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ORIGINAL ARTICLE

'Such a lot of bother': Qualitative results of a home trial of a wearable electronic vision enhancement system for people with age-related macular degeneration

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Abstract

Purpose: Wearable electronic low vision enhancement systems (wEVES) improve visual function but are not widely adopted by people with vision impairment. Here, qualitative research methods were used to investigate the usefulness of wEVES for people with age-related macular degeneration (AMD) after an extended home trial.

Methods: Following a 12-week non-masked randomised crossover trial, semi-structured interviews were completed with 34 participants with AMD, 64.7% female, mean age 80.2 (±6.0) years, mean distance visual acuity 0.81logMAR (±0.32). Reflexive thematic analysis was used to analyse the data.

Results: Four themes were developed: (i) early positivity and potential; (ii) you're not good enough: performance barriers of the device; (iii) you're annoying: practicality barriers of the device and (iv) we can fix this together. First, participants expressed joy in an aesthetically appealing device perceived as potentially enabling, different and complementary to their current solutions. Imagined usefulness included not only reading, shopping and television but also resuming abandoned hobbies. The second theme captured performance barriers that restricted numerous activities but were most acutely noted with manipulation tasks. Barriers included image quality, screen size and short-lived adverse effects. The third theme conveyed the multiple practical challenges that caused annoyance, preventing imagined usage even when performance appeared superior to other solutions. Slow start-up times and the inability to use wEVES dynamically prevented integration within users' lifestyles. The final theme reflected that wEVES remained a desirable concept, but future iterations require inclusive design methodology to ensure development is directed by consumers' needs.

Conclusions: Performance and practicality barriers limit the usefulness of a device initially seen as desirable. Current devices do not align with users' requirements for flexible use, even when performance is good. Improvements in technology may solve performance barriers, but these changes must be inclusively designed and evaluated to ensure the device integrates more successfully into the lives of users with AMD.

KEYWORDS
AMD, head-mounted display, image enhancement, low vision aid, visually impaired persons, wearable devices, wEVES

INTRODUCTION

Wearable electronic vision enhancement systems (wEVES) are an example of assistive technology (AT) designed for people with vision impairment (VI). wEVES consist of a head-mounted device with screens in front of each eye displaying real-time images from near, intermediate and far distances. The user can manipulate the images to alter the levels of magnification, contrast and brightness. Devices can be broadly split into two categories:[1]

1. *Enclosed devices*, using commercial headsets for complete visual immersion, with brighter and broader images than alternatives. Examples include IrisVision Live 2.0 (irisvision.com/irisvision-live-2-0) and GiveVision (givevision.net/en/sightplus).
2. *Non-enclosed devices* are lighter, spectacle-like devices that allow users to see their surroundings around the screen content. Examples include eSight Go (esighteyewear.com/esight-go) and NuEyes Pro 4 (www.nueyes.com/pro4).

wEVES have been shown to improve measures of visual function,[1–8] vision-related quality of life (VRQoL)[9] and some instrumental activities of daily living (IADL).[1,5,10–12] However, device weight,[4,9,13] handling,[5] views of others,[2] adverse effects[4,12] and the confined nature of enclosed devices[14] may limit successful wear.

Mainstream and specialist AT are increasingly used by people with VI,[15–17] with competent use linked to improved health outcomes.[18] While electronic AT adoption is growing fastest among older people with VI, younger users still dominate usage.[19,20] Older adults face greater challenges in adopting new technology due to experiential, physiological and cognitive factors,[21] as well as inaccessible design,[22] slower training uptake[23,24] and a lack of suitable training resources.[25,26] Therefore, it is important to evaluate the unique experiences of older adults when using AT.

Age-related macular degeneration (AMD) is a chronic disease in older adults, causing progressive loss of central vision. AMD is a leading cause of untreatable sight loss[27,28] and is associated with declining visual acuity, functional ability and decreased quality of life.[29–32] The principal methods of rehabilitation support for people with AMD are modifications to magnification, lighting and contrast,[15] with the needs and approach to rehabilitation of older adults differing significantly from those of the younger working-age population.[29,33] wEVES are frequently marketed as suitable AT for people with AMD despite limited evidence for their use by this population.

International standards recommend using randomised control trials (RCT) to evaluate the medical uses of virtual reality and augmented reality products.[34] There is a widely recognised need for an RCT to evaluate the usefulness of wEVES[35,36] and other rehabilitative solutions for people with AMD.[15,37] This necessity is particularly pressing as earlier work investigating wEVES were largely observational studies in mixed populations with no control group,[38] with a paucity of projects seeking participants' qualitative views when exploring the impact of worn technology.[39]

This study aims to investigate the qualitative views of people with AMD towards wEVES following a 12-week crossover RCT to answer the following research question:

What are the experiences of people with AMD using non-enclosed wEVES compared to their existing low vision solutions?

Key points

- Users' initial optimism and positivity at the potential of wearable electronic low vision enhancement systems was not sustained following an extended home trial.
- Problems with practicality limited the usefulness of wearable electronic low vision enhancement systems, even for tasks where they improved performance, indicating the need for user-centred measures to assess their suitability.
- People with age-related macular degeneration see wearable electronic low vision enhancement systems as a valuable idea but want inclusive input to improve the current limitations of the devices.

