

Quality of Life Assessment of Severely Visually Impaired Individuals Using Aira Assistive Technology System

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Purpose: To assess patient-reported quality of life outcome improvements in severely visually impaired (SVI) individuals using the Aira system over a 1-year follow-up period.

Methods: Aira is an on-demand assistive technology designed for SVI. Aira subscribers were recruited and administered the validated 28-item Impact of Vision Impairment-Very Low Vision Questionnaire by phone before starting Aira with follow-ups at 3 months and 1 year. Total score and validated subset scores of activities of daily living, mobility, and safety (ADLMS) and emotional well-being (EWB) were assessed. Pearson correlation analyses and paired *t*-tests were used to examine the data.

Results: Fifty participants (mean, age, 52.5 years; 25 males, 25 females) were recruited with a mean of 401 ± 66.3 days to follow-up. The initial total score (mean, 53.1 ± 18.9) significantly improved at 1 year (mean, 63.1 ± 16.2 ; $P = 0.0002$). The initial ADLMS score (mean, 30.7 ± 11.3) significantly improved at 1 year (mean, 37.2 ± 10.7 ; $P = 0.001$). The initial EWB score (mean, 22.5 ± 8.5) significantly improved at 1 year (mean, 25.9 ± 8.0 ; $P = 0.0001$). There was no significant difference between the 3-month and 1-year total ($P = 0.972$), ADLMS ($P = 0.897$), and EWB scores ($P = 0.700$). There was a significant correlation between minutes used and improvement in total ($r = 0.371$; $P = 0.009$), ADLMS ($r = 0.302$; $P = 0.035$), and EWB ($r = 0.439$; $P = 0.002$) scores.

Conclusions: Aira use significantly improves Impact of Vision Impairment-Very Low Vision total, ADLMS, and EWB scores for SVI individuals at 3 months. This improvement is sustained at the 1-year follow-up and correlated with total minutes used.

Translational Relevance: Aira technology may provide sustained improvement in quality of life for SVI, and further study to evaluate the usefulness of this technology to assist SVI may be beneficial.

Introduction

With an estimated 36 million people who are blind and an additional 216.6 million people who are severely visually impaired (SVI) (visual acuity of better eye $<20/200$) globally,¹ visual impairment is one of the leading disabilities worldwide.² By comparison, in 1990, there were 159.9 million people who were reported to be SVI.¹ In the United States alone, there were a reported 1.02 million blind people in 2015, which is expected to double by 2050.³ This increasing number of those affected by vision loss has been attributed to general population growth as well as the growth of the geriatric population in particular.⁴ In 2015, there were 617.1 million people who were 65 years

or older worldwide. By 2050, that number will increase to an estimated 1.6 billion.⁵

It is well-established that vision loss leads to poorer quality of life owing to socioeconomic consequences and negative health outcomes including depression, declining cognition, falls, and injuries.⁶⁻¹¹ On a national scale, in 2011 the economic burden of vision loss was estimated to be \$139 billion.¹²

In recent years, there have been many efforts to provide technological assistance to those who have untreatable severe visual impairment. With the recent boom of technological advancements in cameras and headwear, many companies have been approaching the problem by combining augmented reality with head-worn devices such as Glass (Google, Mountain View, CA) and HoloLens (Microsoft, Redmond, WA).¹³⁻¹⁷

