ORIGINAL INVESTIGATION

Longitudinal Trends in Case Histories and Rehabilitative Device Assessments at Low Vision Examinations

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SIGNIFICANCE: Understanding longitudinal changes in why individuals frequent low-vision clinics is crucial for ensuring that patient care keeps current with changing technology and changing lifestyles. Among other findings, our results suggest that reading remains a prevailing patient complaint, with shifting priorities toward technology-related topics.

PURPOSE: This study aimed to understand changes in patient priorities and patient care in low vision over the past decade.

METHODS: We conducted a retrospective study of examination records (2009 to 2019, 3470 examinations) from two U.S. low-vision clinics. Automated word searches summarized two properties of the records: topics discussed during the case history and types of rehabilitative devices assessed. Logistic regression was used to model the effects of examination year, patient age, patient sex, and level of visual impairment.

RESULTS: Collapsing across all years, the most common topic discussed was reading (78%), followed by light-related topics (71%) and technology (59%). Whereas the odds of discussing reading trended downward over the decade (odds ratio, 0.57; $P = .03$), technology, social interaction, mobility, and driving trended upward (odds ratios, 4.53, 3.31, 2.71, and 1.95; all Ps < 0.001). The most frequently assessed devices were tinted lenses (95%). Over time, video magnifier and spectacle assessments trended downward (odds ratios, 0.64 and 0.72; $P = .004$, 0.04), whereas assessments of other optical aids increased. The data indicate several consistent differences among patient demographics.

CONCLUSIONS: Reading is likely to remain a prevailing patient complaint, but an increase in technology-related topics suggests shifting priorities, particularly in younger demographics. "Low-tech" optical aids have remained prominent in low-vision care even as "high-tech" assistive devices in the marketplace continue to advance.

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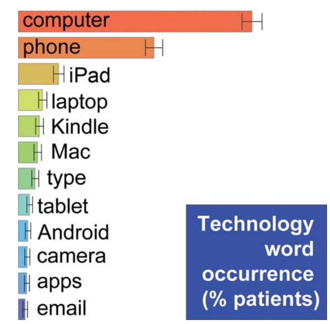

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People with impaired vision can face increased challenges when performing many activities, leading to reduced quality of life.[1–9] When visual impairment cannot be corrected with medical treatment or conventional refractive optics, low-vision care and rehabilitation services are an important option. These services involve providing information, training, and devices that aim to help individuals to maximize their residual vision and to participate in desired activities.[10] Basic rehabilitation is tailored toward an individual's needs and goals but can also be informed by empirical research on common challenges faced by people with impaired vision and on the efficacy of compensatory strategies and devices.[11–15]

To better understand the needs of people seeking low-vision care, as well as the services provided to them at clinics, several prospective and retrospective clinical studies have been conducted.[5,16–21] These prior clinical studies identified activities such as reading, driving, and mobility as being among the most common goals for patients with low vision, which is consistent with laboratory research on the impact of visual impairment on performance of these tasks.[22,23] Whereas some studies have investigated differences in needs associated with different demographics (e.g., age and sex),[5,13] none have examined how the goals of patients with low vision are changing over time. Examining longitudinal trends can play an important role in keeping up with potential shifts in the needs and priorities for services. Other studies have characterized patterns and longitudinal trends in prescribing rehabilitative devices from the 1970s to the early 2000s, but information about potential shifts in practice patterns in recent years is lacking.[24–27] Here, we used a retrospective study design to characterize trends over the past decade in the topics discussed during low-vision patient case histories and the types of rehabilitative devices assessed in low-vision examinations at two clinics.

METHODS

Data Set

A retrospective study was conducted on deidentified electronic health record data from the Low Vision Clinic at the Meredith W. Morgan University Eye Center in Berkeley, California, and LightHouse for the Blind and Visually Impaired in San Francisco, California, between June 1, 2009, and June 1, 2019. This research was reviewed by an independent ethical review board and conforms with the principles and applicable guidelines for the protection of human subjects in biomedical research.

The two sites have a shared electronic health record system. No major version updates were made during the period under study, and most of the care providers worked at both sites. The care providers were optometry interns and residents under the supervision of faculty. The electronic health record fields analyzed include examination year, patient age at examination, patient sex, diagnosis codes, complaint notes, and refraction fields. Complaint notes contain free-form text with clinician notes that are recorded during the case history, in which patients are typically asked about their vision goals, current devices and adaptations, mobility, light sensitivity, and activities of daily living. The refraction fields contain information about trial frame refraction and the different rehabilitative devices that were assessed during the examination. At both sites, rehabilitative specialists are available to make additional assistive technology recommendations, but these encounters are not recorded in the electronic health record.

Only the first examination from each patient who visited the clinics during this period was analyzed. Thus, if a patient returned for multiple visits, only the earliest visit was analyzed. Patients may have also visited the clinics before the start date of our analysis (i.e., they may already be established patients). However, it was standard practice to take a detailed case history at each visit, regardless of whether the patient was established or new. The analysis was restricted to patients who were 18 years or older at the time of the examination. A total of 3638 examinations that met these initial criteria were retrieved. Examinations were excluded under the following conditions: no diagnosis code or refraction information present, incorrect examination format used (i.e., not a low-vision examination), and low-vision demonstration only (i.e., not a comprehensive low-vision examination). In total, 168 examinations were removed based on these exclusions, leaving 3470 examinations for analysis. The numbers of examinations per calendar year were 329 (2009), 446 (2010), 414 (2011), 353 (2012), 349 (2013), 292 (2014), 325 (2015), 275 (2016), 264 (2017), 283 (2018), and 140 (2019).

Of the patients included in this study, 2585 (74%) had *International Classification of Diseases* (*ICD*) codes for level of visual impairment recorded, with either *ICD-9* or *ICD-10* codes used. These codes were used in the analysis as the metric of visual ability because of variability in recording practices for other metrics, such as visual acuity, visual field size, and contrast sensitivity. We dichotomized patients into two groups: moderate impairment (group 1) and severe impairment to total blindness (group 2). The levels of visual impairment associated with these two groups are summarized in Table 1.[28,29] Note that the transition from *ICD-9* to *ICD-10* in October 2015 included a shift in the acuity ranges included in each *ICD* category. Therefore, group 1 includes moderate low vision (*ICD-9*) and category 1 (*ICD-10*); group 2 includes all other categories in *ICD-9* and *ICD-10*. For analyses of overall frequency, we consider all 3470 records; for regression analyses, we consider only the 2585 records with *ICD* codes so that impairment level can be used as a regressor. Missing *ICD* codes likely reflect cases in which the clinician determined that the visual acuity or visual fields did not meet the *ICD* requirements for visual impairment.

All statistical analyses were conducted in MATLAB (The MathWorks, Inc., Natick, MA), and a *P* value of less than .05 was deemed as statistically significant. Because multiple comparisons were conducted in each analysis, the Benjamini-Hochberg procedure was used to control the false discovery rate at 5%.[30]

Topics Discussed during Case History

The frequency with which different topics were discussed during the case history was quantified using an automated search for a set of keywords in the complaint notes. The keywords were classified into predetermined topic categories modeled after the Low Vision Rehabilitation Outcomes Study, in which a specialist generated a standard set of query terms related to a set of functional complaints (Table 2).[5] We omitted the *hobby* category because of the challenge of generating a comprehensive hobby list, and we omitted the *assistive device* category because we instead include an in-depth analysis of rehabilitative devices that were assessed with each patient. We combined the *out-of-home activities* and *walking* categories into a single *mobility* category, as was done for some analyses in the previous study.[5] Lastly, additional words were added to some categories to be more comprehensive. In particular, we added more technology words to allow for a more focused analysis of technology-related trends over time. To expand the technology word list, common technology words, such as those in the original list, were input in the web-based tool relatedwords.org. Patients for whom the complaint notes were empty (n = 408) or for whom a standard template with some keywords included was copied into the record (n = 22) were omitted from this analysis. These omissions resulted in 3040 patients in the overall frequency analysis and 2267 patients in the regression analysis (because of the additional exclusion of empty *ICD* codes for regression), which represents 88% of the possible data.