METHODS

Participants

Participants with VI primarily due to AMD were recruited using convenience sampling from a low vision service in Birmingham, UK and local Macular Society support groups. Participants were excluded if they were non-English speakers or failed the six-item cognitive impairment screener.[40] In keeping with the headset manufacturer's advice, participants with self-reported intense motion sickness, epilepsy, uncontrolled high blood pressure and heart disease were also excluded (see Table 1).[41]

Study design and procedure

This study is part of a larger mixed-methods investigation examining the usefulness of wEVES for people with AMD. The methodology of the 12-week non-masked crossover trial of wEVES compared with habitual low vision coping strategies is available[42] and will be briefly reproduced here. An unpublished focus group of five participants with AMD selected the most suitable device for the intervention from a representative sample of wEVES currently available in the UK. The Eye5 (eyedaptic.com/eye5/) is a non-enclosed, spectacle-style wEVES with tethered controls on a repurposed Motorola G100 Android smartphone running proprietary software (see Figure 1a,b). Large, high-contrast controls allowed the user to modify image magnification, brightness and contrast. The display input is selectable to show images from either the head-mounted camera or the higher resolution smartphone camera.

A baseline clinic assessment was undertaken to collect demographic data and measures of visual function. A low-vision assessment and subjective refraction were completed in keeping with current UK guidelines,[43] including dispensing optical magnifiers and guidance with non-optical aids and technology. Before the home trial, participants completed documented face-to-face training on device use and received additional support during the trial by phone or in person as needed. The study used an AB/BA crossover design, with arm A being 6 weeks with wEVES and existing low vision solutions and arm B 6 weeks with existing solutions only. Participants were asked to use the device in their daily lives but not for tasks involving movement due to manufacturers' advice with similar devices[44,45] and the unknown risk of falling when using wEVES.

Data were collected in a series of individual semi-structured interviews at the participant's home after completing the wEVES arm of the trial. Interviews were conducted from July 2023 to May 2024 by researcher AM using a topic guide (see Appendix 1) developed from a pilot study assessing wEVES among non-users.[14] Open-ended questions explored user experience, the times the device was used, comparisons to existing solutions and ways to improve the design and usability of the current device. Audio-recorded interviews were pseudo-anonymised and transcribed before being analysed line by line using NVIVO (Release 14) software (qsrinternational.com). Reporting of data observed the Standards for Reporting Qualitative Research (SRQR).[46]

TABLE 1 Inclusion and exclusion criteria for the trial.

Inclusion criteria	Exclusion criteria
Vision loss is primarily due to AMD, which affects the participant's daily life	Existing wEVES user
People who are 18 years or over	Other forms of ocular pathology causing significant vision impairment
Able to undertake assessments in English	Significant deterioration in vision reported in the 2 months before entry
Passed the short form Mini-mental State Evaluation (MMSE: adapted for vision loss)[40]	Planned curative ocular surgery (e.g., cataract operation) in the study time
Able to operate the controls of the wEVES	Balance-related disorders, e.g., Ménière's disease
Not an existing wEVES user	Heart disease
Hearing sufficient to undertake a telephone interview	Uncontrolled high blood pressure
	Vision is good enough to hold a current UK driving licence

Abbreviations: AMD, age-related macular degeneration; wEVES, wearable electronic vision enhancement systems.

Qualitative data analysis

Reflexive thematic analysis (RTA)[47–49] was chosen to develop themes from the data, which required the authors to consider their influence on the interpretation of the data. The topic area is uncontroversial, and participants were assumed to be willing and confident to provide open and honest accounts of their thoughts towards the devices. Therefore, an inductive, semantic approach was taken, which is compatible with exploratory qualitative research, allowing themes to be developed from the data without a preconceived framework.[50] Philosophically, the authors adopted a critical realist stance to describe and summarise the data, which can be seen as realist ontology with a relativist epistemological[51] and is compatible with mixed-methods data collection.[52]

Determining an endpoint based on data saturation is challenging in RTA due to the subjectivity in interpreting themes.[53] Here, power calculations decided the sample size for the related quantitative study and all interviews were analysed.

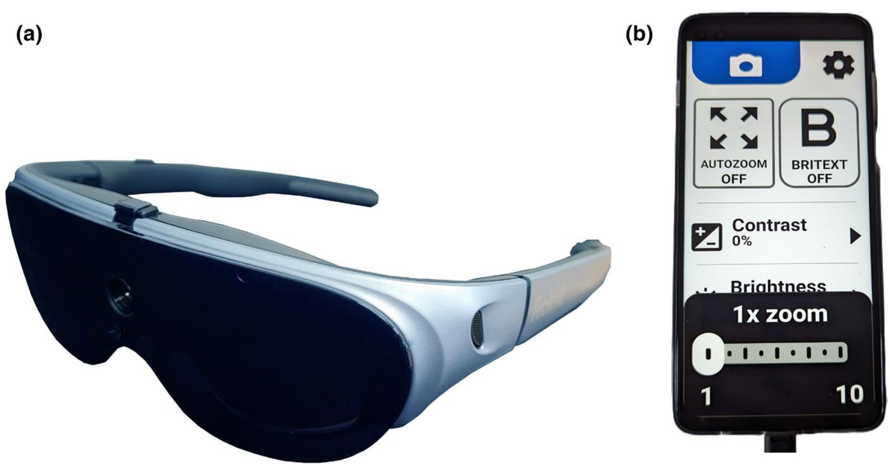

FIGURE 1 (a) Eyedaptic Eye5 Headset (Image with permission visionaid.co.uk/wearable-solutions/eye5). (b) Eyedaptic Eye5 Tethered handset with controls (image Author's Own).