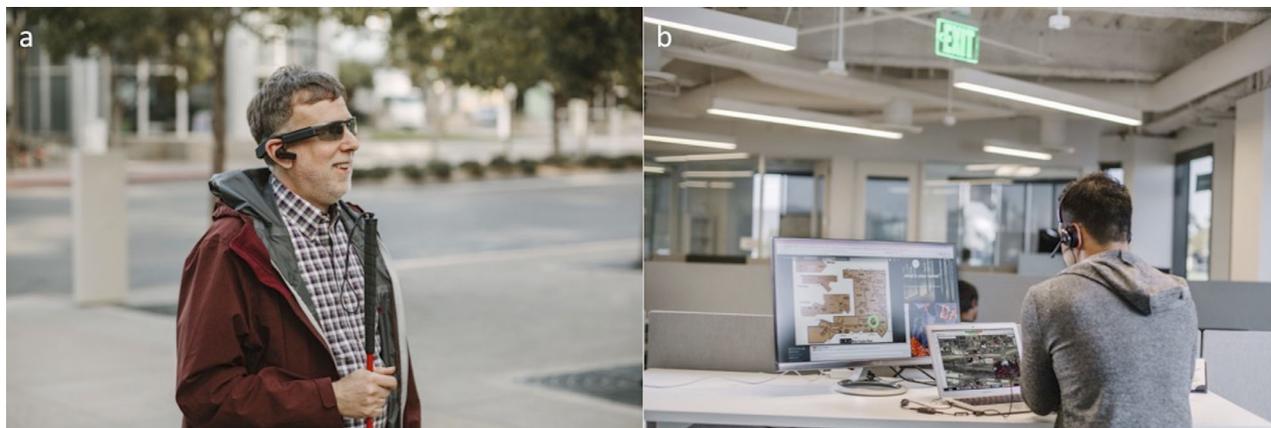


Figure 1. (a) SVI individual using Aira with livestreaming to (b) agent with module consisting of the device's video view and applications that assist with task coordination. Pictures courtesy of Aira.

Aira (available in the public domain at <https://aira.io/>; Aira Tech Corporation, La Jolla, CA) uses on-demand augmented reality assistive wearable technology designed for the SVI but relies on human–human intelligence instead of computed artificial intelligence or unidirectional output as its method of assistance. The user wears glasses with a video camera mounted that, when activated, livestreams to an “agent” who assists the user in the specified task. The agent has access to a module of live stream video and applications, such as maps, providing enhanced real-time tracking (Fig. 1). This model allows for collaboration to solve a spectrum of issues commonly encountered by SVI individuals, including navigation, reading, and even more complex tasks such as musical lessons.¹⁸ In a separate study by Nguyen et al.,¹⁶ an analysis of more than 10,022 sequential calls to the Aira service revealed that the most common tasks requested were reading, navigation, and home management for men and women. The top three categories for women were reading (35%), navigation (31%), and home management (17%). The top three categories for men were navigation (35%), reading (35%), and home management (16%). The lowest category was family (0.2%) for both women and men.

To the best of our knowledge, there are currently no long-term studies of low-vision assistive technologies demonstrating a quantitative impact in improving quality of life for the SVI. Many of the current quality-of-life studies on low vision aids do not extend beyond a 3-month follow-up period.¹⁶ There is a major need in the low vision field for objective validation and study of new low vision technologies to determine not only whether these technologies can improve quality of life

in this population, but also whether they can sustain that improved quality of life.

Our group has recently published the results of a prospective study looking at how Aira improved quality of life after using this assistive technology system for 3 months.¹⁶ Using the 28-item Impact of Vision Impairment-Very Low Vision (IVI-VLV) Questionnaire specifically validated for low vision patients,¹⁹ we administered this instrument by phone before starting Aira with a follow-up at 3 months. This study demonstrated the use of Aira significantly improved IVI-VLV total score for SVI individuals. Total score as well as validated subset scores of activities of daily living, mobility, and safety (ADLMS) and emotional well-being (EWB) were assessed and showed improvement regardless of minutes used.¹⁶ Here, we present the prospective 1-year follow-up data from 50 participants who continued using the Aira system to determine whether the demonstrated improvement in IVI-VLV total score and ADLMS and EWB subscores at the 3-month follow-up is sustained at the 1-year follow-up.

Methods

Patients

All 69 subscribers who were initially recruited from December 2016 to December 2017 for the prior study by Nguyen et al.¹⁶ were invited to participate in this study. Of the 69, 50 participants who continued to use the Aira system are included in the current analysis.

Inclusion criteria for the study were English-speaking patients with severe vision impairment, which

is defined as visual acuity of the better eye being less than 20/200, agreement to complete the IVI-VLV questionnaire, and age of 18 years or older at the time of inclusion.

