Hearing and vision screening for preschool children using mobile technology, South Africa

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Abstract

Objective To implement and evaluate a community-based hearing and vision screening programme for preschool children in the Western Cape, South Africa, supported by mobile health technology (mHealth) and delivered by community health workers (CHWs).

Methods We trained four CHWs to provide dual sensory screening in preschool centres of Khayelitsha and Mitchells Plain during September 2017–December 2018. CHWs screened children aged 4–7 years using mHealth software applications on smartphones. We used logistic regression analysis to evaluate the association between screening results and age, sex and test duration, and, for hearing, excessive background noise levels.

Results CHWs screened 94.4% (8023/10 362) of eligible children at 271 centres at a cost of 5.63 United States dollars per child. The number of children who failed an initial hearing and visual test was 435 (5.4%) and 170 (2.1%), respectively. Hearing test failure was associated with longer test times (odds ratio, OR: 1.022; 95% confidence interval, CI: 1.021–1.024) and excessive background noise levels at 1 kHz (e.g. OR for left ear: 1.688; 95% CI: 1.198–2.377). Visual screening failure was associated with longer test duration (OR: 1.003; 95% CI: 1.002–1.005) and younger age (OR: 0.629; 95% CI: 0.520–0.761). Of the total screened, 111 (1.4%) children were diagnosed with a hearing and/or visual impairment.

Conclusion mHealth-supported CHW-delivered hearing and vision screening in preschool centres provided a low-cost, acceptable and accessible service, contributing to lower referral numbers to resource-constrained public health institutions.
Introduction

Sensory inputs of hearing and vision during early childhood development support the achievement of optimal language, speech and educational outcomes. Early detection of sensory impairments is essential for facilitating early childhood development, socioemotional well-being and academic success, as well as the sustainable development goals related to education.

Hearing and vision impairments are the most common global developmental disabilities in children younger than 5 years, affecting 15.5 and 25.2 million, respectively, 95% of whom live in low- and middle-income countries. Services are usually unavailable or inaccessible in these countries because of an absence of systematic screening programmes for children, prohibitive equipment cost and a shortage of trained personnel. An awareness and knowledge of sensory impairments, their potential impact on a child’s development and potential rehabilitative solutions are also poor among early childhood practitioners in underprivileged communities.

The evidence base on the value of community-based programmes incorporating mobile health technology (mHealth) for hearing and vision loss is growing. Community health workers (CHWs) play an important role in improving access to hearing services, including in screening and raising community awareness. mHealth has been recognized as increasingly important in supporting the achievement of the sustainable development goals and addressing access and affordability in underserved populations; it also has the potential to improve health system efficiency, quality of preventative care and health outcomes. Validated smartphone applications (apps) – including automated tests for hearing and vision screening, pre-specified screening protocols for result interpretation, cloud-based data management for surveillance of programme performance and geolocation-based referral – allow CHWs to undertake decentralized screening and identify cases for referral. CHWs have reported such apps as user-friendly and efficient.

The feasibility of community-based services facilitated by CHWs and supported by mHealth for hearing screening in homes and in early childhood development centres (informal day care centres for preschool children) in Gauteng, South Africa, has already been assessed. A model based on preschool centres is particularly relevant for low- and middle-income countries, where systematic newborn hearing screening is unavailable and school-entry screening is potentially the first point of access to services.
Continuing from these feasibility studies, we implemented an mHealth-supported screening programme in which children’s hearing and vision services were provided by CHWs in preschool centres. We describe this community-based service-delivery model and evaluate its success in terms of acceptability (consent return numbers), coverage (number of eligible children screened), quality indicators (duration of tests and number of hearing tests conducted under conditions of excessive noise levels), community-based second screening attendances and diagnostic centre referral attendances. We also discuss the challenges met during this implementation and the strategies developed to overcome these.