Rehabilitative Device Assessments

The frequency, number, and type of rehabilitative devices that were demonstrated to each patient were determined using an automated search of free-form text for each patient. Many different types of devices were demonstrated over the decade, so we generated a set

TABLE 1. Categories used for level of visual impairment and associated descriptions (*ICD-9* and *ICD-10*)

	Visit date	International classification of disease category	Corrected visual acuity or visual field of better-seeing eye
Group 1: moderate impairment	Before October 2015	*ICD-9*: moderate low vision	20/70 to 20/160
	October 2015 and after	*ICD-10*: category 1	20/80 to 20/200
Group 2: severe impairment to total blindness	Before October 2015	*ICD-9*: Severe low vision to total blindness	20/200 or worse
	October 2015 and after	*ICD-10*: categories 2–5	20/250 to NLP or VF less than 10° in diameter

For *ICD-10* codes, the first value in the official ranges are 20/70 and 20/200 noninclusive. Here, we indicate the next possible line on the visual acuity chart for consistency with *ICD-9* codes such that all ranges in the table are inclusive. Descriptions are based on published *ICD* guidelines.[28,29] NLP = no light perception; VF = visual field.

TABLE 2. Topics and associated keywords

Topic	Keywords
Reading	Read, print, **reading**
Television	Television, TV
Driving	Driv*, drove, road, **street**
Social interaction	Face, kids, people, son, daughter, facial, church, **faces**, **husband**, **wife**, **spouse**, **parent**, **friend**, **friends**
Light related	Glare, dim, dark, night, light, photosen*
Employment and school	School, blackboard, job, courses, employ*, occupation, work, **chalkboard**, **whiteboard**, **class**, **classroom**
Technology	Computer, type, typing, mouse, palm pilot, kindle, **laptop**, **iPod**, **iPad**, **tablet**, **Galaxy**, **Android**, **Mac**, **phone**, **application**, **apps**, **Bluetooth**, **touchscreen**, **WiFi**, **wireless**, **cellular**, **Blackberry**, **Motorola**, **email**, **texting**, **messaging**, **camera**, **browser**, **ebook**, **internet**, **Google**, **chat**, **Skype**, **stream**, **streaming**, **video**, **Microsoft**
Home activities	Writ*, cook, cooking, mail, ingredients, recipes, clothes, packag*, clean*, paperwork, bill, check, yard, microwave, bath, label, oven, eat*
Mobility	Getting around, getting places, shop, transportation, go out, going out, travel, leav* home, store, grocery, supermarket, bump, curb, ran into, step, walk, navigat*, balance, trip, fall, stair, ground, moving around, o&m, orientation and mobility, terrain, maneuvering

*Indicates that we allowed for multiple permutations of a word (e.g., drive, driving, driver). Boldface indicates words that we added to the original source word list. Both the topics and keywords were modeled after Table 1 in the Low Vision Rehabilitation Outcomes Study with additional keywords added for specific topics.[5]

of categories after consultation with low-vision specialists and included both “low-tech” (optical) and “high-tech” (electronic) tools (Table 3). Both clinical sites offer separate electronic device evaluations with a low-vision rehabilitation specialist, which are not recorded in the electronic health records. Information about which demonstrated devices, if any, were ultimately prescribed to the patient is also not recorded. Thus, although electronic tools are demonstrated in the examination room, the tools included here are only a partial list. Nonetheless, these data provide an important snapshot of the primary tools that are being demonstrated to patients during their examination. Patients for whom there were no demonstrations (n = 227) were omitted from this analysis. These omissions resulted in 3243 patients in the overall frequency analysis and 2465 patients in the regression analysis (~95% of the possible data).

Regression Models

We used multivariate logistic regression to model the probability of each topic being discussed and the probability of each device being demonstrated at an examination as a function of the year of examination, as well as the patient age (in years), patient sex, and impairment level (group 1 vs. group 2). Individual patients were modeled as random effects. For the topics analysis, we found that the verbosity of the records increased over the decade (e.g., the average number of words recorded per patient was 151 in 2009 and 237 in 2019), so we included a variable in the model controlling for overall word count. In addition to the main effects listed previously, we included one interaction term between patient age and year of examination, because we hypothesized that different age groups may have experienced changes in needs differently over the decade. Models were fit to binary data. Models fit using the raw values of continuous predictors did not converge, so the continuous predictors (patient age, year of examination, and word count) were *z* scored before fitting to facilitate finding an accurate model. In the results text and all tables, odds ratios for main effects of year of examination and age at examination are reported for rescaled coefficients to reflect the change in units of 10 years. Models were fit to a random sample of 80% of the data (1814 for the analysis of topics discussed, 1972 for the device demonstrations), and accuracy for predicting

TABLE 3. Categorization and description of rehabilitative devices

Device	Type	Definition
Tinted lenses	Optical	Colored lenses and filters (e.g., to reduce glare and ocular discomfort)
Refractive spectacles	Optical	Ophthalmic glasses that require a refraction (e.g., progressive addition lenses, bifocals, single-vision lenses)
Handheld magnifier	Optical	Handheld optical devices that magnify nearby objects
Handheld telescope	Optical	Handheld optical devices that spot or magnify distant objects, or expand visual field when used inversely
Other head-borne optical devices	Optical	Prefabricated (i.e., “over the counter”) or customized low vision tools worn like spectacles (e.g., prism readers, OptiVisor, microscopics, bioptics, prism fitting for hemianopic field loss)
Stand magnifier	Optical	Optical devices mounted into a base, magnifying objects when rested on the surface underneath
Electronic magnifier	Electronic	Desktop and portable digital magnifiers
Other electronics	Electronic	Built-in accessibility features on consumer computers, tablets, and phones as well as advanced low-vision aids (e.g., NuEyes, OrCAM, IrisVision)

the remaining 20% was assessed by calculating the area under the receiver operating characteristic curve, which represents the trade-off between false-positive and true-positive classifications for a range of thresholds on the response probabilities estimated by the regression (ranging from 0 to 1).[31]

To visualize differences in trends for patients of different ages, we grouped patients into five age groups. Because there is no uniform standard for age groups in low vision, we base these cohorts on the Medical Subject Heading dictionary (https://www.ncbi.nlm.nih.gov/mesh/68009273). The five groups correspond to young adult (18 to 24 years), adult (25 to 44 years), middle aged (45 to 64 years), aged (65 to 79 years), and 80 years and older (≥80 years). For the word frequency regression analysis, the numbers of patients in each age group were 134, 312, 482, 336, and 550, respectively. For the device demonstration regression analysis, the numbers were 133, 326, 510, 382, and 621, respectively. We also used these age groups to conduct follow-up stratified analyses in the case of interactions between patient age and examination year. Specifically, when a significant (or marginal) interaction was observed, we calculated simple effects coefficients for examination year in each of the age groups and examined them separately. Other than the removal of the coefficient for age, these models were the same as the main models.

