

1 **Discovering the unmet needs of people with difficulties understanding speech in noise**
2 **and a normal or near-normal audiogram**

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4 Kiri Mealings¹, Ingrid Yeend¹, Joaquin T. Valderrama^{1,2}, Megan Gilliver¹, Jermy Pang¹,
5 Jason Heeris¹, and Pamela Jackson¹

6 ¹National Acoustic Laboratories, Sydney, Australia

7 ²Department of Linguistics, Macquarie University, Sydney, Australia

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9 Corresponding Author:

10 Dr Kiri Mealings

11 National Acoustic Laboratories

12 Level 5 Australian Hearing Hub

13 16 University Avenue

14 Macquarie University, NSW, 2109, Australia

15 Email: kiri.mealings@nal.gov.au

16 Phone: +61 2 9412 6731

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Abstract

Purpose: A proportion of people with a normal audiogram or mild hearing loss (NA-MHL) experience greater than expected difficulty hearing speech in noise. This preliminary exploratory study employed a design thinking approach to better understand the clinical pathway and treatment options experienced by this population.

Method: Exploratory survey data was analysed from 233 people with NA-MHL who had consulted a clinician and 47 clinicians. Qualitative analysis was performed on interview data from 21 people with NA-MHL and 7 clinicians.

Results: Results revealed that noisy environments, such as restaurants, were where many people experienced listening difficulties. Most people with NA-MHL were not offered a treatment option at their audiology appointment and their satisfaction with the appointment was diverse. Many clients reported frustration at being told that their hearing was “normal”.

Data from clinicians showed that there is no standard test protocol for this population, and most felt that they did not have adequate training or resources to help NA-MHL clients.

Conclusions: This study discusses the research needs regarding the experience of those with NA-MHL, their help-seeking behaviours, and treatment options. Understanding these needs is the first step to designing projects to improve the quality of life of this population.

42 Introduction

43 The most common and widely used test of hearing thresholds is pure tone audiometry.
44 However, the audiogram does not always reflect a client's real-world listening abilities. There
45 is a proportion of people who, despite having an audiogram showing normal hearing or mild
46 hearing loss (NA-MHL), experience greater than expected difficulty hearing speech in noise
47 and have unmet needs regarding the clinical pathway and treatment options (Zhao &
48 Stephens, 2007). Spankovich et al. (2018) found that 15% of adults with four frequency
49 average audiometric thresholds ≤ 25 dB HL in each ear had self-reported hearing difficulties.
50 Similarly, Tremblay et al. (2015) found 12% of adults with normal hearing (defined as
51 thresholds < 20 dB HL at 0.5, 1.0, 2.0, 3.0, 4.0, 6.0, and 8.0 kHz) had self-reported hearing
52 difficulties. In other studies, Kumar et al. (2007) reported 10% of people with normal hearing
53 at their clinic complained of hearing loss; Saunders and Haggard (1992) reported an
54 unpublished study by R.R.A. Coles showing that 5% of adults referred to ear, nose, and throat
55 clinics have normal hearing; and Hind et al. (2011) found that 5.1% of children and 0.9% of
56 adults referred to audiology clinics had normal hearing (defined as thresholds < 20 dB HL at
57 0.5, 1.0, 2.0, and 4.0 kHz).

58 Cases of people who have difficulty hearing speech in noise, despite having normal or
59 near-normal audiograms, have been documented since the mid-1900s by King (1954) and
60 Kopetzky (1948) and since 1992 the disorder has been referred to as King-Kopetzky
61 Syndrome (Hinchcliffe, 1992). Because normal audiometric results do not explain a client's
62 hearing difficulties, clinicians are often at a loss as to how to manage patients (Zhao &
63 Stephens, 2007). As a result, clients in the past have been reassured that they do not have a
64 hearing problem, or are told their issues are psychological (Zhao & Stephens, 2007).

65 Much of current audiology practice follows a bio-medical model of detecting,
66 measuring, and remediating biologically based impairments, rather than a bio-psychosocial

67 model (Pryce & Wainwright, 2008). The bio-psychosocial model takes into account the
68 social, psychological, and behavioural components of an illness (Engel, 1977) and has a focus
69 on understanding the client's subjective experience and how that can help diagnosis and
70 outcomes (Borrell-Carrio, Suchman, & Epstein, 2004). Instead of following the bio-medical
71 model, Pryce (2006) and Pryce and Wainwright (2008) took a qualitative approach
72 investigating these clients' clinical experiences and coping strategies. Pryce (2006)
73 investigated coping strategies used by people with NA-MHL and reported that proactive
74 coping strategies included directing speakers to adjust their behaviour, changing the
75 environment, disclosure, and humour. Reactive coping strategies included concentrating to
76 piece together the communicative message, bluffing, avoiding communication, asking for
77 repeats, and lip-reading. Pryce (2006) found that what determined whether a clinical
78 encounter was positive or not was whether an explanation that accounted for the symptoms
79 the client was experiencing was provided by the clinician. Coping ability was more positive
80 and successful in reducing emotional stress when the clinicians explained the disorder so
81 clients gained a better understanding of it. Reassuring a client that their hearing was not
82 impaired did not reduce distress, but instead increased emotional distress and fear, and came
83 across as dismissive. Clients were more likely to use strategies that reduce distress when they
84 felt that the problems discussed with the clinician had been acknowledged and given some
85 explanation.

86 Pryce and Wainwright (2008) further explored the clinical encounter of people with
87 NA-MHL. They found that positive encounters were characterised by the client feeling that
88 their problems had been taken seriously, and that the clinician had satisfactorily explained the
89 symptoms. Negative encounters were characterised by the clinician being dismissive, the
90 client being concerned that they had wasted the clinician's time, confusion about the purpose
91 and legitimacy of the diagnostic tests, questioning of test results, and increased anxiety about

92 alternative causes for the symptoms such as dementia or mental health problems. The authors
93 concluded that effective communication between client and clinician and acknowledging the
94 legitimacy of their disorder are key in determining the success of the clinical encounter.

95 Rehabilitation for people with NA-MHL is very varied, and there is no universal
96 management program for these clients (Zhao et al., 2008). Generally, a simple hearing aid
97 fitting will not help and a rehabilitative strategy is needed to help minimise participation
98 restriction (Zhao et al., 2008). Zhao et al. (2008) suggest that counselling and using hearing
99 tactics are the most relevant approaches for rehabilitation management for people with NA-
100 MHL. Counselling can help the client come to terms with their hearing difficulty and the
101 clinician can be a valuable support in helping the client adapt and manage their hearing
102 difficulties. Clients benefit most when the clinician assists them in developing coping
103 strategies rather than merely diagnosing a problem. Hearing tactics such as changing social
104 interaction and the physical environment, and observing the speaker can help the client hear
105 better in a noisy environment. The most important tactic for these clients is to improve the
106 signal-to-noise ratio and avoid reverberant conditions.

107 Another possible remediation strategy for people with NA-MHL but greater-than-
108 expected difficulty listening in noise is using a hearable. A hearable is a device that “fits in or
109 on an ear that contains a wireless link, whether that’s for audio, or remote control of audio
110 augmentation” (Hunn, 2016). Recently hearables have been rapidly growing in popularity.
111 Hearables can automatically improve the hearing experience of the listener by filtering out
112 background noise, and as they are less complex than hearing aids offer a cheaper option than
113 purchasing a traditional hearing aid. Nuheara (Nuheara Ltd., Perth, Australia) is an Australian
114 company that has developed IQbuds, which are earbuds that filter out noise. Hunn (2016)
115 reports that Nuheara are making the point that because the world is becoming increasingly
116 noisy, even those whose hearing is fine need help having conversations. Nuheara, like several

142 A design thinking approach was adopted in order to focus directly on the experiences
143 of the individuals suffering with the issue – in this case difficulty understanding speech in
144 noise. According to Yock et al., 2015, the needs finding stage of the design thinking identify
145 phase involves three activities: strategic focus, needs exploration, and need statement
146 development. The strategic focus of this study was to improve the listening-in-noise
147 difficulties experienced by people with NA-MHL and greater than normal difficulty hearing
148 speech in noise and assist clinicians who see this population. The needs exploration activity
149 aimed to identify the specific problems that require attention for these groups through
150 exploratory surveys, so results from a large number of participants could be collected, and
151 empathy interviews, so that people’s insights could be explored further in a smaller number
152 of participants. Exploratory surveys rather than validated questionnaires were used in this
153 preliminary investigation so that the questions could be tailored to this group and open ended
154 questions could allow participants to expand more on their insights. Empathy interviews were
155 conducted to understand the person’s thoughts, feelings, and motivations, so their behaviours
156 and needs could be better understood. The needs arising from the findings of the exploration
157 phase are presented in the discussion as ways to address problems in the population that
158 would provide a positive outcome.

159 *Participants*

160 Survey results were obtained from 1213 adults. Of these 1213, 1164 were from the
161 NA-MHL population and 49 were from clinicians. An information section at the beginning of
162 the survey assured the participant that their personal information and any data collected as
163 part of the research project would be treated as strictly confidential. At the end of the survey
164 participants had the option to sign up for an interview. Interviews were conducted either via
165 phone or in person, and were audio recorded and transcribed for later analysis. Participants
166 were read the National Acoustic Laboratories (NAL) privacy policy and gave either verbal or

167 written consent to the interview and having it recorded and transcribed. Links to the surveys
168 for the NA-MHL group and clinicians were circulated via social media, online forums, and
169 audiology newsletters. Nuheara participants were recruited separately via an email sent out to
170 all Nuheara clients worldwide. Interviews were requested with senior staff in hearing aid and
171 audio technology companies, as well as hearable startups. There were no incentives for the
172 participants to take part other than helping us with our research and being given the
173 opportunity to have their say.

174 NA-MHL Group

175 *Exploratory Survey*

176 As well as completing the survey, the criteria for inclusion in the NA-MHL group
177 survey data was that they had to be an adult who self-reported in the survey as having 1) a
178 normal audiogram or mild hearing loss, 2) difficulty hearing speech in noise, and 3)
179 previously seen a clinician about their hearing difficulties. This left 233 NA-MHL
180 participants (78 females). Sixty-seven were from the general population, and 166 were
181 recruited from the database of Nuheara.

