching individuals would maneuver around them instead. For example, P01 (LNV/TB) wears an orange vest with the words “visually impaired” and notes that he is “*about 80% convinced that people can’t read it*”. However, because the bright orange color represents danger, he described the vest when viewed by others, as “*be[ing] like Moses parting the Red Sea.*” While participants highlighted unease when wearing these vests (as they did not want to be seen as different to others), it was a trade-off that they accepted in order to reduce the burden of concentrating on situational factors (e.g., maintaining a suitable distance from third parties) while focusing on the run itself.

Most participants described eschewing a cane for running as being impractical and/or dangerous, but if they do use one, it is with a roller. The cane was described as slowing runners down. It would also lead to the hands being encumbered, so was not a preference while running. P01 (LNV/TB) recounted a story of using one while running in high school and nearly “*stabbed*” himself in the stomach when the cane got stuck in the ground ahead of the runner. P08 (LNV/TB) likes using a cane and notes the feeling of independence it gives him, but that is tempered by fear of running too fast and losing control. P08 went on to note an interesting technique used if a cane is employed known as “shore lining”, which is used to find the edge of a surface when the texture of that surface changes (e.g., a street where the edge is defined by a grass line or a seam) so they can monitor how a path continues [33]. In particular, P08 used the technique to help predict turns in his path. He stated “*...when there is a route or terrain that has turns, and you don’t have the ability to predict when it turns, if you are lucky there is a texture difference between the road and the off road.*”

**4.2.3 Electronic Equipment/Technology.** Participants’ current use of technology was largely limited, if at all, to helping keep track of performance. These include FitBit and Strava. Some indicated that they had experience with or knowledge of specialized technologies for obstacle detection (e.g., Sunu Band and WeWalk cane, both which provide vibrational output when obstacles are detected) but expressed their dissatisfaction with aspects of the specialized technologies. P01 (LNV/TB), for example, likes to use an Apple watch for haptic feedback of weigh points, but has issues with the “*bulkiness*” of the WeWalk cane. In addition, P01 has not used the Sunu Band because he believes the natural running motion of one’s arms can “*throw the Sunu Band for a loop*” and postulated that specialized technologies offer more promise to people just starting out running who need additional guidance, rather than for competitive athletes like himself.

There was also some hesitancy in using non-AT technology due to issues of not quite being ready for prime time. P03 (SVA), a competitive runner notes that current technology “*is just not*

*responsive enough for sports*” due to the speed associated with the running event and the current rate of “*responsiveness from the technology*.” P11 (SVA) who is an intermediate level runner with some competitive experience, expressed a lack of confidence in the sustainability of using technology for “*...a really long run, like a marathon*”. It was thought to be overloading in terms of output, be challenging to listen to in a noisy environment, and could weigh down the user unless designed effectively. This is consistent with the findings of work such as [25] and [26] that found accuracy decreased when an athlete on a track transitioned from fast walking to running.

When asked how technology might be designed to offer feedback that may reduce the dependence on guides, many agreed that some form of wearable accessory (either on the wrist or some form of smart clothing) with recognizable and easily understood haptic feedback might be of value. Haptic cues could be perceived even in noisy environments, or when cognitively attending to the run. In addition, participants commented on improving the BVI running experience by focusing on various ways technology could be designed to assist in object detection.

P08 (LNV/TB): “*I think that moving object detection...to avoid bumping into someone...or whatever that you need to keep your [COVID-19 related] social distancing.*”

P12 (SVA): “*If there was a way to create a technology that was more suitable for running than a cane is because I wouldn't want to take a cane to the gut or something like that, but does what the cane does. It alerts people to the fact that I'm blind and points out obstacles.*”

Participants described preferring technology which does not require additional cognitive resources or occlude any additional channels. For example, P07 (LNV/TB) suggested, “*...a combination of haptics and auditory feedback, just to reduce the cognitive load so that I could concentrate on where I was going, and then have those pieces of information offered off at the right time so I can make the decisions in a timely manner.*”

### 4.3 Challenges Faced During a Running Event

**4.3.1 Ambient Effects on the Running Event.** While many of the participants expressed a preference for running outdoors, environmental factors were often cited as limiting their ability to run outside with confidence. The lack of ambient light seems to be a negative for those with some vision, but not an issue with those that are totally blind. P06 (SVA with photosensitivity) notes the perfect running conditions for him is “*somewhat cloudy*” as his eyes do not adjust well to alternating, “*pockets of sun and pockets of shade*.” P03, P05, and P11 (all SVA) prefer to not run at night. P05 notes that running in the dark could “*expose [her] to danger*” as her vision worsens at night. P04 (LNV/TB), on the other hand, prefers night running due to lack of other people being around.

