The Sonic Eyewear Project (SEP):
Echolocation Technology that Enables the Blind to See with Sound.

The Sonic Eyewear Project is echolocation technology built into designer frames for people with 0-25% vision that protects the eyes, increases obstacle detection to 30 feet, and cuts echolocation training times at blind training centers in half. Unlike other assistive technologies (ATs) for the blind that simply alert users of nearby objects, our solution generates flashes of sound energy that solicit echoes from the environment while leveraging the processing power of the brain to echolocate and navigate the world.

Problem Statement

1.3 million Americans were legally blind in 2010, and the National Eye Institute expects that number to triple to 4.1 million by 2050 [i]. Globally, 253 million people suffered from moderate to severe visual impairment in 2015, and global estimates are expected to total 700 million people by 2050 [ii]. Additionally, research findings suggest that visual impairment negatively affects educational activities and economic progress [iii], while reducing quality of life [iv], and increasing risk of death [v]. Fortunately, equal opportunity laws for people with disabilities, as well as increased social awareness and the advent of ATs for the blind, have improved both their quality of life and their ability to gain employment and live independently. The blind and visually impaired (BVIs) are now known to hold leadership positions throughout government, universities, and Fortune 500 companies.

Echolocation is the location of objects by reflected sound, and is particularly used by animals such as dolphins and bats. A human tongue-clicking echolocation technique known as FlashSonar has shown incredible promise by a completely blind man named Daniel Kish. Having mastered FlashSonar, Kish has enough confidence to ride a bicycle on public streets, hike in the wilderness by himself, and do many other things that sighted people do. Through his non-profit foundation, World Access for the Blind, Daniel and his team teach BVIs the FlashSonar method, and they continue to generate incredible results; however, their reach is limited and has a steep learning curve with regard to making the "right" type of tongue-click that is optimal for human echolocation. As a result, large portions of the BVI population remain unable to gain access to or afford the training that could otherwise result in massive quality of life improvements.


Figure 1. Daniel Kish who is completely blind, rides his bike while using FlashSonar to navigate

Existing Solutions

There is a plethora of ATs for BVIs on the market, ranging from the traditional white cane to smartphone apps and everything in between. When it comes to technologies that assist with spatial awareness, however, there is a common theme that subtly hints at the implicit bias most sighted inventors are plagued with, which is: *that BVIs are perceived to have a capability deficiency.* In this proposal, we take the rare but empowering stance that while blindness *is* a challenge, BVIs are not deficient – just differently abled. Unfortunately, most ATs on the market today heavily process information about the environment and deliver it to the BVI user in the form of sounds, vibrations, or electric signals. This design approach creates a high sense of technological dependency and deprives BVIs of their personal autonomy.

[Sonar Glasses] are for sale online ($799-$999) and are described as a mobility aid for BVI individuals. They work by emitting inaudible UHF signals and measuring the time of reflected waves. If an object is within the adjustable detection range of 3, 6, or 9 feet, then the device vibrates at the temples as a signal to the user. This AT does protect the eyes and help avoid head collisions, but it is not cost-effective for the average BVI. This AT processes all signals, creating strong device dependency for the user.

Figure 2 Sonar glasses

The *iGlasses Ultrasonic Mobility Aid* ($99.95) uses the same obstacle detection method as the Sonar Glasses, but instead uses increasing frequency vibrations as objects get closer to the user, ranging from 9 to 0 feet. It also emits a beeping sound to let the user know when the battery is low. While this device is more affordable and offers hands-free obstacle detection for the upper body, the detection range is very short and it conditions the BVI to become dependent on the technology for spatial awareness.

Figure 3 iGlasses Ultrasonic Mobility Aid

Vision-800 Glasses technology ($200) allows the blind to experience their surroundings via image-to-sound renderings. The device processes pictures into sounds that is transmitted by headphones, allowing users to perceive height and distance based on sound pitch and timbre; however, it comes with head straps due to its heavy weight, is very fragile, and only has a 1-hour battery life which makes it impractical for use throughout the day. This device processes signals for the user, causing the BVI to become heavily dependent on the technology for spatial awareness.

