Assessing daily-life benefit from hearing aid noise management: SSQ12 vs. ecological momentary assessment

LINE STORM ANDERSEN[1], KLAUDIA EDINGER ANDERSSON[1], MENGFAN WU[1], NIELS PONTOPPIDAN[2], LARS BRAMSLØW[2], AND TOBIAS NEHER[1,*]

[1] *Institute of Clinical Research, University of Southern Denmark, Odense, Denmark*

[2] *Eriksholm Research Centre, Snekkersten, Denmark*

In audiological research, assessing daily-life benefit from hearing aid (HA) noise management (NM) is a challenge. While ecological momentary assessment (EMA) using smartphone-connected HAs has recently emerged as a promising tool for real-life data acquisition, there is a lack of research linking this method to established ones such as the SSQ12 questionnaire. In the current study, 12 hearing-impaired participants were asked to assess two HA fittings using a well-known questionnaire and a smartphone-based EMA method combining soundscape logging with momentary self-reports. The two HA fittings differed in terms of their NM settings (no NM vs. cardioid microphones and noise reduction activated). The participants were aged 23-75 years and had different occupations and lifestyles. The testing period for each fitting was 2 weeks. Overall, the EMA and SSQ12 scores were higher for the setting with NM activated, but this difference was only statistically significant in case of the SSQ12. The soundscape data showed that only few participants experienced noisy surroundings frequently. Future work on EMA-based HA assessment should therefore address the interplay between the tested HA features and the auditory ecology of the participants.

INTRODUCTION

For the assessment of daily-life experiences, questionnaires are widely used in both clinical and research settings and are generally of much value. Nevertheless, a well-known shortcoming of questionnaire-based assessments is the so-called memory bias (Schwarz, 2011). Memory bias describes how the human memory system compromises memory recollection, resulting in potentially imprecise data. More recently, ecological momentary assessment (EMA) has emerged as a promising alternative for subjective data acquisition. In contrast to the retrospective assessments performed with questionnaires, EMA is based on momentary assessments and thus avoids memory bias. In the field of audiology, EMA using smartphone-connected hearing aids (HAs) has gained much interest lately. In addition to the participants' self-reports provided via a smartphone app, the acoustic environments or 'soundscapes' can be logged by the HAs. This has made it possible to explore the acoustic environments that HA users typically encounter (Jensen and Nielsen, 2005), the efficacy of advanced HA features (Wu *et al.*, 2018) or the way someone's sense

*Corresponding author: tneher@health.sdu.dk

Proceedings of the International Symposium on Auditory and Audiological Research (Proc. ISAAR), Vol. 7: Auditory Learning in Biological and Artificial Systems, August 2019, Nyborg, Denmark. Edited by A. Kressner, J. Regev, J. C.-Dalsgaard, L. Tranebjærg, S. Santurette, and T. Dau. The Danavox Jubilee Foundation, 2019. ISSN: 2596-5522.

of hearing loss is influenced by the regular assessment of daily-life listening experiences (Henry *et al*., 2012; Galvez *et al*., 2012).

The purpose of the current study was to compare EMA to an established method for daily-life HA assessment – the 12-item version of the Speech, Spatial and Qualities of Hearing scale (SSQ12) questionnaire (Noble *et al*., 2013). More specifically, we investigated (i) if EMA and the SSQ12 can document real-life benefit from a directional microphone setting combined with noise reduction, and (ii) if the results from the two types of assessments are in agreement with each other.

METHODS AND MATERIALS

Participants

Participants were recruited via social media groups for HA users, the hearing clinic at Odense University Hospital, private otologists and communication centres. The inclusion criteria were a minimum age of 18 years, mild-to-moderate, symmetric, bilateral, sensorineural hearing loss, a general aptitude to handle hearing aids and smartphones, and prior experience with smartphone use. A total of 13 participants were enrolled in the study, 12 of whom completed it. Table 1 provides an overview of their characteristics, while Figure 1 shows their audiograms. Hearing thresholds varied considerably, with pure-tone average hearing losses ranging from 20-54 dB HL (mean: 42 dB HL).

Participant	Age (yrs)	HA experience (yrs)	Occupation
1	47	41.0	Student
2	73	21.0	Retired
3	24	14.0	Employed
4	72	15.0	Retired
5	42	0.04	Maternity leave
6	75	6.0	Retired
7	23	18.0	Student
8	66	8.0	Retired
9	40	0.04	Employed
10	71	5.0	Retired
11	72	5.0	Retired
12	44	5.0	Employed

Table 1: Overview of the participants' characteristics.