RESULTS

Patient Demographics

Collapsing across all years, there was a relatively balanced sex distribution with 44% males and 56% females. The mean age was 62 years (range: 18 to 103 years), and the average female was older than the average male (female mean age = 65 years; male mean age = 58 years). The four most prevalent causes of visual impairment were age-related macular degeneration (29%), glaucoma (16%), retinitis pigmentosa (7%), and diabetic retinopathy (7%). Of the patients with *ICD* codes, the majority (65%) were in group 1 rather than group 2 (the group 1 percentage was 63% during the period in which *ICD-9* codes were used, and 69% in the period when *ICD-10* codes were used). These demographic trends were relatively consistent over time, as shown in Fig. 1, and consistent with prior studies reporting characteristics of individuals seeking low-vision care in the United States.[16,17]

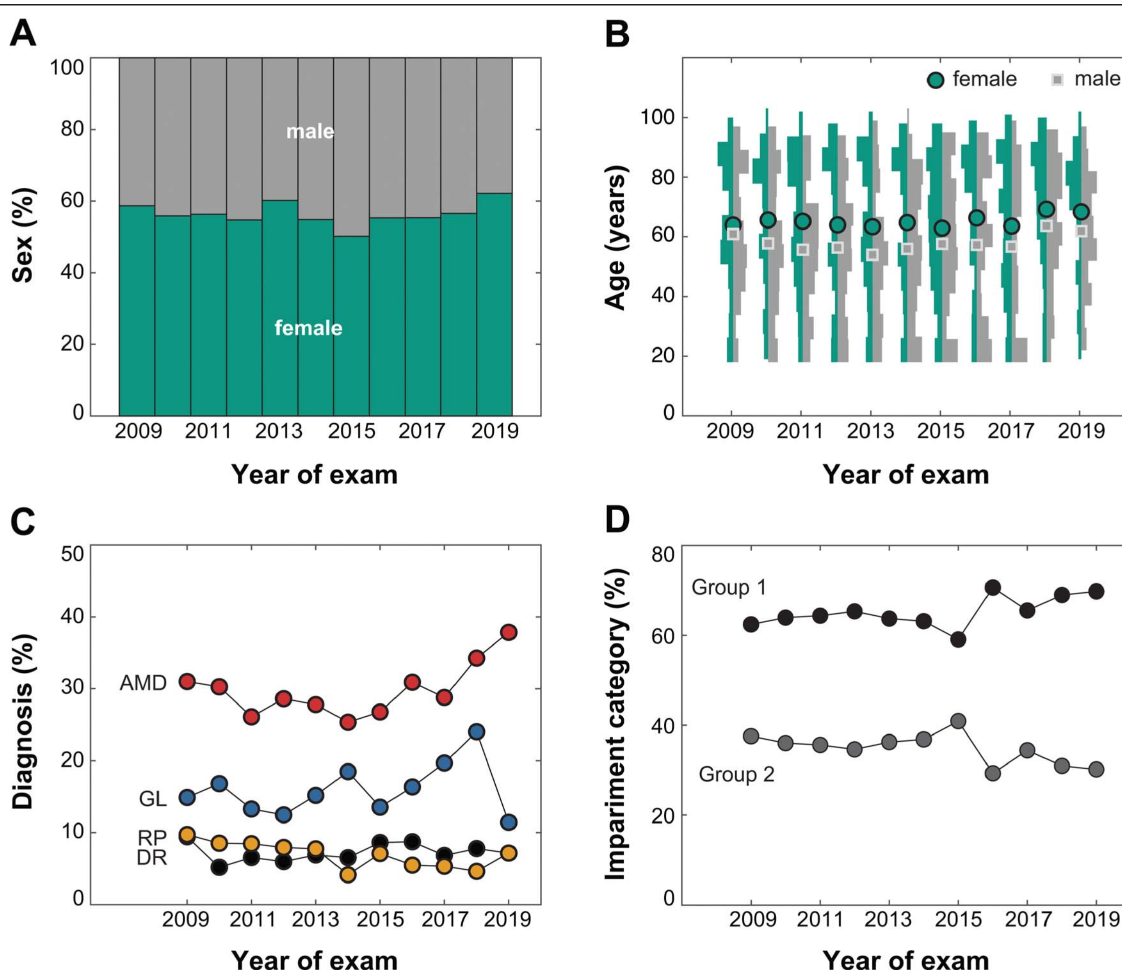

FIGURE 1. Patient demographics over the decade. (A) Percentage of patients with female (green) and male (gray) sex for each year. (B) For each year, violin plots illustrate the distribution of patient ages for females (left/green) and males (right/gray). The mean for each year is indicated with a circle/square for females/males, respectively. (C) Percentage of patients with each of the top four most common diagnoses for each year. Note that some patients had multiple diagnoses. (D) Percentage of patients in each visual impairment group for each year (Table 1). These percentages are relative to the total number of patients with *ICD* vision impairment codes filled in. AMD = age-related macular degeneration; DR = diabetic retinopathy; GL = glaucoma; RP = retinitis pigmentosa.

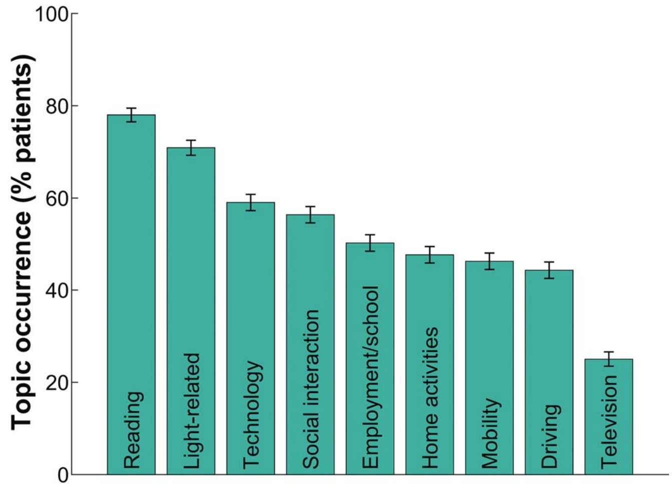

FIGURE 2. Percentage of patients for whom at least one word in each topic category was noted in the case history, collapsed across all years. Error bars represent 95% binomial confidence intervals.

