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Abnormal EEGs in Cognitively and Physically Healthy Oldest-Old: Findings from *The 90+ Study*

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Abstract

People aged 90 and older (oldest-old), the fastest growing segment of the United States population, are known to have high rates of spells of all types, including strokes, transient ischemic attacks, and seizures. This study examined the prevalence of EEG abnormalities in 12 physically and cognitively healthy oldest-old (mean age=94) with no history of seizures or spells. Abnormalities were found in 83% of participants: temporal intermittent polymorphic slowing was seen in 67%, background slowing (alpha rhythm <8 Hz) was present in 33%, and temporal intermittent rhythmic delta was found in 17%. The high rates of EEG abnormalities found in these physically and cognitively healthy participants prompt reappraisal of pathological significance in this unique population.

Keywords

Electroencephalography (EEG); aging; oldest-old; temporal intermittent rhythmic delta activity (TIRDA)

Introduction

The oldest-old comprise the fastest growing segment of the United States population (US Census Bureau, 2004). High rates of spells including strokes, transient ischemic attacks (TIAs), and seizures have been described in this age group (Bots et al., 1996; Bots et al., 1997; Hauser et al., 1993; Olafsson et al., 2005). A comprehensive medical work-up is generally required to differentiate these conditions and help guide the physician to an appropriate medical intervention, if needed. To determine whether an episode was a seizure, a routine outpatient EEG recording is often done to look for interictal epileptiform abnormalities. Prior studies indicate that such EEG abnormalities may occur in a minority of non-epileptic individuals (e.g., Zivin & Ajmone-Marsan, 1968). However, these studies primarily examined younger individuals, and it is uncertain whether these findings can be extrapolated to the elderly. This study examined the prevalence of EEG abnormalities in physically and cognitively healthy, non-symptomatic oldest-old.

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Methods

Study participants are members of *The 90+ Study*, a population-based prospective study of longevity and brain aging in the oldest-old. *The 90+ Study*, initiated in 2003, consists of 1280 participants (77% female) 90 years old and older (average=94 years). *The 90+ Study* participants are predominantly Caucasian (99%) and are highly educated (63% have some college or more). These demographics represent those of older adults who lived in Southern California in the early 1980's (these participants were originally recruited for the Leisure World Cohort Study in 1981).

Trained examiners evaluate participants in *The 90+ Study* biannually. During this structured, in-person evaluation participants receive a neuropsychological battery including the Mini-Mental State Examination, a measure of general cognitive function (MMSE; Folstein et al., 1975). Also included are tests of memory, language, and executive function, which have been previously described (Whittle et al., 2007). Medication use at each visit is obtained through self-report and verified by viewing the medication container whenever possible. A self-report medical history is also compiled at each visit. Participants who were cognitively healthy (MMSE \geq 26) with no history of strokes, TIAs, head trauma with loss of consciousness, or seizures, and not taking psychotropic or neurological medications at their most recent visit were asked to participate in the present study. The study was approved by the Institutional Review Board at the University of California, Irvine, and all participants signed informed consent.

Each participant had a one-hour, 21-channel EEG including single electrocardiogram and dual electrooculogram channels. The electrodes were applied according to the International 10-20 system; all impedances were under 5,000 ohms. The recordings were acquired on a 32-channel Nihon-Kohden digital EEG system while the participant lay supine in a darkened room with their eyes closed. Photic stimulation at four through 20 Hz was the only activation procedure used. The EEGs were read by a neurologist (HLK) with two board certifications in clinical neurophysiology: American Board of Clinical Neurophysiology and Qualification in Clinical Neurophysiology (through the American Board of Psychiatry & Neurology).

The background alpha rhythm was considered abnormal (slow) when it occurred at a frequency of less than 8 Hz (Hubbard et al., 1976; Oken & Kaye, 1992). Similar to previous studies (Arenas, Brenner, & Reynolds, 1986; Klass & Brenner, 1995), temporal intermittent polymorphic slowing was only called abnormal when: 1) it was present in one temporal region (at a time), not solely synchronous across both temporal regions at the same time, 2) it was clearly present during the awake state, and 3) occurred more than once during the recording session. The criteria used to define abnormal temporal intermittent polymorphic slowing were also used to determine temporal rhythmic intermittent delta activity (TIRDA), apart from the morphological difference between these two types of abnormalities.

Results

Ten out of twelve participants (83%) had abnormal EEGs. Figure 1 shows the distribution of abnormalities among the participants. The participants had an average age of 94 (range: 91-99; 8 females) and MMSE of 29 (range: 26-30). Slowing of the background alpha rhythm (<8 Hz) was found in 33% of participants. Temporal intermittent polymorphic slowing (delta range) was seen in 67% of participants, occurring as either single waves or brief (\leq 3-4 second) bursts. Figure 2 shows an example of the temporal intermittent polymorphic slowing. TIRDA was seen in 17% of participants, occurring in bursts that lasted at least several seconds (\geq 5 seconds). An example of left-sided TIRDA is shown in Figure 3. Both

the temporal intermittent polymorphic slowing and the TIRDA occurred throughout the awake and drowsy states. No other types of epileptiform abnormalities were recorded.