182 *Interviews*

183 Interviews were conducted with a subset of 21 people (6 female) with NA-MHL.

184 Clinicians

185 *Exploratory Survey*

186 The inclusion criteria was that the participants had to be clinicians practicing
187 clinically with adult clients. Forty-nine clinicians completed the online survey but two were
188 excluded from the final sample as they worked solely with paediatric clients. The results of
189 the remaining 47 clinicians (36 female), aged 23-63 years are reported, although the number
190 of responses varied between items (minimum n = 39).

191 *Interviews*

192 Interviews were conducted with seven clinicians (4 female) whose main motivation
193 for participating was to advance the field and contribute toward future clinical developments.

194 *Exploratory Surveys*

195 The exploratory surveys were developed by the authors with questions selected to
196 specifically understand the experiences and needs of this population. The questionnaires were
197 not designed to be used as a validated survey tool, rather, they were designed solely for the
198 purpose of this exploratory study.

199 NA-MHL Group

200 The survey for the NA-MHL group is shown in Appendix A. It was divided into four
201 parts: about you; your hearing; your hearing test appointment; and following your hearing
202 test appointment. Questions in the ‘about you’ section included demographic questions and
203 filter questions to ensure the participant had a normal audiogram or mild hearing loss, had
204 difficulty hearing speech in noise, and had seen a clinician about their hearing difficulties.
205 Questions in the ‘your hearing’ section further characterised the participants’ hearing
206 problems, for example, if they asked people to repeat themselves when conversing in noisy
207 places. The ‘your hearing test appointment’ section included questions about the tests
208 conducted in the appointment and the participants satisfaction with the appointment and
209 treatment options. Finally, the ‘following your hearing test appointment’ section included
210 questions about the willingness of the participant to trial different treatment options,
211 questions about hearables, and a question asking about ideal solution/s.

212 Clinicians

213 The survey for the hearing health professionals (hereafter called clinicians) who see
214 NA-MHL clients in clinical practice is shown in Appendix B. It divided into four parts: about
215 you; about your NA-MHL clients; appointment/ rehabilitation process; and the future of NA-
216 MHL. The ‘about you’ section asked about the clinician’s gender, location, years of

217 experience, areas of clinical work and how they would describe the typical characteristics of
218 this group. The section ‘about your NA-MHL clients’ explored how many they see, what
219 ages, referral paths, their perception of clients’ difficulties including situations and
220 environments, their reasons for presenting, and how they describe their difficulties. ‘The
221 appointment/rehabilitation process’ section asked which assessment tools the clinician uses,
222 how the results are used to discuss treatment, treatment uptake, whether clients receive aural
223 rehabilitation and if not why not, which treatment options clients receive and effectiveness of
224 treatments, influences of clients’ decision to pursue or not pursue treatment, whether the
225 clinician recommends hearables, what outcomes are measured, clinician’s confidence in
226 recommending treatment, what form of rehabilitation would they prefer to provide, whether
227 they feel they have sufficient training to help this group, what is needed to better help this
228 group, barriers to rehabilitation services, and further comments about their experience with
229 NA-MHL clients. The final section, ‘the future of MHL’ elicits their view on NA-MHL
230 clients’ underlying problem, and asks for suggestions about the type of research they’d like to
231 see about issues for NA-MHL clients.

232 NA-MHL Group

233 The interview script for the NA-MHL group is shown in Appendix C. It was divided
234 into four parts: characterising your hearing difficulties; perceptions of yourself; the pathway
235 to the clinic; and rehabilitation. For the ‘characterising your hearing difficulties’ section,
236 participants were encouraged to share a story about a situation that they had experienced
237 difficulty hearing speech in noise, and were prompted about what they did, how they felt, and
238 what the impact was. For the ‘perceptions of yourself’ section, participants were asked if their
239 family and friends knew about their difficulties and if they had adapted their behaviour. The
240 ‘pathway to the clinic’ section asked the participant to describe their visit to the clinic and
241 comment on both how the results were explained and their feelings about them. The

242 ‘rehabilitation’ section asked if the participant had been offered any treatment options and
243 what their experience with the treatment was like. This section also explored what people
244 thought about traditional hearing aids, hearables, a remote microphone, and communication
245 training as possible treatment options.

246 Clinicians

247 The interview script for clinicians who saw clients with speech-in-noise difficulties
248 with NA-MHL is shown in Appendix D. It was divided into six parts: about you as a
249 clinician; your experiences with NA-MHL clients; the assessment; treatment options; clinical
250 insights; and further comments. The ‘about you’ section asked about their motivation to do
251 the interview, years as an audiologist and their current role. The ‘your experiences’ section
252 asked how frequently they saw NA-MHL clients, an example of a clinical experience with
253 one of them, and other appointments where things went differently. The ‘assessment’ section
254 explored the sorts of assessment tools they use to understand their NA-MHL clients’
255 difficulties, how helpful these tools are, the clinician’s confidence in making decisions, and
256 communicating the results. The ‘treatment’ question asked what rehabilitation tools they offer
257 and how comfortable they feel with these. It then sought their thoughts on four treatment
258 options (traditional hearing aids, hearables, remote microphones, and communication
259 training). The ‘clinical insights’ section asked for thoughts on the importance of the problem
260 and how well understood it is. Clinicians also had the opportunity to provide additional
261 comments or ask questions about the study which the interviewer would answer at the end of
262 the interview.

263 *Data Analysis*

264 Exploratory Surveys

265 Descriptive statistics were calculated using Excel 2016 (Microsoft Inc., Redmond,
 266 WA) and MATLAB (Natick, Massachusetts: The MathWorks Inc.). Open-ended questions
 267 were coded for key themes.

268 Interviews

269 A content analysis was used for interpreting the interview data with a focus on finding
 270 quotes that identified the unmet needs of the study groups as per the design thinking method
 271 (Yock et al., 2015).

272

273 **Results**

274 *Participant Demographics – NA-MHL Group and Clinicians*

275 Exploratory Surveys – NA-MHL Group

276 The ages of the 233 NA-MHL participants are shown in Table 1. Most participants
 277 (56%) were based in Australia or the United States of America (29%). The overall self-
 278 reported health of the participants was either ‘good’, ‘very good’, or ‘excellent’ (97%).

279 Table 1: Age distribution of NA-MHL group participants.

Age	Percentage of Participants
18-34	15%
35-64	67%
65+	18%

280

281 Exploratory Surveys – Clinicians

282 The majority of clinicians were based in Australia (74%), and the others in the United
 283 Kingdom (22%) and the United States of America (4%). Most of the clinicians’ main
 284 workplace was located in an urban setting (70%), while the others worked in regional (24%)
 285 and rural/remote area (6%). Table 2 shows the clinical experience of the clinicians. More than

286 half the clinicians worked exclusively in assessment and rehabilitation with adults (60%), and
 287 the others with a mixed paediatric and adult caseload (40%). Table 2 also shows the number
 288 of NA-MHL clients clinicians report seeing per month. Clinicians identified self-referral
 289 (79%), and the GP (66%), as the two main client referral pathways to a hearing clinic
 290 appointment. Referral via Ear Nose and Throat specialists (19%), nurses (6%) and
 291 workplaces (6%), were less frequent; other sources included speech pathologists,
 292 psychologists and the Department of Veterans' Affairs.

293 Table 2: Clinical experience of the participating clinicians and number of NA-MHL clients
 294 clinicians report seeing per month.

295

296

		Percentage of Clinicians
Clinicians' clinical experience	Inexperienced (≤ 5 years)	26%
	Experienced (6-20 years)	40%
	Very experienced (> 20 years)	34%
Number of NA-MHL clients clinicians report seeing per month	0-1	32%
	2-5	45%
	6-10	21%
	10+	2%

297

298 Interviews – NA-MHL Group

299 All participants who took part in the interviews for the NA-MHL group were adults
 300 from Australia who self-reported speech-in-noise difficulties despite having a normal
 301 audiogram or mild hearing loss, and had seen a clinician for their hearing difficulties.

302 Interviews – Clinicians

303 All clinicians who took part in the interviews were also from Australia. Six of the
304 seven clinicians who took part in the interviews had worked in the hearing field for 11-20
305 years in various roles including paediatric and/or adult diagnosis, assessment and
306 rehabilitation, higher education and research. Eighty-six percent estimated that they saw five
307 or less clients with NA-MHL per month, and 14% saw six to ten per month.

308 *Exploratory Survey Results – NA-MHL Group and Clinicians*

309 *The Experience of NA-MHL*

310 *Typical Characteristics of NA-MHL Group*

311 Clinicians typically described these clients as having normal audiograms or mild
312 high-frequency sensorineural hearing loss (61%), speech-in-noise difficulties (38%) and
313 associated issues including anxiety, fatigue and social withdrawal (30%). They also, but less
314 frequently, described them as presenting with a mismatch between subjective and objective
315 test results (13%); being less aware of their own hearing problem than others e.g., family
316 members (9%); and working in noisy environments (9%).

317 *Situations Related to NA-MHL Difficulties*

318 When clinicians were asked to rank seven common hearing difficulties reported by
319 clients with NA-MHL, situations involving listening to speech in background noise and
320 multiple talkers received the highest ranking. When asked to describe difficult
321 communication situations, clinician's and NA-MHL participants' responses referred to
322 features of both the environment and speaker. In most cases these descriptions of
323 environments specified physical locations (e.g., restaurants/cafes [27% of NA-MHL; 68% of
324 clinicians], shopping centres [3%; 15%], and bars/pubs [10%; 23%]) (see Figure 1).
325 Clinicians also described clients having difficulty in offices, especially when the design was
326 open plan (11%). The NA-MHL group also described more general features of the

327 environment that contributed to their difficulties (e.g., reverberant venues like classrooms
328 [4%] and windy places [2%]).

329 [Insert Figure 1 here]

330

331 Both groups made reference to social environments that were problematic. Thirty-
332 three percent of the NA-MHL group and 79% of clinicians described listening environments
333 with multi-speaker situations (including parties and groups) as difficult, with a number
334 mentioning family gatherings specifically.

335 Difficult situations were also described as resulting from features of the speaker. In
336 terms of speaker location, distance was noted by both groups (4% of the NA-MHL group and
337 8% of the clinicians), and speaker not facing the listener was an issue noted by 8% of the
338 NA-MHL group. The NA-MHL group also described difficulties relating to voice quality
339 (e.g., soft voice [6%], strong accents [3%], and unclear speech [3%]).

