

Narrative Review on Data-logging

Lough, M.^{1,3}, Dickinson, A-M.^{2,3} & the BAA Service Quality Committee³

¹ Manchester Centre for Audiology and Deafness, The University of Manchester. ² Salford Royal NHS Foundation Trust. ³ BAA SQC

Background Given that previous studies suggest the majority of audiologists think that data-logging is useful^{1,2}, it is important to consider what we actually know about this hearing device feature. To this end, a structured narrative review of the literature in peer-reviewed journals was conducted.

Results

Only the main findings from the full-text review of the adult/general data-logging literature are presented here. Implant- and paediatric-specific literature will be reported on at a later date. The blue "tear drops" refer to the number of papers that met the respective inclusion criterion.

Efficacy/reliability of 15 data-logging

The efficacy of data-logging largely appears to have been "validated" by studies comparing data-logged hearing aid use times with patient self-report (n = 8). An outcome that is common to six of these studies is that self-reported hearing aid usage (whether recorded via direct questioning, or outcome measures such as the GHABP, IOI-HA or IOI-HA-SO) is highly correlated with data-logged hours of use when participants are informed about data-logging from the outset. In the remaining two studies, correlation is not assessed. However, the finding that self-reported usage, on average, is greater than data-logged usage (by 1.11 to 2.27 hours per day, n = 3), seems to have been given disproportionate emphasis. It is concluded, exclusively, that patients *overestimate* their hearing aid use, reinforcing the notion that data-logging is objective and by extension, more truthful than self-report. None of the eight papers, however, consider that data-logging may *underestimate* use. Given that hearing aids only tend to store data after a set amount of time has elapsed (e.g. after 15, 30 or 60 minutes), and that other factors may reduce storage ability (e.g. low battery level), this supposition is certainly a feasible explanation that has not been given sufficient attention in these studies.

Only one of the included papers describes testing the hearing aid usage data-logging feature in the lab. Data-logging in the commercially-available experimental hearing aids was verified at 14, 35, 56, 84 and 112 hours. This showed that data-logging was subject to increasing error over time. However, it should be recognised that this paper was from 1998, and therefore such error may not exist for more modern hearing aids.

Accuracy of logging acoustic scene classification data is addressed in two papers. The first shows that data-logging is accurate in recording acoustic scene classifications in the main, although it is suggested that the output only reflects the predominant hearing aid setting after a set amount of time (e.g. 30-60 minutes), and is not sensitive to shorter-term changes. This study was conducted three years ago, however, it only tested one model of hearing aid. The authors of the second paper make the point that reliability of acoustic scene classification data-logging can be verified by comparing left and right logs; the premise being that the auditory environments should be the same for both hearing aids if worn together. This was corroborated for 60 of their participants for whom the data was archived. Right and left data-logs were highly correlated for 52 participants; five were correlated but less so, and three were not but had low usage times.

Potential benefits 32

Data-logging appears to be most beneficial for research purposes due to its assumed objectivity, its reflection of real world hearing aid use and its ability to contextualise observations. Among the included papers, it has been put to a variety of uses, but by far the most promising application is in "big data" research. This is illustrated in eight of the included papers. Two main approaches are described: 1) anonymised data from hearing aid manufacturer repositories (comprising hearing aid data-logs as well as other stored clinical information, such as pure tone average) are analysed retrospectively, or 2) data are collected prospectively by hearing aids connected wirelessly to a smartphone. The link with a smartphone enables more data to be stored, more frequently, than with hearing aids alone, meaning that hearing aid usage can be calculated more accurately. The potential benefits of both approaches additionally include:

- being more realistic than a controlled study, due to being able to capture data from a much wider sample of the population,
- being able to build up a more detailed picture of which factors (e.g. environmental, lifestyle or health) affect daily hearing aid usage patterns and effectiveness, particularly when used in combination with other health sensors,
- the ability to inform hearing aid design (e.g. automatic fine-tuning), clinical practice and public health policy.

In terms of the potential clinical benefits of data-logging, a variety of suggestions have been made in the included literature. There is no universally-accepted opinion on whether hearing aid provision triggers neurophysiological change or impacts on cognitive function, or on what amount of use is required to produce this. However, if accepted as true, it is conceivable that data-logged usage time is potentially beneficial for setting meaningful goals in respect of treatment adherence. Only one of three studies on these topics provided information that was tangible enough to be applied in a clinical setting. This study showed that you are more likely to see an improvement in speech-in-noise test scores over the first 30 days of being fitted with hearing aids if you have a data-logged average daily use of more than 6 hours. It should be borne in mind that this was demonstrated with a sub-group of ten participants with moderate hearing loss only.

Furthermore, it is conjectured that data-logging can serve a "fault"-finding purpose, alerting the clinician to explore certain issues. For example, data-logging can, highlight when additional programmes are not being used, are used incorrectly, or may be required; identify patients who require closer monitoring; indicate when gain adjustments are required (manually, or as a precursor of data-learning); and highlight when there is asymmetry in hearing aid use (as previously described). One study of 181 hearing aid wearers at a 6 month follow-up showed that participants who reported at least one issue had 3.3 fewer hours of use per day (than those with no issues). The clinical utility of this may be that when data-logged daily hours of use are low, patients may well have issues with the hearing aids that require attention, the most frequently reported being the ear mould, sound quality and handling. But on a practical level, there is no clear answer as to what constitutes "low use", and this issue is muddled by the fact that many factors are purported to affect data-logging results, such as, hearing aid algorithms, tolerance of noise, whether a streamer or mobile phone is available for changing hearing aid settings, pure tone thresholds, experience with hearing aids, usage pattern (including proportion of time in noise), readiness for hearing aid provision, and whether hearing aids are fitted bilaterally (and if so, whether sequentially).