Methods

Study setting and preparation

We implemented our screening programme within the preschool centres of the partially informal townships of Khayelitsha and Mitchells Plain of the Western Cape province, South Africa, during September 2017 to December 2018. The joint population of Khayelitsha and Mitchells Plain was estimated as 702,234 in 2011, including 61,094 children aged 5–9 years. Most are not native English speakers. The majority (97.0%; 181,145/186,803) of households within the study area are classified as low- and middle-income, with 15.7% (29,408/186,803) having no income.

Before implementation, we conducted a situational analysis of the potential referral routes to hearing and vision services and established follow-up pathways. We tested and finalized a simplified one-page consent form and screening protocols. We formed partnerships with local non-profit organizations supporting the preschool centres in the community and introduced the screening programme via the quarterly symposiums of preschool centre principals.

Appointment of CHWs

We appointed four CHWs to conduct the combined sensory screening across all preschool centres within the study area. We placed an advertisement on notice boards within the community and conducted interviews with candidates. The four CHWs (one project administrator and screener combined and three screeners) were appointed on a contract basis for the duration of the programme and were paid a monthly salary. Members of the community themselves, these CHWs had a deep understanding of relevant cultural beliefs and biases regarding health services and sensory impairments. None of the CHWs had received any formal training on hearing or vision health care previously.
The audiologist managing the project delivered a 5-day training course to the CHWs on hearing and vision theory, the screening process, observation of screening in the field, practical training on using the equipment and assessment of a child’s responses. The course was held at the Carel du Toit Centre, Cape Town, South Africa, the site of the project implementation partner and employer of the audiologist. The course delivery costs were included in the project management fee. CHWs performed initial screening under supervision. The project manager chaired weekly meetings at the Carel du Toit Centre with the CHWs, allowing for further training based on any queries.

**Implementation**
We mapped all preschool centres (facility name, geolocation and contact person) within the study area using the facility-mapping feature of the mobile platform and invited principals to sign a participation agreement. Within the participating centres, the parents of attending children (4–7 years) indicated their agreement to be included in the study by returning a signed consent form. To increase accessibility, we provided the parent or caregiver with the option to complete the form either in English or in their native language. CHWs distributed posters and leaflets within the preschool centres, emphasized the importance of hearing for learning to centre staff and shared information on the risk factors and signs of hearing loss.

Using mHealth, CHWs performed hearing and vision screening of all children who returned signed consent forms at their respective preschool centres during the 265 screening days held over the 16-month period. The amount of time spent on screening at a particular preschool centre depended upon its size; at any one centre, screening was usually available for some portion of a single day up to a maximum of 2 days at a date agreed in advance with the preschool principal. CHWs performed an immediate rescreen if a child failed the first screening test. Screening results were automatically sent to the child’s parent or caregiver via text message through the mHealth cloud platform. In the case of no available contact number, parents had access to the project administrator’s number and could send a free text to the project administrator, requesting a telephone call with the results.

Children who failed the initial hearing screening (at 25 dB hearing level at 1, 2 and 4 kHz) and rescreening (at 25 dB hearing level at the frequencies at which the child failed the initial test) received a community-based second screening (at 0.5–8 kHz) 1 week later at their preschool, including otoscopy. The project audiologist conducted this second screening, enabling the CHWs to continue with their schedule of initial screenings. Children who failed
this second screening were referred to public health diagnostic audiology services. Children who failed the initial vision screening and rescreening (a visual acuity of less than 0.3 LogMAR (logarithm of minimum angle of resolution) in both eyes, or less than 0.4 LogMAR in one eye regardless of acuity in the other eye) were referred to primary health care facilities for a diagnostic optometric evaluation.

Parents were informed about their child’s referral by letter and reminded by telephone the day before the diagnostic evaluation. All follow-up services and interventions were provided by public health services, for example, hearing aids, spectacles or other medical intervention. CHWs kept a record of all costs incurred and challenges encountered and provided feedback to the project manager who tracked results and outcomes.

