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Research paper

Differences by sex, ear, and sexual orientation in the time intervals between successive peaks in auditory evoked potentials

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ABSTRACT

Auditory evoked potential (AEP) data from two studies originally designed for other purposes were reanalyzed. The auditory brainstem response (ABR), middle-latency response (MLR), and long-latency response (LLR) were measured. The latencies to each of several peaks were measured for each subject for each ear of click presentation, and the time intervals between successive peaks were calculated. Of interest were differences in interpeak intervals between the sexes, between people of differing sexual orientations, and between the two ears of stimulation. Most of the differences obtained were small. The largest sex differences were for interval I → V in the ABR and interval N1 → N2 of the LLR (effect sizes > 0.6). The largest differences between heterosexuals and nonheterosexuals were for the latency to Wave I in both sexes, for the interval Na → Nb in females, and for intervals V → Na and Nb → N1 in males (effect sizes > 0.3). The largest difference for ear stimulated was for interval N1 → N2 in heterosexual females (effect size ~0.5). No substantial differences were found in the AEP intervals between women using, and not using, oral contraceptives. Left/right correlations for the interpeak intervals were mostly between about 0.4 and 0.6. Correlations between the ipsilateral intervals were small; i.e., interval length early in the AEP series was not highly predictive of interval length later in the series. Interpeak intervals appear generally less informative than raw latencies about differences by sex and by sexual orientation.

1. Introduction

Following the presentation of a brief acoustic stimulus such as a click, a succession of peaks is evoked in the brain waves that are detected using simple electrode arrays on the scalp (e.g., Hall, 2007). This succession of peaks is known as the auditory evoked potentials (AEPs). The most common way to analyze and report AEP data is to measure either the time elapsed between stimulus presentation and the maximum magnitude of the peak of interest (the latency), or the amplitude of that peak measured from its maximum magnitude to the following minimum magnitude (e.g., Davis, 1976). By convention, the succession of peaks seen is divided into three temporal groups: the auditory brainstem responses (ABRs) having peak latencies between 0 and about 10 ms, the middle-latency responses (MLRs) having peak latencies between about 10 and 50 ms, and the long-latency responses (LLRs) having peak latencies between about 50 and 300 ms (Picton et al., 1974).

A number of factors affect the latencies of the peaks in the AEP (for a review, see Burkard and Don, 2007). However, because the peaks are loosely associated with anatomical regions within the central auditory nervous system (e.g., Møller, 1998), the time intervals between the latencies of successive peaks do provide a rough measure of the transmission times between regions of the brain, and these intervals have proved to be useful for neuro-diagnostic purposes (Hall, 2007). The presence of neurological pathology typically leads to a prolongation of the interpeak intervals (Møller, 2007). The transmission times of the ABR have been studied most extensively (e.g., Fabiani et al., 1979; Griffiths et al., 1989).

Calculating interpeak intervals has been most common for early peaks such as the interval between wave I and wave III (I → III),

List of Abbreviations: ABR, auditory brainstem response; AEP, auditory evoked potential; Ht, heterosexual; LLR, long-latency response; MLR, middle-latency response; OAE, otoacoustic emission; OC, oral contraceptive; PAMR, post-auricular muscle response.

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between wave III and wave V (III → V), or between wave I and wave V (I → V) of the ABR (e.g., Fabiani et al., 1979; Griffiths et al., 1989; Grillon et al., 1989; Skoff et al., 1980; Rosenhall et al., 2003). Less commonly, investigators sometimes have reported interpeak intervals between later waves such as Na, Pa, and Nb of the MLR (e.g., Davis and Zerlin, 1966; Grillon et al., 1989; Ozdamar and Kraus, 1983). The interval I → V has been labeled "central conduction time" (Gorga et al., 1988) and is used clinically to assess the presence of retrocochlear pathology between the auditory nerve and the brainstem.

AEPs long have been known to exhibit sex differences in latency or amplitude of certain peaks (e.g., Cowell et al., 1994; Stockard et al., 1978). The most commonly studied peak is wave V of the ABR, and both its latency and the interpeak interval I → V are shorter (faster) in females than in males (Beagley and Sheldrake, 1978; Stockard et al., 1978; Jerger and Hall, 1980). Although sex differences are well established in adults, the results are less clear-cut in infants and young children where sex differences sometimes are not observed (e.g., Sininger et al., 1998; Stockard et al., 1979). In a previous paper, we presented evidence that certain AEP peaks also are different in latency or amplitude in people of different sexual orientations (McFadden and Champlin, 2000). Specifically, we showed that the mean values for homosexual and bisexual females can be shifted in the direction of males (called "masculinized"), and the mean values for homosexual and bisexual males can be shifted so far away from the female means that they exceed the means for the heterosexual males (called "hyper-masculinized"). A masculinization also has been observed in the otoacoustic emissions (OAEs) of nonheterosexual females, but the OAEs of heterosexual and nonheterosexual males did not differ (McFadden and Pasanen, 1998, 1999; reviewed by McFadden, 2008, 2009).