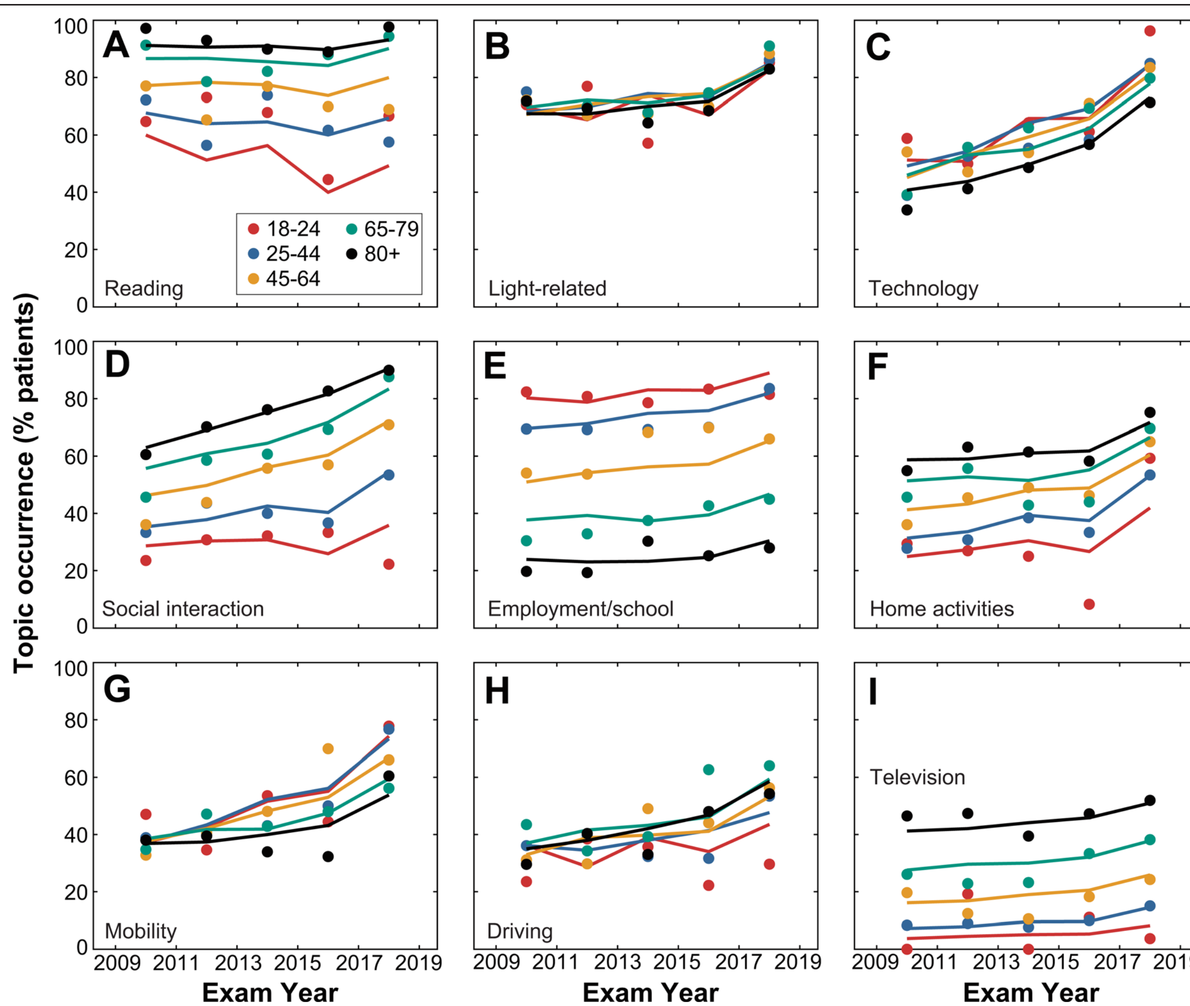

FIGURE 3. Raw data and logistic regression model for topics discussed in the case history as a function of examination year and patient age. Each panel plots the percentage of patients with at least one word in each topic noted in the case history as circles, binned in increments of 2 years for examination year and into the age cohorts for patient age in years: 18 to 24 (red), 25 to 44 (blue), 45 to 64 (gold), 65 to 79 (green), and ≥80 (black). Data represent a random sample of 80% of patients to which the model was fit. Lines show the average fitted probability for these data in each year and age bin. Note that the data points and fits both reflect additional variation because of different proportions of patient sex and visual impairment level in each bin.

Topics Discussed during Case History

Overall Frequency of Topics Discussed

Collapsing across all years, the most common topic that appeared in the case history notes was *reading* (78%, n = 2372) (Fig. 2). *Light-related*, *technology*, *social interaction*, and *employment/school* words were also noted in more than half of the case histories. However, the number of keywords in each topic category was not equal, so in subsequent analyses we focus on changes in these topics over time, rather than overall frequency. To examine whether any topics had a consistent tendency to co-occur, we conducted an exploratory analysis in which we examined the pairwise joint probability distribution of these topics. When compared with the expected joint probabilities if all topics were independent, we did not see strong evidence for correlations, so in subsequent analyses, we continue to treat these topics as separate variables.

Regression Model of Topics Discussed

We first focus on the main effects of the examination year, along with interactions between examination year and patient age (Fig. 3; Tables 4, 5). We found that more recent years were associated with

TABLE 4. Logistic regression models for each topic

	Reading	Light	Technology	Social	Employment/school	In home	Mobility	Driving	TV
Exam year									
Odds ratio*	**0.57**	1.47	**4.53**	**3.31**	1.33	1.46	**2.71**	**1.95**	1.55
95% CI	**0.35–0.94**	0.97–2.23	**3.07–6.69**	**2.24–4.90**	0.91–1.96	1.02–2.11	**1.88–3.88**	**1.35–2.80**	0.99–2.45
t Stat	**–2.22**	1.81	**7.63**	**5.99**	1.46	2.05	**5.40**	**3.60**	1.90
P	**.03**	.07	**<.001**	**<.001**	.14	.04	**<.001**	**<.001**	.06
Age at exam									
Odds ratio*	**1.39**	1.00	**0.92**	**1.38**	**0.66**	**1.23**	**0.93**	1.02	**1.51**
95% CI	**1.31–1.47**	0.95–1.05	**0.88–0.96**	**1.31–1.44**	**0.63–0.69**	**1.17–1.28**	**0.89–0.98**	0.98–1.07	**1.42–1.61**
t Stat	**11.53**	–0.09	**–3.58**	**12.90**	**–16.05**	**8.81**	**–3.04**	1.11	**13.06**
P	**<.001**	.93	**<.001**	**<.001**	**<.001**	**<.001**	**.002**	.27	**<.001**
Year × age									
Ratio of odds ratio	1.08	0.98	0.93	**1.19**	0.94	0.95	**0.86**	1.07	0.93
95% CI	0.95–1.23	0.88–1.10	0.84–1.04	**1.06–1.33**	0.83–1.05	0.85–1.05	**0.78–0.96**	0.97–1.19	0.81–1.07
t Stat	1.14	–0.3	–1.23	**2.99**	–1.12	–0.99	**–2.80**	1.3	–1.0
P	.25	.75	.22	**.003**	.26	.32	**.005**	.19	.30
Sex (F)									
Odds ratio	**1.44**	0.88	**0.7**	**1.36**	**0.77**	**1.37**	1.00	0.86	0.96
95% CI	**1.13–1.85**	0.70–1.10	**0.61–0.93**	**1.10–1.67**	**0.63–0.95**	**1.12–1.67**	0.82–1.22	0.70–1.05	0.76–1.21
t Stat	**2.91**	–1.13	**–2.6**	**2.85**	**–2.41**	**3.06**	–0.01	–1.47	–0.36
P	**.004**	.26	**.008**	**.004**	**.02**	**.002**	.99	.14	.73
Impairment level (group 2)									
Odds ratio	**0.49**	0.85	**0.75**	**1.45**	0.91	**1.34**	**1.29**	**0.38**	**1.33**
95% CI	**0.38–0.63**	0.68–1.07	**0.61–0.93**	**1.16–1.80**	0.73–1.13	**1.09–1.65**	**1.05–1.59**	**0.31–0.47**	**1.05–1.69**
t Stat	**–5.69**	–1.4	**–2.60**	**3.30**	–0.84	**2.75**	**2.46**	**–8.8**	**2.33**
P	**<.001**	.16	**.009**	**.001**	.40	**.006**	**.01**	**<.001**	**.02**
Word count									
Odds ratio	**1.94**	**2.33**	**2.08**	**1.60**	**1.49**	**1.7**	**1.66**	**1.50**	**1.32**
95% CI	**1.65–2.28**	**2.01–2.71**	**1.83–2.36**	**1.42–1.81**	**1.33–1.67**	**1.60–2.01**	**1.49–1.86**	**1.35–1.67**	**1.18–1.48**
t Stat	**8.09**	**11.05**	**11.19**	**7.62**	**6.96**	**9.92**	**9.07**	**7.42**	**4.82**
P	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**
Intercept	1.65	1.30	0.73	0.19	0.19	–0.24	–0.17	0.08	–1.33
AUC	0.74	0.70	0.73	0.73	0.80	0.75	0.66	0.69	0.72