The average background alpha for all participants was 8.6 Hz (range: 7-10). Those participants with background slowing (generally indicative of mild to moderate generalized cerebral dysfunction) were significantly older ($\bar{x}=96$) than those without ($\bar{x}=93$; $t(11)=2.55$; $p<0.05$). Neuropsychological scores did not differ between participants with background slowing and participants without. Of the eight participants with temporal slowing (consistent with localized cerebral dysfunction of the temporal region), four were classified as bi-temporal, three as left temporal, and one as right temporal. Two of the participants with bi-temporal slowing had slowing that was more prominent on the left side. Participants with temporal slowing did not perform more poorly on any neuropsychological test when compared to subjects without. There were no significant differences on tests of memory or verbal ability between participants with left temporal slowing (including subjects with bi-temporal left > right) compared to those without. Specific deficits could not be assessed in the one participant with right temporal slowing.

The most surprising finding in this study was TIRDA in two of the participants. TIRDA may indicate an increased risk for focal epileptic seizures in certain clinical settings. One participant had bi-temporal TIRDA and the other had it detected only on the left side. The two participants with TIRDA did not have different medical histories, neuropsychological scores, or history of spells than other participants.

Less significant EEG findings include benign variants such as mu waves and wicket spikes ($n=4$). All 12 participants became drowsy during the study; sleep was attained in 11. Photic stimulation elicited a driving response in six participants but did not induce any anomalous brain activity.

Discussion

The rate of abnormality (83%) in this study indicates that prevalence of EEG abnormalities in cognitively and physically healthy oldest-old is very high. In younger healthy elderly both background alpha rhythm slowing and temporal intermittent polymorphic slowing have been observed in varying portions of participants (for a comprehensive review, see Klass & Brenner, 1995). The few previous EEG studies with non-symptomatic participants aged 90 and older found widely varying levels of EEG abnormalities (Obrist, 1954; Hubbard et al., 1976; Oken & Kaye, 1992). For example, a study with extremely healthy subjects over 84 (taking no medications) found that 52% of the participants had intermittent temporal slowing (Oken & Kaye, 1992). A study with less healthy seniors aged 80-94 found that only 17% had delta activity (Obrist, 1954). However, this study only had three participants aged 90 and older so the lower rate of abnormalities could be due to the younger age of the participants. The rates of abnormalities in the current study are higher than those found in previous studies, consistent with the extremely advanced age of the participants and the lack of stringent health requirements.

Temporal slowing, a relatively common abnormality in the elderly (e.g., Arenas, Brenner, & Reynolds, 1986; Shigeta et al., 1995), was the most frequent in the present study. The cause of temporal slowing is still unknown but one study found that it was related to deep cerebral white matter hyperintensities in participants over 84 (Oken & Kaye, 1992). No relationship between temporal slowing and history of hypertension or any other cardiovascular factor was found in the present study. However, the small sample size used in this study makes this examination difficult. For example, only one participant had history of congestive heart failure and only one had history of atrial fibrillation. Larger sample sizes will ultimately be

necessary to determine whether a relationship between cardiovascular risk factors and temporal slowing exists in the oldest-old. A disproportionate number of the temporal slowing abnormalities found in this study were lateralized, particularly the left side, despite the fact that these participants did not manifest focal neurological or neuropsychological abnormalities. Other studies have reported similar findings with left lateralization (Hubbard et al., 1976; Torres et al., 1983; Arenas, Brenner, & Reynolds, 1986), however, the reason remains uncertain.

The significance of background alpha slowing (<8Hz) in the oldest-old remains in dispute. Some researchers have proposed that background alpha decreases during normal aging but most agree that below 8Hz is abnormal (Klass & Brenner, 1995). Background frequency has been shown to decrease in people with dementia and depression. Interestingly, participants in the current study with background slowing were older than those without suggesting an association with age; no difference in depression or cognitive scores was found. A previous EEG study in healthy participants over 84 found 23% to have alpha slowing (Oken & Kaye, 1992). The slightly higher rate in the current study (33%) is in keeping with the older age of the participants.

The most unexpected finding in this study, TIRDA, is of uncertain significance. While rhythmic EEG patterns have been related to drowsiness in older adults (frontal rhythmic delta activity, Santamaria & Chiappa, 1987), the TIRDA recorded in the current study was present during the awake state. TIRDA has generally been examined as interictal activity present in some people with a history of temporal lobe epilepsy (Normand, Wszolek, & Klass, 1995). More specifically, one study found that TIRDA was related to complex partial seizures; TIRDA was present in 27% to 35% of recordings (awake and sleep, respectively) in younger people with partial epilepsy (Reiher et al., 1989). The incidence of epilepsy, particularly partial epilepsy, is known to increase exponentially in the elderly (Hauser et al., 1993; Olafsson et al., 2005). There are two possible explanations for the TIRDA in the current study. First, in the oldest-old, brain areas predisposed for seizures may manifest subtle epileptiform EEG abnormalities (such as TIRDA) rather than the usual spikes and sharp waves. The participants in the current study had no history of seizures or spells but they may be at a higher risk than those without TIRDA. Second, in this age group, TIRDA may be an age-related EEG finding without epileptiform significance. Future research in this group of oldest-old and others will be needed to elucidate these issues.

