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Event-related potentials accompanying motor preparation and stimulus expectancy in the young, young-old and oldest-old

Edward J. Golob*, Vahagn Ovasapyan, Arnold Starr

Department of Neurology, Institute for Brain Aging and Dementia, University of California, Irvine, CA, USA

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Abstract

Although aging is accompanied by neurobiological changes and increased susceptibility to many neurological disorders, little is known about neurophysiological changes that start in old age. Here, neurophysiological changes during old age were assessed by recording brain potentials associated with motor preparation and stimulus expectancy (contingent negative variation, CNV) in young-old (60–69), oldest-old (85–98), and young (17–23) subjects. Individual trials began by a button press, followed 2.5 s later by either a low or high pitch tone. In the "motor" condition subjects responded following high pitch tones ($P = 0.20$); in the "non-motor" condition subjects did not respond. Motor condition CNV amplitudes in the oldest old were more positive than the young and young-old groups, which were similar. In the non-motor condition, the young-old and oldest-old had similar CNV amplitudes that were positive in polarity, and were significantly different from young subjects. Motor potentials before button presses that started the trials were comparable among groups. Results show that neural activity associated with motor preparation and stimulus expectancy changes during advanced age, and that group differences can be modulated by task requirements.

Keywords: Contingent negative variation; CNV; Readiness potential; SPN; P50; Go/no-go

1. Introduction

Aging is accompanied by substantial changes in neurobiological and cognitive function. Some measures exhibit monotonic changes as a function of age, such as reductions in processing speed inferred from behavioral measures [6,58] and latency of certain brain potentials (P300) [21,27,46]. Other measures accelerate with increasing age, such as various tests of fluid intelligence [34], fine motor control [61] and possibly white matter integrity [44] cf. [1,64]. The incidence of Alzheimer's disease increases exponentially after approximately age 60 [31], but may decline in the early 90s [40]. Neurological disorders such as Parkinson's disease [40] and stroke [54] also show a substantially increased incidence after age 60.

Taken together, the above findings demonstrate that different cognitive and neurobiological factors exhibit a variety of temporal patterns during the development of age-related changes, and that some changes may only become apparent in early old age. In contrast, experimental studies of aging often define the effects of aging by comparing one group of older subjects, typically ranging between ages 60 and 80, with young college students. Although this approach captures important age-related differences, it cannot evaluate the development of changes within old age. An experimental design using two older groups at age extremes (early old age, late old age) is useful because it can define neurobiological changes that occur during old age, identify variables associated with preservation of cognitive abilities, and can provide data to distinguish neurological disorders from what is nominally considered healthy aging.

The purpose of this study was to define changes in brain activity occurring between young adulthood, early old age, and late old age. Differences between groups of young (17–23 years) young-old (60–69 years), and oldest-old (85–98 years) subjects were evaluated using a self-paced contingent negative variation (CNV) task. The CNV is a well-studied brain potential that develops during a short (∼1–5 s) interval between two task-relevant stimuli, with the second "imperative" stimulus typically requiring a motor response [7,68]. The CNV occurring just before the imperative stimulus, often called the "late CNV" to distinguish it from potentials elicited by the first stimulus, is

* Corresponding author. Tel.: +1 949 824 6088; fax: +1 949 824 2132.
E-mail address: egolob@uci.edu (E.J. Golob).

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Table 1
Demographic information

	Young	Young-old	Oldest-old
n	12	12	12
Age	20.2 ± 2.0 (17–23)	65.8 ± 2.6 (61–69)	90.6 ± 3.8 (85–98)
Education	14.2 ± 1.6	15.3 ± 3.2	15.7 ± 1.9
M/F	6/6	5/7	6/6

Note: values are mean ± S.D. Age ranges are shown in the parentheses.

generated by a network of cortical and subcortical structures that includes prefrontal, posterior parietal, temporal, premotor, primary motor and somatosensory cortex, and the basal ganglia [4,19,23,25,55]. Among these regions some exhibit large structural changes with age, such as prefrontal cortex, while other regions, such as primary motor cortex, show slight changes with age [49,50]. Thus, the study of the CNV could provide information relevant for defining the performance of neural networks that utilize structures differentially affected by aging. Previous studies that compared late CNV amplitudes in young and older subjects reported similar [16,24,66] or somewhat smaller [36,39] amplitudes for older relative to young subjects.

In addition to examining CNV changes during old age, the present study also evaluated age differences as a function of task by contrasting conditions that did or did not require motor preparation. It was predicted that age differences would be greater and/or more likely in the condition that does not require motor preparation. Presumably, when motor preparation is required the CNV would largely reflect activity generated by regions especially important for motor preparation, such as supplementary motor, premotor, and primary motor cortex; regions that do not show major structural changes with age [49].

2. Methods

2.1. Subjects

There were three groups of subjects in this experiment (young, young-old, and oldest-old; see Table 1). Young subjects were UC Irvine undergraduates who received course credit for their participation in the experiment. Subjects in the young-old and oldest-old groups were recruited from the Successful Aging Program and the Center for Aging Research and Education at UC Irvine.

Ten out of 12 young-old subjects and 9/12 subjects in the oldest-old group were given the same battery of neuropsychological tests (see [20] for details). All older subjects given neuropsychological tests performed within normal limits. Results from selected tests are shown in Table 2. Episodic memory was assessed using the WMS-III logical memory subtest [70] and the CERAD word list learning task [41]. Language tests included the 30-item version of the Boston naming Test [30] and controlled oral word association (FAS fluency)[62]. Executive function was tested with the trailmaking tests A and B [51]. Visual-spatial skills were evaluated with the WAIS-III block design test [69]. The mini-mental state examination [17] was used as a

Table 2
Neuropsychological test results

	Young-old ($n = 10$)	Oldest-old ($n = 9$)	P values (t-tests)
CERAD word list			
5 min delayed recall	8.1 ± 1.2	5.8 ± 2.5	<0.03
30 min delayed recall	7.7 ± 0.7	6.0 ± 2.6	ns
5 min delayed recognition	20.0 ± 0.0	19.9 ± 0.3	ns
30 min delayed recognition	19.9 ± 0.3	18.6 ± 2.6	ns
WMS-III logical memory			
Immediate recall	41.8 ± 10.0	38.0 ± 8.7	ns
Delayed recall	26.6 ± 7.0	22.4 ± 8.2	ns
Boston naming test	28.5 ± 1.3	26.7 ± 2.5	ns
FAS verbal fluency	49.7 ± 9.4	49.4 ± 14.8	ns
WAIS-III block design	34.1 ± 9.9	32.1 ± 14.4	ns
Trailmaking test A (s)	30.8 ± 14.2	60.1 ± 33.6	<0.03
Trailmaking test B (s)[a]	72.7 ± 14.5	123.4 ± 35.1	<0.01
MMSE[b]	29.3 ± 0.8	28.5 ± 1.4	ns
Geriatric depression rating scale	1.0 ± 2.0	1.0 ± 1.1	ns

Note: neuropsychological results presented above were from subgroups of subjects that were given a standard test battery. All values are raw scores (mean ± S.D.).

[a] One oldest-old subject did not perform trailmaking test, Part B.

[b] MMSE: mini-mental state exam. For MMSE, $n = 12$ for the oldest-old.