Hot Topics in Vestibular Research

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Over the last decade or so the employment of selective acoustic and inertial stimulation methods has led to a number of important advances in vestibular research which have made it possible, at least in principle, to assess each of the five human end organs independently. These new methods, including e.g. the vestibular evoked myogenic potential (VEMP) (Colebatch et al. 1994), as well as providing new tests of vestibular function, also provide new tools for investigating some basic physiological and anatomical properties of the vestibular system. However, these advances are not without controversy (e.g. see Todd 2014ab). Having been in the thick of it over a number of years I would like to share some issues in the hope that these will stimulate lively discussion and debate, and potentially lead to future collaborations. So in a series of forthcoming postings I will be raising a number hot topics in vestibular research.

Hot topic 1: Low frequency sensitivity of the vestibular system and its significance

An important issue which has taken up much effort in vestibular research is that of frequency tuning. This is important for at least two reasons. One is that it helps to define the optimal stimuli for clinical testing. Another, at a more basic level, is that it provides an insight into the mechanisms of transduction.

Frequency tuning in the old VEMP (Colebatch et al. 1994), now commonly referred to as a cervical VEMP (or C-VEMP), has been well-established for the use of air-conducted (AC) sound stimulation where a best frequency of about 500 Hz was demonstrated (e.g. Todd et al. 2000; Welgampola and Colebatch 2001). A similar tuning was also shown for bone-conducted (BC) sound (Sheykholeslami et al. 2001) using a clinical stimulator (e.g. the Radioear B72). It is these data which guided the common usage of a stimulus frequency of 500 Hz in VEMP testing, in addition to the common use of clicks.

A 100 Hz vibration sensitivity

With the advent of the ocular VEMP (or O-VEMP) (Todd et al. 2007) and the adoption of use of mini-shakers for stimulation (e.g. Todd et al. 2008a; Rosengren et al. 2009), it was possible to explore a wider range of stimulus frequencies in experiments. This led to the discovery that in addition to the 500 Hz sensitivity there was also another sensitivity of lower frequency at about 100 Hz (Todd et al. 2008b, 2009a). This sensitivity was such that it was found possible to detect responses in the O-VEMP to 100 Hz vibration below the threshold of hearing, and at higher intensities observe response of such magnitude that it was possible to see them in single trials without averaging (Todd et al. 2010). Several experiments conducted to explore the 100 Hz sensitivity suggested that it could
be detected for both O-VEMP and C-VEMP pathways but that there were both peripheral and central mechanisms involved (Todd et al. 2009b). These experiments led to the hypothesis that it was specifically utricular in origin, possibly reflecting its unique anatomical properties, e.g. that it is only membranously attached, unlike the saccule which is rigidly attached to the temporal bone (Uzun-Coruhlu et al. 2007). Subsequent experiments showed that in fact two tuning peaks, one at about 100 Hz and another at about 500 Hz, can be detected for both AC and BC stimuli (Zhang et al. 2011, 2012).

So what is the significance of this 100 Hz sensitivity? I suggest that there are at least three cases which may demonstrate a significance. The first case concerns the possibility that it represents a conserved ancient hearing mechanism which may still have some normal function in humans. The second is that it may be responsible for some pathophysiology hitherto unrecognized. The third is that it may constitute the physiological basis for some new clinical tests of vestibular function. I explore each of these three cases below.

**A conserved amphibian hearing mechanism?**

At a basic science level the sensitivity is reminiscent of the remarkable seismic sensitivity of amphibian otolith organs to low-frequency vibration (Narins and Lewis 1984). In these animals low-frequency vibration plays an important role in vocal communication, not least during the courtship season. Could it be the case that higher vertebrates, including mammals and humans, have conserved a similar frog-like low-frequency sensitivity? And could such a sensitivity still play a biological role in humans? In fact there is quite a lot of evidence, although some circumstantial, that suggests an affirmative to both these questions. One important example, which has clinical implications, because of its potential impact on hearing, is the propensity of humans to expose themselves to low-frequency vibrations, e.g. at loud music events. It could be argued that gatherings of humans at such loud music environments are analogous to the gathering of frogs, or indeed fish, reptiles, birds, and many other species within the vertebrate classes, during courtship rituals (Todd 2001, 2007). I will return to this is issue in more detail in a later posting.

**“Wind Turbine Syndrome”**?

Another case, possibly related to the above, where such low-frequency sensitivity may be important is so-called “Wind Turbine Syndrome” (Pierpont 2009). It has been claimed that the acoustic noise from wind turbines gives rise to a pathological condition mediated by the vestibular system. With the massive expansion of the wind energy industry there has been a concomitant rise in the number of claims of health effects from people living in close proximity to turbines. While such effects may not be in dispute, the claim that they are mediated by the vestibular system is highly controversial (Salt and Hullar, 2010; Leventhall 2009). Further basic research will be required to resolve this issue.

**A utricular origin of vibration induced nystagmus?**
From a more immediately clinical perspective the 100 Hz vibration sensitivity has direct application in the case of vibration induced nystagmus (VIN). VIN has been demonstrated to be a useful clinical test of unilateral vestibular dysfunction (Hamann et al. 1999; Ohki et al.2003; Dumas et al. 2011). The essential observation is that VIN nystagmus to one side predicts a lesion on the opposite side to the direction of the nystagmus. However, the mechanism is poorly understood, and it is complicated by the fact that vibration may also activate spindle receptors in the sternocleidomastoid muscles, as well as vestibular receptors (Popov et al. 1996). Nevertheless, the pattern of nystagmus observed is suggestive of a utricular involvement (Dumas et al. 2011). The possible link between the abnormality of low-frequency vibration evoked VEMPs in unilateral vestibular dysfunction (e.g. see Govender et al. 2011) and VIN is surely a fruitful line of future research.

References


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