This study indicates that caution is required when using EEG to diagnose seizures and encephalopathies in the elderly given the evidence of a high background rate of EEG abnormalities in healthy elderly. As the population of extremely aged persons grows, more research about this special group will be needed. Additional studies with larger groups of elderly individuals and longer follow up are required to corroborate the findings of this study, and to elucidate the clinical significance.

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Participant characteristics and EEG results

Subject	Age	Gender	EEG Result	Intermittent Temporal Slowing	Slowing of Background Alpha	Temporal Intermittent Rhythmic Delta
1	91	F	Normal			
2	94	M	Normal			
3	95	M	Abnormal		■	
4	95	M	Abnormal	■	■	
5	99	M	Abnormal	■	■	
6	93	F	Abnormal	■	■	
7	94	F	Abnormal	■		
8	94	F	Abnormal	■		
9	95	F	Abnormal	■		
10	92	F	Abnormal	■		
11	91	F	Abnormal	■		■
12	93	F	Abnormal			■

67%	33%	17%
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Figure 1. Shows age, gender, and EEG result for each participant.

Intermittent polymorphic temporal delta



Figure 2. Displays intermittent polymorphic temporal delta (right > left); the clearest example in this tracing is highlighted with a black box.

Temporal intermittent rhythmic delta activity

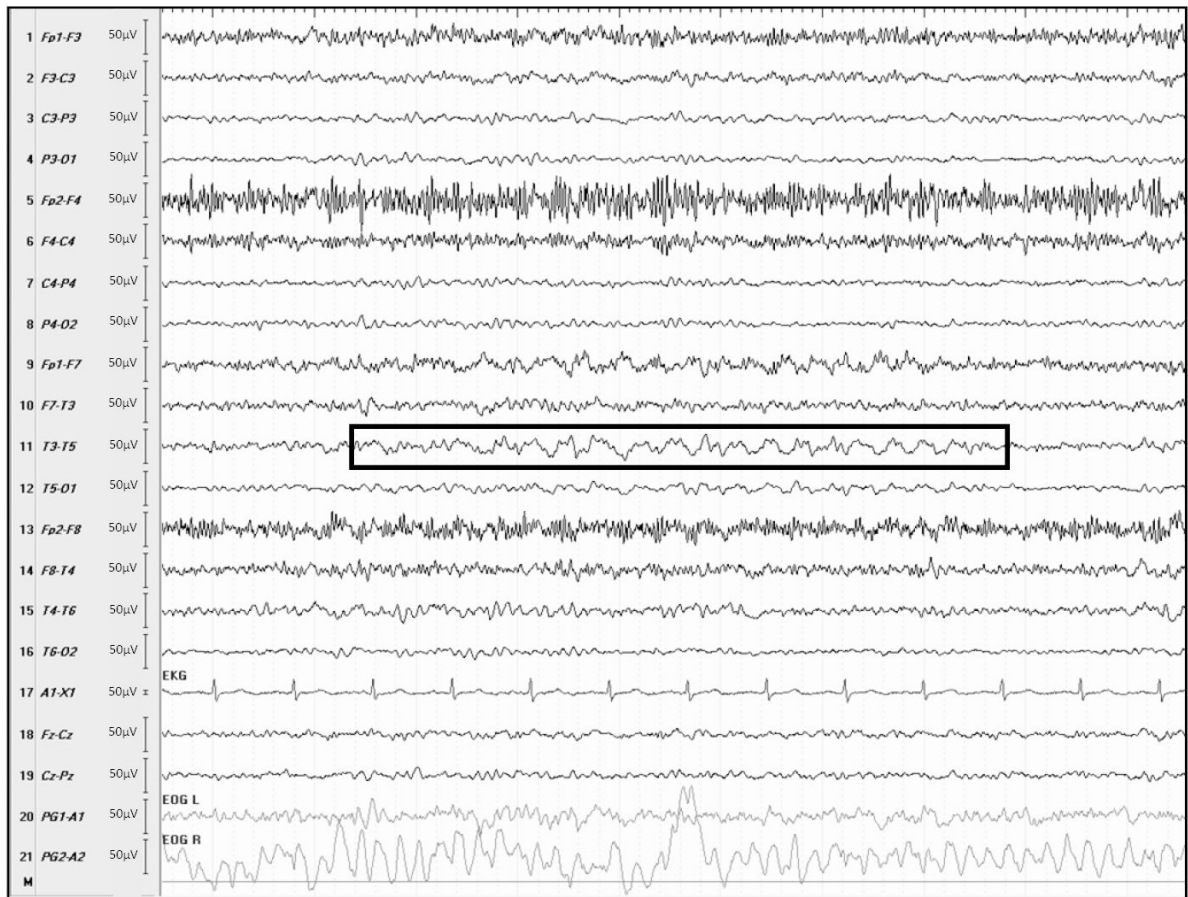


Figure 3. Shows an example of left-sided TIRDA; the clearest example in this tracing is highlighted with a black box.