Findings suggested that whether one was a casual or competitive runner seemed to have influenced how they approached running during inclement weather. Uncertainty and the limiting of alternative choices available for BVI runners affected nearly all their attitudes to a degree, but abandoning the running event seemed to be somewhat dependent on if they are more casual

or competitive. A total of nine participants described themselves as casual/hobbyist runners, or runners that do so for fun or as a means of exercising and staying in shape. The other four participants described themselves as very active in competitive running, participating in marathons and even triathlons. P01 (LNV/TB), for example, who participates in both marathons and triathlons, notes a willingness to run in most weather conditions other than ice and snow due to concerns of slipping and injuring himself. If it is cold, P01 described using a treadmill, noting a degree of comfort with the platform but also because of how much he travels for work, the ability to run on a treadmill is important. P03 (SVA) also participates in triathlons noted liking to run in the rain and being “*okay with the mud*.” P11 (SVA), who describes herself as an intermediate runner, runs in, “*...all sorts of conditions*.” Some noted issues with outdoor running conditions, not as much during inclement weather, but after the weather event was finished, citing the uncertainty caused by ad hoc changes in the condition of even a familiar running surface when effective visual feedback is not available. For example, P02 (SVA), the one exception within the group of “serious” runners, indicated that she does not like running after it has rained due to concern for slipping and inability to “*see puddles*”, some of which can be quite deep. If footing is lost as a result, it may impact the run.

Participants that do not run competitively expressed more of a reluctance to braving the elements. P05 (SVA), a hobbyist jogger, stated that she will not run in the rain, noting concern for slipping and in general that she “*wouldn't feel safe*.” P07 (LNV/TB), who describes his interest in running as “*just for fun*” (although they did participate in events in the past), also indicated that he usually runs, “*when it is sunny or not raining*.” P09 (LNV/TB), a hobbyist jogger, doesn't mind running during inclement weather but is “*skeptical*” of ice.

**4.3.2 Non-Ambient Obstacles Encountered while Running.** The interviews revealed concerns regarding several obstacles that might be encountered when attempting a run. Some concerns described were thought by participants to be similar to those faced by sighted runners (e.g., the situational awareness required to cross the street and avoid running afoul of traffic or of other humans within the runner's area of influence). The participants in this study emphasized that the issues are exacerbated when running while visually impaired. In particular, it was revealed that it can sometimes be difficult for other runners to understand that, because they are visually impaired, they may not react with the same implicit course altering maneuvers that might be expected with other sighted runners. Situational awareness was also noted as the reason some of the participants do not wear headphones or otherwise listen to music/podcasts while running, some even noting that, if running with someone, they considered headphone use to be rude or otherwise detracted from the ability to socialize.

There were many aspects of the environment in which they ran, that the participants revealed to be of concern due to lack of effective visual feedback. There were general concerns regardless of course choice involving issues such as navigation cues (e.g., when to turn and how acute is the turn radius) and tree limbs.

Obstacles below waist height were thought of as tougher to detect or predict. Some concerns while running on the sidewalk/street included: cars parked in a driveway but that stuck out a little too much into the sidewalk, uneven pavement and cracks, and the presence of children/pets. For trail running, participants expressed the need to be aware of uneven and irregular surfaces, rocks, tree trunks and fallen branches.

Solutions primarily involved off-loading the feedback responsibility to an outside source, which was almost exclusively their running guide. As was previously noted, most participants used a guide and indicated use of a tether. For the majority of our participants, the greater the degree of visual impairment, the more dependent the runner was on obtaining effective cues from the guide. Because of this reliance on the guide, effective communication was seen as key. As P02 (SVA) illustrates regarding one of her guides: *...communication was really a struggle in the beginning...it's this kind of trial-and-error thing, just like learn timing and learn it right. It's again, communication.*

While some of the cues, particularly for sub-events such as when a turn is happening, were gleaned by the movements of the tether, the primary preferred and utilized feedback modality was verbal. Participants consistently indicated that they needed terse and easy to understand verbal commands. When prompted for how far in advance a verbal cue was required, participant responses were varied; some wanted consistency in timing, others preferred to have a consistent number of strides as the unit of measure. Some indicated that a single response at the appropriate interval was desired, others expressed the need of using a count-down.

