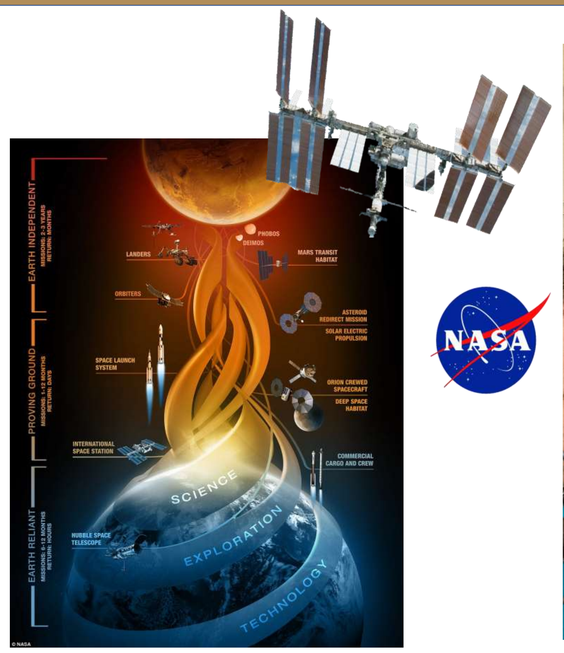
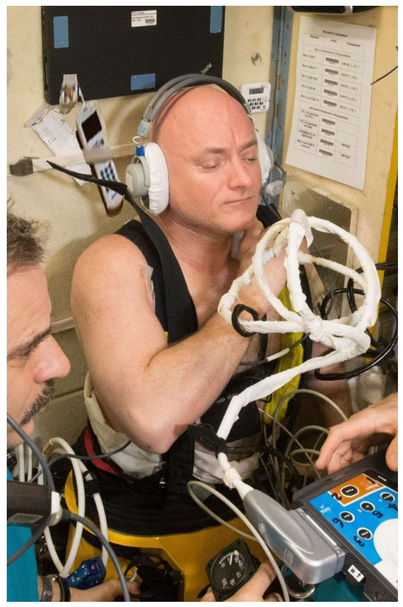
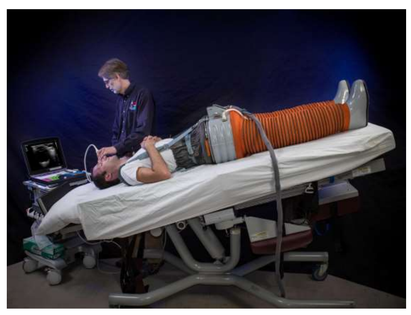
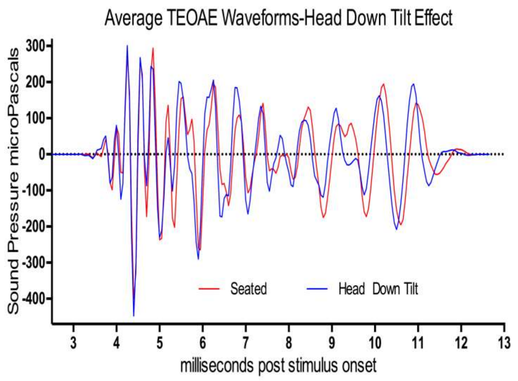
OAEs in space -and in the future