We wished to know if the elapsed times between successive peaks in the AEPs also can differ between heterosexual and nonheterosexual males or females, and if sex (or ear) differences exist in intervals other than interval I → V of the ABR. To maximize the sample size, the data from a previously published study (McFadden, 2000; McFadden and Champlin, 2000) were pooled with later-collected data using substantially the same recruitment and measurement procedures.

2. Methods

2.1. General

The analyses reported here were performed on data collected in two AEP studies designed for purposes other than measuring the time intervals between successive peaks in the AEP waveforms. The first data set was the basis for two previous reports (McFadden, 2000; McFadden and Champlin, 2000). The second data set was collected over a period of several years beginning soon after the publication of the first study. The AEP procedures, equipment, and analyses were essentially identical for the two studies. The data collection and data analysis procedures are described briefly below; additional details can be found in McFadden (2000) and McFadden and Champlin (2000). The research protocols for both studies were approved in advance by the Institutional Review Board of The University of Texas.

2.2. Subjects

For the first study, data were collected from 49 heterosexual females, 57 nonheterosexual females, 50 heterosexual males, 53 nonheterosexual males (plus 35 additional heterosexual females who were using oral contraceptives – see below). For the second study, data were collected from 75 heterosexual females, 25 nonheterosexual females, 64 heterosexual males, and 27 nonheterosexual males; all these females were non-users of oral contraceptives. Because usable data occasionally were missing for an interval or an ear, the Ns varied slightly across conditions and comparisons. The Ns contributing to the various comparisons, and the breakdown for heterosexuals and nonheterosexuals, are provided as part of the results.

The means (and standard deviations) for years of age in study 1 were: 21.2 (3.6), 26.1 (6.6), 24.1 (4.5), and 25.3 (5.8) for the heterosexual females, nonheterosexual females, heterosexual males, and nonheterosexual males, respectively; the average age of the heterosexual females using oral contraceptives was 21.3 (2.4). The means (and standard deviations) of the years of age in study 2 were: 20.2 (2.0), 21.8 (2.4), 20.3 (2.5), 22.0 (3.3) for the heterosexual females, nonheterosexual females, heterosexual males, and nonheterosexual males, respectively. Some subjects in study 2 were twins, but for same-sex twins, only one member of each pair was included (pseudorandomly) in the data analysis here.

2.3. Procedure

For both studies, subjects were recruited using advertisements on campus and in the campus newspaper and by word of mouth. Notices about the studies also were distributed to on-campus organizations for nonheterosexuals. Prospective subjects were screened for recent exposure to intense sounds and recent use of various drugs. Because ABRs are known to fluctuate with the menstrual cycle (Elkind-Hirsch et al., 1992a, 1992b, 1994), test sessions for females in both studies were scheduled during the midluteal phase of the cycle (days 16–26). Because oral contraceptives can masculinize AEPs (McFadden, 2000), the data from users and non-users of oral contraceptives are treated separately here.

After informed consent was obtained, subjects were screened audiometrically. This included otoscopy, audiometric screening at the frequencies between 250 and 6000 Hz in both ears, and tympanometry. To pass the hearing screening, a subject's hearing had to be 15 dB Hearing Level or better at octave frequencies from 250 to 4000 Hz and 20 dB or better at 6000 Hz. Each subject completed a questionnaire containing items about history of exposure to intense sounds and drugs, and items about various aspects of sexual behavior. In study 2, OAEs were collected as well as AEPs. The single test session lasted approximately 2 h in study 1 and approximately 2–2.5 h in study 2.

For both studies, sexual orientation was assessed using versions of the two traditional Kinsey items about fantasy and experience, plus an additional multiple-choice item asking for a self-assessment of orientation (heterosexual, homosexual, bisexual). When answers were inconsistent or incomplete (human-subjects regulations required allowing subjects not to answer individual questions), the data for that subject were excluded from the analyses. For the analyses reported here, the homosexual and bisexual subjects were pooled to create one nonheterosexual group per sex.

The two studies contributing data to this report differed in one important regard: namely, no LLR conditions were tested in study 2, only ABRs and MLRs. Accordingly, the Ns here for the LLR intervals are considerably smaller than those for the other interpeak intervals. One reason for omitting LLRs from study 2 was that the first study revealed no differences by sexual orientation in either latency or amplitude for any of the LLR peaks (McFadden and Champlin, 2000); also, LLRs require considerable time to collect. A second difference between the two studies that proved relevant during data analysis (see below) was bioamplifiers from different manufacturers.