340 Situations including amplified speech was also noted as a problem for those with NA-
341 MHL. Both groups noticed difficulties with the TV (11% of NA-MHL group and 8% of
342 clinicians). Some NA-MHL group participants also mentioned listening on the phone (3%) as
343 well as loudspeakers in open spaces such as airports or train stations (1%).

344 *Reported Impacts of NA-MHL*

345 Impacts reported by clinicians and the NA-MHL group included both emotional and
346 social/behavioural impacts. Clinicians reported that clients described the biggest emotional
347 impact of hearing difficulty as experiencing frustration (48%), but also said it caused them
348 embarrassment (21%), anxiety/depression (14%), and stress and annoyance (11%). They
349 reported that the main functional (day-to-day) impact clients described was social (41%)
350 including isolation, reduced enjoyment, and feeling left out.

351 *Experiences of Seeking Help*

352 There were a number of reasons why people with NA-MHL were reported to have
353 had their hearing assessed. Two of the most common motivations for seeking a hearing test
354 described by both the NA-MHL group and clinicians were self-perception of hearing
355 difficulty (24%; 32%) and family pressure (14%; 43%).

356 Other reasons given by NA-MHL group participants included, employment/routine
357 health checks (21%), or for other hearing issues (e.g. surfers' ear, middle ear infection,
358 surgery; tinnitus; or family incidence of hearing difficulty). Approximately 4% of NA-MHL
359 group participants noted hearing assessment was opportunistic (e.g. a free hearing test in a
360 shopping centre).

361 Clinicians also reported work as a motivator for NA-MHL clients with 32%
362 describing visits resulting from difficulties clients were facing at work, and others noting
363 clients concerns that hearing difficulties would negatively impact their job security (e.g.,
364 police officer, bar worker). Clinicians also reported motivators of social isolation experiences
365 (27%), frustration (11%), and tinnitus (5%) by their NA-MHL clients.

366 *Assessment Tools*

367 Figure 2 shows the clinical tools clinicians find useful with NA-MHL clients; some
368 answers focused on diagnostics and some on treatment and rehabilitation options. This figure
369 shows that clinicians find speech-in-noise testing (44%), pure tone audiometry (37%) and
370 discussion of communication strategies and tactics (28%) the most useful clinical tools.

371 For NA-MHL group participants, nearly all reported recalling having an audiogram
372 (94%). However, fewer participants recalled speech-in-quiet testing (33%), and speech-in-
373 noise testing (22%). When asked whether the tests results explained their hearing difficulties,
374 37% of participants reported "yes-fully". The most common feedback received by
375 participants reporting partial-satisfaction (33%) or no-satisfaction (29%) was that 1) they did
376 not accept being told that their hearing was normal or normal for their age, and 2) the tests

377 were incomplete and not representative of their difficulty, particularly when a speech-in-noise
378 test was not conducted.

379 [Insert Figure 2 here]

380

381 A large proportion of NA-MHL participants (79%) reported that they were not offered
382 a follow-up appointment. Some participants recalled being told that follow-up was not
383 needed as there was little that could be done for their normal or (near-to-normal) hearing.
384 Other NA-MHL participants reported they believed that their disinterest in buying a hearing
385 aid influenced their clinician's decision to not offer a follow up.

386 Some follow-up appointments reported by the participants were due to reasons
387 unrelated to their NA-MHL experiences (e.g. wax removal, hearing aid fitting, yearly
388 review/work assessment.) A small number of participants did report follow-ups to track their
389 hearing performance over time to detect potential deterioration, and/or reported feeling that
390 the clinician was concerned for their welfare.

391 *Discussing Results*

392 Clinicians reported that they do not use the above mentioned tools to discuss hearing
393 and treatment options with their clients in a uniform or standardized way. When asked how
394 they used results to discuss hearing and treatment options with their NA-MHL clients, the
395 most common response was use of counselling about hearing and communication tactics
396 (60%) and stress and anxiety (7%). Some clinicians discussed either the potential
397 effectiveness of hearing aid/s, offered hearing aid trials (19%), or recommended ALDs
398 (12%), while others reassured their clients that their hearing was 'OK' (12%). Several
399 clinicians indicated that they refer clients for central auditory processing disorder (CAPD)
400 assessment (5%) or auditory training (2%). Ten clinicians mentioned that they explain the

401 measured results (e.g., speech test) and use these to lead into discussion related to the issues
402 the client reports and possible rehabilitation options.

403 *Satisfaction with Appointments*

404 Just over a quarter of NA-MHL group participants (26%) reported that they were
405 ‘very satisfied’ with their hearing appointment. A further 46% reported being ‘partially
406 satisfied’, and 26% reported being ‘not satisfied’. Reasons for satisfaction included the belief
407 that results accurately reflected hearing difficulties. For some, the lack of diagnosable loss
408 was itself viewed as a positive outcome and cause for satisfaction, particularly where the
409 assessment was work-related. Others reported that a ‘mild loss’ result provided a possible
410 explanation for their difficulties and was therefore positive.

411 In contrast, positive results were a reason for dissatisfaction for some participants.
412 They reported disappointment at the failure for their “good” results to account for their ‘real-
413 life’ difficulties, and the resultant lack of opportunities for recommended treatments.
414 Participants felt the options provided were limited and/or insufficient to solve their problems.
415 Some felt that the clinician pushed to sell hearing aids, and some mentioned that the cost of
416 hearing aids was prohibitive.

417 Participants also described concerns that testing was not comprehensive. Comments
418 included suggestions that testing was not sufficient to describe their difficulty or seemed
419 biased by the clinician’s interpretation.

420 *Experiences of Treatment*

421 *Treatments Offered*

422 Less than a quarter of participants recalled receiving any offer of treatment from
423 the clinician. Of these, the majority of recommendations (80%) were for a hearing aid.

424 Figure 3 shows participants’ willingness to use different options that may help
425 improve their communication experience. This figure shows that 1) the number of

426 participants ‘ready & willing’ to use hearables was significantly higher than those willing to
427 use hearing aids (62% vs. 32%); 2) a large number of participants (60%) were willing to try a
428 smartphone app used with earphones aiming to improve their communication experience in
429 noisy scenarios; and 3) the most popular options for willingness to use in the future was
430 hearing aids (46%) and an online communication training course (36%).

431 [Insert Figure 3 here]

432

433 When asked about their preferred solutions for improving their communication
434 experience, NA-MHL group participants often used words such as discreet, unobtrusive,
435 invisible, inexpensive, and easy-to-pair with smartphones. One participant described the ideal
436 solution as “*a very small device that is barely noticeable and is very comfortable to wear (i.e.
437 doesn’t block the ear canal). Blocks/cancels background noise, but not speech and allows
438 phone calls in noise. Low cost < \$1000*”.

439 *Treatment and aural rehabilitation options and uptake*

440 When asked whether, in their experience, NA-MHL clients typically receive any form
441 of aural rehabilitation approximately one third (30%) of the clinicians answered “no”, two
442 thirds (61%) answered “yes”, and the rest indicated they “don’t know”. Figure 4 shows the
443 reasons clinicians selected to explain why some clients do not receive any aural
444 rehabilitation. The top three were that clients were either not interested (31%) e.g., one
445 clinician wrote “*clients are reluctant to use devicesthey want a cure not a partial solution
446 that still relies on them having to use a device*”, not eligible (29%), or the clinician thought
447 that appropriate rehabilitation options were not available for this population (19%). A further
448 5% of clinicians indicated that affordability also affected whether clients received
449 rehabilitation and 14% answered they “don’t know”.

450 [Insert Figure 4 here]

451

452 Figure 5 shows the clinicians' estimate of the percentage of NA-MHL clients that
453 they see who do choose treatment (if offered). Fifty-one percent of the clinicians surveyed
454 estimated that $\leq 10\%$ of the clients that come to see them choose treatment for their speech-
455 in-noise difficulties. Clinicians suggested that cost (54%), self-perceived difficulty (30%) and
456 motivation (26%) were the main factors influencing the clients' decision to pursue treatment;
457 they also suggested that, to a lesser degree, the utility (5%) and appearance (7%) of devices,
458 client age (5%) and clinician recommendation/s (5%) played a role.

459 Clinicians estimated that clients choosing rehabilitation typically received one or
460 more of the following: counselling (79%), individual (49%) or group (9%) communication
461 training, hearing aid/s (49%) or other hearing devices such as ALDs (51%), remote
462 microphones (26%), hearables (19%) or referral to another service (23%). They also
463 responded that other rehabilitation included speech pathology, central auditory processing
464 disorder intervention, and internet and app 'training'.

465 [Insert Figure 5 here]

466

467 *Hearables*

468 Just over half (53%) of the clinicians who responded indicated that they never
469 recommend hearables to their NA-MHL clients and a further 24% rarely did. The proportion
470 of clinicians who sometimes, or often recommended hearables for these clients was
471 comparatively low (22%). One clinician disclosed that "*I was really excited about hearables*
472 *.... they are just so big I think they are unusable although there is a need for them.*"

473 *Treatment Outcomes*

474 For NA-MHL group participants using hearing aids, satisfaction was diffuse (see
475 Figure 6). Both satisfied and dissatisfied users reported some negatives associated with their

476 use (e.g. the cost-benefit was considered too low, practical difficulties of wearing devices
477 such as incompatibility with headphones/Bluetooth devices).

478 [Insert Figure 6 here]

479

480 Figure 7 illustrates clinicians' opinion about how effectively seven potential treatment
481 options (hearing aids, other hearing devices, counselling, individual or group communication
482 training, hearables and remote microphone) address the speech-in-noise difficulties
483 experienced by people with NA-MHL. Overall, the majority of clinicians rated hearing aids,
484 other hearing devices, counselling and individual communication training as either 'a little'
485 or somewhat effective' but were 'unsure' about the effectiveness of group communication
486 and hearables. Remote microphones were most frequently rated as either 'somewhat' or 'very
487 effective'.

488 [Insert Figure 7 here]

489

490 *Measurement of Rehabilitation Outcomes/Success*

491 Clinicians measured the outcomes or 'success' by measuring client satisfaction
492 (74%), Client Oriented Scale of Improvement (COSI; National Acoustic Laboratories) goals
493 (55%), family member feedback (53%), questionnaire (30%) and speech tests (26%). One
494 clinician indicated that they do not measure outcomes, another that they do not hear back
495 from clients, and another that none of their clients had accepted treatment.