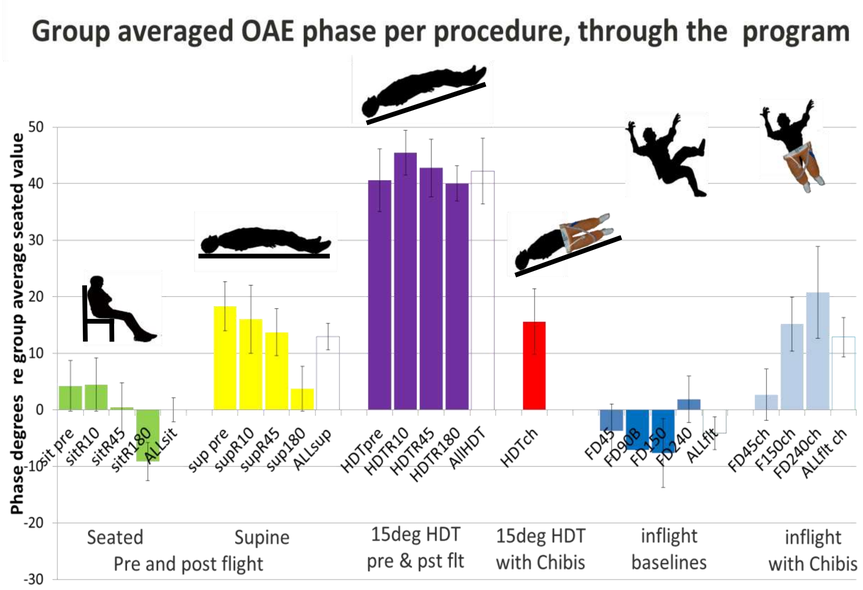


NASA is developing systems for manned deep space missions, including ways to protect the physiological and psychological well-being of the crew for long periods. Long duration spaceflight adversely affects the eyes of astronauts a condition known as Spaceflight-Associated Neuro-ocular Syndrome (SANS). The damage looks as though it cold be a result of excess intra cranial fluid pressure (ICP) due to body fluid shifts in the absence of gravity. NASA's Fluid Shift Project has employed Otoacoustic Emissions on board the International Space Station as one of several techniques capable for detecting changed ICP. P.I's and coordinators for OAE measurements were Drs Richard Danielson and Douglas Ebert. NASA grants NNX13AK30G, NNX13AJ12G, and the Human Health and Performance Contract (HHPC).



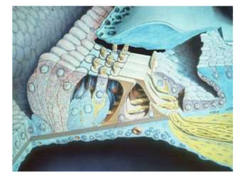


The cochlea is in pressure equilibrium with intracranial pressure. TEOAEs provide a stable signal source with which to detect changes in cochlear pressure (after Avan et al) . OAE phase is advanced by increased tension of the oval window. As a ground level control astronauts' ICP was increased by tilting the head down, and lowered by applying lower body negative pressure (see above left). Tilting shortened OAE latency (right). TEOAEs were recorded using the Otodynamics Ltd Otoport. OAE phase of 10 astronaut's TEOAEs recorded in microgravity on the ISS was compared to their seated ground based reference measurements. See figure below. OAEs clearly detected the effect of tilting the head down but surprisingly inflight and ground based seated OAEs were almost identical! There was little evidence of a rise in ICP from OAE data. Research continues….



OAEs ARE OUR ONLY PRACTICAL WINDOW ON A VITAL COCHLEAR PROCESS

- **Can we use OAEs more effectively?**
- **What OAE instrument features will help us do this?**
- **What more could OAEs offer audiology in future?**



OAEs are great for Screening - how can OAE screening be made even better?

OAEs have proved to be fast, reliable and cost effective for screening the well baby population. The risk of auditory neuropathy in the at-risk population means the OAEs have to be combined with ABR screening for this group. The sensitivity to cochlear disorders of TEOAE and DPOAE screening with moderate stimulus levels is very high. However the prevalence of middle ear fluid and ear canal debris in the hours after birth can lower the specificity of OAE screening to less than ideal.

How can OAE infant screening be made better? If the instrument detected acoustic impedance anomalies during the screening then unnecessary referrals could be avoided. If healthy middle ear function were confirmed with absent OAEs in one test then a priority referral could be initiated. Time and resources would be saved by not re-screening.

Speed of screening is important. Signal processing and noise rejecting algorithms can be further improved to speed up testing. But fitting the probe takes time and improvements can be made here - e.g. so the cable doesn't leverage the fitting and increase noise. Even wireless OAEs probes are a possibility. The usability and ergonomics of the screening instrument and probes can always be improved.

There also needs to be more clarity about which frequencies need to be tested. OAE screening is frequency specific. Why? 'Gold Standard' ABR screening is not. The AABR stimulus focuses on the 4kHz octave. Should OAEs do the same - avoiding the additional noise at lower frequencies? False responses must be minimised. The sensitivity of OAE screening instruments must be proved by testing for absent responses in nursery noise with zero stimulation. We need to have clear standards and methods for that 'calibration'.