Figure 4 Vision-800 Glasses

The Argus® II Retinal Prosthesis System *("Argus II")* is known as the bionic eye ($150,000). The technology induces visual perception in BVIs by providing an electrical stimulation to the retina via surgical implants which receive wireless instructions from the patient-worn computer. The high cost makes it prohibitive to the average BVI user, and their website states: *effectiveness of this device has not been demonstrated.* Similar to the ATs above, this device processes all signals for the user, making BVIs dependent on the technology.

Figure 5 The Argus II

Though echolocation methods are widely known as a means of improving spatial awareness throughout the BVI community, the modes by which the highly effective tongue-clicking echolocation technique known as FlashSonar is taught remains a barrier for many. Mastering FlashSonar can exponentially improve BVI quality of life, however, it can be challenging to learn due to the special type of tongue-clicking sounds it requires BVIs to master. The current training can be expensive, time consuming, and require in-person guidance only found in specific locations. Such high barriers to entry result in many BVIs, many of whom are socio-economically challenged, not being able to learn the FlashSonar technique that could otherwise greatly improve their quality of life.

Proposed Innovation

SEP bridges the accessibility gap by creating a cost-effective, integrative solution that improves upon manual FlashSonar by automating and standardizing the sounds of the ideal tongue-click, thereby improving the resolution of reverberations received from the surroundings. The technology grants BVIs who are unable to visit training facilities with the ability to immediately begin learning FlashSonar to detect obstacles up to 30 feet in the privacy of their homes. SEP technology can also augment traditional teaching approaches at echolocation training facilities, reducing training times by as much as 50%, resulting in cost and time savings for these organizations as well as BVIs who participate in echolocation programs.

Many ATs belong to a class of technologies known as sensory substitution devices (SSDs), which work by taking in visual data, then processing it into auditory or tactile information for the BVI user. Unlike most SSDs which heavily process the incoming signal, however, SEP technology generates flashes of sound energy to create echoes from the environment, *while utilizing the processing power of the brain* to echolocate and navigate the world.

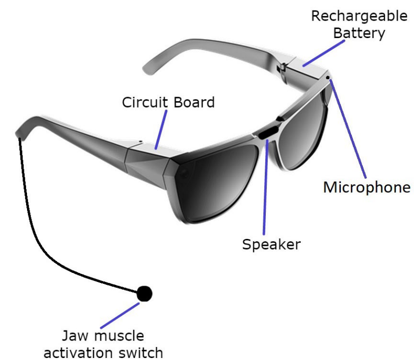

Figure 6 Prototype concept of SEP technology

ATs provide a special opportunity to push the limits of the brain's ability to rewire itself. Certain aspects of the brain's 'visual' sections that process shape and motion become activated in blind AT users. Brain scans have demonstrated that the part of the brain that processes vision "turns on" when BVIs use echolocation techniques. SEP technology, unlike most other ATs, primarily leverages the brain's ability to strengthen and form new connections within itself when using echolocation techniques. By habitualizing BVIs to make sense of echoed sound waves with their brains, SEP technology improves personal autonomy while reducing their technological dependence.

Measuring Success

The SEP team recently completed an accelerated startup course hosted by the Bay Area NSF Innovation Corps on the UC Berkeley campus. The highly immersive course prompted us to quantify our value propositions in such a way that made it possible to measure the implementation and effectiveness our technology for our customer segments. We will collect data on the following outcome indicators so we can identify what is or isn't working and find out why:

- **Quality of life** - The Psychosocial Impact of Assistive Device Scale (PIADS) is a survey that is used to measure the impact of ATs on the functional independence, well-being, and quality of life for BVIs (See Appendix 2). The PIADS has been shown to be a reliable indicator of AT acceptance by measuring how much a technology increases or decreases 26 factors for the user (for example: competence, happiness, independence, etc.) PIADS data will be collected weekly from BVIs at echolocation training centers. We have set a PIADS score of 80% or higher as the success threshold for our technology's impact.