Potential disadvantages 13

Despite one paper showing that 94% of surveyed audiologists in New Zealand perceive data-logging as being useful for counselling, when compared to other advanced hearing aid features, it is not considered in such high regard. In a separate study, "data management" ranked lowest in terms of perceived importance among audiologists from German-speaking countries. This may reflect an awareness in the profession that data-logging is not entirely precise (for the reasons already specified) and therefore requires supplementary information to be clinically useful.

Another possibility raised in one paper is that auditory scene data-logging will only be as accurate as the auditory scene classifier itself; in other words, unless the audio information is recorded in real time for reference, you can only determine what settings the hearing aid has been in, rather than what environments the patient has been in. Furthermore, data-logging cannot give any insight into a patient's listening situations when a hearing aid is not in use, so as a clinician, you would only ever see a sample of their "auditory life".

If a hearing aid is not worn at all, it is clear that no benefit will be gained from it, however, greater data-logged hearing aid use does not necessarily equate to greater patient benefit in terms of satisfaction or reduced disability. This is emphasised in one paper, and exemplified in another that found that there was no significant correlation between change in MAPHAB scores and data-logged hours of hearing aid use.

Even the benefits of data-logging for "big data" research do not come without some limitations. For example, unless datasets contain some personal information, there is a limit as to what can be inferred from the results; in one study, some observed anomalies suggested loan aids were used on various patients. Furthermore, the large search space can lead to false positives and can be costly in terms of management and security.

Conclusions / Future Directions

- Data-logging efficacy and reliability have only been investigated in relation to hearing aid usage and acoustic scene classification in the included papers. For the former, a bias in favour of data-logging (i.e. over self-report) is prevalent in the literature. More detail on the contribution of non-patient factors, such as hearing aid algorithms, to data-logging reliability is warranted in future studies in order to redress the balance.
- Data-logging has a lot to offer hearing health research, particularly since the advent of hearing aid-compatible mobile phone applications. However, the included papers reveal far less substantiated evidence for the direct clinical benefits of data-logging for patients.
- It is surprising that there is such a paucity of research on ethical and legal considerations surrounding data-logging, particularly as contemporary hearing aids (coupled wirelessly to smartphone apps) are able to process a wide range of personal data. Research focussing on hearing aid users' awareness of, and opinions on, such issues will be invaluable in ensuring that concerns are adequately addressed in clinical practice.

Method

Publish or Perish 7 was used to perform 3 Google Scholar literature searches using the following search terms: "datalogging" hearing, "data logging" hearing, "data-logging" hearing } up to 15/7/2020
n = 2,682

Patents and duplicates removed
n = 1,404

Titles and abstracts were screened for suitability, based on whether they shed light on the following aspects of data-logging in hearing devices:

- Efficacy/reliability of data-logging
- Potential benefits
- Potential disadvantages
- Ethical issues/personal impact of data-logging
- Legal issues (including data privacy and security)

n = 1,278

Records excluded
Reasons: irrelevant content, not peer-reviewed, full-text not in English, full-text not freely available (n = 10)
n = 1,155

Papers grouped by topic area
n = 122

Implants (paed./adult)
n = 25

Paediatrics
n = 32

Records excluded
Reasons: irrelevant content, not peer-reviewed, full-text no longer available (n = 3)
n = 25

Full-text review of adult / general focus papers
n = 65

Total included
n = 40

Ethical issues/personal impact of 1 data-logging

One article, written from an Audiology teaching standpoint, touches *briefly* on different clinical approaches to deal with discrepancies between self-reported and data-logged hours of use. It was stated that trying to "catch patients out" with data-logging is not a patient-centred approach, and that teachers should encourage students of Audiology to consider the pros and cons of clinician- and patient-centred approaches to discrepancies. No research was found that attempted to explore the ethics or personal impact of data-logging, from a hearing aid recipient's perspective.

Legal issues (including data privacy and security) 3

Only three papers, two of which happen to have the same first author, raised potential data privacy/security issues. One was in the form of a warning to other researchers: "Longitudinal studies involving wearable computing may... pose serious privacy risks. Depending on the level of instrumentation, these systems may record the actions, locations, preferences, and vital signs of participants. Studies must be designed to safeguard this sensitive data, both during the study and afterwards". "Wearable computing" in this study, comprised hearing aids, a streamer and a mobile phone with a specially-designed app installed. In the second study, it is noteworthy that 2/21 participants withdrew from the study shortly after consenting due to security fears, and one of the final sample (n = 16) also did not consent to audio recordings during acoustic scene evaluations.

References

- McMillan, A., Durai, M., & Searchfield, G. D. (2018). A survey and clinical evaluation of hearing aid data-logging: a validated but underutilised hearing aid fitting tool. *Speech, Language and Hearing*, 21(1), 162-171.
- Saunders, G. H., Boff, A., & Teip, L. H. (2020). Hearing care providers' perspectives on the utility of otoscopy information. *American Journal of Audiology*, 29(3), 619-622.
- Wabaz, G., Stewart, M., & Leller, L. (2013). Instrumenting the user: Needfinding by combining data logging and immediate self-reporting. *The Design Society*.

Correspondence to:

melanie.lough@manchester.ac.uk

