12. Kim, A.J., Lazar, A.A., and Slutskiy, Y.B. (2015). Projection neurons in *Drosophila* antennal lobes signal the acceleration of odor concentrations. eLife *4*, e06651.

13. Silies, M., Gohl, D.M., and Clandinin, T.R. (2014). Motion-detecting circuits in flies: coming into view. Annu. Rev. Neurosc. *37*, 307–327.

14. Suzuki, H., Thiele, T.R., Faumont, S., Ezcurra, M., Lockery, S.R., and Schafer, W.R. (2008). Functional asymmetry in *C. elegans* taste neurons and its computational role in chemotaxis. Nature *454*, 114–117.

15. Chalasani, S.H., Chronis, N., Tsunozaki, M., Gray, J.M., Ramot, D., Goodman, M.B., and Bargmann, C.I. (2007). Dissecting a circuit for olfactory behaviour in Caenorhabditis elegans. Nature *450*, 63–70.

16. Owald, D., and Waddell, S. (2015). Olfactory learning skews mushroom body output pathways to steer behavioral choice in *Drosophila*. Curr. Opin. Neurobiol. *35*, 178–184.

17. Suver, M.P., Mamiya, A., and Dickinson, M.H. (2012). Octopamine neurons mediate flight-induced modulation of visual processing in *Drosophila*. Curr. Biol. *22*, 2294–2302.

18. Dacks, A.M., Green, D.S., Root, C.M., Nighorn, A.J., and Wang, J.W. (2009). Serotonin modulates olfactory processing in the antennal lobe of *Drosophila*. J. Neurogenet. *23*, 366–377.

19. Fernandes, V.M., Chen, Z., Rossi, A.M., Zipfel, J., and Desplan, C. (2017). Glia relay differentiation cues to coordinate neuronal development in *Drosophila*. Science *357*, 886–891.

20. Tobin, W.F., Wilson, R.I., and Lee, W.C.A. (2017). Wiring variations that enable and constrain neural computation in a sensory microcircuit. eLife *6*, e24838.

Hearing: The Future of Sensory Rehabilitation?

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A new randomized, double-blind controlled study has found that playing a video game modeled from sensory foraging behavior can improve the aging brain's ability to hear complex signals hidden in background noise.

Untreated hearing loss can significantly impact an individual's ability to communicate with others and decrease quality of life [1]. While enormous technological advances in recent years have made hearing aids smaller and smarter, hearing aid use and satisfaction lag behind these design improvements. In fact, a recent report [2] estimates that nearly 23 million American adults above the age of 50 have hearing loss but do not use hearing aids. Even with today's state-of-the-art technology, the amplified signal produced by hearing aids may sound odd or distorted, and therefore foreign to wearers. This, unfortunately, has caused many to neglect the routine use of hearing aids, and this untreated hearing loss can lead to a deprivation of sound stimulation that will, in time, weaken auditory centers of the brain. With the passing of the Over-the-Counter Hearing Aid Act of 2017 by the U.S. House of Representatives, in the USA at least, hearing aids may soon become more affordable and accessible, and with it, the need to offer hearing rehabilitative services to hearing aid users may become more apparent. In this issue of *Current Biology*, Whitton *et al.* [3] outline a new, inventive, videogame approach to hearing rehabilitation that has promise as a therapeutic option for hearing aid users.

Audiologists recommend auditory training as a supplemental therapy to hearing aids to help re-train the brain to process and interpret the signal that the hearing aid, or another prosthetic hearing device like a cochlear implant, provides. Auditory training, however, can be used by anyone who wishes to refine their auditory skills, not just individuals with hearing loss. Similar to physical therapy following an injury, auditory training typically involves exercises that target an area of weakness. These exercises draw the listener's focus to sonic details, like a subtle change in pitch or rhythm. Other exercises might target higher-level skills, such as working memory or lexical knowledge, to compensate for missing acoustic details that might occur with a bad cell-phone connection or high levels of background noise. In most current training programs, the training is structured as a type of call and response: a sound stimulus is presented, the trainee responds. This is followed by a short pause, and then the same succession of steps repeats for a new item in the training set.