- **Obstacle Detection** – Those who have mastered FlashSonar have demonstrated detection of large obstacles (cars, buildings) up to 50 feet away, and small objects (ex. a dinner plate) up to 15 feet away. Our threshold for successful obstacle detection with SEP technology is 30 feet for large obstacles, and 10 feet for small objects by BVIs at echolocation training centers over a 2-week period.
- **Training Time** – Blind training centers that teach manual FlashSonar require 3-6 weeks of immersive, in-person training before intermediate levels of proficiency can be developed. SEP technology will reduce the FlashSonar training times by 50%.

Challenges to Implementation

During our initial customer discovery process where we interviewed BVIs, doctors, researchers, and occupational therapists at a low-vision conference and the University of California, Berkeley campus, we became aware that BVIs experience a great deal of discrimination and negative social stigma. Unfortunately, many BVIs respond by becoming social hermits and minimize their interactions with the world. Getting SEP technology into the hands of such BVIs who rarely leave their homes could be a challenge. There may also be technology adoption challenges as FlashSonar isn't yet a mainstream concept. We will overcome these barriers by forming alliances with echolocation training centers for the blind, and partnering with influential BVIs such as Daniel Kish who has given TED talks around the world. Figure 8 is a representation of the SEP ecosystem, which includes all the stakeholders involved.