**Technology**

The mHealth technology platform (hearX Group, Pretoria, South Africa) synchronizes patient results between the cloud and the smartphone software. The smartphones host point-of-care hearing and vision screening apps. We used the mHealth evidence reporting and assessment checklist to review and report on our mHealth-supported programme.21

CHWs used the hearScreen app (hearX Group) on a Samsung A3 smartphone with the operating system Android version 8.0 (Google, Mountain View, United States of America), connected to supra-aural Sennheiser HD280 headphones (Sennheiser, Wedemark, Germany) that had been calibrated according to prescribed standards (International Organization for Standardization, ISO 389–1).28 We calibrated the app to monitor environmental noise with the smartphone microphone.14,23,24 Children who failed the initial screen and immediate rescreen were referred to a second screening, at which children were tested via the validated hearTest app29 for threshold testing on the same device across a wider range of frequencies (0.5–8 kHz).

The publicly available Peek Acuity application (Peek Vision, London, United Kingdom) was used to screen visual acuity on the same smartphone. This test follows the standard Early Treatment Diabetic Retinopathy Study chart design, using a Tumbling E optotype, and is capable of acuity measurements consistent with test–retest variability of acuities measured using 5-letters-per-line retro-illuminated LogMAR charts.8

Data collected by the smartphone were uploaded to the cloud storage through mobile telephone networks at the end of each test.23,24 We ensured the security of the mHealth app and server through use of local data encryption at rest using Advanced Encryption Standard
256 bit. We secured authentication with the server via the use of Secure Sockets Layer connections. We ensured that access to smartphone and cloud-based data were protected by user password.

**Data collection and analysis**

We extracted data from the secure cloud-based server to an Excel (Microsoft, Redmond, USA) spreadsheet for statistical analysis using Statistical Package for the Social Sciences software (IBM, Armonk, USA). Using Excel, we recorded and quantified test outcomes (pass or fail), test durations and the numbers being referred to and attending second screenings and diagnostic centres. We used logistic regression analysis to evaluate the association between screening outcome and age, sex and test duration for both vision and hearing screening; for hearing, we also evaluated the association between test outcome and excessive noise levels at each frequency. Significance was set at \( P < 0.05 \).

**Ethical considerations**

Ethical clearance was obtained from the Research Ethics Committee of the Faculty of Humanities of the University of Pretoria on 4 October 2017 (GW20170922HS).

**Results**

The 271 preschool centres participating in our study included a total of 10 362 children. Signed consent forms were returned for 8497 (82.0%) of these children and 8023 (94.4%) of eligible participants were in attendance on screening days to undergo hearing and visual screening (Table 1; Fig. 1 and Fig. 2). One in three (32.3%) parents completed the consent form in their mother tongue as opposed to English. An average of 500 children were screened each month, at a cost of 5.63 United States dollars per child (Table 2).

The number of children who failed the initial screen and rescreen was 435 (5.4%) and 170 (2.1%) for hearing and vision, respectively (Table 1). Hearing test failure was associated with longer test duration (odds ratio, OR: 1.022; 95% confidence interval, CI: 1.021–1.024) and noise levels exceeding maximum permissible ambient noise levels at the 1 kHz test frequency (e.g. for left ear, OR: 1.688; 95% CI: 1.198–2.377; Table 3), but not with sex (OR: 0.891; 95% CI: 0.702–1.131). CHWs failed to perform an immediate vision rescreen for 47 children and these children were assumed to have failed. Vision test failure was associated with a younger age (OR: 0.629; 95% CI: 0.520–0.761) and longer test duration (OR: 1.003; 95% CI: 1.002–1.005), but not with sex (OR: 0.928; 95% CI: 0.726–1.186). Mean initial test
duration for children who passed the screening was 59.2 and 91.2 seconds for hearing and vision, respectively (Table 1).

Of the 389 children who attended a second hearing screening, 124 (31.9%) failed the hearing test again and were referred for a diagnostic evaluation (Table 1). Of the 265 children who passed the second hearing screening, the audiologist referred 66 (24.9%) for wax removal at their local clinic. Of the 94 children who attended a diagnostic referral appointment, 54 (43.5%) were diagnosed with a hearing impairment and nine (7.3%) were discharged from audiology but referred for other developmental interventions; another five children have follow-up appointments to confirm hearing status (Table 1).