The described study was approved by the University of California, San Diego Institutional Review Board. It remained Health Information Portability and Accountability Act-compliant, and continued to adhere to the tenets of the Declaration of Helsinki. After an approved verbal script consent was administered over the telephone, verbal consent was provided by all study participants. Demographic information such as age, sex, and educational level was collected in the initial study.¹⁶

Assessment of Impact of Vision Impairment

All participants were followed during the study period between December 2017 and December 2018. All participants were administered the previously validated IVI-VLV questionnaire (Supplementary Fig. S1). In the original study that validated the IVI-VLV questionnaire by Finger et al., the investigators demonstrated that “IVI-VLV meets all requirements of the Rasch model, and proposed quality criteria for health status questionnaires, such as content validity, internal consistency, reliability, no floor or ceiling effects, and good interpretability.”¹⁹ The total score as well as a validated subset scores of ADLMS and EWB were assessed. The same IVI-VLV questionnaire that was completed by participants at the beginning of the study and again at the 3-month follow-up was re-administered in the exact same order at the 1-year follow-up. Total minutes used during the 1-year study period were obtained from Aira databases.

Statistical Analysis

Pearson correlation coefficients and *P* values were calculated between minutes used and improvement in IVI-VLV total score, ADLMS subscore, and EWB subscore using SPSS Statistics (IBM Corporation, Armonk, NY). The paired *t*-tests and *P* values were calculated between the initial and 1-year follow-up for the total, ADLMS, and EWB scores using SPSS Statistics. Paired *t*-tests and *P* values were also calculated between the 3-month follow-up and 1-year follow-up for the total, ADLMS, and EWB scores and minutes used per month using SPSS Statistics. Linear regression analyses were performed to account for potential confounders for the correlation between total number of minutes used and improvement in IVI-VLV score using SPSS Statistics.

Results

Patient Demographic Information

A total of 69 subscribers who participated in the prior study by Nguyen et al.¹⁶ were invited to participate in the IVI-VLV survey at the 1-year follow-up to assess vision-related quality of life before using Aira. Nineteen participants from the original study were excluded because nine were lost to follow-up, seven stopped using Aira, and three declined the questionnaire. The final study group consisted of 50 participants (mean, age 52.5 ± 13.6 years; 25 males and 25 females). Compared with the initial study cohort, participant group's age, sex, college-level education, and vision status did not significantly differ (Table 1). The mean time to follow-up was 401 ± 66 days. The mean total minutes used over the 1-year period was 1177 ± 1123 minutes (Fig. 2).

Improved Total IVI-VLV Scores, as well as Subset Scores, Were Seen Compared with Initial Scores

We asked whether the IVI-VLV scores increased in patients that used the Aira system between initial intake and 1 year afterwards (Table 2). Assessing with a paired *t*-test, initial total score (mean, 53.1 ± 18.9) significantly improved at 1-year (mean, 63.1 ± 16.2 ; $P = 0.0002$) with a mean change of $+10.0 \pm 17.6$. The ADLMS and EWB scores also showed significant improvement at 1 year compared with the initial survey scores. The initial ADLMS score (mean, 30.7 ± 11.3) significantly improved at 1 year (mean, 37.2 ± 10.7 ; $P = 0.001$) with a mean change of $+6.5 \pm 13.4$. The initial EWB score (mean, 22.5 ± 8.5) significantly improved at 1 year (mean, 25.9 ± 8.0 ; $P = 0.0001$) with a mean change of $+3.4 \pm 5.7$.