496 Figure 8 shows the level of confidence clinicians felt that their recommended
497 treatment options address NA-MHL client concerns. Thirty-three percent and 31%
498 respectively fell in the middle quartiles, while 25% fell in the bottom quartile (least
499 confident) and only 13% fell in the top quartile (most confident).

500 [Insert Figure 8 here]

501

502 Approximately one third (32%) of the clinicians indicated that ideally, of seven
503 potential treatment options (none, hearing aids, other hearing devices, counselling, individual
504 or group communication training, referral), they would prefer to provide other hearing
505 devices to this population. The remaining clinicians preferred counselling (18%) and
506 individual communication training (16%) and a further 11% selected hearing aids. None of
507 the clinicians surveyed considered no treatment as an ideal option and 16% said that they did
508 not know what treatment they would prefer to provide.

509 *Clinical Services*

510

511 *Training and resources*

512 Only a small proportion of clinicians (18%) felt that they had appropriate training and
513 resources to assist NA-MHL clients, and many clinicians (44%) indicated that both their
514 training and resources were inadequate. Others felt either their training (4%) or resources
515 (45%) were inadequate, and the remainder were unsure (9%).

516 When asked for their ideas about what underlies NA-MHL clients' speech-in-noise
517 difficulties, clinicians suggested numerous potential aetiologies. The most common were
518 auditory processing (49%), extended high frequency hearing threshold levels (2%), cochlear
519 synaptopathy or neural pathway deficits (17%), cognition (22%) and psychosocial issues e.g.,
520 motivation, anxiety or stress, expectations (10%). Other miscellaneous suggestions included
521 mild hearing loss, other health conditions, poor communication tactics and distracting
522 technology and the surrounding listening environment.

523 *Clinician needs and barriers to providing rehabilitation services*

524 In order to better help NA-MHL clients, clinicians said they needed evidence-based
525 clinical tools and guidelines (including ecologically valid speech-in-noise tests) (46%),
526 further training and education (34%) about NA-MHL, access to the latest devices and

527 technology (including online training options), improved counselling skills (22%) and
528 resources such as information handouts/leaflets (17%) to give their clients.

529 Clinicians reported that the main barriers they encountered to providing rehabilitation
530 services to NA-MHL clients related to eligibility, funding, and costs (51%). Other barriers
531 included their own clinical inexperience with and lack of knowledge of NA-MHL (22%),
532 lack of evidence based tests and solutions (12%) and the clients motivation to undergo
533 rehabilitation (12%).

534 *Future research suggestions*

535 Clinicians suggested a number of avenues for future research including the
536 development of speech-in-noise assessment tools and advanced hearing aid options, random
537 control trials assessing the effectiveness of different treatment options and outcomes for this
538 population. For example, one clinician surveyed answered that “*it would be useful to have*
539 *research that could lead to an evidence-based test battery, guidelines for management, and*
540 *effective rehabilitation programs*”.

541 ***Interview Results – NA-MHL Group and Clinicians***

542 *The Experience of NA-MHL*

543 In interviews, participants discussed the emotional impact of NA-MHL in relation to
544 their quality of life. Participants described the additional effort required to navigate
545 conversations, including the need to ask for repeats, which could lead to anxiety and less
546 enjoyment of conversations. For example, one participant said “*I find myself concerned if I*
547 *know I’m going to be going to an event where this sort of situation is likely to arise. Not*
548 *agitated, but more feeling like I have to put my armour on a bit and go, okay, well you gotta*
549 *prepare yourself, this is going to happen, and steel myself. And it does take some of the*
550 *pleasure of being around people*”.

551 One participant noted that they took on the responsibility and effort of navigating the
552 communication rather than acknowledging difficulties or tasking the speaker with lengthy
553 repeats: *“I don’t say to people that I can’t hear or I’m having difficulty hearing. In a crowded
554 situation it usually ends up me just saying, “would you mind repeating that, I missed that
555 bit”. Whereas I could have missed the whole conversation. But I generally try to find a way
556 of picking up bits and pieces interpolating what the rest of it must have been”*.

557 As reported by one participant, missing information in conversations provoked
558 frustration, and anxiety about potential misinterpretation/s of their reactions: *“Often the
559 partner is the only one who can be brutally honest with you – saying didn’t you hear them?
560 They were talking to you and you’re just completely ignoring them. I wasn’t aware of a
561 conversation or someone asking the question, and I was horrified to think that I was
562 completely rude”*

563 As a consequence, NA-MHL participants reported making changes in their behaviour,
564 preferences, or daily routines: 1) *“It just makes me feel disinclined to go out, and when I do
565 go I tend to avoid restaurants and cafes and anything which is likely to be a crowd of people,
566 unfortunately”, 2) “And there’s this huge crowd of people in the place and I pretty much I
567 gave up trying to hold a conversation with anyone because there’s just so much background
568 noise that it’s, you know, I have difficulty making out what people are saying or holding an
569 intelligent conversation”*.

570 Experiences of Seeking Help

571 Interviews with the NA-MHL group revealed that the current test battery does not
572 reflect the real-world problems they are having. One participant remarked *“Because I was
573 being tested in the environment that’s just like a clinic, basically, there was no background
574 noise ... it’s not the same as being in a noisy bar and be able to make an actual
575 conversation.”*

576 Interviews with clinicians further highlighted that there is no evidence-based
577 appointment test protocol or guidelines available and clinicians provide different explanations
578 and advice based on similar test results. For example, one clinician said “...*there is an issue*
579 *that people have, where they have normal hearing, but still can't cope well, and it's a bit sad,*
580 *there isn't really a test that we have available for clinicians to use to show whether someone*
581 *has an abnormally high difficulty with noise compared to other people*”. Another said “*I try*
582 *to help them understand the way the hearing system works, how noise works in the world and*
583 *why they absolutely could be experiencing this and I suppose also that it is very personal. I*
584 *let them know that I could have five people with the same test results and they are all going to*
585 *have a very individual experience.*”

586 In the survey results reported previously, only a small number of participants reported
587 follow-up appointments with their clinicians. However, in the interviews one clinician did say
588 “*I always recommend they come in for a free screening every twelve months. It gives an*
589 *opportunity to monitor hearing and let them know if any new technology has come on the*
590 *market*”.

591 Experiences of Treatment

592 Clinicians felt that they did not have rehabilitation options that they were confident in.
593 An interview with one clinician revealed “*I quite often feel that I am not doing a really good*
594 *job because they (clients) come in wanting an answer and I can't give it to them.*” Another
595 said “*I guess not that confident, I think you do kind of feel helpless with this population*
596 *because you don't know what's going to help them, or why they're having greater difficulties*
597 *than they necessarily should be having.*”

598 Interviews with the NA-MHL group also revealed that there is a lack of treatment
599 options for this population, and in particular that clinicians said that hearing aids were not
600 needed as their hearing loss was not great enough. One participant said, referring to their

601 clinician, *“She said basically there’s nothing needed. Because [the hearing loss] was only in*
602 *a couple of minor frequencies, she said you’d hardly even notice it. It’s not at the stage where*
603 *we’re looking at devices or anything to deal with it because she said even if you got fitted*
604 *with the hearing aid or something you probably wouldn't even notice the difference, it’s that*
605 *minor.”* Another participant remarked that *“At that stage, it wasn't at a point where the*
606 *audiologist thought you really need hearing aids, it was more you will need them at some*
607 *point, or you will find them beneficial at some point, but it's touch and go as to whether you*
608 *need from now.”*

609 Additional Experiences

610 Participants from the NA-MHL group highlighted the need for increasing public
611 awareness of their hearing difficulties, improving the design of public venues, as well as
612 promoting healthy hearing habits that would prevent hearing deterioration. As reported by
613 different NA-MHL participants: 1) *“One thing that has occurred to me is like, why there's*
614 *just not more public education and public awareness of the difficulty of some people unable*
615 *to hear in really noisy places; and why it's necessary for venues to have the music turned not*
616 *so loud. You know, for cafes as well... it just feels very the trend in, you know, public bars*
617 *and restaurants and stuff like that, it's just not enough consideration given how noisy a place*
618 *is when you fill it with hundreds of people, and live music, and whatever, you know, like*
619 *chairs that make lots of noise.”*; and 2) *“It’s almost like no thought at all is given to the*
620 *auditory experience and being in a public space these days.”*

621 Future research suggestions

622 Similar avenues for future research were identified in the interviews as the surveys,
623 for example, one clinician reflected in an interview that *“it would be useful for clinicians if*
624 *we had an assessment tool to figure out if someone has poorer than normal speech in noise”*.

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Discussion

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We explored the perspectives of people with NA-MHL and greater than expected difficulty listening in noise and clinicians in order to better understand their experiences of the clinical pathway and treatment. We found that the clinicians' insights resonate with the NA-MHL group lived experiences. Through a design thinking approach, using exploratory surveys and interviews, we identified a number of research needs which would inform clients and clinicians dealing with NA-MHL. We grouped these into three main areas: the experience of NA-MHL, help-seeking behaviours, and treatment. Some of the needs relate to basic research (in terms of describing and understanding the underlying processes), while others are linked to more practical, applied research (particularly in relation to assessment and treatment).

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The Experience of NA-MHL

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This study found that clients and clinicians described features of difficult listening environments, and the lived experience and impact of NA-MHL, similarly. These features relate to the physical characteristics of the environment itself, and more general attributes of the speaker. Background noise involving conversation with other talkers was a primary source of listening difficulty, a finding consistent with Pang et al. (2019) and with laboratory-based investigations reporting poorer speech-in-noise test performances when target speech was masked by other speech sounds relative to speech-shaped noise (Hornsby et al., 2006; Desjardin & Doherty, 2013). Our NA-MHL group also indicated that general features in the physical design of difficult listening environments (for example reverberant and open-plan spaces), and the inherent nature of social events (which generally features substantial speech-based background noise) are problematic (see also Hall III et al., 2002; Hornsby et al., 2006; Mattys et al., 2012). Collectively, this informs the need to encourage the design and building of public spaces in such a way that communication is optimised. Additionally, there appears

651 to be a need to characterise the acoustic environment and ease-of-communication in crowded
652 public venues such as restaurants and clubs in order to provide adults with speech-in-noise
653 difficulties (and the broader community) with an indicator of their potential hearing
654 experience in those places.