A total of 55 children were diagnosed with a visual impairment; however, 21 children were still awaiting diagnostic optometry appointments at the time of reporting (Table 1). Of the 8023 children screened, 111 (1.4%) were confirmed with either a hearing or visual impairment, or both.

Discussion
Our mHealth-supported community-based hearing and visual screening programme was successful in several ways. The programme had a low cost of screening per child, high participation numbers, high attendance of those who failed initial screening and immediate rescreening at the community-based second screening and overall low proportion of children receiving a diagnostic referral to a public health institution. The programme encountered several challenges such as CHW safety, logistics and technology, for which we developed mitigation strategies (Box 1).

Use of the same equipment and minimally trained staff to screen both hearing and vision contributed to the affordability and scalability of the service-delivery model (Fig. 3). The low cost per child for dual screening reported in this study (Table 2) could be reduced further as CHWs continue to gain experience and efficiencies are increased.

Employing CHWs from the community was invaluable for raising awareness with preschool centre staff and parents. Selecting communities where an existing public health pathway to intervention was already in place was another important factor contributing to the success of the model. A high informed consent return was supported by strong community involvement and the provision of simplified forms in local languages. The consent return could be further improved through a free text messaging service (Fig. 3).
Locating the second screening for hearing impairment at the respective preschool centre yielded a high proportion of attendance compared with an earlier project in which rescreening took place at public health care institutions (89.4% versus 39.4%). Although an improved hearing test failure rate was achieved from initial screening and rescreen by CHWs (435/8023, 5.4%) to second screening by audiologist (124/8023, 1.5%), with further training, this second screening could also be conducted by CHWs to reduce the costs further. By achieving a final overall proportion of 1.5% for hearing impairment referral, our programme reduced the number of referrals to resource-constrained public health institutions. We hypothesize that the high proportion of diagnostic appointment attendance (75.8%) was attributable to the early confirmation of initial screening results, reducing the amount of follow-up appointments, and the use of reminders sent to parents.

We identified background noise levels as a significant influence of screening outcome. Most of the failed hearing tests at which background noise levels were excessive (5624/6064, 92.8%) were recorded at the lowest pure tone test frequency (1 kHz); this issue could be addressed by increasing the hearing level (from 25 to 30 dB) to minimize noise interference at this test frequency.

Mean test duration for hearing screening (combined initial and immediate rescreen time) was shorter than for a previous study (66.8 versus 177.8 sec), because hearing level was only rescreened at frequencies failed in the initial screening. Longer test durations were associated with failed screening outcomes for both hearing and vision; this is because more test trials were required for true positives. Longer test durations associated with false positives were because of poor comprehension of instructions and delayed or incorrect responses.

The importance of an automatically initiated rescreen (included for hearing but not visual screening) was highlighted by the fact that 47 children were not immediately rescreened for vision due to tester error. Age did not affect results for hearing screening, but vision failure rates were twice as high in children aged 4 years compared with children aged 6–7 years, possibly because of a lack of comprehension or attention.

Our observed prevalence of hearing (0.7%) and visual (0.7%) impairments was lower than the previously published estimates for young children of 2.4% and 3.9%, respectively. This might be because children with impairments are potentially less likely to attend a preschool centre, are still awaiting confirmation of status or, in the case of more
severe impairments, have already been identified and are attending impairment-specific programmes. We could not find other published results with which to compare our observed prevalence of dual sensory problems. Although small, this prevalence highlights the importance of screening for both hearing and visual impairment; identifying an impairment in one modality does not predispose or preclude an impairment in the other.

Our study had limitations. No ophthalmic supervision was provided to CHWs and no measure of the quality of CHWs was available. A control group would have been valuable. The resource constraints in low- and middle-income countries were highlighted by the number of children still awaiting appointments at the end of the study period.9–11

Children with disabilities in LMICs are often unsupported without timely detection.9 In accordance with the leave no one behind movement that supports the sustainable development goals,5,38 we have shown that a decentralized mHealth-supported service-delivery system can provide increased access to hearing and vision services for preschool children in poor communities. Efficient design of such a system requires a holistic approach, including the use of digital technology, the training and monitoring of CHWs, the support of community partners and effective referral systems.