No Change in Total IVI-VLV Scores, as well as Subset Scores Were Seen Compared with the 3-Month Follow-Up

We asked whether IVI-VLV scores changed in patients that used the Aira system beyond 3 months to 1 year (Table 3). When comparing to the 3-month total score, no significant difference was found between 3 months (mean, 63.2 ± 14.5) and 1 year (mean, 63.1 ± 16.2 ; $P = 0.972$) with a mean change of -0.1 ± 12.0 . There was no significant difference between the 3-month ADLMS score (mean, 37.1 ± 8.7) and the 1-year score ($P = 0.897$), with a mean change of $+0.1 \pm 9.8$. There was no significant difference between the

Table 1. Demographic Data of 1-Year Follow-up Group and Those Excluded from the 3-Month Follow-Up

	Total Participants 1-Year Follow-Up	Participants from 3-Month Follow-up Excluded	χ^2 P Value
Age, y			
<55	24	7	0.485
>55	23	10	
Declined to answer	3	2	
Sex			
Male	25	9	0.845
Female	25	10	
Vision status			
Blind	24	12	0.249
Light perception	15	2	
Low vision	6	4	
Declined to answer	5	3	
Education level			
High school	4	3	0.304
College	24	9	
Graduate	21	4	
Declined to answer	1	3	

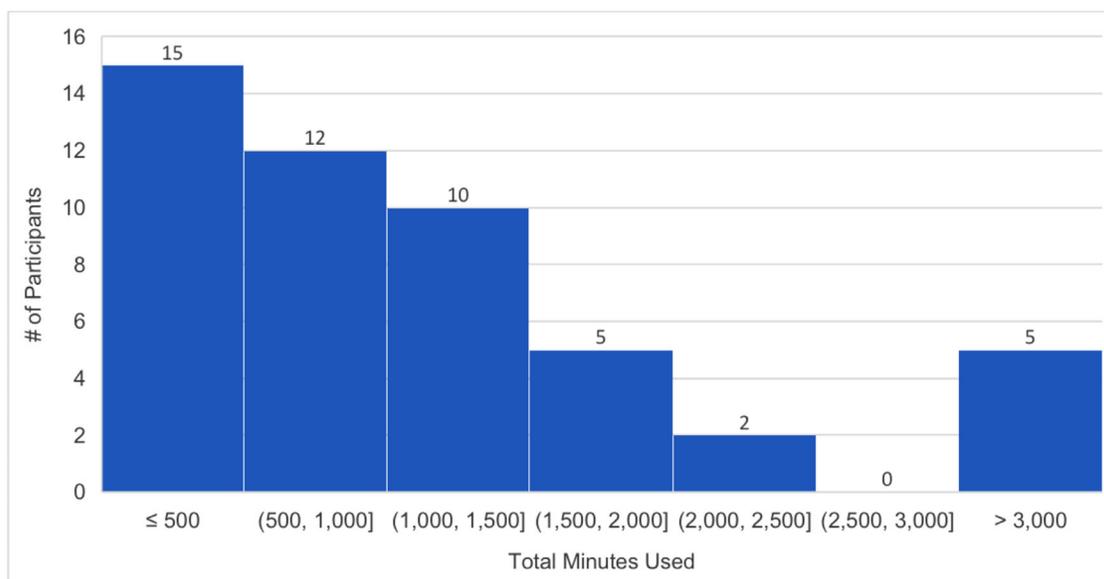


Figure 2. Distribution of total Aira minutes used over 1 year.

3-month EWB score (mean, 26.1 ± 7.5) and the 1-year score ($P = 0.700$) with a mean change of -0.2 ± 4.4 .

Positive Correlation Between the Total Number of Minutes Used and Improvement in IVI-VLV Score

We then looked to determine if there was a correlation between the number of minutes used by individu-

als and improvement in their total, ADLMS, and EWB scores (Table 4). At the 1-year follow-up timepoint, there was a significant correlation between minutes used and improvement in total IVI-VLV ($r = 0.371$; $P = 0.009$) and EWB ($r = 0.439$; $P = 0.002$) scores, accounting for potential confounders including sex, age, and education level (Table 5). There was significant correlation between minutes used and improvement in ADLMS score ($r = 0.302$; $P = 0.035$); however,