655 Characteristics

656 In asking participants and clinicians about their experiences, the authors attempted to
657 form an understanding of NA-MHL and its impact. The experiences described by the NA-
658 MHL group and clinicians provide important insights about needs requiring attention in both
659 the help-seeking and treatment stages.

660 The experiences also inform the need for defining the group, not just in relation to
661 behavioural test findings (such as audiograms, speech-in-noise test results), but also
662 psychosocial characteristics. Both clients and clinicians were clear that a discrepancy exists
663 between behavioural test results and self-reported hearing difficulties, which is consistent
664 with findings of several other researchers (Alicea & Doherty, 2017; Spankovich et al., 2018).
665 This emphasises the importance of conducting basic research to form a consensus, and
666 develop accurate criteria for defining and characterising the NA-MHL population in order to
667 promote effective communication between clients and clinicians, leading to appropriate
668 treatment/remedial measures.

669 Impacts

670 Reduced enjoyment of social activities, frustration, anxiety, and withdrawal and
671 isolation are some of the emotional and social impacts reported by our NA-MHL group,
672 which in some cases resulted in changes to social behaviour and preferences. These
673 emotional and social impacts are also reflected in previous studies of those with normal
674 hearing thresholds but difficulties listening in noise (Alicea & Doherty, 2017; Hornsby &
675 Kipp, 2016). However, in practice, little has been done to address this and appointments are

676 often clinician-centred, with a substantial amount of time spent providing technological
677 solutions to hearing difficulties rather than addressing the psychosocial needs of clients
678 (Meyer et al., 2017; Grenness et al., 2014). Increasingly, the importance of understanding and
679 addressing the psychosocial impacts of hearing difficulties is being acknowledged and
680 integrated into more holistic models of hearing health care in order to improve clinical
681 outcomes for those with hearing difficulties (Heffernan et al., 2016; Ekberg et al., 2014).

682 *The Experiences of Help Seeking for NA-MHL*

683 It is noteworthy that the two main motivations for seeking hearing assessment in our
684 NA-MHL group were self-referral (24%), and family pressure (14%). Other reasons for
685 seeking help included employment requirements, other auditory complaints, and unplanned
686 opportunities to get a hearing assessment e.g. a free hearing test in a shopping centre. Given
687 that self-assessment and help-seeking behaviour is one of the most robust predictors of
688 intervention uptake, an opportunity exists to implement more effective strategies that would
689 motivate the remaining 72% of those receiving assessment for reasons other than self-referral
690 or an opportunistic test. This has additional implications for client-clinician engagement, and
691 the potential to influence intervention decisions and hearing health outcomes (Laplante-
692 Levesque et al., 2011; Poost-Foroosh et al., 2011; Pryce et al., 2016). Furthermore, clients'
693 readiness to seek help for hearing difficulties should not be misconstrued as readiness to
694 engage in treatment (Claesen & Pryce, 2012).

695 Assessment Tools

696 Our results indicated that at the very least clinicians and clients require improved
697 assessment procedures and ideally the development of standardised clinical assessment
698 protocols. In order to be effective, these need to take into account the NA-MHL group's
699 functional difficulties in addition to their objective listening performance results. Such an
700 approach would enable more effective monitoring and provide justification for follow-up

701 appointments. Better quality methods would likely also improve the NA-MHL group's
702 confidence in hearing assessment procedures, although this should not preclude assessing
703 hearing difficulties from the clients' perspectives, including their motivation and reasons for
704 seeking help (Claesen & Pryce, 2012). For many years, researchers have sought to investigate
705 NA-MHL within the context of a bio-medical model, but have yet to reach a consensus
706 regarding the underlying nature and experience of the hearing difficulty. Future research
707 efforts may be better directed towards the importance of managing the symptoms and
708 addressing the functional impacts of this population (Pryce & Wainwright, 2008; Bramhall et
709 al., 2019; Convery et al., 2019).

710 *Satisfaction with Appointments*

711 The majority of our NA-MHL group expressed dissatisfaction with the outcomes of
712 the assessment appointment, which for some, resulted in limited recommended treatment
713 options. In part, this stemmed from the belief that the current test battery is unable to fully
714 account for the difficulties the clients present, and that there is heterogeneity of advice based
715 on similar test results. A converging pattern of responses was observed in a study by Pryce
716 and Wainwright (2008) who investigated help-seeking for medically unexplained hearing
717 difficulties. They reported that confusion (with respect to reason for testing), questioning of
718 test results (on the basis of validity and sensitivity of the assessment tool), and dismissal (the
719 notion that symptoms are not recognised or accepted as legitimate) were some of the salient
720 characteristics of 'negative consultations', which are also seen as barriers to the coping
721 process for clients. Moreover, when discussion of test results are clinician-led rather than
722 client-focused, clients' preferences were not heard (resulting in lack of shared decision-
723 making), and expectations not met. Therefore, an opportunity exists to develop better
724 guidelines for explaining results to the NA-MHL group, and to enhance clinicians
725 communication and empathic listening skills as a means of validating and addressing clients'

726 concerns thus facilitating client-clinician interactions (Pryce & Wainwright, 2008; Laplante-
727 Levesque et al., 2011; Ekberg et al., 2014; Pryce, 2015; Convery et al., 2019).

728 *The Experience of Treatment*

729 Perhaps unsurprisingly, many clinicians do not feel confident recommending
730 treatment, as there is very little research on the efficacy of remedial options for this
731 population (Pryce, 2015). This informs the need to gather evidence about the effectiveness of
732 different treatment options to increase clinician confidence in addressing clients presenting
733 concerns.

734 Treatment Offered

735 Clients reported a diverse range of satisfaction with treatment options offered, and
736 that these were in contrast to their own treatment preferences. This may reflect a lack of
737 client-clinician engagement in our NA-MHL group, as it is known this relationship directly
738 influences the level of agreement about treatment plans, irrespective of clients' willingness to
739 use it (Adams et al., 2012; Convery et al., 2019). Additionally, clinicians from our study felt
740 that their recommendations played a minor role in clients' decision making, which
741 contradicts what we know from this research.

742 Less than a quarter of participants recalled receiving any offer of treatment from
743 the clinician. Of those that were offered treatment, the majority (80%) of recommendations
744 for this group involved hearing aids. This occurred even though there is currently limited
745 evidence supporting the benefit of hearing aids for those with NA-MHL (Roup et al., 2018)
746 and despite the body of literature indicating that providing this population with informational
747 counselling, and personalised communication strategies to reduce communication disruption,
748 particularly in environments where listening difficulties occur, is proven to be helpful (Borg
749 & Stephens, 2003; Claesen & Pryce, 2012).

750 The NA-MHL group's preferred treatment often takes into consideration factors such
751 as costs, appearance, and compatibility with smartphones, which is in contrast to clinicians'
752 impression that the main factors that influence treatment uptake are motivation, self-
753 perceived difficulty and costs. This mismatched perception of personal factors that contribute
754 to the decision making process for treatment acceptance may be a barrier to successful
755 treatment. Furthermore, clinicians revealed that uptake of treatment is very low for the NA-
756 MHL population due to number of reasons that includes disinterest, reluctance, lack of
757 suitable treatment options, and affordability. For clinicians, this signals the need to modify
758 their approach to identifying treatment needs from the clients' perspective in order to
759 encourage a more co-operative relationship and facilitate compliance to treatment.

760 *Treatment Outcomes*

761 Only 13% of clinicians felt confident that their recommended treatment options
762 address NA-MHL client concerns. Clinicians commented that they feel unsure about what is
763 going to help a client with these difficulties. This is not just true for clinicians; Pang et al.
764 (2019) found that 43% of people experiencing difficulties hearing speech in noise indicated a
765 lack of awareness of remediation tools available. Therefore there is a need to evaluate
766 treatment options to provide an evidence base of what interventions may help this population.
767 To date there has not been much research in this area except Roup et al. (2018) who recently
768 investigated mild-gain hearing aids as a treatment option for adults with a normal audiogram
769 but self-reported hearing difficulties in complex listening situations. Roup et al. (2018) found
770 significant improvements in the participants' self-reported hearing difficulties and their
771 speech-in-noise performance when using the device. This study recognised, however, that it
772 did not include a placebo control group, so we are now conducting a study to assess if there is
773 a placebo effect.

774 Hearing aids are not the only potential solution for people with NA-MHL. Clinicians
775 also noted other hearing devices, counselling, and communication training as options for this
776 population. In fact, approximately one third of the clinicians indicated that they would prefer
777 to provide other hearing devices to this population. Therefore more research is needed to
778 assess if other hearing devices such as hearables can benefit people with NA-MHL.
779 Interestingly, Pang et al. (2019) found this population actually preferred the idea of
780 communication training over devices as a remediation option, so future research into the
781 efficacy of training is also needed.

782 There is also a need to understand why some options may work better for some clients
783 than others, and characterise what aspects affect a particular client's success from the
784 treatment. This will help predict which option a client may benefit from most. Furthermore,
785 there is a need to evaluate individuals' desire to use treatment and their acceptability of
786 technological solutions. Many NA-MHL participants commented that they wanted a discreet
787 option, so it is important that this is taken into consideration by the clinicians so they are
788 suggesting options that the client would be comfortable using. There is also a need to develop
789 better training/support for clinicians to work with clients through their treatment pathway.

790 *The Design Thinking Approach*

791 Using a design thinking approach differs from much of the current research in the
792 field. Most research focuses on the bio-medical model of detecting, measuring, and
793 remediating biologically based impairments, rather than understanding the needs and
794 experiences of the individual. The advantage of using a design thinking approach is that it
795 allows researchers to understand aspects of a problem via direct communication with those
796 involved. This is the first step to finding new solutions that can address the problem (Yock et
797 al., 2015). The design thinking approach in the current study provided insight into the daily
798 lives of those experiencing speech-in-noise difficulties and the clinicians who see these

799 people. This allowed us to identify the needs to address these issues as discussed above.
800 Understanding this population's needs is the first step to designing effective projects that may
801 eventually improve their quality of life.