*Odds ratios for main effects of year of examination and age at examination are reported for rescaled coefficients so as to reflect change in units of 10 years. Bolded values represent statistically significant coefficients ($P < .05$) after correction for false discovery rate. All models were fit to 1814 observations (80% of the data) with 5 main effects and 1 interaction (listed in the first column). Individual patients were modeled as random intercepts. For sex and visual impairment level, odds ratios reflect the change in probabilities associated with female sex (referenced to male sex) and group 2 (referenced to group 1). 95% CI = 95% confidence interval; AUC = area under the curve; F = female.

TABLE 5. Follow-up analyses of the effects of examination year stratified by age group for all models with a significant or marginal interaction between year of examination and patient age

Exam year effects	Mobility	Social	Computer	Phone
For ages 18–24 y				
Odds ratio*	4.09	0.72	0.65	**260.60**
95% CI	0.90–18.51	0.17–3.13	0.16–2.56	**23.97–2833.45**
t Stat	1.84	–0.44	–0.63	**4.61**
P	.07	.66	.53	**<.001**
For ages 25–44 y				
Odds ratio*	**5.25**	1.19	1.76	**36.11**
95% CI	**2.09–13.14**	0.50–2.87	0.72–4.32	**11.38–114.65**
t Stat	**3.55**	0.40	1.24	**6.11**
P	**<.001**	.69	.216	**<.001**
For ages 45–64 y				
Odds ratio*	**4.92**	**3.46**	0.94	**26.74**
95% CI	**2.41–10.02**	**1.70–7.03**	0.47–1.85	**10.50–68.10**
t Stat	**4.40**	**3.44**	–0.19	**6.91**
P	**<.001**	**.001**	.85	**<.001**
For ages 65–79 y				
Odds ratio*	1.51	**6.45**	1.16	**36.22**
95% CI	0.67–3.40	**2.60–16.00**	0.52–2.60	**11.40–115.10**
t Stat	0.99	**4.03**	0.37	**6.11**
P	.32	**<.001**	.71	**<.001**
For ages ≥80 y				
Odds ratio*	1.54	**5.75**	**3.27**	**4.77**
95% CI	0.80–2.95	**2.52–13.13**	**1.58–6.75**	**2.20–10.33**
t Stat	1.30	**4.16**	**3.20**	**3.97**
P	.19	**<.001**	**.001**	**<.001**

Bolded values represent statistically significant coefficients ($P < .05$), without correction for multiple comparisons. All models included four main effects (examination year, sex, visual impairment level, and word count), but only the examination year coefficients are shown. Individual patients were modeled as random intercepts.

greater odds of discussing *technology*, *social interaction*, *mobility*, and *driving* (Figs. 3C, D, G, H). Odds ratios for these topics, reflecting the increase in probability that a topic was discussed from the beginning to the end of the decade, ranged from 1.9 (*driving*) to 4.5 (*technology*). For *mobility*, we observed a significant interaction between examination year and patient age, suggesting that the increase in discussing *mobility* over time was steeper for younger patients than for older patients (Fig. 3G, Table 5). For *social interaction*, we observed an age-related interaction in the opposite direction: the upward trend over time was steeper for older patients (Fig. 3D, Table 5). Only one topic, *reading*, was associated with a significant decrease over time, with an odds ratio of 0.57 over the decade (Fig. 3A). Whereas this decrease was descriptively steeper in younger ages, the interaction with age was not statistically significant.

Several of the topics were also associated with main effects of patient age, sex, and level of visual impairment. Age effects (with no interaction with examination year) were pervasive, with older age associated with increased odds of discussing *reading*, *social interaction*, *home activities*, and *television*. Older age was associated with decreased odds of discussing *technology* and *employment/school*. Female sex was associated with decreased odds of discussing *technology* and *employment/school* and increased odds of discussing *reading*, *social interaction*, and *home activities*. Greater visual impairment (group 2) was associated with decreased odds of discussing *reading*, *technology*, and *driving* and increased odds of discussing *social interaction*, *home activities*, *mobility*, and *television*. As expected, increased word count was associated with increased odds of discussing all topics. Model accuracy for the held-out data regarding each topic was medium to high, with areas under the receiver operating characteristic curves ranging from 0.66 (*mobility*) to 0.80 (*employment/school*).

Technology Words

Our previous analysis suggests an increasing tendency for technology to be discussed during low-vision examinations. Technology likely plays a key role in the changing challenges and available assistive tools for patients with low vision, so we conducted a more detailed analysis of this topic. Fig. 4A shows the overall percentage

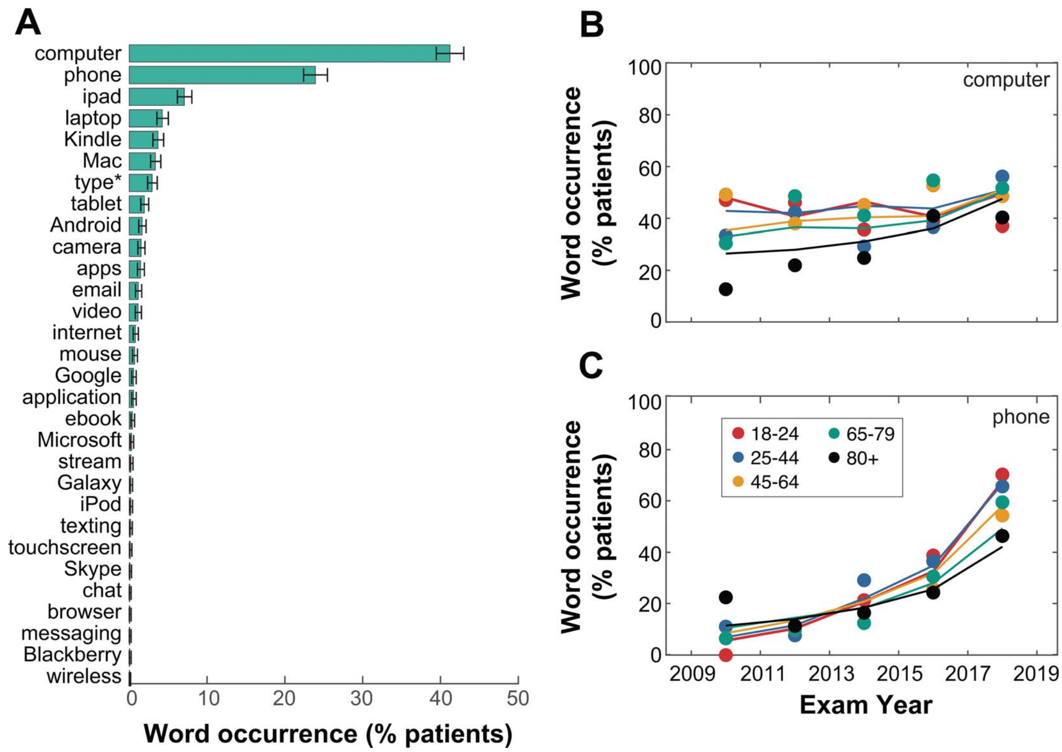

FIGURE 4. Technology words analysis. (A) Frequency of discussing technology words in the case histories collapsed across all years. Error bars represent 95% binomial confidence intervals. (B, C) Raw data and logistic regression model for discussing computers and phones as a function of examination year and patient age. Data are plotted in the same manner as Fig. 3. *Note that *type* and *typing* have been combined.

