

Editorial: Eriksholm Workshop on Ecologically Valid Assessments of Hearing and Hearing Devices

This supplement is the product of the 6th Eriksholm workshop on Ecologically Valid Assessments of Hearing and Hearing Devices that took place at the Eriksholm Research Centre in Snekkersten, Denmark, on August 25–28, 2019. The series of Eriksholm workshops has a history of nearly 25 years, with the first one taking place in 1996. The purpose of the workshops is to gather a small group of international experts to discuss and advance a current or emerging topic judged to be of high interest to hearing science. The resulting advancement should include a summary of the current knowledge base, identification of knowledge gaps, and prioritization of future research and development, and may further include consensual definitions of widely used topic-related terms, an outline for an outcome measure, or a conceptualizing framework. Outputs of the previous five Eriksholm workshops have been presented in supplements on Auditory deprivation and acclimatization (Arlinger et al. 1996), Self-report outcome measures in audiological rehabilitation (Cox et al. 2000), Candidature and delivery of audiological services for the special needs of older people (Kiessling et al. 2003), Wideband absorbance measures of the middle ear (Feeney et al. 2013), and Hearing Impairment and Cognitive Energy: The Framework for Understanding Effortful Listening (FUEL) (Pichora-Fuller et al. 2016). All workshops are funded (travel, accommodation, and meals) by the William Demant Foundation (former Oticon Foundation), with the topics of the workshops proposed by Oticon's Eriksholm Research Centre. Eriksholm is also responsible for appointing the convenors of the workshops but is not engaged in the further organization or facilitation of them.

In December 2017, funding for the 6th Eriksholm workshop was secured and we were invited to become co-convenors of a workshop on “ecological validity.” As described in more details in the introduction of the consensus paper (Keidser et al., 2020, this issue, pp. 5S-19S), the term “ecological validity” started making inroads in hearing research publications early this century. Some of these publications have merely referred to “ecologically valid test situations,” or “ecologies,” with the intended meaning being assumed to require no explanation. Of interest for this workshop was the increasing number of publications referring to “more ecologically valid research findings.” What exactly does this mean: does it have a conceptual meaning and is it important, and if so, what are the experimental factors that influence it? Our own interest in this topic has developed during long-standing careers investigating the effects of advanced signal processing strategies on user performance and preference, and improving hearing devices and substantiating their benefits to users, respectively. Over the years, we independently formed

the opinion that there was a disconnect between behavioral data collected in the laboratory and real-life experiences reported by test participants, and that hearing disability and hearing device benefit were highly context dependent. That is, we needed new ways to study the diverse manners in which hearing plays a role in real world function, and new ways of assessing hearing and device benefit in the laboratory, to produce outcomes that better reflected real-life experiences.

A multi-disciplinary group of 16 experts was gathered to examine and discuss the technical, environmental, and human factors affecting ecological validity in hearing research. We were directed to include in this workshop several participants from outside the core field of hearing science to stimulate new thoughts and ideas. We were also asked to include a member of the Eriksholm Research Centre, if members from other hearing device manufacturers were invited. Apart from these directives, the selection of participants was entirely our responsibility. The final group brought to the workshop experience in Audiology, Biotechnology, Cognition, Engineering, Kinesiology, Neuroscience, Physics, Psychoacoustic, Psychology, and Qualitative Health Care. The group differed from previous workshop groups by having a high representation of participants from industry, including Caduff (Biovotion), Carlile (X—The Moonshot Factory), Launer (Phonak), Lunner (Oticon—Eriksholm), Mehra (Facebook), Slaney (Google), and Smeds (Widex). This was the result of a wish to tap into knowledge of advanced technologies and methodologies, and new ideas, not yet well integrated in academic hearing research.

During the workshop, consensus-building activities were organized around four themes: (1) Definition of ecological validity and reasons for striving to improve it; (2) Laboratory assessments of hearing and devices: replication, personalization, and application; (3) Assessments of hearing and devices in the real world: emerging technologies and approaches; and (4) Requirements for ecologically valid assessment: the holistic approach. Regarding theme 1, participants were before the workshop presented with a draft definition of “ecological validity” as it may apply to hearing science and were asked to provide their thoughts on reasons for striving for more ecologically valid outcomes in hearing-related research, and the potential beneficiaries. These responses were analyzed by the coconvenors and a consolidated response was presented to participants and briefly discussed at the opening of the workshop to create a reference point against which to validate the output of further discussions. On the final day, participants were divided into two groups. Reflecting on the intervening discussion, one group worked on the definition of ecological validity, and the other on the purpose statements. The results from each group were then introduced to the other group, which was then given time to further fine-tune the statements. The session concluded with a plenary discussion of the resulting statements in order to reach consensus. For themes 2 to 4, the consensus-building activities were kicked off with a series of 20-min presentations on predefined topics from individual participants, that provided