802 *Limitations*

803 While design thinking provides helpful insight into the issues that need to be
804 addressed from the people experiencing the problem, it has its limitations. For example, it
805 deals with the symptoms that people are experiencing rather than addressing the underlying
806 mechanisms that are causing the problem. Therefore, using a design thinking approach along
807 with a bio-medical model approach is important so that both aspects of the problem are
808 addressed. This study also had other limitations. We surveyed two different NA-MHL
809 groups: sixty-seven of the participants were from the general population, but 166 were
810 recruited from the database of Nuheara, a hearables company. The responses between the two
811 groups were similar, but it is important to note the selection bias as the Nuheara group are a
812 unique population. Most of the Nuheara participants were male (84%) and middle-aged, so
813 caution is required when generalising the results to the general population. This group also
814 had a bias of experiencing a specific product and its marketing. Another limitation is the use
815 of self-reported surveys. Self-report studies have validity issues as they rely on people's
816 accurate judgement and memory of events. This is also an issue in using interview data as
817 participants might either exaggerate or understate their symptoms, or misremember
818 situations. Ecological momentary assessments where a person fills out a survey on their
819 phone while they are in the event is one way of minimising this issue which could be used in
820 the future. Additionally, the surveys were not piloted or validated as this is not part of the
821 exploratory design thinking process. It may therefore be useful to conduct a follow-up study
822 with that includes the assessment of validity and reliability of the questionnaires. Further, this
823 study had a focus on hearables as potential interventions for this population as hearables are

849 individual situation. Consequently, there is a need to evaluate different treatment options for
850 different individuals to determine which option a client may benefit from most. Addressing
851 these needs and those discussed in the paper may help improve the quality of life of people
852 with NA-MHL and help clinicians diagnose, support, and provide appropriate rehabilitation
853 strategies for the population.

854

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858

859 **Data Accessibility Statement**

860 Data will be made available upon reasonable request.

861

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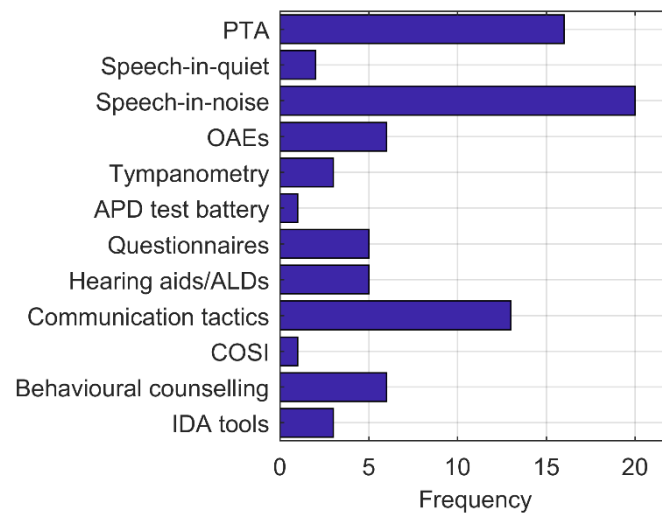
Figures



981

982 Figure 1. Listening environments clients report most difficulty in according to clinicians.

983



984

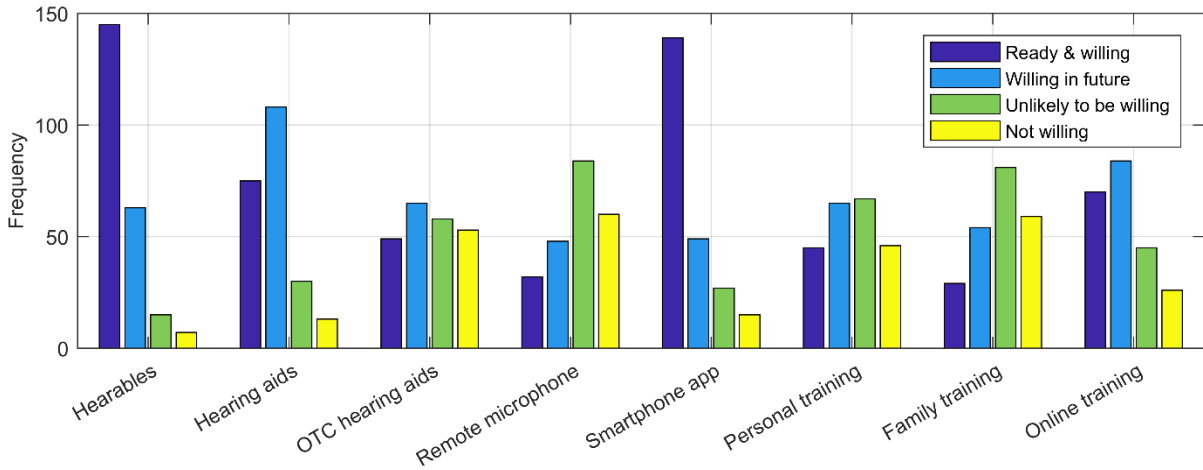
985 Figure 2. The clinical tools clinicians find useful with clients with a normal audiogram or

986 mild hearing loss (NA-MHL) clients. ALDs, assistive listening device; APD, auditory

987 processing disorder; COSI, Client Oriented Scale of Improvement (National Acoustic

988 Laboratories); IDA, Idainstitute; OAEs, otoacoustic emissions; PTA, pure tone audiometry.

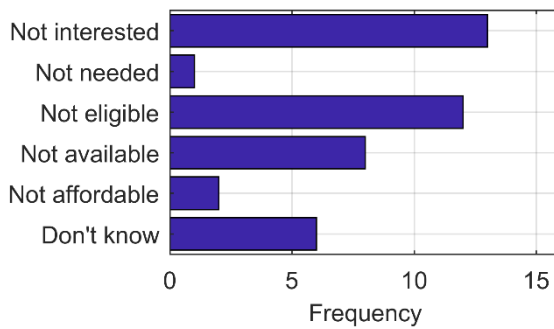
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991 Figure 3. Number of participants willing to use different options that aim to improve their
 992 communication experience. OTC, over the counter.

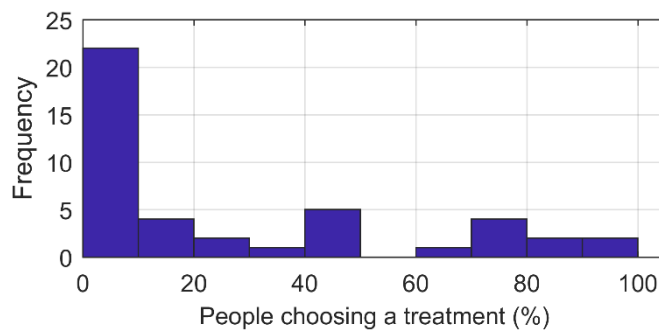
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995 Figure 4. Number of clinicians reporting different reasons that explain why clients with a
 996 normal audiogram or mild hearing loss (NA-MHL) do not receive aural rehabilitation.

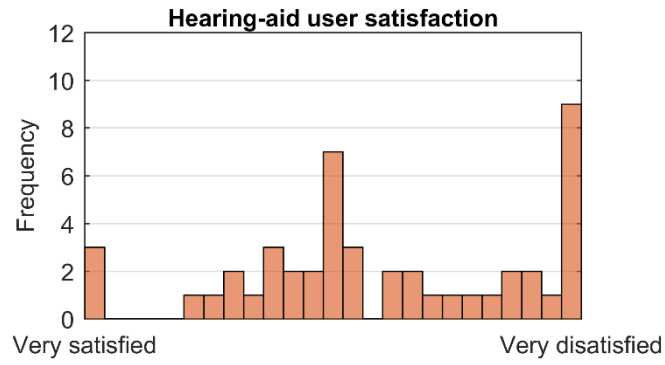
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999 Figure 5. Number of clinicians reporting the percentage of clients with a normal audiogram
 1000 or mild hearing loss (NA-MHL) who, if offered, choose treatment.

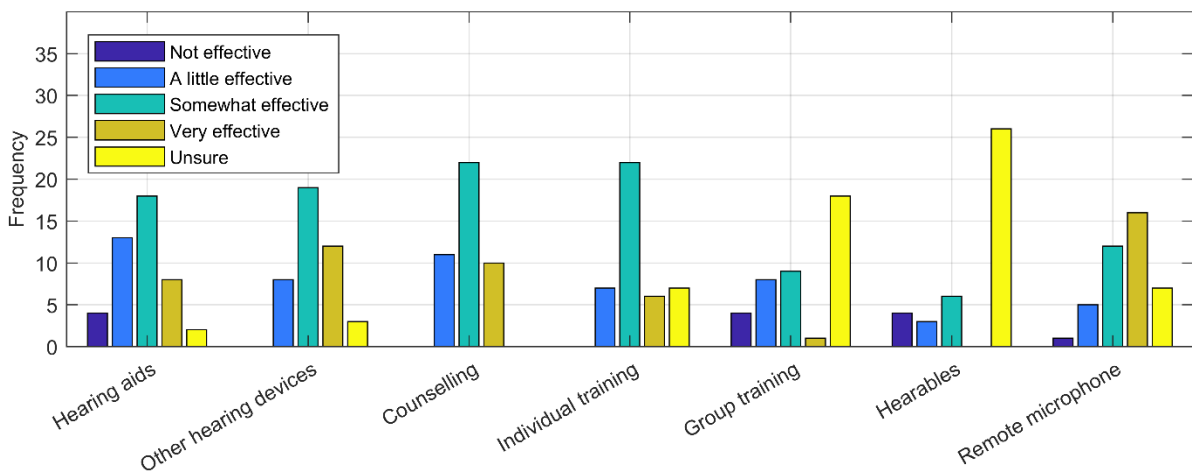
1001



1002

1003 Figure 6. Number of participants reporting different levels of hearing aid satisfaction.

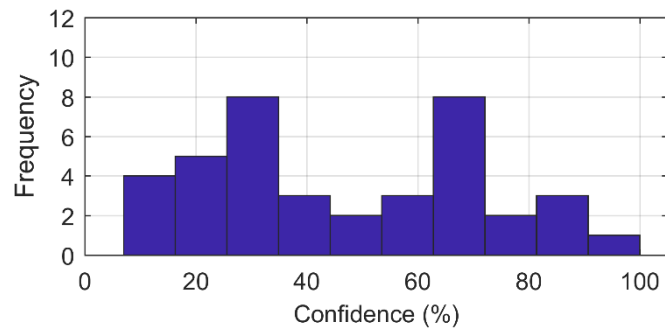
1004



1005

1006 Figure 7. Clinicians estimate of effectiveness of treatment options for clients with a normal
1007 audiogram or mild hearing loss (NA-MHL) and speech-in-noise difficulties.