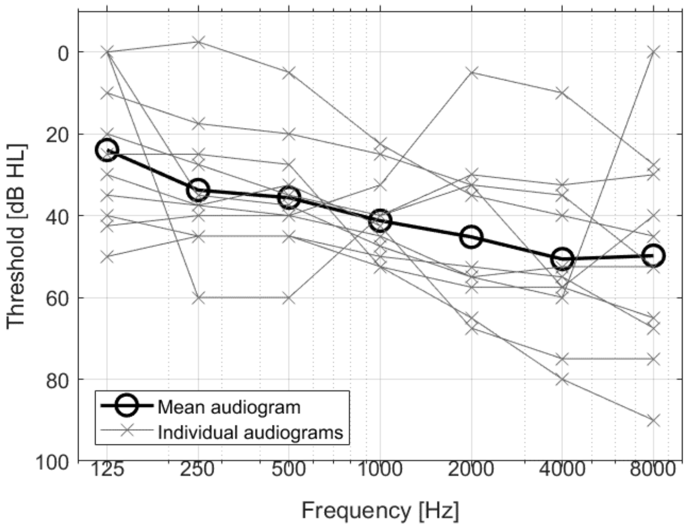

Fig. 1: Mean and individual audiograms averaged across left and right ears.

HA fittings

The HAs used were research prototypes (Oticon EVOTION mini-RITE). The devices classified the acoustic environment (or soundscape) continuously into one of four possible categories: Quiet, Speech, Noise or Speech in Noise. Two HA settings were tested: (i) Pinna-omni without noise reduction (NM_{OFF}), and (ii) fixed cardioid microphones with default noise reduction activated (NM_{ON}). The two settings were chosen with the aim of creating a clear acoustic contrast. The participants tested each HA setting for two weeks (see Study design).

SSQ12 assessments

The SSQ12 questionnaire consists of 12 items from the original SSQ questionnaire (Gatehouse and Noble, 2004). More specifically, there are five speech-related items, four items related to spatial hearing and three related to other qualities of hearing. For each item, a rating scale from 0-10 is used, with a higher score indicating a better outcome. In the current study, the participants were asked to complete a paper version of the SSQ12 twice, that is, once after each 2-week HA trial period.

EMAs

The EMAs were carried out using a custom smartphone app designed by Oticon A/S, which was installed on an iPhone SE device. The app prompted the participants to assess their listening experiences eight times a day. The prompts occurred randomly between 8 am and 8 pm. Since the study lasted for four weeks (see Study design), the participants were expected to complete 224 assessments to obtain a compliance score of 100%. The participants were able to carry out additional, voluntary assessments (resulting in a compliance score >100%). An assessment started with three questions (see Figure 2). The first two questions related to the overall listening experience (pleasant/good vs. unpleasant/bad) with the current HA setting, while the third question enquired if the current assessment was related to speech understanding. If the participant reported this to be the case, four additional questions followed. These questions related to the ability to follow a conversation, the perceived difficulty in following a conversation and the experience of effort. For each of these questions a rating scale from 0-10 was used, with a higher score indicating a better outcome. The questions and rating scales were used as implemented in the app, that is, they were not adapted to correspond to the SSQ12 items.

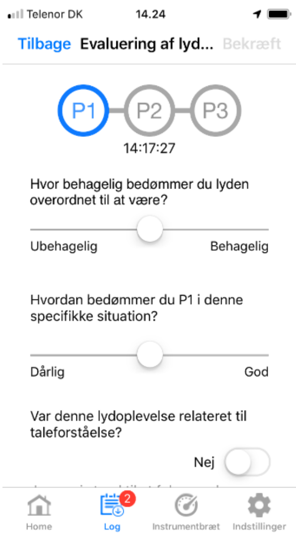

Fig. 2: Screen dump of the smartphone app showing the first three questions relating to the user's overall listening experience with the current HA program ('P1') and the relation to speech understanding.

Study design

The current study followed a single-blinded, balanced crossover design with a duration of 2 × 2 weeks. Figure 3 illustrates the general layout. The order in which the two HA settings were tested was counterbalanced across the participants.

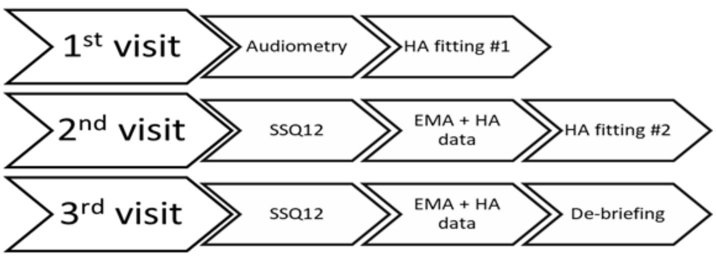

Fig. 3: Outline of study design.