Future research should focus on evaluating the cost–effectiveness and impact of detection and intervention on educational and psychosocial outcomes; the perceived acceptability of such screening programmes to parents and caregivers; and the potential integration of other mHealth services, for example, developmental delay screening,39 towards a more comprehensive community-based service.

Acknowledgements
We thank the implementation partners, namely the Carel du Toit Centre and Trust, the Western Cape Department of Health and the Hear the World Foundation.

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Competing interests:
Stefan Launer is employed by Sonova AG, a Swiss manufacturer of hearing instrument technology. Andrew Bastawrous is CEO of not-for-profit Peek Vision. The relationship between De Wet Swanepoel and the hearX Group includes equity, consulting and potential royalties.
References


Box 1. Challenges and mitigating strategies of mHealth-supported community-based programme, South Africa, September 2017–December 2018

Safety in community: link to CHW WhatsApp group, with warnings about protests or high-risk areas to avoid on certain days; considering the cultural hierarchy, one CHW was a male.

Safety of equipment: arrangements were made at the local clinic to safely lock away equipment overnight.

Charging equipment: CHWs charged power banks at home and then used to charge devices overnight.

Noise levels in preschool centres: (i) mHealth monitored noise for quality control; (ii) tests were conducted in neighbours’ homes if the centre was too noisy, involving the community further; and (iii) future protocol for high-noise settings will involve screening at 30 dB (instead of 25 dB) hearing level at 1 kHz.

Absenteeism: (i) project administrator telephoned the preschool centre principal in advance to inform parents that children should attend on that day; (ii) staff fetched children from home or telephoned parents to bring children; and (iii) school and cultural holidays were avoided for screening, but used for CHW training and administration.

Travelling in community: the implementation partner (Carel du Toit Centre) provided a car allocated to community outreach for CHWs to use.

Language diversity: we appointed a diverse team of CHWs from the communities who could speak local languages.

Informed consent: we provided a simplified single-page consent form in multiple languages, as well as the option for parents to send a free text requesting a call from the project administrator.

Diagnostic follow-up attendance: parents were reminded of diagnostic appointments by telephone the week before the appointment, with the CHW emphasizing the importance of attendance, in the parents’ native language.

Technology: (i) CHWs informed the project manager of problems; (ii) we held retraining and problem solving during weekly meetings; and (iii) we reported challenges and suggestions to hearX Group for developers to consider.

CHW: community health worker.
Table 1. **Children screened for hearing and visual impairment via mHealth-supported community-based programme, South Africa, September 2017–December 2018**

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Children screened n = 8023</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hearing impairment</td>
</tr>
<tr>
<td>No. (%) who failed initial screening</td>
<td>2313 (28.8)</td>
</tr>
<tr>
<td>No. (%) who failed immediate rescreen</td>
<td>435 (5.4)</td>
</tr>
<tr>
<td>Of 3972 boys</td>
<td>205 (5.2)</td>
</tr>
<tr>
<td>Of 4051 girls</td>
<td>230 (5.7)</td>
</tr>
<tr>
<td>Of 1066 children aged 4 years</td>
<td>55 (5.2)</td>
</tr>
<tr>
<td>Of 3671 children aged 5 years</td>
<td>213 (5.8)</td>
</tr>
<tr>
<td>Of 3286 children aged 6–7 years</td>
<td>167 (5.1)</td>
</tr>
<tr>
<td><strong>Mean test duration (SD), sec&lt;sup&gt;b&lt;/sup&gt;</strong></td>
<td>66.8 (62.3)</td>
</tr>
<tr>
<td>Of those who passed</td>
<td>59.2 (44.2)</td>
</tr>
<tr>
<td>Of those who failed</td>
<td>200.2 (136.9)</td>
</tr>
<tr>
<td>No. (%) of those who failed immediate rescreen and attended community-based second screen</td>
<td>389 (89.4)</td>
</tr>
<tr>
<td>No. (%) of those who failed community-based second screen</td>
<td>124 (31.9)</td>
</tr>
<tr>
<td>No. (%) of total who received diagnostic referral</td>
<td>124 (1.5)</td>
</tr>
<tr>
<td>No. (%) who attended referral</td>
<td>94 (75.8)</td>
</tr>
<tr>
<td>No. (%) of total with confirmed diagnosis</td>
<td>54 (0.7)&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