1008



1009

1010 Figure 8. Clinicians' confidence that treatment options address concerns of clients with a
1011 normal audiogram or mild hearing loss (NA-MHL).

1012

1013

Appendix A – NA-MHL Group Survey

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1048

1) Do you have difficulty understanding speech in noisy environments?

- Yes
- No

2) Have you had a hearing test before?

- Yes
- No

3) How did your audiologist/clinician describe your hearing test result?

	Normal	Mild	Moderate	Severe/Profound	Unsure
Left Ear	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Right Ear	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

4) Are you:

- Female
- Male
- Indeterminate/intersex/unspecified

5) How old are you?

- 18-34 years
- 35-64 years
- 65 or over

6) Do you speak a language other than English?*

- No, English only
- Yes, Italian
- Yes, Greek
- Yes, Cantonese
- Yes, Arabic
- Yes, Vietnamese
- Yes, Mandarin
- Yes, other (please specify):: _____

7) What country do you live in? (if in Australia, please enter your postcode)

- 1049 8) Select the option that best describes your current job
- 1050 Community/personal worker
- 1051 Clerical/administrative worker
- 1052 Labourer
- 1053 Machinery operator/driver
- 1054 Manager
- 1055 Professional
- 1056 Sales worker
- 1057 Technician/trade worker
- 1058 Student
- 1059 Full time home duties
- 1060 Retired
- 1061 Currently not working
- 1062 Other - Write In: _____
- 1063
- 1064 9) In general, would you say your health is
- 1065 Excellent
- 1066 Very good
- 1067 Good
- 1068 Fair
- 1069 Poor
- 1070
- 1071 10) When you have free time, do you:
- 1072 almost always prefer to do something with others
- 1073 usually prefer to do something with others
- 1074 sometimes like to be with others but also enjoy spending time by yourself
- 1075 usually prefer to spend time alone
- 1076 almost always prefer to spend time alone
- 1077
- 1078 11) Do you, or other people notice any problems with your hearing?
- 1079 Yes, please describe: _____
- 1080 No
- 1081 I don't know
- 1082
- 1083 12) Do you mishear and confuse similar sounding words (e.g. "fifty" and "fifteen", "thirsty"
- 1084 and "Thursday", "ships" and "chips". etc.) in quiet places?
- 1085 Never
- 1086 Rarely
- 1087 Sometimes
- 1088 Often
- 1089 Almost always
- 1090
- 1091 13) Do you ask people to repeat themselves when conversing in noisy places?
- 1092 Never

- 1093 Rarely
- 1094 Sometimes
- 1095 Often
- 1096 Almost always
- 1097
- 1098 14) Are you able to focus easily when doing non-listening tasks (e.g. reading, chores)?
- 1099 Never
- 1100 Rarely
- 1101 Sometimes
- 1102 Often
- 1103 Almost always
- 1104
- 1105 15) Tinnitus is defined as any sound that a person can hear internally that is not present
- 1106 externally. It may be heard as a buzzing, ringing, whistling, hissing or pulsing sound. Have
- 1107 you ever experienced tinnitus?
- 1108 Never
- 1109 Occasionally
- 1110 Sometimes
- 1111 Frequently
- 1112 Almost always
- 1113 Unsure
- 1114
- 1115 16) Where do you hear the tinnitus?
- 1116 Left ear only
- 1117 Right ear only
- 1118 Both ears
- 1119 In my head
- 1120 Other - please describe: _____
- 1121
- 1122 17) Who prompted you to seek hearing assessment or treatment?
- 1123 _____
- 1124 _____
- 1125 _____
- 1126 _____
- 1127
- 1128 18) Can you describe the situations in which you experience your listening difficulties?
- 1129 _____
- 1130 _____
- 1131 _____
- 1132 _____
- 1133
- 1134 19) What tests were conducted in your appointment? Please select all that applies
- 1135 Hearing tone test ('press the button when you hear a beep/tone')
- 1136 Speech-in-quiet test (test repeating words or sentences without background noise)

- 1137 Speech-in-noise test (test repeating words or sentences in noise)
- 1138 Other - Write In: _____
- 1139 Unsure

1140

1141 20) Do you feel that the information the audiologist/clinician gave you about your hearing

1142 test results adequately explained your hearing difficulties?

- 1143 Yes - fully
- 1144 Yes - partially
- 1145 No

1146

1147 21) Why?

1148 _____

1149 _____

1150 _____

1151 _____

1152

1153 22) Were you offered a device or treatment option(s)?

- 1154 Yes
- 1155 No

1156

1157 23) What does it involve?

1158 _____

1159 _____

1160 _____

1161 _____

1162

1163 24) Are you satisfied with the treatment plan?

1164 0 _____ [] _____ 100

1165

1166 25) At the end of your hearing test appointment, were you satisfied with the outcome?

- 1167 Yes, very
- 1168 Yes, somewhat
- 1169 No

1170

1171 26) Why?

1172 _____

1173 _____

1174 _____

1175 _____

1176

1177 27) Did your audiologist suggest a follow up appointment (in relation to things discussed in

1178 the hearing test appointment)?

- 1179 Yes
- 1180 No

1181

1182 28) Why?

1183 _____

1184 _____

1185 _____

1186 _____

1187

1188

1189 29) Which of the following options would you consider using to assist with your listening
 1190 difficulties?

	Ready & willing	Willing in future	Unlikely to be willing	Not willing
Smartphone App: An app used with earphones which provides different settings for different situations to amplify a speaker's voice or a specific sound source over background noise.	()	()	()	()
Personalised Hearing Aids: On-ear or in-ear devices fitted by a professional; may also include additional features to assist in hearing	()	()	()	()

in different situations.				
Store-bought Hearing Aids: On-ear or in-ear devices that are purchased online or in non-specialist stores without individual fitting. These would be cheaper than professionally fitted hearing aids and might be limited in features.	()	()	()	()
Hearables: Earphones that automatically improve the hearing experience of the listener by filtering out background noise.	()	()	()	()
Remote Microphone with Earphones: A microphone device worn by the speaker that transmits speech to the	()	()	()	()

listener's earphones.				
Personal Communication Training Course: Run by a professional, the course would provide opportunity to discuss communication issues and practice listening strategies.	()	()	()	()
Family Communication Training Course: Run by a professional, the training course would help you and your partner and/or family/friends to discuss communication difficulties and practice strategies.	()	()	()	()
Online Communication Training Course: An online training course, completed at	()	()	()	()

<p>your own pace that provides tips and information for communicating and listening in difficult situations.</p>				
--	--	--	--	--

1191

1192 30) Please rank how important (from most to least) the following factors are when choosing a
 1193 treatment option:

1194 _____ Cost

1195 _____ Efficacy of treatment

1196 _____ Appearance/stigma

1197 _____ Ease of use

1198

1199 31) Are there other treatment/remediation options you would be willing to try?

1200 _____

1201 _____

1202 _____

1203 _____

1204

1205 32) Before today, did you know what a hearable was?

1206 () Yes

1207 () No

1208

1209 33) Do you know where you can purchase a hearable?

1210 () Yes

1211 () No

1212

1213 34) Please list down all the places you could use a hearable to improve listening to speech in
 1214 noisy situations:

1215 _____

1216 _____

1217 _____

1218 _____

1219

1220 35) Please list down all the places you could purchase a hearable from:

1221 _____

1222 _____

1223 _____

1224 _____

1225

1226 36) Would you use a hearable if it made it easier to listen to speech in noisy situations?

1227 Yes

1228 No

1229 Unsure

1230

1231 37) Why not? Please check all that applies

1232 I am not interested in rehabilitation

1233 I do not think I need rehabilitation

1234 I am not eligible for rehabilitation services

1235 I do not think the rehabilitation options are appropriate for me

1236 Affordability

1237 Don't know

1238 Other - please explain:: _____

1239

1240 38) What is your ideal solution to your listening difficulties?

1241 _____

1242 _____

1243 _____

1244 _____

1245

1246 39) How did you find out about our survey?

1247 Facebook

1248 Twitter

1249 LinkedIn

1250 Reddit

1251 Email

1252 A friend

1253 1 in 6 Newsletter

1254 Hearing Matters Magazine

1255 Other - Write In: _____

1256

1257

1258 Thank You!

Appendix B – Clinician Survey

1259

1260

1261 1) A little about you

1262 Gender

1263 Male1264 Female1265 Indeterminate/unspecified/other

1266

1267 Age: _____

1268

1269 Where do you mainly work?

1270 Australia1271 Other: _____ *

1272

1273 Where is your main workplace located?

1274 City/urban area1275 Regional1276 Rural/Remote

1277

1278 How many years' experience do you have as an audiologist?

1279 Less than 2 years1280 3-5 years1281 6-10 years1282 11-20 years1283 More than 20 years

1284

1285 Which of the following best describes your clinical work?

1286 Paediatric assessment and/or rehabilitation1287 Adult assessment and/or rehabilitation1288 Both paediatric and adult diagnostic assessment and/or rehabilitation1289 Diagnostic vestibular work

1290

1291 2) How would YOU describe the typical characteristics of this group?

1292 *If it helps, think about what descriptions you would use to help a new audiologist identify*
 1293 *people who might be part of this NH-MHL group. e.g., The shape of their audiogram? Their*
 1294 *results on other tests? In addition to speech-in-noise issues, what are their common*
 1295 *complaints?*

1296 _____

1297 _____

1298 _____

1299 _____

1300

1301 3) How many clients do you see each month who would meet this NH-MHL definition?

1302 1 or less

- 1303 2-5
- 1304 6-10
- 1305 Over 10

1306

1307 4) Overall, what is the approximate proportion (in %) of NH-MHL clients you see in each
1308 age range below?