Table 2. Initial and 1-Year Follow-up *t*-test for Total, ADLMS, and EWB Scores

	Total			ADLMS			EWB		
	Initial	1-Year Follow-up	Change	Initial	1-Year Follow-up	Change	Initial	1-Year Follow-up	Change
Mean	53.1	63.1	10.0	30.7	37.2	6.5	22.5	25.9	3.4
SD	18.9	16.2	17.6	11.3	10.7	13.4	8.5	8.0	5.7
<i>P</i> value	0.0002			0.001			0.0001		

Table 3. Three-Month Follow-up and 1-Year Follow-up *t*-test for Total, ADLMS, and EWB Scores

	Total			ADLMS			EWB		
	3-Month Follow-up	1-Year Follow-up	Change	3-Month Follow-up	1-Year Follow-up	Change	3-Month Follow-up	1-Year Follow-up	Change
Mean	63.2	63.1	-0.1	37.1	37.2	0.1	26.1	25.9	-0.2
SD	14.5	16.2	12.0	8.7	10.7	9.8	7.5	8.0	4.4
<i>P</i> value	0.972			0.897			0.700		

Table 4. Pearson Correlation Between Total Minutes Used and Change in Total, ADLMS, and EWB Scores from Initial to 1-Year Follow-up

	Total	ADLMS	EWB
Pearson <i>r</i>	0.371	0.302	0.439
<i>P</i> value	0.009	0.035	0.002

after adjusting for potential confounders, this correlation was no longer significant.

Decrease in the Number of Minutes Used Per Month Was Seen Compared with the 3-Month Follow-Up

We also looked to determine if there was a change in number of minutes of Aira used per month from the 3-month to the 1-year follow-up. Minutes used per month at 3-month follow-up (mean, 120.3 ± 108.7) significantly decreased at 1-year follow-up (mean, 99.8 ± 93.8; *P* = 0.026).

Discussion

In this prospective study, we extend the results of our prior initial 3-month analysis of the Aira service¹⁶ to determine whether the demonstrated improvements in IVI-VLV total score and ADLMS and EWB subscores at the 3-month follow-up are sustained at the 1-year follow-up. We found that Aira use continues to improve IVI-VLV total score and the ADLMS and EWB subscores for SVI individuals at 1 year. This finding suggests that the Aira assistive technology for

SVI individuals may improve quality of life beyond the initial 3-month improvement and is sustained as a useful instrument in their lives.

This improvement is correlated with total minutes used, which is a novel finding compared with the results of the 3-month follow-up study. At 3 months, we found there to be no correlation between the number of minutes used and the total score change (*P* = 0.098), and ADLMS (*P* = 0.055), and EWB (*P* = 0.051) subscores.¹⁶ We discussed three possibilities for why we did not see a correlation between the participant’s minutes use and their improvement in IVI-VLV scores at the 3-month follow-up, including a subjective security blanket phenomenon, an inadequate number of participants, and a short follow-up study period. The results of this extended study may suggest that the lack of statistical significance in the initial study was secondary to inadequate length of the study or, less likely, a small sample size. This finding suggests that Aira’s impact on increasing quality of life results from a dose-dependent increased use of the product. This improvement also may be due to the increased length of time with SVI, because participants have had more time to adapt to their vision loss and to optimize Aira’s role within their lives. The analysis of Aira calls by Nguyen et al.²⁰ revealed significant differences in types of calls, distribution of call types, duration, and time of call by sex and vision status. This study revealed that blind and light perception users had higher use rates than those with low vision and women had higher use rates than men.²⁰ However, in our study, there was no significant difference in vision level or sex between those who continued to use Aira at 1 year and those who did not.