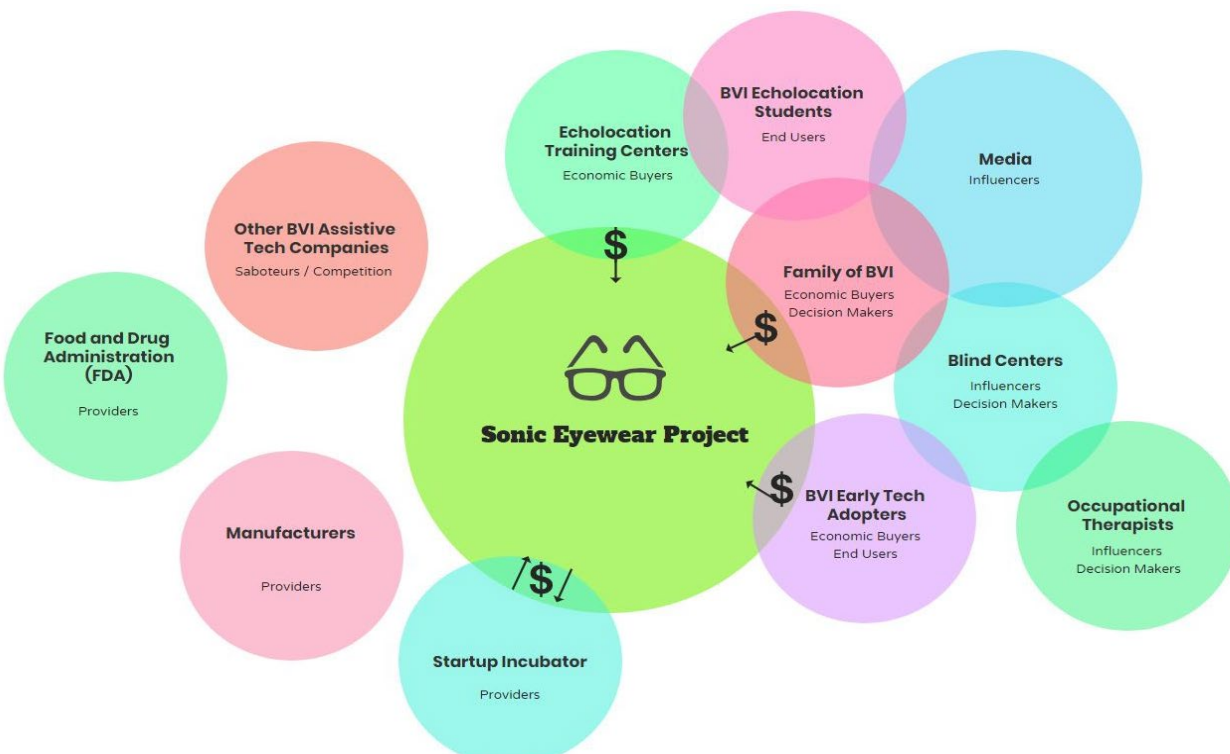

Figure 7 Ecosystem of the Sonic Eyewear Project

Partnerships Developed

The SEP team was invited to tour and discuss our technology with the vice president of engineering at ***Bolt.io headquarters in San Francisco***, which is a startup incubator with an in-house team of world-class engineers that specializes in pre-seeding hardware technological innovations - often as the first investor. Additionally, we are grateful to receive ongoing startup advising from ***Bryson Gardner***, who directed the technological roadmap of 25 Apple products and is highly experienced in concept-to-market development. Our team is officially being mentored by ***Edmond Macaluso*** over the next several months; he is an entrepreneur and technology venture advisor with expertise in startups, ramp-up, funding, strategic planning, and business development. SEP has been incredibly fortunate to have the opportunity to speak directly with ***Daniel Kish***, who has agreed to consult with us in San Francisco during his speaking event at Stanford in early April 2019. We have also formed strong relations with the ***Lighthouse for the Blind in San Francisco***, and have been invited to participate in their monthly BVI AT pitch sessions.

Implementation Timeline

Our goals for the next 12 months are to perform a deep dive into customer discovery, get the project accepted into a start-up incubator, and to create a functional prototype of our technology that satisfies those value propositions most desired by our customer segments.

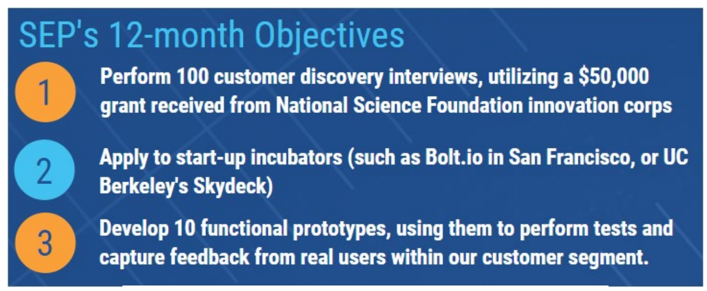

Figure 8 SEP's 12-month objectives

Having been awarded a $50,000 grant from the NSF i-Corps to strictly perform customer discovery for our technology (i.e. no prototyping allowed), the SEP team will spend the Summer of 2019 travelling around the USA performing a minimum of 100 user in-depth interviews in order to collect rich data from blind training centers, low vision conferences, nonprofits for the blind, and highly independent and technologically savvy BVIs. We will use this data to further refine our customer segments and develop the value propositions of our technology. Since the NSF grant isn't approved to fund any prototyping, awards received from the Big Ideas competition will be used to satisfy the prototyping research and development goals of this proposal.