1309 _____ Under 12 years

1310 _____ 13-17 years

1311 _____ 18-34 years

1312 _____ 35-64 years

1313 _____ 65 or over

1314

1315 5) What are the main referral paths for your NH-MHL clients? (*Tick all that apply*)

1316 Client self-referred

1317 Ear Nose Throat Specialist

1318 Doctor/General Practitioner

1319 Nurse

1320 Workplace/Employer

1321 Other - Write In: _____

1322

1323 6) What listening environments do these clients report having most difficulty in? (i.e.,
1324 physical spaces that are frequently described as difficult)

1325 _____

1326 _____

1327 _____

1328 _____

1329

1330 7) In what listening situations do these clients report experiencing most difficulty? (e.g.,
1331 location/number of conversation partners or sound source)

1332 _____

1333 _____

1334 _____

1335 _____

1336

1337 8) Are there any other common reasons that these clients give for making an appointment to
1338 see you? (e.g. need for better communication experience at work)

1339 _____

1340 _____

1341 _____

1342 _____

1343

1344 9) How do NH-MHL clients describe the functional (day-to-day) and emotional impact that
1345 their hearing difficulties have on them?

1346 _____

1347 _____

1348 _____

1349 _____

1350

1351 10) Out of the following categories, what are the most common hearing difficulties NH-MHL
1352 clients report having? (*rank from most to least frequent*)

1353 _____Speech in one-on-one conversation

1354 _____Speech over distance

1355 _____Speech without visual cues (e.g. conversing while driving)

1356 _____Other - Write In

1357 _____Speech in background noise

1358 _____Multiple talkers

1359 _____Listening to music

1360 _____Talking on the phone

1361

1362 11) What clinical tools do you find useful with NH-MHL clients?

1363 _____

1364 _____

1365 _____

1366 _____

1367

1368 12) How do you use these results to discuss NH-MHL clients' hearing and discuss treatment
1369 options with them?

1370 _____

1371 _____

1372 _____

1373 _____

1374

1375 13) What percentage of people with NH-MHL that come to see you, choose treatment (if any
1376 treatment is offered)?

1377 _____

1378

1379 14) In your experience do these clients typically receive any form of aural rehabilitation?

1380 No

1381 Yes

1382 Don't know

1383

1384 15) If NH-MHL clients do not receive any aural rehabilitation is this due to:

1385 Client is not interested in rehabilitation

1386 Client does not need rehabilitation

1387 Client is not eligible for rehabilitation services

1388 Appropriate rehabilitation options are not available for this population

1389 Affordability

1390 I'm not aware of treatment options available for this population

1391 Other - Write In: _____

1392 Don't know

1393

1394 16) If they do receive rehabilitation, what type of rehabilitation do they typically receive?

1395 *(tick all that apply)*

1396

1397 *Hearables: A hearable is a wireless in-ear computational earpiece. Essentially it is a micro*
 1398 *computer that fits in the ear canal and utilises wireless technology to supplement and*
 1399 *enhance the listening experience.*

1400 Hearing aids

1401 Other hearing devices (e.g. ALDs)

1402 Counselling

1403 Individual communication training

1404 Group communication training

1405 Referral to another service

1406 Hearables

1407 Remote microphone

1408 Other - Write In: _____

1409

1410 17) In your opinion, how effective are the following treatments for addressing speech-in-
 1411 noise difficulties experienced by people with NH-MHL?

	1. Not at all effective	2. A little effective	3. Somewhat effective	4. Very effective	Unsure
Hearing aids	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other hearing devices (e.g. ALDs)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Counselling	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Individual communication training	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Group communication training	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Hearables	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Remote microphone	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
----------------------	--------------------------	--------------------------	--------------------------	--------------------------	--------------------------

1412

1413 18) What influences NH-MHL clients' decisions to pursue (or not to pursue) treatment?

1414

1415

1416

1417

1418

1419 19) Do you generally recommend hearables to your NH-MHL clients?

1420 Never1421 Yes - Rarely1422 Yes - Sometimes1423 Yes - Often

1424

1425 20) If NH-MHL clients do receive rehabilitation, how do you measure outcomes/success?

1426 *(Tick all that apply)*1427 Speech testing1428 Questionnaire1429 COSI goals1430 Client's satisfaction1431 Family member feedback.1432 Other - Write In: _____

1433

1434 21) How confident do you feel that your recommended treatment options address your NH-
1435 MHL clients' concerns?

1436 0 _____ [] _____ 100

1437

1438 22) Ideally, what form of rehabilitation would you prefer to provide NH-MHL clients?

1439 None1440 Hearing aids1441 Other hearing devices1442 Counselling1443 Individual communication training1444 Group communication training1445 Referral1446 Other1447 Don't know

1448

1449 23) Do you feel that you have appropriate training and resources to help NH-MHL clients?

1450 Yes1451 No - Inadequate training1452 No - Inadequate resources

1453 No - Inadequate training & resources

1454 Not sure

1455

1456 24) What do you think clinicians need to better help NH-MHL clients? (e.g. clinical tools,
1457 devices)

1458 _____

1459 _____

1460 _____

1461 _____

1462

1463 25) Are there any particular barriers you experience providing rehabilitation services towards
1464 NH-MHL clients?

1465 _____

1466 _____

1467 _____

1468 _____

1469

1470 26) Do you have any further comments about your experiences with NH-MHL clients?

1471 _____

1472 _____

1473 _____

1474 _____

1475

1476 *The Future of NH-MHL*

1477 27) Do you have any ideas about what underlies the speech-in-noise difficulties of NH-MHL
1478 clients?

1479 _____

1480 _____

1481 _____

1482 _____

1483

1484 28) Do you have any suggestions about the type of research would you like to see conducted
1485 about issues for clients with NH-MHL?

1486 _____

1487 _____

1488 _____

1489 _____

1490

1491 29) How did you find out about our survey?

1492 Facebook

1493 Twitter

1494 LinkedIn

1495 Reddit

1496 Email

1497 A friend

1498 1 in 6 Newsletter

1499 Hearing Matters Magazine

1500 Other - Write In: _____

1501

1502 Thank You!

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Appendix C – NA-MHL Group Interview Script

1. What motivated you to do this interview?

Characterising your hearing difficulties

2. Can you describe to me a situation in which you experienced difficulty hearing speech in noise?

→ What did you do?

→ How did you feel?

→ When was the first time you noticed your difficulties?

→ How long ago was this?

→ What is the impact of the difficulty (if any)?

Yourself

3. Do your family and friends know about your difficulties?

→ **Yes:** Can you expand on this?

→ **No:** how do you think they would respond?

4. Have they adapted their behaviour to assist you with your difficulties?

→ **Yes:** in what ways?

→ **No:** what would be helpful?

Pathway to the clinic

5. What motivated you to seek an appointment/advice with an audiologist/clinician?

6. Please describe your visit/s to the clinic

7. What were the results of the testing?

8. How were the results explained/described to you? How did you feel about this?

Rehabilitation

9. Were you offered any treatment options?

→ **Yes:** what options did you try? Why/why not?

→ What was your experience of starting the treatment?

→ Tell me what situations you tried it in, and how effective it was?

→ Will you continue to use it?

→ Is there anything else you would like to try?

→ **No:** Would you like to have been offered something?

There is a number of possible treatment options that might be available. We're interested in what you think about the following options: (we're just exploring what people think about them)

- Traditional hearing aid? (On-ear or in-ear devices fitted by a professional; may also include additional features to assist in hearing in different situations).

- 1552 ▪ Hearable? (Earphones that automatically improve the hearing experience of the
1553 listener by filtering out background noise).
1554
- 1555 ▪ Remote microphone? (A microphone device worn by the speaker that transmits
1556 speech to the listener's earphones).
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- 1558 ▪ Communication training (personal or online)? (A course that provides tips and
1559 information for communicating and listening in difficult situations).
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1561 *Further comments*

1562 Do you have any further comments?

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1564 Thank you for your participation, we appreciate your time in doing this interview with us.

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Appendix D – Clinician Interview Script

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1. What motivated you to do this interview?
2. How long have you been an audiologist?
3. What is your role? Could you describe what that role involves?
4. How long have you been in your current role?

We're interested in adults who have difficulty hearing speech in noise, but when tested have a normal or mild hearing loss.

5. Roughly how many clients do you see per month that would fit this description?
(NOTE: If they don't see these clients, check whether they discuss these cases with any colleagues. If no experience at all, thank them for their time and terminate interview)
 6. Take a moment to think about the clients you've seen with speech-in-noise difficulties, can you describe your clinical experiences seeing one of these clients.
 - ➔ How did they describe their problem?
 - ➔ How did you feel during the appointment?
 - ➔ Were there any solutions that you recommended? Did you think they'd be helpful? Is that what you'd usually do?
 - ➔ Did you have any further follow-ups with the client?
 7. Are there other appointments where things have gone differently? How?
- Assessment*
8. What sort of tools do you use to understand the difficulties this population is having?
 - ➔ Why
 - ➔ How helpful are they in the decision making process?
 9. Generally, how confident do you feel about making decisions for this population?
 10. How do you describe the results to the clients?
 11. How do clients respond to your advice?
 12. Is that a common response?

Treatment

13. What types of rehabilitation tools do you usually offer?
14. How successful or comfortable do you feel with these treatment options?
15. What do you think about the following treatment options:

- 1615 → Traditional hearing aid? (On-ear or in-ear devices fitted by a professional; may also
 1616 include additional features to assist in hearing in different situations). Pro and con?
 1617 Would you recommend it?
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- 1619 → Hearable? (Direct to consumer earphones that automatically improve the hearing
 1620 experience of the listener by filtering out background noise). Pro and con? Would you
 1621 recommend it?
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- 1623 → Remote microphone? (A microphone device worn by the speaker that transmits
 1624 speech to the listener's earphones). Pro and con? Would you recommend it?
 1625
- 1626 → Communication training (personal or online)? (A course that provides tips and
 1627 information for communicating and listening in difficult situations). Pro and con?
 1628 Would you recommend it?
 1629

1630 *Clinical Insights*

1631 16. In the broader context of hearing health care, where does this problem (of speech-in-noise
 1632 difficulties) fit in?

1633 i.e.

1634 → Is it a big or small issue?

1635 → Is it well understood or poorly understood?
 1636

1637 17. How much effort/resources/research do you think should be put into helping these
 1638 people?
 1639

1640 *Comments*

1641 18. Do you have any questions or further comments?
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1643 Thank you for your participation. We appreciate you taking the time to share your insights
 1644 with us.
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