OAEs in the clinic. Making full use of their potential.

OAEs offer audiology so much more than a "yes/no" screener. Even so their most common use in the clinic focuses on the objective confirmation of cochlear dysfunction. Although DPOAE measurements are a quantitative measure -interpretation is often limited to 'good or bad' - barely more than screening.

Michael Gorga and others have done much to improve the interpretation of DP-grams, using large populations to define normative and marginal ranges. This Is valuable when subjective responses just can't be obtained or when this OAE assessment conflicts with the audiometry. DPOAEs should only be a substitute for audiometry as a last resort. Since the beginning of OAE use there have been attempts to obtained accurate threshold estimates from DPOAES. Averaged over a large population, DPOAE levels, or 'DP thresholds DO correlated with hearing threshold- but the accuracy for individual patients is still quite poor. The poor individual accuracy of DPOAE threshold estimation is not at all surprizing. OAEs are NOT a hearing test! They record the efficiency of the only first stage of the auditory system- from middle ear through to the travelling wave and outer hair cell function. It is inner hair cell transduction that has a 'threshold' sensitivity and which activates multiple synapses that transfer the encoded stimulus to the auditory nerves.

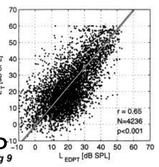
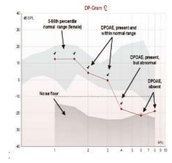


Fig 9



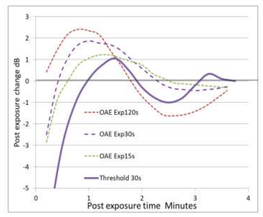
Hearing Threshold = ME efficiency x OHC efficiency x IHC efficiency x synaptic x neural efficiency

So of course good OAEs correlate with hearing threshold, as does a good middle ear - but they don't and can't determine threshold. To think of DP-grams only as an objective audiogram is to miss the unique value OAE measurement. As part of an integrated audiological test battery OAEs can help locate and delineate specific pathologies and the nature of changes to hearing. Sadly OAEs are rarely used as part of a systematically applied clinical diagnostic test battery. For example if moderate hearing loss is already confirmed an OAE test will be often be skipped as of 'no additional value'. But the rarer conditions will be missed- as auditory neuropathy was missed for decades before OAEs!

And remember that the state of an ear is not fully characterised by a single DP-gram at default settings or even several DP grams done at different levels. Current OAE research is far ahead of clinical practice in seeking to better understand the generation of OAEs and the subtle effects of pathology, overstimulation, otological stress, genetic factors and ageing. Researchers explore the cochlea otoacoustically with a much richer palette of stimulus forms and levels than is possible in the clinic. They measure DP growth functions, latency, tuning and efferent suppression and more. But even if these facilities were made available on clinical instruments such 'advanced' measurements take time that can only be allocated in proportion to their value to the patient. Clinically proven interpretations of advance OAE measurements isn't available yet and wont be until there is wider participation in clinical research with these techniques. It's a 'chicken and egg' dilemma. But Audiology must not allow our window on the most vulnerable hearing mechanism to be relegated to 'screener' status. .

Hearing Changes - so do OAEs There is something more we can do with OAEs- before we get that full 'interpretation'. OAEs are normally very stable over time. Changes of only a dB over a period can be significant indicators of varying cochlear function. Routinely taking a reference DP gram on all patients would enhance the value of period reviews - yet this is seldom considered. There are some improvements to OAEs instrument needed to optimise such a practice. Extension of OAE measurements above 8kHz is one obvious step. That's not an easy step as using OAEs to monitor of cochlear function relies on their accuracy and reproducibility. Ear canal acoustics and probe fitting variability work against this. But the problem of OAE measurement accuracy and reliability IS being overcome. Thevenin acoustic calibrated probes and forward pressure calibration in the ear can greatly improve the situation.

Routine precision monitoring of cochlear function with OAEs is in sight!.



OAEs can record changes in cochlear function as in this oscillatory 'recovery' of hearing from a brief noise exposure. This reveals the cochlear homeostatic process at work .