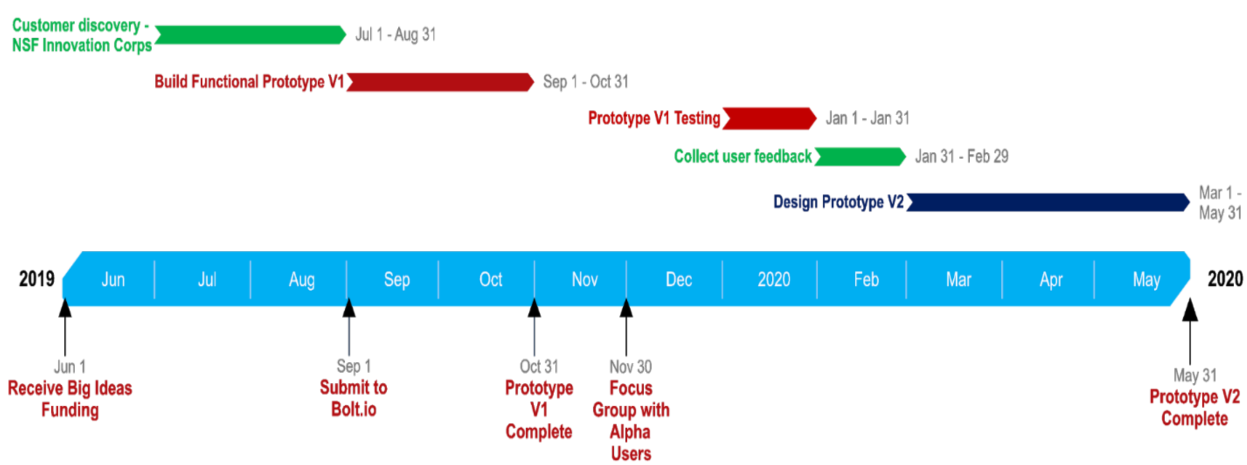

Figure 9 SEP's 12-month timeline for Big Ideas

Projected Budget

The following budget estimations will satisfy the necessary to steps of the 12-month timeline illustrated earlier in this proposal. Decisions made to further reduce costs include:

- Website development and hosting will be executed in-house, incurring zero costs.
- Legal and entrepreneurial guidance will be received at zero cost via UC Berkeley.
- Marketing materials will be completed in-house, at substantially reduced costs.

We will apply for the following opportunities to further fund the Sonic Eyewear Project:

- NSF Small Business Innovation Research (SBIR) program: $1.5 million
- Bolt.io Startup Accelerator: $200,000
- University of California, Berkeley Skydeck Startup Accelerator: $100,000

SECTION 1. PROJECTED EXPENSES		
I. Supplies Cost	Supplies Cost Details	Total
Recycled 3D Filament Samples: 4x50-gram spools of ABS, PLA, HiPs, and PET	Samples are $15 each	$60
Recycled Bulk 3D Filament: 5x750-gram spools	Selected filament will be purchased in bulk 5 spools x $35	$175
SPEAKERS: iPhone 7 internal speaker, Google Pixel internal speaker, Quark speaker	Varieties of small form-factor traditional and directional speakers to determine their applicability to our design	$300
Bose Audio Sunglasses	Bose Audio Sunglasses will be dismantled to better understand the engineering of smart eyewear.	$200
Snapchat Spectacles	Snapchat Spectacles will be dismantled to better understand the engineering of smart eyewear.	$200
Subtotal Supplies		$935
II. Travel & Transportation Costs	Travel Cost Details	Total
Audio Engineering Society (AES) Convention 2019: October 16-19 @ Javits Convention Center, New York, NY Rocky Mountain Audio Fest 2019: September 6-8 @ Gaylord Convention Center, Denver, CO	These conventions showcase the latest in audio technology that may be useful in SEP eyewear. Cost breakdown includes attendance of 2 SEP members.	
	Airfare to New York (economy)	$800
	Airfare to Colorado (economy)	$700
	Convention fees	$600
	Hotels (shared room)	$600
Subtotal Travel		$2,700
III. Personnel Costs	Personnel Cost Details	Total
SEP Team	Annual salary for the entire core team.	1
Eyeware Design Consultant	Design specialist for the ergonomic and aesthetic development of SEP frames. Estimating $95/hour (40 hours)	$3,800
Subtotal Personnel		$3,801
IV. Other Project Costs	Other Cost Details	Total
Marketing Materials	Printing, inks, paper, postage, etc. that will be used during prototype testing.	500
Packaging and Postage	Shipment of prototype V1 to / from focus group members for testing and feedback	$2,000
Subtotal Other Costs		$2,500
TOTAL PROJECTED EXPENSES		$9,936
Additional Grant or Prize Money	Additional Grant or Prize Money Details	Total
NSF i-Corps $50,000 grant	This funding may only be used with the NSF Program to improve customer discovery for the Sonic Eyewear Project (travel, lodging, meals).	$0.00
Subtotal additional grant or prize money		$0.00
SECTION 2.FUNDING GAP		
PROJECTED FUNDING GAP		$9,936