Whitton *et al.* [3] take an unorthodox approach to auditory training for hearing aid users that shares many features with playing a musical instrument, arguably one of the oldest, naturalistic forms of auditory training. The documented benefits of music training extend from improved quality of life, including stress reduction [4], to enhanced processing of complex auditory signals, such as speech in noisy backgrounds [5,6]. The training program developed by Whitton *et al.* [3] works through a closed-loop design that is implemented as a video game on a touch-screen tablet computer. In this video game, sound is modified in real-time, in response to micro movements of the player's finger as it slides across the touch screen, similar to how a violinist places and then subtly refines her finger on the string to adjust the pitch of the instrument. The game involves foraging for a hidden puzzle piece, the location and shape of which are cued by a faint sound that is blanketed by the chatter of many people talking simultaneously. Think of the video game as an advanced version of the 'Hot–Cold' children's game, where the player must rely on auditory cues to estimate the distance to a prize. The video game principles are directly modeled from animal foraging behavior, in which an animal navigates an environment using sensory cues and spatial memory to find a target [7]. Using their novel approach to auditory training, Whitton *et al.* [3] trained older adults with hearing aids for eight weeks (2.5 hours/week in 30–60 minute blocks). Through repeated play, hidden sound pieces were found quicker, using more efficient foraging paths, even as the level of background babble intensified.

Auditory training programs are evaluated in terms of not only how they improve the specific skills that are practiced, but also how they benefit untrained skills, including general sensory, social, and cognitive skills, which have real-world relevance when communicating in noisy environments, such as a crowded restaurant. Whitton *et al.* [3] show that foraging for weak acoustic signals in a closed-loop video game improved game play itself. But more importantly, training also led to generalized gains on clinical tests of hearing in noise, and these gains were robust enough to be considered clinically significant. Interestingly, the same clinically-significant gains, however, were not seen for an active control group that underwent more traditional approaches to training using the same tablets for the same time period.

A review article published in 2013 [8] critically evaluated more than a dozen studies that have implemented computer-based auditory training in the older adult, hearing-impaired population. Across the board, the reviews were generally lukewarm. Of the 13 studies that underwent in-depth scrutiny, only three used random group assignment, although for all three the process of randomization was judged to be weak or otherwise flawed. The review concluded by stating that despite auditory training programs having great therapeutic potential, published evidence for their efficacy in hearing-impaired listeners has not always followed strict, scientific guidelines for conducting unbiased research. Consequently, this has yielded weak evidence for guiding clinical practice. Yet, even in the short time since the review was published, changes are afoot. The field is now starting to see more auditory training studies [9,10], including the one by Whitton *et al.* [3], adopt stricter scientific protocols.

Are closed-loop auditory training programs the wave of the future? Are we looking at the modern face of auditory rehabilitation? A roadblock to wide-scale clinical implementation is that few audiologists currently offer auditory training as a clinical service, given limited insurance reimbursement. Moreover, the success of any training program, whether supervised by a clinician or implemented as a home remedy, boils down to the cost of the program, the time commitment to undertake the training, and the degree to which the training engages the participant. The Whitton *et al.* [3] study is part of a growing movement to harness the design features, including the addictive qualities, of action video games for therapeutic purposes [11]. The smaller footprint and decreasing costs of high-quality audio-video interactive devices has allowed computerized brain training to make the giant leap from the laboratory to the home. Along with it, a new variety of for-profit brain training programs have emerged. We have all seen and wondered about TV adverts for commercial brain-fitness games that promise grandiose, far-reaching improvements. In response to the increased popularity of commercially available brain fitness programs and concern about exploitative, snake-oil sales tactics regarding strong scientific underpinnings, a group of 75+ experts in the fields of aging and neuroscience released a position statement in 2014 [12] urging the scientific community to investigate these commercial programs with the most stringent scientific criteria, such as randomized control designs. The position statement also warned that short-term training of any type rarely produces long-term benefits.