Statistical analyses

The collected data were analysed using Microsoft Excel and IBM SPSS Statistics v25. Statistical significance was assessed using 2-tailed paired *t*-tests. The EMA scores were pre-processed by taking the median across all ratings made by a given participant in a given soundscape (Quiet, Noise, Speech, Speech in Noise). Due to the design of the app, assessments reported as being unrelated to speech understanding contained data from the first three questions only whereas speech-related assessments contained data from all seven questions (see above). For the sake of brevity, the analyses below focus on the data from the speech-related assessments. Furthermore, they focus on overall SSQ12 or EMA scores rather than scores for individual items.

RESULTS

SSQ12 assessments

Table 2 summarises the SSQ12 data. Seven participants gave the NM_{ON} setting higher (better) SSQ12 ratings; the other participants rated the NM_{OFF} setting higher. Overall, the difference in mean scores for the two HA settings was statistically significant ($t_{11} = -2.9$, $p = 0.01$). At the individual-item level, the NM_{ON} setting scored higher on all but two SSQ12 items. However, the scores for the two HA settings did not differ from each other for any single SSQ12 item (all $p > 0.05$).

Participant	Mean score NM_{OFF}	Mean score NM_{ON}	Difference
1	5.5	6.0	0.5
2	5.0	4.5	-0.5
3	6.0	6.6	0.6
4	4.0	6.4	2.4
5	5.5	6.7	1.2
6	6.2	6.2	0.0
7	6.0	6.7	0.7
8	5.5	6.8	1.3
9	5.0	6.8	1.8
10	8.0	8.8	0.8
11	7.0	8.4	1.4
12	6.2	7.7	1.5
Average	**5.8**	**6.8**	**1.0**

Table 2: Mean SSQ12 scores for, and differences between, the NM_{OFF} and NM_{ON} settings for each participant and across them.

EMAs

In total, the participants provided 3140 EMAs, 1749 of which they reported as being related to speech understanding. Furthermore, 1398 assessments were made with the NM_{ON} setting engaged and 1742 assessments with the NM_{OFF} setting engaged. Given the requirement to complete at least eight assessments per day, the participants had to carry out a minimum of 224 assessments over the 2 × 2 week test period. From Table 3 it is apparent that compliance varied greatly across the 12 participants.

Participant	No. of EMAs	Compliance (%)
1	99	44
2	470	210
3	75	33
4	317	142
5	261	117
6	373	167
7	88	39
8	141	63
9	217	97
10	402	179
11	346	154
12	351	157
Total	**3140**	**117**

Table 3: Number of EMAs and compliance score for each participant and the group as a whole.

Overall, the EMA scores were 0.24 scale units higher for the NM_{ON} setting than for the NM_{OFF} setting. At the individual level, participants 1, 2, 7, 9 and 12 rated the NM_{ON} setting higher, whereas participants 4, 6 and 8 gave the NM_{OFF} setting slightly higher ratings. The difference in mean EMA scores between the two HA settings was not statistically significant ($t_{11} = 1.6$, $p > 0.1$). The same was true for all individual EMA items (all $p > 0.1$).

SSQ12 assessments vs. EMAs

On average, the speech-related EMA scores were higher than the SSQ12 scores (means: 8.4 vs. 5.4 scale units) and showed also more spread across participants (standard deviations: 1.7 vs. 1.0 scale units). The observed difference in mean scores for the two methods was statistically significant ($t_{11} = -2.6$, $p = 0.03$). In spite of these differences, the two datasets showed the same overall preference for a given HA setting for all but one participant.

Soundscape logging

Table 4 shows, for each participant, the number of EMAs made per soundscape category. As can be seen, only 10% of the data were collected under noisy conditions. When comparing the EMA scores for the NM_{ON} and NM_{OFF} settings as a function of soundscape, it was found that the NM_{ON} setting received higher scores in all but the quiet category, for which the NM_{OFF} setting dominated (data not shown). Moreover, EMAs classified by the HAs as containing speech were ~50% of the time *not* reported as being speech-related by the participants.

Participant	Quiet	Noise	Speech	Sp. in No.	Total
1	58	3	34	4	99
2	239	15	177	39	470
3	15	16	32	12	75
4	225	2	90	0	317
5	78	33	99	51	261
6	303	8	58	4	373
7	51	0	37	0	88
8	82	2	50	7	141
9	87	9	111	10	217
10	183	18	178	23	402
11	150	20	173	3	346
12	236	4	83	28	351
Total	**1707**	**130**	**1122**	**181**	**3140**
Percentage	**54%**	**4%**	**36%**	**6%**	**100%**

Table 4: Number of EMAs per participant for the Quiet, Noise, Speech and Speech in Noise (Sp. in No.) soundscapes as well as in total.