Reflexive statement

Interviews and principal data analysis were conducted by AM, a 54-year-old white male fully sighted optometrist with 30 years of experience within VI support services. To avoid deductive or superficial analysis, JM coded four records for comparison and reflection. Mind maps and coding diagrams were used to display and analyse data, with differences resolved through discussion. The research team refined and adapted the generated themes to ensure the separation of ideas and accurate representation of the data. Table 2 details the authors' involvement in the six stages of RTA.

Ethical considerations

This study was approved by the Ethics Panel at Anglia Ruskin University, UK (ETH2223-3787), registered ISRCTN16865847 and followed the principles of the Declaration of Helsinki. All participants gave informed written consent to take part in the study.

RESULTS

Overview of themes

Data were collected from 34 participants, 64.7% were female, with a mean (SD) age of 80.2 (6.0) years and mean (SD) distance visual acuity (VA) of 0.81 (0.32) logMAR. The mean (SD) training time to reach competency with the device was 123 min (27), with two training sessions needed by 30/34 and a third face-to-face session to achieve competency required by 4/34 participants. Table 3 presents the participants' characteristics, using pseudonyms rather than numbers to reflect their position as collaborators rather than experimental subjects. Interviewees were encouraged to develop their answers fully to open-ended questions, and interview lengths ranged from 3 min 35 s to 25 min 33 s (median: 11 min 32 s).

Exploration and interpretation of the data resulted in the development of four themes:

(1) Early positivity and potential.
(2) You're not good enough: Performance barriers of the device.
(3) You're annoying: Practicality barriers of the device.
(4) We can fix this together.

The themes show participants' shifting thoughts from their initial impressions of the device through their discovered reality to considering ways of improving and adapting future generations of wEVES (see Figure 2). Within the themes, the personal pronoun 'you' was used to highlight the participants' use of language to personify the device and to reflect their high levels of engagement with the study's outcomes.

TABLE 2 Authors' contribution to the six phases of reflexive thematic analysis.[54] Abbreviations indicate author initials.

Phase	Author involvement
Phase 1: Data familiarisation	AM conducted and transcribed interviews verbatim. Interviews and transcripts were listened to and read multiple times to enable deep familiarisation with the content. Initial notes were discussed with JM
Phase 2: Coding	AM coded interviews using NVIVO software. Codes were developed iteratively using a largely semantic framework towards meaning. JM independently coded four records to ensure consistency and inductive interpretation of the data
Phase 3: Generating initial themes	AM collapsed codes with similar content and clustered codes with shared ideas to develop candidate themes
Phase 4: Developing and reviewing themes	AM and JM reviewed candidate themes to check their fit with the data and ensure they reflected the patterns in the data set. All other authors reviewed this process MC, KL
Phase 5: Refining and naming themes	AM further reviewed the dataset to refine themes to ensure a strong core concept and clear differentiation from other themes. All other authors reviewed this process i.e., JM, MC and KL
Phase 6: Writing up	AM selected extracts of the data set as illustrative examples of the themes. AM wrote the final paper with input from all other authors JM, MC and KL

Theme 1—Early positivity and potential

The first theme captured a widely felt sense of joy and excitement at the potential wEVES offered, particularly in the early stages of the intervention. The concept of wEVES was embraced and perceived as enabling and, crucially, different and complementary to participants' existing solutions.

> When I started with them, I was quite…. I don't know what the word is…. *"delighted"* that there was something that maybe would help me in my life,
>
> [Ruth]

The notion of a wearable device was not only welcomed but was also reported to be a desirable solution that participants were actively seeking. This appeal resulted from the new opportunities offered by wEVES and due to the constraints of participants' current solutions.

> You see, I have MS [multiple sclerosis] as well, so sometimes this left side of mine doesn't work, so I can't hold things to write. So, to try holding a magnifying glass and write I can't do it.
>
> [Maria]

Participants' self-imagined uses for wEVES when they started the trial were widely discussed, with many

TABLE 3 The demographic characteristics and visual function of the study participants, Cert. Status, SSI, SI and NR refer to the UK certification of vision impairment categories, namely Severely Sight Impaired, Sight Impaired and Not Registered; A, Asian; Dist VA, binocular distance acuity following subjective refraction; Near (N), threshold font size read at 25 cm with appropriate reading addition; VA, visual acuity; VI, vision impaired; WB, White British; WO, White Other; Health was self-reported as very good, good, fair, bad or very bad.[55] Existing Low Vision Solutions where D, distance optical; E, electronic vision enhancement systems; N, near optical; O, Optical Character Recognition device; S, Smartphone used as an aid; secondary ocular pathology or treatment where C, cataract; D, diabetes with background or no retinopathy; G, glaucoma; I, IOL; LE, left eye; M, macular hole; R, retinal detachment.