While a number of participants described expecting to fall at turns or on uneven terrain, one participant highlighted the extent of injuries faced resulting from being hit by moving cars while running. The participant had developed an expectation that they would be struck again, due to the lack of environmental awareness encountered when running without a guide present. While this did not deter the participant from running, the expectation developed was considered concerning.

### 4.4 Insights for Designers/Researchers to Better Support Blind Runners

As the result of the deeper phenomenological analysis and coding of interview excerpts, a set of insights was produced to provide a more empathic accounting of the BVI running experience. These serve as opportunities for researchers and interface designers to better support BVI runners or those who may be interested in becoming a runner. This is particularly topical with initiatives to help individuals with low levels of physical activity to become more active. The developed themes are summarized below. The implications for design and actionable insights for development are reviewed in Section 5.

**4.4.1 Addressing Uncertainty.** This theme is perhaps the most obvious and certainly is present in research addressing support of BVI individuals. Visually impaired runners cannot perceive various aspects of the running experience and, as the result, require assistance of some kind in order to facilitate and complete a running

event. The uncertainty that is inherent in a BVI runner's experience often leads to having to adjust preferences as to where and when to run. Aspects include, but are not limited to, course navigation, course condition, and detection/negotiation of objects. For example, P07 (LNV/TB) describes an issue with bushes and cars that are parked on the street, leading to uncertainty as to how much space is available to pass. P08 (LNV/TB) notes that uncertainty leads him to *"never, never, never listen to music"* while running.

**4.4.2 Quality of Assistance.** Because BVI runners require assistance in order to complete the running experience, they place a tremendous amount of importance on being able to trust in the assistance they are using. P02 (SVA) tries to always use the same guide because, *"...I'm a little scared putting my, I don't want to be dramatic and say my life, but my safety in their hands."* P03 (SVA), notes that he is *"one hundred percent reliant"* on his guide when he runs.

Due to the dependence on the running guide for effective feedback, being able to have a solid working relationship with a guide was viewed as essential. Most participants agreed that some degree of training was needed to get to know each other, their tendencies, and ultimately what is needed and expected of each other during a run event before a good working relationship can be established. If runner and guide cannot get on the same page quickly, that guide is likely not to be used in the future. Therefore, the issue is not just of available assistance, but the quality of that assistance. P08 (LNV/TB) describes why a rich understanding between runner and guide is important:

*"...there is a stream coming up that we have to jump over. One foot, two feet, one meter, three, like one and a half meter? How much? For those kinds of things, my friends familiar with my protocol know."*

P09 (LNV/TB) goes on to describe some of the potential misunderstandings that may occur until training is completed and a level of quality and trust are established:

*"You can get a sense if someone has, in the back of their mind, like, 'Oh my gosh [they] almost tripped' or whatever and that can be like a real impediment to establish a great guide relationship, because sighted people fall too, and it's not that big of a deal."*

It is important to note, at least in the case of human assistance, that the concept of trust is a two-way street; it is as important for the guide to trust the runner as it is for the runner to trust the guide. As P10 (LNV/TB) observed:

*"For a lot of people that have guided me, I was the first [BVI] person they ever guided, and so I would teach them how to guide. I think that's kind of the blind runner's responsibility."*

In situations where a guide was needed for one-time support (e.g., when competing in an event in a different city), participants described using social media and their own networks with a view to recruiting a guide who they may have just chatted with briefly prior to the race. Other instances were identified where participants were running independently but needed a guide as additional support for part of the journey. In both situations, it was challenging to train a guide on-the-fly. The worry was that by not being able to perceive directions quickly, it could lead to a fall for both parties.



There were also concerns from the guides, as to whether they were presenting information in an appropriately descriptive manner, or being too verbose. As an example, P01 highlighted that being a seasoned runner, he doesn't need information about the terrain or upcoming slopes as those can be detected. He prefers a description of the scenery, if it is an unfamiliar location he is running in (e.g., marathon in a new city).