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input to working group discussions. For the working group sessions, participants were divided into three groups to discuss and identify current knowledge/knowledge gaps and future research priorities related to the theme in question, as well as to develop a set of requirements for achieving more ecologically valid outcomes in hearing research. The working group sessions were followed by a plenum session where each group presented their consolidated views and ideas. These were then discussed by all. On the final day, the ideas brought forward by each group were further debated and fine-tuned.

Before the conclusion of the workshop, participants reflected on their own presentations in the context of the discussions of the previous days, and proposed an outline for a paper that could be tied to at least one of the identified purposes of striving for more ecologically valid outcomes of hearing research. During this discussion, it became clear that a stronger impact could be achieved with less repetition if some papers were consolidated. This was the case for three pairs (Campos & Launer, 2020, this issue, pp 99S-106S; Carlile & Keidser, 2020, this issue, pp 56S-67S; and Carpenter & Campos, 2020, this issue, pp 107S-119S). These papers were allowed more space if needed. Due to the wide range of themes covered at the workshop, some of which were not directly connected to hearing research, it was further recognized that adopting a single format for the papers was not feasible. For these reasons, this supplement of *Ear and Hearing* includes papers of the type “research article,” “current state of knowledge,” “review,” and “point of view,” which vary in length. Following the workshop, the first author of each paper took responsibility for finalizing a draft with input from all co-authors. The drafts were subsequently reviewed by two other workshop participants and, after further revisions, by the co-convenors. Because the papers present a collection of interrelated themes sharing the common context of the workshop, they have not undergone the regular peer-review process. They have, however, been read and commented on by members of the Editorial Board of *Ear and Hearing* before being finalized, with the goal of ensuring clarity and coherence. A similar procedure has been used for previous supplements on Eriksholm Workshops.

The consensus paper (Keidser et al., 2020, this issue, pp. 5S-19S) presents the results of the debates which took place at and after the workshop, concerning the four main themes described earlier. It offers a definition of the concept of “ecological validity” when applied to hearing research, outlines four purposes of striving for more ecological validity, surveys common variables and phenomena that can affect the ecological validity of findings, and provides an example for how to assess the level of ecological validity of a study outcome. It further enrolls various ancillary themes (e.g., types of research studies and categories of typical test variables) in its attempt to bring order to the overall field and draw conclusions regarding the current state of the art, knowledge gaps, and priorities for future research.

Following the consensus paper, the supplement is arranged as follows. First, eight papers describe and discuss initiatives and thoughts within the hearing science community to advance the ecological validity of research outcomes, both in the laboratory and in the field. These are followed by two papers that provide examples of how ecological validity can be considered with a holistic approach in mind. The final three papers introduce and discuss technologies that may in the future provide means of producing evidence possessing high ecological validity.