On that point, while the generalized effects of training were striking in the Whitton *et al.* [3] study, the benefits were transitory, with performance gains on clinical tests of hearing in noise regressing two months after game play stopped. But regression, or at least fast-paced regression, may not be inevitable for all forms of auditory training. Other short-term training studies have found that benefits extend out six months beyond training [13] or that the neural benefits of training outlive the behavioral benefits [14]. Yet, the most enduring effects occur when auditory training (or auditory stimulation, more generally) occurs earlier in life, as has been observed in studies of former musicians [15,16], adopted children who are no longer exposed to their native language [17], and aging laboratory animals that received auditory training while young [18]. If research advances in the direction it is currently heading, it may be possible, in the not too distant future, to turn back the neurobiological clock, enabling longer-lasting behavioral and neural changes following short-term training [19]. Moreover, it may soon be possible to regrow sensory cells in the human inner ear [20], rendering hearing aids, at least in their current incarnation, obsolete.

REFERENCES

1. Mulrow, C.D., Aguilar, C., Endicott, J.E., Tuley, M.R., Velez, R., Charlip, W.S., Rhodes, M.C., Hill, J.A., and DeNino, L. (1990). Quality-of-life changes and hearing impairment: A randomized trial. Ann. Intern. Med. *113*, 188–194.

2. Chien, W., and Lin, F.R. (2012). Prevalence of hearing aid use among older adults in the United States. Arch. Intern. Med. *172*, 292–293.

3. Whitton, J.P., Hancock, K.E., Shannon, J.M., and Polley, D.B. (2017). Audiomotor perceptual training enhances speech intelligibility in background noise. Curr. Biol. *27*, 3237–3247.

4. Kokotsaki, D., and Hallam, S. (2011). The perceived benefits of participative music making for non-music university students: a comparison with music students. Music Ed. Res. *13*, 149–172.

5. Parbery-Clark, A., Skoe, E., Lam, C., and Kraus, N. (2009). Musician enhancement for speech-in-noise. Ear Hear. *30*, 653–661.

6. Zendel, B.R., and Alain, C. (2012). Musicians experience less age-related decline in central auditory processing. Psychol. Aging *27*, 410–417.

7. Whitton, J.P., Hancock, K.E., and Polley, D.B. (2014). Immersive audiomotor game play enhances neural and perceptual salience of weak signals in noise. Proc. Natl. Acad. Sci. USA *111*, E2606–E2615.

8. Henshaw, H., and Ferguson, M.A. (2013). Efficacy of individual computer-based auditory training for people with hearing loss: a systematic review of the evidence. PLoS One *8*, e62836.

9. Anderson, S., White-Schwoch, T., Parbery-Clark, A., and Kraus, N. (2013). Reversal of age-related neural timing delays with training. Proc. Natl. Acad. Sci. USA *110*, 4357–4362.

10. Saunders, G.H., Smith, S.L., Chisolm, T.H., Frederick, M.T., McArdle, R.A., and Wilson, R.H. (2016). A randomized control trial: supplementing hearing aid use with listening and communication enhancement (LACE) auditory training. Ear Hear. *37*, 381–396.

11. Hamari, J., Koivisto, J., and Sarsa, H. (2014). Does gamification work? — a literature review of empirical studies on gamification. In System Sciences (HICSS), 2014 47th Hawaii International Conference on System. Sciences, 3025–3034.

12. Allaire, J., Backman, L., Balota, D., Bavelier, D., Bjork R., Bower, G., Braver, T., Buckner R., Bunge, S., Cabeza, R., et al. (2014). A Consensus on the Brain Training Industry from the Scientific Community, Max Planck Institute for Human Development and Stanford Center on Longevity, accessed September 12, 2017, http://longevity.stanford.edu/a-consensus-on-the-brain-training-industry-from-the-scientific-community-2/).

13. Song, J.H., Skoe, E., Banai, K., and Kraus, N. (2012). Training to improve hearing speech in noise: Biological Mechanisms. Cereb. Cortex *22*, 1180–1190.