Pseudonym	Sex	Age (years)	Living	Cert. status	Ethnicity	Years VI	Health	Dist VA (logMAR)	Near (N)	Training time (min)	Existing low vision solutions	Secondary ocular pathology
Alec	Male	78	Spouse/Partner	SSI	WB	9	Very good	0.94	44	90	D N S E	C
John	Male	77	Spouse/Partner	SI	WB	6	Fair	0.68	22	140	N S	C
Emily	Female	85	Alone	SI	WB	10	Fair	0.86	18	190	N S O	I
Elsie	Female	83	Alone	NR	WB	0.5	Very good	0.76	18	140	N S	I
Jacqueline	Female	87	Alone	SI	WO	1.5	Fair	0.62	14	115	N S E	I G
Mary	Female	78	Alone	NR	WB	5	Very good	0.48	11	140	N	I
Margaret	Female	93	Spouse/Partner	NR	WB	9	Good	0.28	18	100	N S	I
David	Male	87	Alone	SSI	WB	15	Fair	1.08	28	100	D N	C
Katherine	Female	71	Alone	SI	WB	2	Fair	0.78	28	90	N S	C
Joscelyn	Female	75	Spouse/Partner	SI	WB	2.5	Very good	1.2	80	120	N S	D
Mira	Female	84	Alone	NR	A	7	Good	0.6	9	125	D N S	R, LE
Gwen	Female	75	Spouse/Partner	NR	WB	12	Good	0.46	11	95	N S	I
Marilyn	Female	79	Alone	SSI	WB	13	Very good	1.48	80	120	N S E	I
Ronald	Male	88	Spouse/Partner	SI	WB	8	Good	0.48	9	185	D N E	I G
Virginia	Female	79	Spouse/Partner	SI	WB	12	Fair	0.56	14	125	N S	I
Donald	Male	70	Spouse/Partner	SSI	WB	5	Fair	0.9	28	105	N S	C D
Thomas	Male	88	Spouse/Partner	NR	WB	4	Fair	0.56	22	120	N	I D G
Ruth	Female	82	Alone/Carers	SSI	WB	8	Fair	0.94	44	145	D N S	C
Samuel	Male	87	Spouse/Partner	SSI	WB	10	Very good	1.46	80	110	D N O	I
Charles	Male	77	Spouse/Partner	SSI	WB	4	Fair	1.08	44	130	D N S O	I
Alice	Female	70	Alone	NR	WB	1	Good	0.6	44	90	D N S	C
Patricia	Female	76	Alone	SI	WB	2	Good	0.6	11	120	D N S E	I M LE
Judith	Female	89	Alone	NR	WB	2	Fair	0.72	36	175	N S E	C G
Richard	Male	66	Spouse/Partner	SI	WB	1.5	Good	0.78	11	120	D N S	C
William	Male	80	Spouse/Partner	SI	WB	7	Good	1.6	80	130	N E	I G
Nancy	Female	82	Alone	SI	WB	7	Good	0.84	28	120	N S E	C G
Maria	Female	79	Spouse/Partner	NR	WB	6.5	Fair	1	44	145	N	C D
Martha	Female	83	Alone	NR	WB	3	Fair	0.9	22	145	N E	I G
Carol	Female	82	Spouse/Partner	NR	WB	2.5	Fair	0.46	14	120	N S	I

(Continues)

TABLE 3 (Continued)

Pseudonym	Sex	Age (years)	Living	Cert. status	Ethnicity	Years VI	Health	Dist VA (logMAR)	Near (N)	Training time (min)	Existing low vision solutions	Secondary ocular pathology
Shirley	Female	81	Alone	NR	WB	4	Very good	0.46	22	85	D N S	I
Betty	Female	76	Spouse/Partner	NR	WB	10	Fair	0.52	5.5	120	D N	I
James	Male	75	Spouse/Partner	SI	WB	4	Good	0.66	28	75	N S	I D
Barbara	Female	79	Alone	NR	WB	0.5	Very good	1	36	100	D N	C G
Robert	Male	87	Spouse/Partner	SSI	WB	0.5	Good	1.32	44	160	N E	I D

participants anticipating assistance with the frequent and significant challenges of sustained and survival reading tasks. In addition, the device was almost universally expected to be beneficial for watching television. Participants' recognition that current solutions were either absent or had significant limitations stoked their desire for usefulness in these areas.

> Television would be the number one, viewing television would be the number one.
>
> [John]

> I mean I would have bought virtually anything just to be able to see (the) telly, you know, I mean it's a big part of your life.
>
> [Samuel]

The possibility offered by wEVES' ability to provide hands-free magnification over a range of working distances was seen as unique and enabling. The new functionality allowed speculation of effectiveness with daily activities that participants may continue to undertake with difficulty, such as writing, shopping, social events, cooking and eating.

> …it's like with me doing the pepper, I ain't got a clue how much. But I think with the focus of the glasses I think I'd be able to sit and eat food better as well.
>
> [Donald]

> Going into shops is an absolute misery now, I can't even go in and buy a card because I can't see the cards and K[partner] is hopeless!
>
> [Shirley]

In addition, imagined usefulness extended to include hobbies and activities where participants have very restricted ability or may have abandoned tasks altogether, such as crafts, do-it-yourself, theatre and gardening.