NA: not applicable; SD: standard deviation.

<sup>a</sup> This number includes 123 children who failed the immediate rescreen plus 47 children who were erroneously not rescreened.

<sup>b</sup> Initial screen duration for vision; combined initial and immediate rescreen for hearing.

<sup>c</sup> 21 awaiting appointment.

<sup>d</sup> 5 awaiting confirmation.

<sup>e</sup> 8 awaiting confirmation.

<sup>f</sup> 11 awaiting confirmation.
Table 2. **Cost of screening for hearing and visual impairment via mHealth-supported community-based programme, South Africa, September 2017–December 2018**

<table>
<thead>
<tr>
<th>Service or goods</th>
<th>Total cost for programme</th>
<th>US$</th>
<th>Cost per month</th>
<th>Cost per child</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobile testing devices (four hardware sets)</td>
<td>4 163.78</td>
<td>260.24</td>
<td>0.52</td>
<td></td>
</tr>
<tr>
<td>Software (hearScreen, Peek Acuity)</td>
<td>4 404.80</td>
<td>275.30</td>
<td>0.55</td>
<td></td>
</tr>
<tr>
<td>Device calibration</td>
<td>499.69</td>
<td>31.23</td>
<td>0.06</td>
<td></td>
</tr>
<tr>
<td>Telecommunication</td>
<td>1 432.00</td>
<td>89.50</td>
<td>0.18</td>
<td></td>
</tr>
<tr>
<td>Salaries of CHWs (three screeners)</td>
<td>14 604.16</td>
<td>912.76</td>
<td>1.82</td>
<td></td>
</tr>
<tr>
<td>Salaries of CHW (both project administrator and screener)</td>
<td>9 759.04</td>
<td>609.94</td>
<td>1.22</td>
<td></td>
</tr>
<tr>
<td>Project management (including delivery of training course to CHWs)</td>
<td>3 560.32</td>
<td>222.52</td>
<td>0.44</td>
<td></td>
</tr>
<tr>
<td>Travelling (2.77 Rand per km)</td>
<td>4 243.84</td>
<td>265.24</td>
<td>0.53</td>
<td></td>
</tr>
<tr>
<td>Administration</td>
<td>1 545.60</td>
<td>96.60</td>
<td>0.19</td>
<td></td>
</tr>
<tr>
<td>Programme resources (stationary, power banks, posters)</td>
<td>968.80</td>
<td>60.55</td>
<td>0.12</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>45 182.03</strong></td>
<td><strong>2 823.88</strong></td>
<td><strong>5.63</strong></td>
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</tr>
</tbody>
</table>


- a Programme was running over 16 months.
- b Total number of children was 8023.
- c In April 2019, 1 South Africa Rand is equivalent to US$ 0.069.
Table 3. **Failed hearing tests because of maximum permissible ambient noise levels being exceeded at different test frequencies, South Africa, September 2017–December 2018**

<table>
<thead>
<tr>
<th>Ear</th>
<th>1 kHz</th>
<th></th>
<th></th>
<th>2 kHz</th>
<th></th>
<th></th>
<th>4 kHz</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. (%)</td>
<td>OR (95% CI)</td>
<td>No. (%)</td>
<td>OR (95% CI)</td>
<td>No. (%)</td>
<td>OR (95% CI)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>2816 (35.1)</td>
<td>1.688 (1.198–2.377)</td>
<td>144 (1.8)</td>
<td>1.772 (0.510–6.162)</td>
<td>80 (1.0)</td>
<td>0.534 (0.156–1.821)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>2808 (35.0)</td>
<td>2.770 (1.931–3.974)</td>
<td>128 (1.6)</td>
<td>1.835 (0.482–6.988)</td>
<td>88 (1.1)</td>
<td>1.790 (0.307–10.427)</td>
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</table>