DISCUSSION

The current study explored (i) if EMA and the SSQ12 can document daily-life benefit from NM, and (ii) if the results from the two methods are in agreement with each other. Both assessment methods indicated a difference in mean scores between the two tested HA settings in favour of the NM_{ON} setting. However, this difference was only statistically significant in case of the SSQ12. Moreover, the EMA scores were generally higher than those obtained using the SSQ12, and they also showed more spread across participants. One possible explanation for these differences in outcome could be that the EMA items were used as implemented in the app (see above). Consequently, they were not identical to the SSQ12 items, which might be more suited for evaluating HA fittings (e.g. in terms of the formulations used to describe daily-life listening situations).

Another factor that could have influenced the outcomes of the current study was the heterogeneity of the participants. The participants varied considerably across several parameters such as audiometric configuration, age, occupation and HA experience. Humes *et al.* (2018) found that with increasing HA experience HA users spend more time in noisy environments. Comparing Tables 1 and 3, it is also apparent that the older users tested here were more inclined to complete EMAs, which could potentially have biased the collected data in the direction of their auditory ecologies.

The shortage of assessments carried out in noisy conditions agrees with the findings of Jensen and Nielsen (2005) who reported that HA users spend most of their time at home or in conversation with less than three people. The general lack of noise in the participants' daily surroundings likely restricted the efficacy of the NM_{ON} setting, since directional microphones and noise reduction are meant to attenuate noise. In future work, it could be beneficial to target EMAs of this type of HA technology more specifically, e.g., by recruiting participants with specific auditory ecologies.

The discrepancies observed when comparing HA- and user-logged soundscapes were probably related to the fact that current HA soundscape classification algorithms are oblivious to the user's intent. Whether or not a speech signal is of relevance to the user depends on acoustic and non-acoustic factors, which can change over time. To achieve better correspondence between HA- and user-logged soundscapes, future EMAs would have to be able to capture user-related intentional aspects, too.

REFERENCES

Galvez, G., Turbin, M. B., Thielman, E. J., Istvan, J. A., Andrews, J. A., and Henry, J. A. (**2012**). "Feasibility of ecological momentary assessment of hearing difficulties encountered by hearing aid users," Ear. Hearing, **33**, 497-507, doi: 10.1097%2FAUD.0b013e3182498c41.

Gatehouse, S., and Noble, W. (**2004**). "The Speech, Spatial and Qualities of Hearing Scale (SSQ)," Int. J. Audiol., **43**, 85-99, doi: 10.1080/14992020400050014.

Henry, J. A., Galvez, G., Turbin, M. B., Thielman, E. J., McMillan, G. P., and Istvan, J. A. (**2012**). "Pilot study to evaluate ecological momentary assessment of tinnitus," Ear. Hearing, **33**, 179-290, doi: 10.1097%2FAUD.0b013e31822f6740.

Humes, L. E., Rogers, S. E., Main, A. K., and Kinney, D. L. (**2018**). "The acoustic environments in which older adults wear their hearing aids: Insights from datalogging sound environment classification," Am. J. Audiol., **27**, 594-603, doi: 10.1044/2018_AJA-18-0061.

Jensen, N., and Nielsen, C. (**2005**). "Auditory ecology in a group of experienced hearing-aid users: Can knowledge about hearing aid users' auditory ecology improve their rehabilitation?," Research Report, Eriksholm Research Centre.

Noble, W., Jensen, N. S., Naylor, G., Bhullar, N., and Akeroyd, M. A. (**2013**). "A short form of the Speech, Spatial and Qualities of Hearing scale suitable for clinical use: The SSQ12," Int. J. Audiol., **52**, doi: 10.3109/14992027.2013.781278.

Schwarz, N. (**2011**). "Why researchers should think "real-time": A cognitive rationale," in: M. R. Mehl & T. S. Conner (eds.), *Handbook of Research Methods for Studying Daily Life*, New York: Guilford.

Wu, Y. H., Stangl, E., Chipara, O., Hasan, S. S., DeVries, S., and Oleson, J. (**2019**). "Efficacy and effectiveness of advanced hearing aid directional and noise reduction technologies for older adults with mild to moderate hearing loss," Ear. Hearing, **40**, 805-822, doi: 10.1097/AUD.0000000000000672.