of case histories with an occurrence of each of the technology keywords in our list (words that were searched for but never appeared, n = 6, are omitted). *Computer* and *phone* were the most frequent technology words, appearing in 41 and 24% of records, respectively. Note that the *phone* keyword includes words such as "smartphone" and "iPhone." We fit the frequency of each of these words with a logistic regression model. We found significant main effects of examination year for both words and a significant interaction with age for *phone* (the age interaction for *computer* was marginal; no correction for multiple comparisons was used, because only two words were analyzed) (Figs. 4B, C; Tables 5, 6). For both words, the odds of being discussed increased over the decade, with a substantial increase for *phone* (odds ratio, 19.82). Also for *phone*, younger age was associated with a steeper increase over the decade. For *computer*, there was a significant main effect of age, suggesting that older age was associated with lower odds, and a marginal interaction between age and examination year, suggesting a tendency for a steeper longitudinal increase with older age, particularly in the age group ≥80 years. Female sex and greater visual impairment (group 2) were both associated with lower odds of the word *computer* being discussed.

Rehabilitative Device Assessments

Overall Frequency of Devices

Across all years, 93% (n = 3243) of patients had at least one device demonstrated to them during their examination. Of these patients, the most common devices by far were *tinted lenses* (95%), whereas *handheld magnifiers* (63%) and *refractive spectacles* (56%) were also demonstrated to more than half of the patients (Fig. 5).

Regression Model of Device Assessments

Overall, the accuracy of the regression models for predicting device assessments was lower than the models predicting the topics discussed (areas under the receiver operating characteristic curve ranged from 0.54 to 0.69) (Table 7). This pattern suggests that variations among the devices demonstrated to the patients were less well predicted by the longitudinal and demographic predictors used in our model. Nonetheless, more recent years were associated with higher odds of assessing several optical aids, including *tinted lenses*, *handheld magnifiers*, *handheld telescopes*, and *other head-borne optical devices* (Figs. 6A, B, F, G). More recent years were associated with decreased odds of assessing *refractive spectacles* and *electronic magnifiers* (Figs. 6C, D). None of these longitudinal effects had a significant interaction with patient age.

Odds of assessing several devices increased with age (*handheld magnifiers*, *electronic magnifiers*, *stand magnifiers*, and *other head-borne optical devices*), whereas older age was associated with decreased odds of assessing *handheld telescopes*. Greater visual impairment (group 2) was associated with lower odds of several devices (*handheld magnifiers*, *refractive spectacles*, *stand magnifiers*, and *handheld telescopes*) and increased odds of an *electronic magnifier* demonstration. No consistent sex-related differences were observed.

DISCUSSION

Reading and Magnifying Aids

According to our keyword search, reading was the most common topic discussed during the case history. Collapsing across all years,

TABLE 6. Logistic regression models for the words *computer* and *phone*

	Computer	Phone
Exam year		
Odds ratio*	**1.44**	**19.82**
95% CI	**1.00–2.07**	**12.42–31.63**
t Stat	**1.98**	**12.54**
P	**.05**	**<.001**
Age at exam		
Odds ratio*	**0.92**	0.97
95% CI	**0.88–0.96**	0.91–1.03
t Stat	**–3.62**	–1.09
P	**<.001**	.28
Year × age		
Ratio of odds ratio	1.10	**0.75**
95% CI	1.00–1.22	**0.65–0.86**
t Stat	1.89	**–4.09**
P	.06	**<.001**
Sex (F)		
Odds ratio	**0.74**	1.14
95% CI	**0.61–0.90**	0.90–1.45
t Stat	**–2.97**	1.09
P	**.003**	.28
Impairment level (group 2)		
Odds ratio	**0.72**	1.15
95% CI	**0.58–0.89**	0.90–1.47
t Stat	**–3.08**	1.09
P	**.002**	.28
Word count		
Odds ratio	**1.60**	**1.72**
95% CI	**1.44–1.79**	**1.52–1.94**
t Stat	**8.62**	**8.65**
P	**<.001**	**<.001**
Intercept	–0.16	–1.40
AUC	0.67	0.81

*Odds ratios for main effects of year of examination and age at examination are reported for rescaled coefficients so as to reflect change in units of 10 years. Bolded values represent statistically significant coefficients ($P < .05$) after correction for false discovery rate. All models were fit to 1814 observations (80% of the data) with 5 main effects and 1 interaction (listed in the first column). Individual patients were modeled as random intercepts. For sex and visual impairment level, odds ratios reflect the change in probabilities associated with female sex (referenced to male sex) and group 2 (referenced to group 1). 95% CI = 95% confidence interval of the odds ratios; AUC = area under the curve; F = female.

the observed frequency and demographics associated with reading were largely consistent with previous reports.[4,5,13,17,18,21] We found, however, that the odds of discussing reading decreased slightly as the decade progressed. Improved accessibility options within personal devices (e.g., magnification and screen readers) may address minor reading challenges, thus decreasing the priority of this topic. Nonetheless, reading remains a common topic each year, suggesting that additional development around reading aids remains essential. To some extent, the decrease in odds we observed for discussing reading may derive from changes in the words people were using to talk about reading on electronic devices (e.g., "using the phone" rather than "reading text on the phone"). Indeed, as daily reading tasks shift more onto electronic devices, improvements in technologies that support reading digital text are imperative.[32–34]

Both optical and electronic magnifiers assist in nondigital reading and other near work, and both device types were demonstrated to patients. We observed an increase in assessments of optical magnifiers (handheld magnifiers), which is consistent with trends identified in a prior longitudinal study covering earlier decades, and a decrease in assessments of electronic magnifiers as part of the low-vision examination over time.[25] However, we do not have data about the devices that were demonstrated after the examination by a rehabilitation specialist, so it is also possible that, over time, more electronic magnifier demonstrations were integrated into other parts of the patients' visit. Optical magnifiers are relatively easy-to-use, low-cost tools but require good hand dexterity (handheld) or an appropriate working distance (stand), which may introduce challenges particularly for higher magnification powers. These optical limitations can be addressed by electronic magnifiers that come in both portable and desktop sizes and can include additional features such as optical character recognition. Electronic magnifiers also provide higher magnification compared with optical systems and the flexibility to adjust the magnification and contrast level within one system. The downside to electronic magnifiers is that they require some level of technology savviness and have higher price points. Regular consumer electronics, such as computers and smartphones, may be supplementing or replacing dedicated electronic magnifiers, which may explain the downward trend over time we observed in assessing these devices.[35–37]

Technology Topics

Our findings suggest an increasing tendency to discuss technology-related topics over time. Indeed, by the end of the decade, technology words were as frequent as reading words. This increase was observed across age groups, although younger age was associated with a higher probability of discussing technology. Previous research found that individuals who lose vision after age 60 years were more likely to ask rehabilitation professionals for technology support, whereas younger individuals were more likely to use online resources or acquaintances.[35] However, during initial case history discussion, younger patients may still comment on their technology proficiency or share what technology they are currently using.