**4.4.3 Presenting Appropriate Feedback.** As Card, Moran and Newell famously noted, the "Model Human Processor" can be thought of as a system consisting of three continuously interacting sub-systems: perceptual, cognitive, and motor [7]. Because BVI runners have limitations preventing complete use of their perceptual sub-system, they require feedback from their assistant. The feedback produced must use the appropriate modality for the runner to best be able to perceive, interpret and react relative to the situation at hand (e.g., non-voice audio, voice audio, haptic, tug on a rope). Attention must also be paid to the level and degree of output data (e.g., intensity and frequency of output signal, diversity of signal, clarity of signal, and signal lead time.) P07 (LNV/TB) notes appropriate feedback as why he prefers their guide to run behind them: *"I think the advantage to having the guy running from behind, is that you're free to move your arms and because they're holding on to your shoulders there basically steering you with their hand on your shoulders...And it's not really so much of a strong sense of control but just, kind of providing that feedback to know when to turn or that type of stuff."*

If a runner is running fast, or in an area of many obstacles, immediate and appropriate feedback is essential. P04 (LNV/TB) indicated the importance of obtaining feedback, *"just in time"* because she reacts *"pretty fast anyways."*

**4.4.4 Supporting Autonomy.** During the interviews, most participants noted the desire for being able to run without having to rely on the availability of a running guide. P02 (SVA), for example, indicated that they *"love [their] guides"*, but *"would love to find a piece of technology that will...help me out and see if I can get back to running by myself."* In addition, there seem to be a recognition of a balancing act between what a BVI runner does to minimize dependence and what they assume others will do (e.g., relying that other runners, cars, or animate objects in general will do their part). P07 (LNV/TB) would like to see technology, possibly incorporating GPS and *"perhaps some other components which would also offer obstacle detection and other information"* so that he could figure out a way to run completely independently. P11 (SVA) perhaps summarized it best: *"I think the ability to be able to run independently more would definitely be worth it...to have something that, where on a day where I can't get a guide, and I really want to go for a run by myself, and I wouldn't have otherwise done it. I mean, that would be pretty life altering."*

Another interesting finding which also supports the theme of autonomy was the use of DIY technologies to support the running event. For example, as noted in Section 4.2, all but one of the participants that used tethers while running with a guide, employed "make-shift" tethers as opposed to a piece specifically designed for

that purpose. Also, becoming a parent, has led P08 (LNV/TB) to an interesting workaround for assistance in trail running: *"After I became a [parent], whenever we go to the trail, we have a stroller and our baby sits there. [My spouse] controls the stroller and I put my hand on the stroller handles and use the stroller as a medium to be guided. So instead of directly receiving the information from the person, I'm receiving the information indirectly..."*

**4.4.5 Supporting Socialization.** P11 (SVA) praised technology but also expressed concern for using technology to replace a human guide. On one hand, as was referenced in the "Supporting Autonomy" sub-section above, she noted the potential *"life altering"* value technology would have in freeing dependence on others. However, in the same thought she noted: *"I wouldn't replace the guide. For me...It's a social thing and it's something I really enjoy...I think the guide has certain benefits that are not related to logistics."*

When prompted with a follow-up question where the interviewer asked if a hypothetical kind of technology was created that gave them the necessary cues needed, so they could still run with a group, but not needing a member of that group to actually be a guide, P11 responded with: *"That would be awesome. Just to be able to run with someone and not have to use a tether, just to be able to chit chat with them without them having to provide all the cues."*

P12 (SVA) described how running with a group can create bonds that go beyond running assistance: *"What tends to happen is I'll meet someone through a group run, like Achilles run, and you're like 'Wow this worked out pretty well'. It's kind of like dating. Like, 'Oh this went well we should have a second run.' because you like this person and they seem to know what they are doing, I didn't get injured or run into a wall."*

Therefore, while it may seem at first to be in contrast to the "Supporting Autonomy" theme above, even if runners want the freedom to run independently, if somehow given a viable option to do so, would more often than not, still choose to run with others. During the initial portion of the interview, many participants noted the need to stay in shape/exercise and/or prepare for competition as the motivation behind why they run. However, one theme that consistently began to emerge from many of the participants after deeper discussion was the fact that running allows for greater socialization. At least four of the study participants belong to "Achilles International", an organization currently in 25 countries with a mission to transform the lives of people with disabilities through athletic programs and social connection [1]. Participants described how they would use this organization to, not only find running guides, but people in general so they can run in groups.