> Again, as I said, anything which is hands free in my own case, I would love to be able to do some model making. Assembling plastic kits anything as simple as that which you need two hands and you need to be able to see.
>
> [Alec]

> Cinema, theatre. I could buy the cheapest theatre ticket right at the back. At the moment in the cinema, I sit in the front.
>
> [Mira]

The theme also includes the largely positive perception of the device's aesthetics. Participants agreed that wEVES which are designed to look like a pair of spectacles was an important trait for them. While recognising this concept

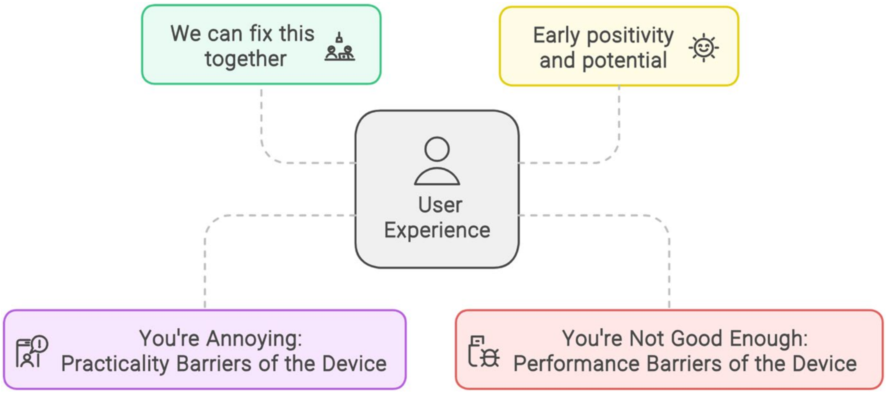

FIGURE 2 Image illustrating the four developed themes.

is not perfectly delivered by the device tested, it was welcomed as something they were willing to wear alone or in front of others.

> It was just like a pair of spectacles, you know, anybody can wear them….You know I ain't proud. I want to see better! You know? And if something comes, that I could see better with it. You know, provided it was easy to wear. Easy to wear like they are, that would be fine.
>
> [Samuel]

> Obviously, they could be made to look more like normal glasses, but that didn't bother me. I didn't think they were that bad.
>
> [Joscelyn]

Theme 2—You're not good enough: Performance barriers of the device

The second theme acknowledged that, at times, the device's functional performance did not meet users' needs and was insufficient for users to complete desired tasks. This limitation of performance was widespread among the participants and noted across a broad spectrum of different desirable activities, including reading, computer use and watching television. However, performance limitation was most acutely noted with activities that required manipulation, such as crafts and writing.

> I was so looking forward to being able to thread the needle…I couldn't do it. I'm usually quite a patient person, but I couldn't do it, and it just really made my eyes really tired.
>
> [Virgina]

Users' feelings of limitations with the device's hardware included insufficient image quality to complete the desired task.

> I've tried using them for my craft I've been up in my craft room. And…. big disappointment there [pauses to collect herself]. If I just wear the glasses, the image is just not good enough.
>
> [Carol]

In addition, insufficient screen size, poor colour rendering and difficulty with the screen position when looking down to read were commonly reported problems with the hardware.

> Normally, you just turn and look…and you see it all, whereas with that [wEVES] if you didn't manoeuvre your head around a little bit, you didn't really get a true picture.
>
> [Thomas]

Transient adverse effects were reported by a minority of users and included headaches, nausea and diplopia. The effects were reportedly short-lived and spontaneously resolved when the device was removed, but their presence was enough to prevent the continuation of successful use for some users.

> I found it very, very tiring on my eyes using those and they became sore. So then most times I would give up if it was a long thing that I had to read.
>
> [Ruth]

For some, the performance gap was considered to have been wholly created by a device incapable of delivering the desired visual function. However, performance issues were also seen to be caused by the users' aspirations for a magical, simplistic solution that the participants retrospectively understood may have been too much to hope for.

> …you just want a pair of glasses that you could put on, like magic glasses and you can see everything, you know, like they do in the films.
>
> [Joscelyn]

Theme 3—You're annoying: Practicality barriers of the device

This theme portrays the common challenges that were reported where wEVES did not integrate seamlessly into the lives of their intended users. There was a series of echoed narratives of annoyance with the device that may, in isolation, be viewed as minor, causing dissatisfaction and irritation. However, in addition to the multiple frustrations already inherent within sight loss, these practical issues could ultimately lead to discontinuation of use because wEVES were not perceived as an improvement compared to established solutions.

> Although the print was a little bit better, it wasn't good enough for me to manage with that [wEVES] as opposed to doing it with my magnifying glass.
>
> [Nancy]

Areas of common concern with practicality were the time taken to set up and use the device, the inability to correct for distance refractive error and the heat created by the device. Long set-up times were particularly off-putting as many of the desired tasks involved imagined usage for relatively quick spot tasks currently completed with simple optical magnifiers.

> …things like reading instructions on the things when you're cooking. You couldn't be putting those on could you!
>
> [Carol]

Practicality issues are in addition to and separate from those of device performance. This theme reflects the broad areas that tend not to be directly related to the device under test but may be transferable to the wider genre of wEVES. For example, facial recognition was widely reported as significantly better with the device and a potential source of usefulness and joy for users. However, the need to locate, charge, switch on and then interact with a device meant that even the pleasure of improvement could be lost, which could limit or exclude repeated use in these situations.