Figure 10 Big Ideas 12-month Budget

Team Member Biographies

LT Darryl Diptee, US Navy (retired), is an Education PhD student at the University of California, Berkeley. His research focuses on instructor-student relationships that improve the STEM persistence and achievement of underrepresented minority students. During his 20 years of military service as a cyber-security officer, he led teams on several deployments around globe, often to austere environments that required problem-solving and out-of-the-box thinking to achieve mission success. LT Diptee is a serial innovator and entrepreneur who is passionate about socially impactful technology.

Fatima Perez Sastre is an international student studying entrepreneurship at the University of California, Berkeley. She previously earned a Biomedical Engineering degree from Carlos III University, Spain, and gained extensive experience working with a 3D skin bioprinter start-up. Fatima also completed an MBA with a focus on Biotechnology companies, and is currently interning at a medical startup which recently exited from Y-Combinator. Fatima is deeply passionate about healthcare technology that improves quality of life.

Arnav Gulati is double-majoring in Physics and Data Science at the University of California, Berkeley. He is experienced in analyzing data and constructing creatively unique solutions through science and technology. He is skilled in coding, software engineering, functionality testing, and optimization techniques. Arnav's work focuses on using technology to create positive impact on the social and public front.

Jack Wallis is majoring in Mechanical Engineering at the University of California, Berkeley. He is experienced with object-oriented programming, algorithm analysis, data manipulation in Python, Java, MATLAB, virtual modeling and 3D printing. Jack strives to create and optimize creative solutions to practical societal problems through engineering.

Acknowledgements

The SEP Team would like to express sincere gratitude to the staff of: Big Ideas, NSF Bay Area innovation corps, and University of California, Berkeley, including Amanda Brief, and all the blind and visually impaired people we interviewed throughout San Francisco, CA. Without their combined selfless dedication, this proposal would not be possible.

Darryl Diptee
SEP Team Project Director

Appendix 1 - Life-Cycle Assessment

Product or component *Sonic Eyewear*		Project *Sonic Eyewear Project*		
Date *3/2/19*		Author *Arnav Gulati*		
Notes and conclusions *Total material usage for one pair of glasses. Conclusions: Production is most environmentally costly, so reducing spool waste, recycling speakers, and modularizing the design will allow for easy reusability and more environmentally-conscious updating as well (when need be).*				
Production Materials, treatments, transport and extra energy				
Material or process	**Amount**	**Measure unit**	**Indicator**	**Result**
spools of ABS, PLA, HiPs, and PET	4.00	Spools	382.500	1530.00
Bulk 3D Filament	5.00	Spools	390.000	1950.00
Quark speaker	2.00	Speakers	100.000	200.00
Audio filters	2.00	Filters	200.000	400.00
Screws Nuts Assortment Stainless Steel Screws	2.00	Boxes	110.000	220.00
Plastic Lenses (size adjusted)	10.00	Lens Set	510.000	5100.00
Total [mPt]				**9400.00**
Use Transport, energy and possible auxiliary materials				
Process	**Amount**	**Measure unit**	**Indicator**	**Result**
Paper (for additional packaging / design)	6.00	kg	96.000	576.00
Electricity low-voltage in 3D Printing	10.00	kWh	37.000	370.00
Total [mPt]				**946.00**
Disposal Disposal processes for each material type				
Material and type of processing	**Amount**	**Measure unit**	**Indicator**	**Result**
Excess 3D print (recycled)	1.50	Spools	170.000	-255.00
End of life (break and reuse - plastic modules)	2.50	Spools	170.000	-425.00
End of life (recycle - speaker and tech components)	1.00	Speaker	70.000	-70.00
Paper labelling (recycled)	2.00	kg	16.000	-32.00
Package disposal (recycled cardboard)	4.00	kg	8.300	-33.20
Paper Waste (Landfill)	2.00	kg	4.300	8.60
Final Statistics				
Total [mPt]				**-806.60**
Total [mPt] (all phases)				**9539.40**