It was interesting to note that the undercurrent supporting the social aspect of running was present whether the participant ran with a group or just with a guide. In addition to the quality of assistance as described in Section 4.4.2, participants described the need for a particular type of personality which they would be able to interact with. It was important, not only that the guide knows what to do, not only that the runner trusts them, but that runner and

guide get along. As P10 (LNV/TB) noted: “*Some people say ‘anyone can guide’. That is just not true.*”

The need to restrict interaction that is not adequately socially distanced due to the restrictions brought about by the COVID-19 pandemic, has only exacerbated the need to rely on assistance from one’s social bubble. For example, P09 (LNV/TB) indicated that prior to the lockdowns, she had about six or seven people that she used as guides. This need for socialization is also supported by some of the findings in [31]. In examining mainstream exercise classes, the authors noted that the accessibility of these classes is important for BVI individuals to benefit from knowledge transfer as well as the positive social benefits of attendance [31].

## 5 Discussion

The findings outlined in the previous section point to some important implications for how technology might be designed to better support running and navigation for BVI runners in particular, but also running and/or navigation in general. For example, as was noted in Section 4.1, all study participants indicated that they avoid using treadmills (or view them as a modality of last resort) due to the inaccessibility of treadmills at public gyms, in particular the fact that many of the controls are touch-screen. By designing treadmill interfaces with greater tactility, either through the reintroduction of physical, 3-dimensional buttons and interaction units or incorporating haptics to existing interface, these machines can become realistic exercise alternatives for BVI runners. The improved tactility could support an improved experience for sighted individuals as well, as there might be scenarios during an active running event where one might wish to make adjustments on-the-fly and benefit from a more easily acquired interface unit.

Regardless of ability, all exercise participants must recognize a trade-off that exists between the benefits of any exercise choice and the potential harm in engaging in that exercise [31]. Such a trade-off was noted in this study. The “Addressing Uncertainty” theme from this present study suggests that the added uncertainty associated with the blind running experience exacerbates the variance resulting from this risk/reward mental calculation. Also, the theme “Supporting Autonomy” implies that BVI runners desire more control over how, where, when, and with whom they run. In order to support independence, among other things, information about routes needs to be committed to memory. However, the process of both trying to remember every landmark/obstacle while processing situational factors on the fly can prove exhausting. To reduce the likelihood of challenges, less experienced runners favored running in spaces with minimal chance of unplanned obstacles present. However, not only does this practice limit autonomy, but as was noted in Section 4.1 and P08’s frustration with treadmill use at a gym, even a completely controlled environment can still create potential cognitive overload for a BVI runner.

Insights from runners revealed that if uncertainty coupled with the need for quality assistance due to reduced autonomy is not addressed, it can not only lead to injury (e.g., incorrectly accounting for an obstacle), but also reduce the quality of choices to facilitate the running experience (e.g., not realistically having the option to

listen to music/podcasts.) Finally, the anxiety brought about from not knowing/being overwhelmed might even result in abandoning the running/exercise event altogether as the implication of the risk/reward trade-off prove too daunting. Solutions to unburden the memory yet improve autonomy, therefore, would be valuable.

Technological improvements to alerts offered for things such as route mappings and ad hoc object detection/avoidance as well as improved customization for these experiences might provide an environment that is more certain, less cognitively taxing, and as a result, offer more autonomy and options for the BVI runner. In addition, as was noted in the “Quality of Assistance” and “Supporting Socialization” themes, human guides are not only the most common form of assistance, they are desired. Technology need not only be designed for the BVI runner. Since it appears that a human running assistant/companion appears to be a positive part of the holistic BVI running experience, technology could be designed to train and support running guides to reduce the learning curve needed and improve the quality of service provided.

The implications for design suggested above can be implemented with new ideas and/or new products such as has been offered in research such as [16,25,26,30], but also existing technologies, such as the Sunu Band, could be augmented using some of the insights discussed here. How might we, for example, expand the scope of the feedback mechanisms to help identify positioning on a track described in the above referenced studies to the infrastructure of off-track environments such as specific established trails or even ones that are less well trodden? Could these expansions of scope be synched to devices such as Sunu bands? Or, to promote maximum effective feedback with reduced cognitive load, could feedback mechanisms be incorporated to wearable technology for running guides? If technology could support the alerting of guides to guiding moments on a run, they may not need to deploy as many cognitive resources to always be noting what is coming next and therefore allow for greater socialization, further aiding the “Supporting Socialization” theme.

In examining BVI quality of life, [3] notes that vision loss constrains many aspects of living, including the limiting of where they live. The theme, “Supporting Autonomy” from this present study also supports and adds to the theme of location dependence as the BVI runners in this study express the desire to choose routes for running because of interest or diversity rather than to accommodate physical limitations. In addition, there is the issue brought about by uncertainty due to perceptual limitations resulting in the need of not just some type of assistance, but quality and reliable assistance. Many of the participants in this study expressed the desire to eliminate dependence on corporeal guides. However, this desire for greater autonomy must be balanced with the understanding of the importance that the social component of running with others brings to the overall running experience. In addition, as was noted in [31], the knowledge transfer that can occur during a communal event can also add value to the overall experience that would not be possible during a solo event. Technology clearly plays an important role in the solution to this issue.