> The most enormous plus that I got from it was an emotional one because my grandchildren came to see me… and I was able to see their faces. And I found that quite overwhelming. So that was a massive, massive plus. Because my younger grandchildren, I've never seen their faces properly…I can't tell you how wonderful that was…[But] I got very frustrated with it. I realised that I should have used this and that might have been [better], but by then, I'd given up.
>
> [Marilyn]

Others who saw the advantages of facial recognition found that the prospective benefits were limited because we restricted mobility with the device. This meant the visual improvements offered by wEVES could not be accessed at times when the skill was most needed.

> You can't walk around in them, and if you're going to meet somebody and somebody comes to the door or something, you know, you're not going walking around with them, so you gotta deliberately say, "Oh, there's a person."
>
> By the time you've got the glasses, you've already identified who it is.
>
> [Patricia]

Some participants reflected on the benefit of having separate controls to lessen this device's head-mounted weight. However, for others, even this device's current weight was found to be a challenge for sustained use.

> Well, it's heavy. It's heavy for me. I'm a really weak little woman [laughing]. Maybe a man would be better!
>
> [Jacqueline]

Participants reported that their lives were fluid, with tasks not segmented into single elements demanding that wEVES need the ability to complete multiple tasks simultaneously.

> I'm actually not just sitting and reading. I'm keeping my eye on the telly and I'm doing a bit of this. A bit of that.
>
> [Donald]

When people attempted to integrate distance and near tasks, the current technology's lag in focusing change, limited field of view and lack of flexibility caused problems when trying to shift between tasks. For example, switching attention from the TV to reading or from reading to other items in their room.

> I do everything at a lot slower pace than I did when my eyes were better and I just accept it. But in terms of how those spectacles are structured at the minute everything is slower still. For certain processes…they work, like static processes, but as soon as movement is involved. They don't…
>
> [John]

> I was quite happy sat there using them for [TV] because I wasn't moving my head that much and it's a fairly static situation. When I got these documents and I was putting some on that side and then grabbing these

> and wanting to check whether those were the same as these. I think it was a combination of the glasses and the head movement was not good.
>
> [Alice]

Participants repeatedly mentioned that the multiple challenges using wEVES produced meant the device was not a practical solution for many of the situations where they had anticipated utility.

> It just seemed to be such a lot of bother.
>
> [Nancy]

The constituent elements that comprised the cause of the difficulties varied, but instances of problems with the presence of the wire and separate controls were repeatedly voiced. The wire and controls created challenges from the perspective of setting up and initiating the device, its comfort and even displacing other necessary sensory support from their hearing aids.

> I believe that the glasses could be modified to be wireless. Could have all the adjustments and the charging in the glasses, so I just don't get the point of having the camera, I found it too fussy….
>
> [Donald]

> I may question where the smartphone connector is positioned on the end of the arm because I would think that quite a few people who wear these also have hearing aids. And it may be worth thinking about if there's a better plugging-in point rather than behind the ear.
>
> [Alec]

There was recognition that the image quality offered by the phone's camera was superior and more useful than that of the head-mounted camera. However, participants reflected that utilising this feature affected the usefulness of the device as it broke the critical hands-free characteristic of wEVES.

> When you see something like that and you think "wow glasses" and that's it. But to get the better quality, you've got to use that [handheld camera], which kind of defeats the object.
>
> [Richard]

Theme 4—We can fix this together

The final theme is developed from the users' adversarial and collaborative viewpoints concerning the development of wEVES. User displeasure extended to reflect an overall sense of being let down by their experience of wEVES following the high hopes of the encouraging initial demonstration. These views of dissatisfaction may not be entirely negative, as it can also be interpreted that the intensity of discontentment stems from the desirability of the concept and its perceived potential.

> "…it's frustrating enough as it is, you know, trying to cope with stuff…. Having somebody present something like that kit. And you suddenly think, "Oh my God"… there's a whole new world opening up, and you get a whole new set of problems."
>
> [Katherine]

There was a challenge from participants that the device's more obvious shortcomings appeared to reflect a lack of understanding of the needs of people with AMD or an absence of collaboration in the design and trial phases of development. There were expressions that wEVES must be designed with flexibility, inclusion and individuality in mind.

> I like the concept, but I don't think anybody who's been involved in the design of it had ever been blind.
>
> [Robert]

The device's lack of sizing and limited adjustability was seen as a lack of inclusion and inappropriate for an item that must be worn by people of differing sizes. Many also viewed this attribute negatively as it dictated screen positioning, creating problems with the device's comfort and usability.

> They would need to be more adjustable to your size rather than one-size-fits-all.
>
> [Elsie]

However, this theme also captures the largely cooperative view of participants who recognise that their current assistive solutions all have limitations. There was a strong desire to support the development of future wEVES iterations because the overall idea was still seen as valuable to them. Reported design priorities for the next generation of wEVES included the need for a single self-contained spectacle-style unit that is simple to use, with well-defined tactile controls and minimal start-up time.

> Just make it nice and easy. Just put them on so it would be as quick as using your magnifying glass.
>
> [Nancy]

> Well, I'm not. I'm not very good on technology. I have to be shown everything. My grandkids show me. So you know, things have to be simple and straightforward and easy for me.
>
> [Martha]

Finally, and significantly, the ability to use the device while moving was seen as very desirable. The device's ability to be utilised in a mixture of dynamic situations would enable it to be used as the users had originally imagined rather than being confined to situations defined by the device's capabilities.