Appendix 2 – PIADS Survey

Psychosocial Impact of Assistive Devices Scale (PIADS) Today's Date: ____________________
month/day/year

Client Name: ________________________ ○ Male ○Female
(last name, first name)

Diagnosis: ___________________ Date of Birth: ___________________________
month/day/year

The form is being filled out at: ○ home ○ a clinic ○ other _________

The form is being filled out by: ○ the client, without any help | ○ the client, with help from the caregiver
○ the caregiver on behalf of the client, without any direction from the client | ○ other ____________

Each word or phrase below describes how using an assistive device may affect a user. Some might seem unusual but it is important that you answer every one of the 26 items. So, for each word or phrase, put an "X" in the appropriate box to show how you are affected by using the____________________ (device name).

		Decreases	-3	-2	-1	0	1	2	3	Increases
1	competence		☐	☐	☐	☐	☐	☐	☐	
2	happiness		☐	☐	☐	☐	☐	☐	☐	
3	independence		☐	☐	☐	☐	☐	☐	☐	
4	adequacy		☐	☐	☐	☐	☐	☐	☐	
5	confusion		☐	☐	☐	☐	☐	☐	☐	
6	efficiency		☐	☐	☐	☐	☐	☐	☐	
7	self-esteem		☐	☐	☐	☐	☐	☐	☐	
8	productivity		☐	☐	☐	☐	☐	☐	☐	
9	security		☐	☐	☐	☐	☐	☐	☐	
10	frustration		☐	☐	☐	☐	☐	☐	☐	
11	usefulness		☐	☐	☐	☐	☐	☐	☐	
12	self-confidence		☐	☐	☐	☐	☐	☐	☐	
13	expertise		☐	☐	☐	☐	☐	☐	☐	
14	skillfulness		☐	☐	☐	☐	☐	☐	☐	
15	well-being		☐	☐	☐	☐	☐	☐	☐	
16	capability		☐	☐	☐	☐	☐	☐	☐	
17	quality of life		☐	☐	☐	☐	☐	☐	☐	
18	performance		☐	☐	☐	☐	☐	☐	☐	
19	sense of power		☐	☐	☐	☐	☐	☐	☐	
20	sense of control		☐	☐	☐	☐	☐	☐	☐	
21	embarrassment		☐	☐	☐	☐	☐	☐	☐	
22	willingness to take chances		☐	☐	☐	☐	☐	☐	☐	
23	ability to participate		☐	☐	☐	☐	☐	☐	☐	
24	eagerness to try new things		☐	☐	☐	☐	☐	☐	☐	
25	ability to adapt to the activities of daily living		☐	☐	☐	☐	☐	☐	☐	
26	ability to take advantages of opportunities		☐	☐	☐	☐	☐	☐	☐	

References:

[i] National Eye Institute. Blindness Tables. https://nei.nih.gov/eyedata/blind/tables

[ii] Ackland, P., Resnikoff, S., & Bourne, R. (2017). World blindness and visual impairment: despite many successes, the problem is growing. Community eye health, 30(100), 71-73.

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[iv] Ramrattan, R. S., Wolfs, R. C., Panda-Jonas, S., Jonas, J. B., Bakker, D., Pols, H. A., ... & de Jong, P. T. (2001). Prevalence and causes of visual field loss in the elderly and associations with impairment in daily functioning: the Rotterdam Study. Archives of Ophthalmology, 119(12), 1788-1794

[v] McCarty, C. A., Nanjan, M. B., & Taylor, H. R. (2001). Vision impairment predicts 5-year mortality. British Journal of Ophthalmology, 85(3), 322-326.