Table 5. Linear Regression Analysis on Total, ADLMS, and EWB Scores and Aira Minutes Used

Characteristic	Coefficient (95% CI)	P value	Adjusted Coefficient (95% CI)	P value
Total score				
Aira minutes used	0.006 (0.002 to 0.010)	0.004	0.005 (0.001 to 0.010)	0.019
Sex				
Female			0 ^a	
Male			-10.361 (-19.343 to -1.380)	0.024
Age			-0.250 (-0.578 to 0.708)	0.135
Education level ¹				
High school			0 ^a	
College			1.055 (-17.314 to 19.424)	0.910
Graduate			3.584 (-14.971 to 22.138)	0.705
Doctorate			-5.616 (-25.614 to 14.383)	0.582
ADLMS subscore				
Aira minutes used	0.004 (0.001 to 0.007)	0.015	0.003 (0.000 to 0.007)	0.076
Sex				
Female			0 ^a	
Male			-7.666 (-14.838 to -0.493)	0.036
Age			-0.136 (-0.397 to 0.126)	0.310
Education level ²				
High school			0 ^a	
College			-1.651 (-16.320 to 13.018)	0.825
Graduate			-0.548 (-15.365 to 14.269)	0.942
Doctorate			-5.060 (-21.030 to 10.911)	0.535
EWB subscore				
Aira minutes used	0.002 (0.001 to 0.003)	0.001	0.002 (0.001 to 0.003)	0.002
Sex				
Female			0 ^a	
Male			-2.696 (-5.339 to -0.053)	0.046
Age			-0.114 (-0.211 to -0.018)	0.020
Education level ³				
High school			0 ^a	
College			2.706 (-2.699 to 8.111)	0.326
Graduate			4.131 (-1.328 to 9.591)	0.138
Doctorate			-0.556 (-6.441 to 5.329)	0.853

*Coefficients on Aira minutes are adjusted by age, sex, and education level.

¹Overall predictor significance level for adjusted education level, total score: $P = 0.641$.

²Overall predictor significance level for adjusted education level, ADLMS score: $P = 0.869$.

³Overall predictor significance level for adjusted education level, EWB score: $P = 0.116$.

Another new finding was the overall significant decrease in minutes of Aira used per month from the initial 3 months to the 1-year follow-up. One possible explanation is that, over time, Aira instilled confidence in individuals to perform future tasks without assistance or that subscribers became accustomed to using Aira, resulting in both appropriate task selection and greater efficiency during the assistance session. Further, on the service end, improvements in Aira

software and internal training may have made the service more efficient requiring less minutes to achieve the same goal. From the start of this study in December 2017 to the end of the 1-year follow-up in December 2018, Aira launched the next generation of their smart glasses with an accompanying phone, Aira Horizon (Aira Tech Corporation), and new messaging features, as well as the addition of voice-first technology. Aira provided the Horizon smart glasses for free to those

who signed up to receive them in July 2018. After this time, only those who purchased the Horizon glasses received them.

One limitation of this study is the subjective basis of the patient-reported questionnaires. Given the subjective nature of the questionnaire, the results may be subject to biases, such as social desirability bias, recall bias, and selective recall. As stated in Nguyen et al.,¹⁶ the IVI-VLV questionnaire is particularly sensitive to recall bias because it prompts participants to answer based on their experiences in the past month. However, assessing the effect of visual aids on quality of life necessitates patient-reported outcomes such as self-reported questionnaires because this experience cannot be quantified through objective data.¹⁶ We believe that surveys such as the IVI-VLV, which has been validated in patients with low vision, are the most accurate way to assess quality of life in these low vision patients.

Another limitation of this study was the exclusion of the 19 participants who were within the original 69 participants. Users who chose to continue to use Aira for the full year may have exhibited self-selection bias, because they may have continued owing to subjective improvements in their quality of life, whereas those who ended the service may have not experienced those improvements. In addition, the demographics of Aira users may not be representative of the general population of the SVI. These users are generally well-educated, financially comfortable with the Aira subscription pricing, and technologically competent to interact with the device for at least 1 year. Future studies with a larger sample size and greater representation of the SVI population at large may help to further elucidate the long-term effects and generalizability of the Aira assistive technology among different patient populations.

In conclusion, upon expanding the results of our initial 3-month evaluation of Aira, we demonstrate that use of the Aira assistive technology may improve quality of life in a long-term fashion. Quality of life improvement appears to correlate with greater use of the device. This study demonstrates the need to further explore the quantitative impact of low vision assistive technologies on quality of life.

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