14. Anderson, S., White-Schwoch, T., Choi, H.J., and Kraus, N. (2014). Partial maintenance of auditory-based cognitive training benefits in older adults. Neuropsychologia *62*, 286–296.

15. White-Schwoch, T., Carr, K.W., Anderson, S., Strait, D.L., and Kraus, N. (2013). Older adults benefit from music training early in life: biological evidence for long-term training-driven plasticity. J. Neurosci. *33*, 17667–17674.

16. Skoe, E., and Kraus, N. (2012). A little goes a long way: How the adult brain is shaped by musical training in childhood. J. Neurosci. *32*, 11507–11510.

17. Pierce, L.J., Klein, D., Chen, J.K., Delcenserie, A., and Genesee, F. (2014). Mapping the unconscious maintenance of a lost first language. Proc. Natl. Acad. Sci. USA *111*, 17314–17319.

18. Cheng, Y., Jia, G., Zhang, Y., Hao, H., Shan, Y., Yu, L., Sun, X., Zheng, Q., Kraus, N., and Merzenich, M.M. (2017). Positive impacts of early auditory training on cortical processing at an older age. Proc. Natl. Acad. Sci. USA *114*, 6364–6369.

19. Gervain, J., Vines, B., Chen, L., Seo, R., Hensch, T., Werker, J., and Young, A. (2013). Valproate reopens critical-period learning of absolute pitch. Front. Syst. Neurosci. *7*, 192.

20. Lyon, J. (2017). Hearing restoration: a step closer? JAMA *318*, 319–320.

Ancient DNA: Saber-Toothed Cats Are the Same Beasts After All

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Ancient DNA from the saber-toothed cat *Homotherium* reveals that the late Pleistocene species from Europe and North America were the same. *Homotherium* turns out to be only distantly related to the well-known saber-toothed *Smilodon*.

Sabertooth cats always pique the imagination of children and adults alike. At the mention of a sabertooth cat, we picture gore on the glistening saber canines, and the cat in the throes of a bloody conquest of some long extinct beast, like a mammoth or a giant ground sloth. But there is more to sabertooth cats than this gory, romantic notion. We often forget that sabertooth cats were real creatures, with population dynamics similar to living cats that suffered real consequences due to a lack of prey, or a rapidly changing climate. Sabertooth felids first appear in the mid-Miocene, around 12 million years ago, of the Old World, and soon after came to North America [1,2]. Like other groups of mammals, many different species of sabertooth cats arose and went extinct in the last 12 million years, but by the end of the Pleistocene epoch, approximately 11,500 years ago, all species of sabertooths were extinct. A new study in this issue of *Current Biology* by Johanna Paijmans, Michael Hofreiter and colleagues [3] addresses when one genus of sabertooth cat, *Homotherium* (literally: the 'same beast'), went extinct and what its evolutionary relationship was to another sabertooth cat, the well-known *Smilodon populator*, as well as to extant felids.

The genus *Homotherium* first appears in the early Pliocene of Africa, around four million years ago, and migrated to every continent except Antarctica and Australia (Figure 1). *Homotherium* appears in Europe in the mid-Pliocene and in North America by the late Pliocene. By contrast, *Smilodon* is a New World taxon; however, its parent taxon, *Megantereon*, arose in the Old World, and migrated to North America before giving rise to *Smilodon*. *Smilodon* is first known from the Pliocene of North America and was one of the last sabertooth species to go extinct at the end of the Pleistocene. Although *Smilodon* and *Homotherium* are both sabertooth cats, morphologically, these two species are very distinct. These two extinct cats can be grouped into scimitar-toothed and dirk-toothed cats [2,3]. So-called 'scimitar-toothed' sabertooth cats such as *Homotherium* generally had a more gracile morphology with less mediolateral flattening of their elongated canines and have medium to fine canine serrations. By contrast, dirk-toothed sabercats, like *Smilodon*, were more robust overall with longer, flatter canines, that have few to no serrations. Many scimitar-tooth cats belong to a lineage called the Homotheriini while dirk-tooth cats belong to the Smilodontini.