Regardless of age, the increasing prevalence of mobile technology has changed the nature of daily life, which presents both new benefits and new challenges. For example, computer tasks such as reading e-mails and looking up directions used to be done at home or at work, where individuals can access their mainstay assistive tools. Now, these same tasks can be done anywhere on a smartphone (for those who have one), increasing dependence on mobile assistive technology. The emergence of assistive technology on smartphones, including systems that use computer vision and artificial intelligence, also changes the nature and the priority of daily tasks. These shifts in daily life are a prime example of why it is essential for low-vision care providers to keep up to date on emerging technologies. Our analysis of individual technology words suggests that the importance of phones has increased dramatically over the decade among all age groups but notably among younger patients.

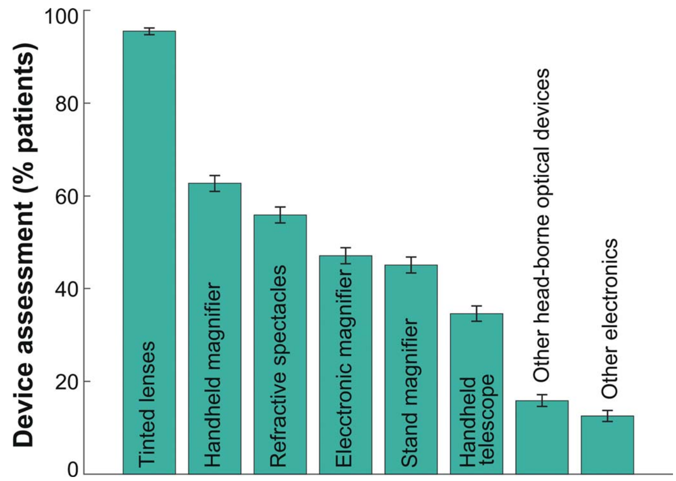

FIGURE 5. Frequency of rehabilitative device assessments. Error bars represent 95% binomial confidence intervals.

This observation supports the importance of usable and effective mobile technology for individuals with low vision. Traditional assistive devices will likely remain at the forefront of low-vision care for now because of their wide acceptance, but advancements in technology and high use in the younger population are clearly influencing low-vision care. Low-vision professionals can play a critical role in addressing the changing challenges of daily life and helping patients acquire knowledge and skills for the latest available technology.

Lighting Concerns and Tinted Lenses

Lighting was one of the most common topics discussed, with no consistent changes over the decade or differences between groups. These results likely reflect the fact that lighting conditions are a universal concern. In a rehabilitative context, lighting concerns are addressed in a range of ways, including improving environmental lighting and providing spectacles with tinted or filtered lenses.[38,39] Indeed, tinted lenses were the most common rehabilitative device demonstrated in this data set. There was no difference in demonstration frequency among the demographics, although there was an overall trend for an increase in tinted lens demonstrations over time. Tinted lenses are commonly prescribed to reduce glare and enhance contrast, but it has been argued that there is limited research supporting improved visual performance.[39] In a rehabilitative context, patients subjectively determine the best filter to improve their vision and visual comfort. These demonstrations remain a mainstay in the current clinics, highlighting the continued priority of "low-tech" aids in rehabilitative services.

Driving and Mobility

Driving and mobility-related topics both trended upward over time, with mobility having a steeper trend for younger ages. Based on visual impairment level, patients in group 1 were more likely to discuss driving compared with patients in group 2, whereas patients in group 2 were more likely to participate in discussions of mobility (which includes walking). This is consistent with what we would expect because of the State of California vision requirements and the visual requirements for safe driving. Those with severe impairment to total blindness (group 2) are less likely to pursue a driver's license and may be more likely to prioritize nondriving mobility concerns.

Consistent with the upward trend in discussing mobility and driving, there was an increase in demonstrations of handheld telescopes, which may be used for spotting distant targets on the go or as a field expander. There was also an increase in demonstrations of other head-borne optical devices, some of which may be used for driving (such as bioptics). Telescopes may require more training and practice to successfully use compared with other traditional low-vision devices. As a result, younger patients may be more likely to be shown this tool because they likely have better hand dexterity and may receive formal training in schools. In addition, the utility of telescopes for assistance in day-to-day life depends on the types of activities someone tends to engage in (e.g., driving, taking public transit). Prior work also suggested that younger patients are more likely to be prescribed rehabilitative devices but did not indicate with which types of devices this trend was associated.[26]

Unlike these optical technologies, emerging wearable electronic vision enhancement systems are not necessarily designed to be used by people while they are in motion (e.g., IrisVision, Pleasanton, CA; Jordy, Enhanced Vision, Huntington Beach, CA), highlighting the continued importance of optics for distance tasks. In some cases, a smartphone camera with digital magnification may replace the role of a handheld telescope on the go. In instances where a patient may have financial or technological constraints, handheld telescopes are still a useful tool. The development of consumer technologies supporting electronic vision enhancement combined with optical see-through designs is opening new possibilities for mobility assistance moving forward.[40–44]

Refractive Spectacles and Other Head-borne Optical Devices

Refractive spectacles and other head-borne optical devices are both optical aids worn on the face. Longitudinal trends for these aids went in opposite directions, with decreasing spectacle demonstrations and increasing demonstrations of other head-borne optical devices. As with any patients who wear refractive spectacles, low-vision patients' distance prescription is unlikely to change after their 20s. As such, the downward trend we observed may reflect clinical experience of the limited visual benefits of an updated but minimally changed refractive prescription for some patient populations. Nonetheless, prior work suggests that approximately 10% of low-vision patients benefit from refractive correction (measured as

TABLE 7. Logistic regression models for each device type

	Tinted lenses	Handheld magnifiers	Refractive spectacles	Electronic magnifiers	Stand magnifiers	Telescope	Other HB optics	Other electronics
Exam year								
Odds ratio*	**3.04**	**1.46**	**0.72**	**0.64**	1.24	**1.60**	**2.16**	0.79
95% CI	**1.30–7.14**	**1.05–2.03**	**0.53–0.98**	**0.47–0.87**	0.91–1.69	**1.15–2.23**	**1.45–3.23**	0.51–1.24
t Stat	**2.56**	**2.256**	**–2.11**	**–2.88**	1.34	**2.79**	**3.76**	–1.01
P	**.01**	**.02**	**.04**	**.004**	.18	**.005**	**<.001**	.31
Age at exam								
Odds ratio*	1.03	**1.13**	1.04	**1.15**	**1.18**	**0.71**	**1.09**	1.03
95% CI	0.92–1.16	**1.08–1.18**	0.99–1.08	**1.10–1.20**	**1.13–1.23**	**0.68–0.74**	**1.03–1.15**	0.97–1.10
t Stat	0.58	**5.52**	1.65	**6.56**	**7.64**	**–14.46**	**2.95**	1.09
P	.56	**<.001**	.10	**<.001**	**<.001**	**<.001**	**.003**	.28
Year × age								
Ratio of odds ratio	1.05	1.05	1.03	1.07	1.12	1.03	1.17	0.99
95% CI	0.81–1.36	0.95–1.16	0.94–1.14	0.98–1.18	1.02–1.23	0.93–1.14	1.04–1.33	0.86–1.13
t Stat	0.37	0.97	0.70	1.45	2.29	0.53	2.50	–0.22
P	.71	.33	.49	.15	.02	.60	.01	.83
Sex (F)								
Odds ratio	0.90	1.03	0.97	0.98	1.09	0.93	0.88	1.00
95% CI	0.55–1.49	0.85–1.26	0.81–1.17	0.82–1.18	0.90–1.31	0.77–1.14	0.69–1.12	0.76–1.30
t Stat	–0.40	0.31	–0.29	–0.20	0.86	–0.69	–1.06	–0.03
P	.69	.76	.78	.84	.39	.49	.29	.98
Impairment level (group 2)								
Odds ratio	1.74	**0.68**	**0.60**	**1.51**	**0.51**	**0.66**	0.84	1.04
95% CI	0.98–3.07	**0.55–0.83**	**0.50–0.73**	**1.25–1.84**	**0.42–0.61**	**0.53–0.81**	0.65–1.09	0.79–1.37
t Stat	1.89	**–3.81**	**–5.23**	**4.19**	**–6.84**	**–3.89**	–1.33	0.25
P	.06	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**	.18	.80
Intercept	3.27	0.92	0.43	0.00	0.16	–0.35	–1.44	–1.90
AUC	0.66	0.65	0.60	0.61	0.66	0.69	0.56	0.54