> … if you were allowed to wear them out, it would be ideal. Absolutely. I wouldn't care what I look like, you know? If you could, if it makes you see, you don't care what you look like.
>
> [Barbara]

DISCUSSION

The qualitative findings are presented from a mixed-methods study designed to understand the usefulness of non-enclosed wEVES for participants with AMD following a prolonged trial. Ease of use and user satisfaction with wEVES have been measured in similar work within mixed populations using validated surveys such as the Quebec User Evaluation of Satisfaction with assistive technology (QUEST)[1,56] and non-validated questionnaires.[2,4,12,57] These earlier findings are informative, showing the direction of user thought albeit within a structured researcher-defined environment. The current use of open-ended exploration of participants' feelings towards wEVES following an RCT home trial is novel. This approach allows a platform for participants' unfiltered voices and obliges us to make sense of our findings on their terms, significantly contributing to any associated quantitative data.

Theme 1

Imagined usefulness of wEVES broadly followed the findings of others, showing user interest in use for television and reading.[3,4,12,58] But within this older population, there was a strong appeal to utilise wEVES for abandoned hobbies such as crafts and the theatre.[14] These additional needs indicate this population's requirement for devices that are suitable for use in public and also supportive of tasks requiring manipulation.

The first theme captured the initial delight and imagined potential of wEVES. However, some studies of enclosed and non-enclosed wEVES demonstrated relatively low levels of user satisfaction despite improvements in visual function and elements of objectively[1] and subjectively[2] measured IADL. Dissatisfaction in these studies was reported to be due to social stigma, aesthetics and limited levels of improvement with the devices tested. In comparison, while the current data mirror these findings of overall displeasure, they also show a shift in user satisfaction over time. After a short demonstration, an initial wave of positivity was followed by an evolving dissatisfaction with the performance and practicality of the non-enclosed wEVES. The dynamic nature of user perceptions means prescribers and purchasers should be cautious about viewing initial positivity as an indicator of long-term success. Additionally, this theme captured the largely positive responses towards device aesthetics, suggesting the Eye5 may satisfy earlier recommendations for smaller and lighter devices,[2,59] but fail to meet other user expectations.

Theme 2

Performance barriers led to an inability to utilise wEVES as users desired, and this was most acutely noted in tasks requiring manipulation skills. The difficulties were caused by factors related to the specifications of the device and were led by user-perceived limitations with the field of view and image resolution. Limitations of the field of view have been reported with several other non-enclosed devices,[2] and a lack of improvement in visuomotor skills has been noted in previous objective studies with other enclosed and non-enclosed style wEVES.[1,12,60] Therefore, while some of the described performance barriers may be related to the tested device, there are indications that the difficulties may be inherent to the wider genre of wEVES.

The data revealed a gap between participant expectations and the device's delivery, although it is unclear how this was divided between the device's underperformance and inflated user expectations. Participants sometimes expressed a desire for 'magic glasses', a self-romanticised concept that may have skewed their perceptions of wEVES. For instance, the weight of wEVES has previously been reported as a significant cause of discontinuation of use.[4,9,13] Despite the Eye5 (78 g) being marketed as 'lightweight' and being significantly lighter than enclosed wEVES such as the IrisVision Live1.0 (498 g), some users still found it uncomfortably heavy. This suggests a discrepancy between manufacturers' claims of lightness compared to similar devices and users' expectations comparing the device's weight to spectacles.

Theme 3

Wearable Electronic Low Vision Enhancement Systems have been shown to produce objective improvements in facial recognition,[1,3,5] which is a desired need for people with AMD.[61,62] However, the present data suggest practicality barriers with wEVES may restrict the usefulness of this and other functional improvements. The device's practicality barriers are driven by how compatible the device is with users' lives. Here, the device was frequently reported as bothersome and annoying, actively adding to the frustrations associated with sight loss, not solving them. This finding is of particular importance as it reflects a dissatisfaction that was not correlated with improvement in functional vision and activity limitation, which are routinely used as the principal outcome measures in research to assess the utility of wEVES.[3–5,7,10,12] To ensure performance improvements translate into sustained user benefits, future research must ensure adequate measures are utilised to capture user satisfaction with the practicality of devices.

The practical use of the device was also limited by the users' desire for a device that can be worn while moving, albeit within a population more at risk of injurious falls.[63–65] wEVES can change spatial awareness and limit field of view. Therefore, it is unsurprising that many manufacturers advise against using wEVES while moving,[44,45] with the eSight Go (esighteyewear.com/esight-go/) being a noted exception. An earlier study inferred the possibility that non-enclosed wEVES could support mobility identification tasks as they found no degradation in the mobility domain of activity limitation.[5] However, there is a lack of work directly evaluating the ability of wEVES to safely support dynamic tasks. Therefore, there is a pressing need for further research in this area.