In the first paper, Smeds et al. (2020, this issue, pp. 20S-30S) make a case for the need to implement test scenarios in the laboratory that capture the essence of everyday listening, and examine what these might be, based on criteria derived from the literature and from an ecological momentary assessment study. The next paper, by Hohmann et al. (2020, this issue, pp. 31S-38S) considers the utilization of Virtual Reality technology to implement more realistic test environments in the laboratory for hearing assessment and hearing device evaluation, including a study showing that behaviors and performances by people with hearing loss in corresponding real and virtual environments are comparable. Four papers then take a closer look at advancing beyond the traditional speech in noise paradigm to obtain more ecologically valid outcomes regarding a person’s ability to participate in everyday conversations. First, Lunner et al. (2020, this issue, pp. 39S-47S) argue for the need to take cognitive processes associated with everyday communication into account and review three newer outcome measures tapping into working memory processing, selective attention, and listening effort, respectively, that have all been demonstrated to be sensitive to hearing impairment and signal-to-noise changes. Second, Grimm et al. (2020, this issue, pp. 48S-55S) make a case for the integration of the physical aspects of self-motion, such as movement of the torso, head, eyes, and hands, that takes place during interactive conversations and review the literature that has demonstrated how such natural behaviors can interact with hearing device benefit. Third, Carlile and Keidser (2020, this issue, pp. 56S-67S), after reviewing recent work on adding realism to traditional sentence-based tests and on second-person neuroscience (i.e., brain function in social and dynamic interaction scenarios), then go a step further to argue for more interactive test paradigms that elicit the brain states present in everyday social interactions. In the final paper of this group, Brungart et al. (2020, this issue, pp. 68S-78S) present and discuss an interactive test paradigm in which a traditional word recognition test is administered live within a party of four participants in a noisy public space, thus demonstrating the feasibility of hybrid studies that combine the strengths of conventional laboratory and field experiments. Moving out into the field, Holube et al. (2020, this issue, pp. 79S-90S) review the current state of using ecological momentary assessment, typically through a smartphone, as an alternative to retrospective self-reports, and discuss the advantages and challenges of this rapidly growing methodology. Rapport and Hughes (2020, this issue, pp. 91S-98S) then introduce qualitative methodologies for collecting data in the field and argue for the value of using qualitative and mixed methods to gain a more nuanced picture of the real-life effects hearing loss can have on people. Expanding on this notion, Campos and Launer (2020, this issue, pp. 99S-106S) highlight the elevated level of comorbidity in people with hearing impairment, and how the effect of a hearing loss spreads to social networks and broader society, providing a general commentary on how ecological validity may be considered with a more holistic perspective in mind. Related to the holistic approach, Carpenter and Campos (2020, this issue, pp. 107S-119S) then review the literature on the relationship between hearing loss, balance, and falls, and identify factors to be considered in the future to obtain more ecologically valid evidence for these relationships and the mechanisms underlying them. The final three papers present and discuss technologies that are envisaged to enhance the participation of people with hearing loss in everyday situations and to provide researchers with more ecologically valid evidence.



Fig. 1. Participants of the 6th Eriksholm Workshop. Back row (from left to right): Giso Grimm, Ravish Mehra, Malcolm Slaney, Mark Carpenter, Inga Holube, Stefan Launer, Thomas Lunner, Andreas Caduff, Douglas Brungart, Simon Carlile, Graham Naylor. Front row (from left to right): Volker Hohmann, Frances Rapport, Karolina Smeds, Gitte Keidser, Jennifer Campos.

First, staying in the domain of the holistic approach, Caduff et al. (2020, this issue, pp. 120S-130S) explain how physiological data can enable insight into the understanding of how chronic conditions (including hearing loss) are evolving in the individual, and review wearable physiological monitoring devices and their requirements to detect relevant body responses for hearing research. Second, Slaney et al. (2020, this issue, pp. 131S-139S) describe new technology focusing on real-time speech recognition, which in the future could be combined with attention-steering technologies, to remove the need for perfect hearing in any communication situation. Such technologies also call for totally new measures by which to assess a person's real-life communication ability. Finally, Mehra et al. (2020, this issue, pp. 140S-146S) introduce a concept of the future, an Augmented Reality platform anticipated to work in conjunction with conventional hearing devices, which through multi-modal sensor integration and artificial intelligence and machine-learning frameworks could render individual digital sensory objects. We hope this collection of papers will bring the reader plenty of inspiration for obtaining future research findings of high ecological validity, to improve our understanding of what it is like to live with a hearing loss, to support development of improved interventions, to enable better assessment of real-life hearing-related function and benefit from different interventions, and to promote optimized and integrated hearing care for those in need.

Finally, we would like to take this opportunity to thank all the participants (see Fig. 1) in the workshop for their time, stimulating discussions, and dedication and hard work to make this supplement a reality. The workshop was a wonderful experience and proved a great forum for fostering new acquaintances and collaborations.