*Odds ratios for main effects of year of examination and age at examination are reported for rescaled coefficients so as to reflect change in units of 10 years. Bolded values represent statistically significant coefficients ($P < .05$) after correction for false discovery rate. All models were fit to 1972 observations (80% of the data) with 4 main effects and 1 interaction (listed in the first column). Individual patients were modeled as random intercepts. For sex and visual impairment level, odds ratios reflect the change in probabilities associated with female sex (referenced to male sex) and group 2 (referenced to group 1). 95% CI = 95% confidence interval of the odds ratios; AUC = area under the curve; F = female; HB = head borne.

an acuity improvement of greater than or equal to two lines on the eye chart).[45] Other head-borne optical devices, on the other hand, offer a flexible range of tools that may provide more effective assistance for some types of daily tasks. These devices include customized hand-free systems, such as bioptics for distance/near magnification or prism fitting for patients with hemianopic field loss.[11,46,47] It is possible that increases in the available types of head-borne optical devices have facilitated more assessments of these types of tools.

Social Interaction, Home Activities, Employment, and School

Topics related to social interactions, home activities, employment, and school likely reflect multifaceted challenges that include reading, technology, lighting, and mobility. These diverse topics nonetheless followed predictable age-related trends. Employment and school are often tied to individuals of working age, so it makes sense that young individuals are more likely to be involved in discussing these topics. Regardless of age or sex, it is important to determine if individuals would like to be in the workforce and connect them with the appropriate resources. On the other hand, social interaction and home activity topics were discussed more with older patients. Research suggests that older individuals with low vision often have a harder time mobilizing and may therefore stay at home for greater amounts of time.[3,48] In particular, increasing discussion of social interaction over time may reflect changing trends in the role and expectations for low-vision care.

Caveats and Limitations

Our data set was limited to a single region within the United States (California, San Francisco Bay Area), which may not be

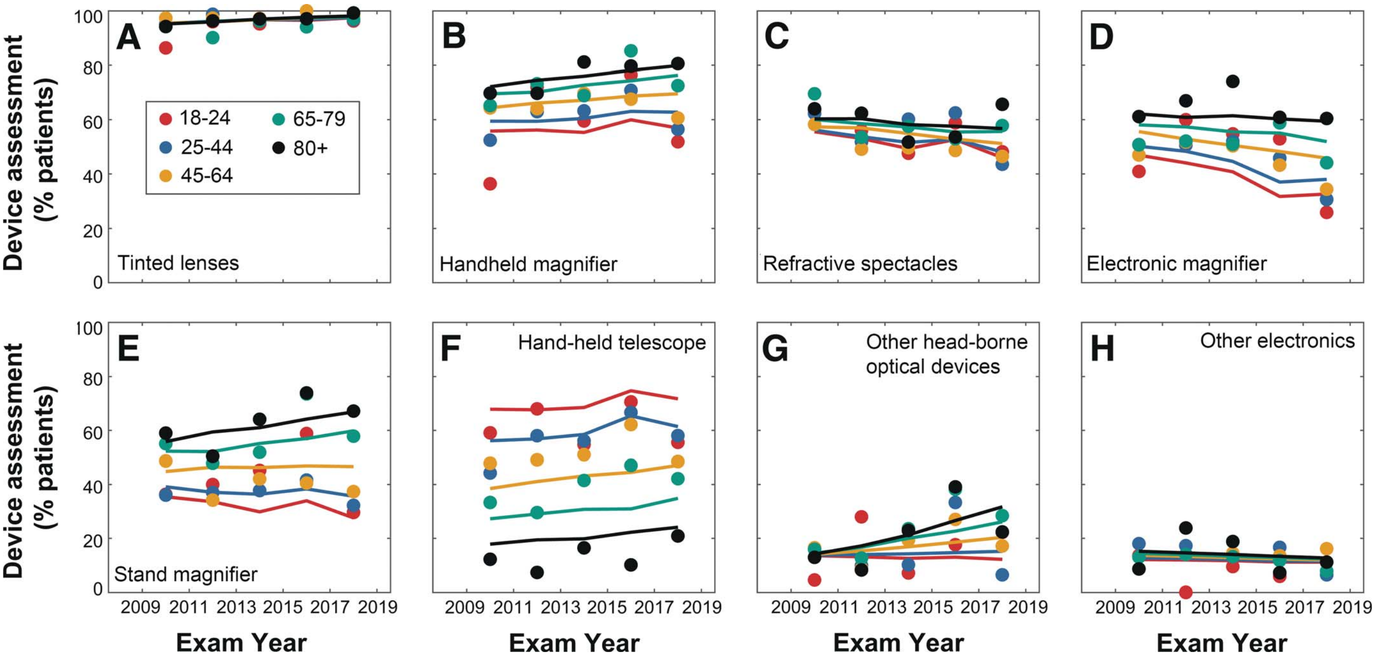

FIGURE 6. Raw data and logistic regression model for rehabilitative device assessments as a function of examination year and patient age. Data are plotted in the same manner as Fig. 4.

reflective of national or global longitudinal trends. Within the clinics examined, interclinician variability and missing or incomplete data resulted in the inability to analyze some factors, which may be important predictors of visual challenges and goals. For example, continuous measures of visual ability, such as visual acuity, visual field size, and contrast sensitivity, would likely allow for a more nuanced analysis of how visual function relates to changes in patient needs and goals over time. Furthermore, over the past decade, there have been changes in charting practices, such as more robust charts and formalized templates, which may affect the relationship between word frequency statistics and actual frequencies with which topics of interest change for the patient population over time.

When determining word frequency in the complaint note free text, we did not differentiate whether topics were discussed in a positive or negative context, such as "has no trouble walking independently" versus "goal is to walk independently." In addition, the keyword list used in this study was adopted from previous work and necessarily does not encompass all the possible keywords under each topic. Importantly, because the complaint notes are written by the clinician, it is likely that demographics and longitudinal trends also incorporate clinician expectations and priorities. In this regard, prospective studies of longitudinal trends would be a valuable addition, because these types of studies can circumvent some sources of variability and potential bias in retrospective investigations. However, our retrospective approach enabled us to examine trends in a large cohort over a long period, both of which are challenging in prospective studies. These issues highlight the importance of using complementary approaches to examine the dynamic nature of patient needs and low-vision care.

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