CI: confidence interval; OR: odds ratio.
Fig. 1. mHealth-supported community-based screening for hearing impairment, South Africa, September 2017–December 2018

- 8023 children attending hearing screening at preschool centres
  - 5710 children passed screen
  - 2313 children failed screen
  - 2313 children immediately rescreened
    - 435 children failed screen
      - 389 children attending community-based second screen
        - 265 children passed rescreen
        - 124 children failed screen
          - 94 children attending diagnostic appointment at health-care centres
            - 35 children with normal hearing
              - 7888 children discharged
            - 54 children with hearing impairment, who receive interventions, and 5 children awaiting confirmation of diagnosis
          - 46 children not attending screen because of being absent on day of testing or having relocated
Fig. 2. **mHealth-supported community-based screening for visual impairment, South Africa, September 2017–December 2018**

8023 children attending vision screening at preschool centres

- 7757 children passed screen
- 96 children passed rescreen
- 46 children with normal vision
- 7889 children discharged
- 266 children failed screen
  - 219 children immediately rescreened
  - 47 children not rescreened and assumed to have failed
  - 170 children failed screen
- 109 children attending diagnostic appointment at health-care centres
- 55 children with vision impairment, who receive interventions, and 8 children awaiting confirmation of diagnosis
- 61 children not attending appointment
  - 21 children still awaiting appointments
  - 40 children did not attend appointment due to caregivers not bringing children or children have relocated

55 children with vision impairment, who receive interventions, and 8 children awaiting confirmation of diagnosis
Fig. 3. **Enabling factors of service-delivery model for hearing and vision care for preschool children, South Africa**

<table>
<thead>
<tr>
<th>mHealth Enabling Factors</th>
<th>Steps</th>
<th>Community Enabling Factors</th>
</tr>
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<tbody>
<tr>
<td>Pilot and Preparation Phase</td>
<td>Locate and Map Early Childhood Development Centres (ECD's)</td>
<td>Situational analysis</td>
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<td></td>
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<td>ECD principals forum</td>
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<td></td>
<td></td>
<td>Appoint and train CHW</td>
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<td>Findings from previous project</td>
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<td></td>
<td>Parental Consent</td>
<td>Partner with local NGO's</td>
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<td>Training and awareness at ECD's</td>
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<tr>
<td></td>
<td></td>
<td>CHW's familiar with context</td>
</tr>
<tr>
<td></td>
<td>Combined Sensory Screening (Hearing &amp; Vision) at ECD</td>
<td>Simplified version in multiple languages</td>
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<td>Empower ECD staff to be advocates</td>
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<td></td>
<td></td>
<td>Raise awareness, parents and children</td>
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<td></td>
<td>Second screen for hearing at ECD</td>
<td>Hearing and vision screened by CHW</td>
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<td></td>
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<td>Simple technology enables CHW to screen</td>
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<td></td>
<td></td>
<td>CHW: understand context, culture &amp; language</td>
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<td></td>
<td>Diagnostic Follow-up and Intervention</td>
<td>Train CHW to conduct rescreen (Future Implementation)</td>
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<td></td>
<td></td>
<td>Train CHW to identify and link children with other barriers to learning to support services (Future Implementation)</td>
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<td></td>
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<td>CHW phone parents before appointment: raise awareness</td>
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<td>Tracking by project manager</td>
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<td></td>
<td>Advocate for children with vision and hearing loss: support ECD staff with training to ensure inclusion</td>
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<tr>
<td>App: smartphone application; CHW: community health worker; mHealth: mobile health technology; SMS: short message service.</td>
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