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REFERENCES

- Arlinger, S., Gatehouse, S., Bentler, R. A., Byrne, D., Cox, R. M., Dirks, D. D., Humes, L., Neuman, A., Ponton, C., Robinson, K., Silman, S., Summerfield, A. Q., Turner, C. W., Tyler, R. S., Willott, J. F. (1996). Report of the Eriksholm Workshop on auditory deprivation and acclimatization. *Ear Hear*, 17(3 Suppl), 87S–98S.
- Brungart, D. S., Barrett, M. E., Cohen, J. I., Fodor, C., Yancey, C., Gordon-Salant, S. (2020). Objective assessment of speech intelligibility in crowded public spaces. *Ear Hear*, 41(Suppl 1), 68S–78S.
- Caduff, A., Feldman, Y., Ishai, P. B., Launer, S. (2020). Physiological monitoring and hearing loss: Towards a more integrated and ecologically validated health mapping. *Ear Hear*, 41(Suppl 1), 120S–130S.
- Campos, J. L., & Launer, S. (2020). From healthy hearing to healthy living: A holistic approach. *Ear Hear*, 41(Suppl 1), 99S–106S.
- Carlile, S., & Keidser, G. (2020). Conversational interaction is the brain in action: Implications for the evaluation of hearing and hearing interventions. *Ear Hear*, 41(Suppl 1), 56S–67S.
- Carpenter, M. G., & Campos, J. L. (2020). The effects of hearing loss on balance: A critical review. *Ear Hear*, 41(Suppl 1), 107S–119S.
- Cox, R., Hyde, M., Gatehouse, S., Noble, W., Dillon, H., Bentler, R., Stephens, D., Arlinger, S., Beck, L., Wilkerson, D., Kramer, S., Kricos, P., Gagné, J. P., Bess, F., Hallberg, L. (2000). Optimal outcome measures, research priorities, and international cooperation. *Ear Hear*, 21(4 Suppl), 106S–115S.
- Feeney, M. P., Hunter, L. L., Kei, J., Lilly, D. J., Margolis, R. H., Nakajima, H. H., Neely, S. T., Prieve, B. A., Rosowski, J. J., Sanford, C. A., Schairer, K. S., Shahnaz, N., Stenfelt, S., Voss, S. E. (2013). Consensus statement:

- Eriksholm workshop on wideband absorbance measures of the middle ear. *Ear Hear*, 34(Suppl 1), 78S–79S.
- Grimm, G., Hendrikse, M., Hohmann, V. (2020). Survey of self motion in the context of hearing and hearing device research. *Ear Hear*, 41(Suppl 1), 48S–55S.
- Hohmann, V., Paluch, R., Krueger, M., Meis, M., Grimm, G. (2020). The Virtual Reality Lab: Realization and application of virtual sound environments. *Ear Hear*, 41(Suppl 1), 31S–38S.
- Holube, I., von Gablenz, P., Bitzer, J. (2020). Ecological momentary assessment (EMA) in audiology: Current state, challenges, and future directions. *Ear Hear*, 41(Suppl 1), 79S–90S.
- Keidser, G., Naylor, G., Brungart, D., Caduff, A., Campos, J., Carlile, S., Carpenter, M., Grimm, G., Hohmann, V., Holube, I., Launer, S., Lunner, T., Mehra, R., Rapport, F., Slaney, M., Smeds K. (2020). The quest for ecological validity in hearing science: What it is, why it matters, and how to advance it. *Ear Hear*, 41(Suppl 1), 5S–19S.
- Kiessling, J., Pichora-Fuller, M. K., Gatehouse, S., Stephens, D., Arlinger, S., Chisolm, T., Davis, A.C., Erber, N.P., Hickson, L., Holmes, A., Rosenhall, U., von Wedel, H. (2003). Candidature for and delivery of audiological services: Special needs of older people. *Int J Audiol*, 42(Suppl 2), S92–S101.
- Lunner, T., Alickovic, E., Graversen, C., Ng, E.H.N., Wendt, D., Keidser, G. (2020). Three new outcome measures that tap into cognitive processes required for real-life communication. *Ear Hear*, 41(Suppl 1), 39S–47S.
- Mehra, R., Brimijoin, O., Robinson, P., Lunner, T. (2020). Potential of Augmented Reality platforms to improve individual hearing aids and to support more ecologically valid research. *Ear Hear*, 41(Suppl 1), 140S–146S.
- Pichora-Fuller, M. K., Kramer, S. E., Eckert, M. A., Edwards, B., Hornsby, B. W., Humes, L. E., Lemke, U., Lunner, T., Matthen, M., Mackersie, C. L., Naylor, G., Phillips, N. A., Richter, M., Rudner, M., Sommers, M. S., Tremblay, K. L., Wingfield, A. (2016). Hearing Impairment and Cognitive Energy: The Framework for Understanding Effortful Listening (FUEL). *Ear Hear*, 37(Suppl 1), 5S–27S.
- Rapport, F., & Hughes, S. (2020). Frameworks for change in hearing research: Valuing qualitative methods in the real world. *Ear Hear*, 41(Suppl 1), 91S–98S.
- Slaney, M., Lyon, R. F., Garcia, R., Kemler, B., Gnegy, C., Wilson, K., Kanevsky, D., Savla, S., Cerf, V. (2020). Auditory measures for the next billion users. *Ear Hear*, 41(Suppl 1), 131S–139S.
- Smeds, K., Gotowiec, S., Wolters, F., Herrlin, P., Larsson, J., Dahlquist, M. (2020). Selecting scenarios for hearing-related laboratory testing. *Ear Hear*, 41(Suppl 1), 20S–30S.

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