Additional awareness of situational factors presented through an interface may offer some further help. This, however, also represents a delicate balancing act between presenting enough situational information and not overloading runners. The considerable diversity in the amount of information that is needed, or the type of information that needs to be presented offers an opportunity to designers and researchers interested in supporting blind runners. In other words, technology must present information in such a way that a BVI runner can completely negotiate the running event without blocking or overutilizing the perceptual channels needed to safely maintain situational awareness while also not inhibiting corporeal socialization.

A key factor for any technology to provide support without perceptual or cognitive overload, is the assurance that any support (technology-based or otherwise) offers timely and appropriate feedback. Providing assistance that offers the most appropriate form of feedback to the user might be useful in this case, but with the understanding that a “one size fits all” solution may not be sufficient. The findings of this study highlight the diversity among runners, the types of obstacles that they found challenging to encounter, and the types of detail that would be useful to them in a future system. For example, while some runners worried about slipping on muddy terrain, others were more worried about sharp drops from the curb to the roadside if depth perception was poor. While some blind users relied mainly on help from others, some used their residual vision to support running. This strongly suggests the need for more customizable solutions. The blind community can sometimes be thought of as a homogenous group by designers, with similar needs, abilities and preferences. The findings in this study highlight that this is not always the case. For example, sunlight was found to impact the time of running for P06 (SVA) due to his photosensitivity as well as the direction with which he could run in. However, this may not be a challenge for those who cannot perceive light. In addition, this study highlighted that not all run for the same purpose. Those who run competitively, for example, need feedback response in real time to effectively participate in competitive training and events. Well trained human guides, perhaps even service animals, can provide the immediate response rate that is needed. However, for technology to truly be a legitimate substitute for corporeal assistance, as was suggested by the comments highlighted by some of the competitive runners in this study, technology must improve so that the feedback is more noticeable, responds faster, and accounts for situational impairments. In a recent study, Gupta et al. [12] examined navigation, identifying common preferences among individuals with similar and different abilities. They proposed a preference-based solution rather than one specifically focused on ability. This could be a valuable asset for all runners.

One of the more revealing, if not surprising findings of this study, was the degree to which existing assistive navigational technology is shunned by BVI participants. While it was the researchers’ expectation that more forms of technology were used to support running, the minority of our participants owned assistive devices specifically for that purpose. This was part borne through experience – potentially from when they had some level of sight.

Nevertheless, runners had come up with their own creative workaround methods, suggesting that commercial technologies may not be the sole solution. Individualization and customization might be an important feature to account for, not only due to the lack of current solutions, but also perhaps because individual and customizable solutions contribute to a sense of personal control and autonomy. Designers should therefore be aware of not only the desire for autonomy, but also the heterogeneity of the community when designing solutions.

## 6 Limitations and Future Work

This research represents an initial inquiry towards a better understanding of the needs and issues of blind and visually impaired runners and therefore offers a starting point for future research to support the BVI running community. While the sample size of 13 provided an overview of experiences for an exploratory study, recruitment was based on the researchers own network and snowball sampling. As was noted in Section 3, all participants were from the United States. The running conditions and infrastructure available that lead to the needs, issues, and concerns may vary considerably to those in other countries and regions of the world. Future work may wish to examine a more diverse geographically based population to determine if different locations, or perhaps varied geopolitical contexts and world views might affect the needs and concerns of BVI runners. An examination of the use of crowdsourcing, its current and/or future use could highlight and contribute to a richer portrait of the efficiency of acquiring running resources. Finally, as this study revealed, the stakeholders in the BVI running domain extend beyond BVI runners. Future work could examine the needs and issues of, for example, running guides and others that offer support for the BVI running experience for a more complete well-rounded analysis of the domain.

## 7 Conclusion

An inquiry was conducted examining the habits, challenges, and desires of blind and visually impaired runners. Contributions from the work include a set of insights that helped provide a deeper understanding of the BVI running experience. It is hoped that the implications developed help designers and researchers identify ways in which technology might be designed to support the BVI running experience and add to the compendium of existing knowledge that supports the health and exercise needs of BVI individuals.

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