Theme 4

The final theme revealed that participants perceived some of wEVES' fundamental shortcomings as indicating a lack of inclusion and understanding of their needs as older adults with disabilities. 'Inclusive design' recognises that disabilities are common and normal, obliging designers to create products and services that cater to the broadest possible audience, regardless of age or ability.[66,67] Evidence suggests a pervasive lack of inclusion when designing AT for people with VI, revealing a conflict between user needs and researcher focus driven by insufficient people with lived experience being included at the concept and design stage of research.[68] Participants reflected that a range of inclusive design improvements were needed, including problems with the device's lack of flexibility and adjustment. While current commercial wEVES offer some adjustability, they are typically produced in one size to fit a range of body shapes and strengths. Inclusive design concepts would suggest that wearable technology should be available in sizes that fully accommodate differences in body size and age-related muscle decline.

Despite the device's current limitations, the current findings indicate that users with AMD are still eager to contribute to the development of new wEVES that are still seen as having potential to support their unmet needs. As already recognised in other types of AT,[69] to improve the utility and acceptance of future iterations of wEVES, it is essential to incorporate collaborative design approaches, with user engagement throughout the design and development process.

Further research

Participants expressed a need for wEVES that support flexible use, including tasks involving movement and manipulation. While previous studies highlighted challenges with visuomotor tasks, further research is needed to determine whether these limitations stem from impaired spatial awareness, convergence, binocularity or device design. Additionally, there is little evidence of the risks of using wEVES while mobile. Understanding how device characteristics affect safety during movement could inform the design of more versatile devices, improve manufacturer warnings and help users form realistic expectations about their functionality.

Reflections and limitations

It is understood that the data captured represent findings from a single point in time influenced by the interviewer, location and method of capture.[70] A rehabilitation professional completing the interviews rather than an independent observer may have influenced participants' openness, particularly in expressing negative views. To address this, participants advised that researchers sought candid opinions and had no commercial interest in the devices or the research outcomes.

This study offers insight into the perspectives of people with AMD in the UK towards the usefulness of wEVES in their vision rehabilitation. Older adults with AMD have specific needs and approaches to AT and vision rehabilitation. Therefore, it is not possible to generalise these findings to those of the wider population with VI. A further limitation of the current work was the cultural homogeneity of the sample, who were overwhelmingly from a white British background, which may reflect the higher prevalence of AMD in white European backgrounds,[71,72] the higher representation of people from other ethnicities within our exclusion criteria[73] or a lower level of engagement in rehabilitation services by minority communities.[74] While the sample presented may be representative of people with AMD attending an urban UK low-vision clinic, further research is needed to determine if these views hold across different countries and cultural contexts.

The convenience recruitment of the present sample may suggest a higher interest in wEVES than in the broader population with AMD. While this sampling potentially introduces a bias towards positive responses, it also provides a pragmatic focus on the views of those likely to seek help from a wearable device.

CONCLUSION

Qualitative data from a sample of older adults with AMD showed participants' initial joy at the potential offered by a welcomed new solution. However, recognition of the limitations of wEVES performance and practicality quickly followed, significantly restricting their usefulness.

The reported performance barriers restricted participants' imagined usage and were largely hardware-related, which may be resolved through iterative improvements in screen and camera technology. The noted practicality barriers were distinct from performance barriers and limited the usefulness of wEVES even when the functioning was good. Therefore, studies designed to understand the utility of wEVES should consider the unique needs of older adults and include measures that evaluate devices' practicality, not just performance.

Finally, manufacturers should recognise that improvements in device performance must also be accompanied by enhancements to the way devices integrate into the lives of their intended users. These developments should be inclusively designed to incorporate the wisdom of those with lived experience, ensuring wEVES become more useful to people with AMD.

AUTHOR CONTRIBUTIONS

Andrew Miller: Conceptualization (equal); data curation (lead); formal analysis (lead); investigation (lead); methodology (equal); project administration (lead); validation (lead); writing – original draft (lead); writing – review and editing (equal). **Jane Macnaughton:** Conceptualization (equal); formal analysis (supporting); investigation (supporting); methodology (supporting); supervision (equal); writing – review and editing (equal). **Michael D. Crossland:** Conceptualization (equal); funding acquisition (equal); methodology (equal); supervision (equal); writing – review and editing (equal). **Keziah Latham:** Conceptualization (equal); data curation (supporting); formal analysis (supporting); funding acquisition (equal); investigation (supporting); methodology (equal); project administration (supporting); supervision (equal); writing – review and editing (equal).

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CONFLICT OF INTEREST STATEMENT

AM, JM, MDC and KL report no conflicts of interest and have no proprietary interest in any of the materials mentioned in this article.

PATIENT CONSENT STATEMENT

All participants gave informed written consent to take part in the study.

CLINICAL TRIAL REGISTRATION

The trial was registered ISRCTN16865847 prior to commencement and followed the principles of the Declaration of Helsinki.

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APPENDIX 1

S1: Topic guide

1. Can you tell me about times when you have used the device and what you thought?

Probes: distance versus near, with others or by yourself, was the device helpful; return to areas the device has been used, but participants have not offered an opinion about the device

2. How does this device compare to the solutions you currently have?

Additional prompt: Does this device offer you anything that your current devices and solutions do not?
Additional prompt: What type of tasks do you feel this type of device is most suitable for?
Additional prompt: What types of tasks do you feel that this type of device is not suitable for?

3. What do you like about the current device?

Probes: Where necessary link back to previous answers and ask them to expand but avoid leading questions about specifics.

4. What do you dislike, and how could this device be changed or improved to make it more useful and usable for you?
5. Do you have anything else you would like to tell us about your experience with the device?