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BLINKING IN PATIENTS WITH MEMORY DISORDERS DURING SHORT TERM MEMORY TASKS

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The occurrence of blinking during short term memory tasks was analyzed for 32 subjects divided into three groups: 12 memory impaired patients, 10 elderly normals (age-matched to the patients), and 10 young normals. The subjects were participating in a study of brain evoked potentials accompanying memory activities. They were instructed not to blink during the performance of the memory tasks for reasons related to the quality of the recorded potentials. In this context, the withholding of blinking can be considered a secondary task. Blinking during the short term memory tasks was inversely related to performance accuracy ($r = -.57$). Age, mini-mental score and reaction time were also significantly related to the frequency of blinking. Dividing the memory patients into two groups according to the incidence of blinking, ("high-blinking" and "low-blinking"), revealed a significant difference in overall task accuracy with the high-blinking group performing more poorly than the low-blinking group.

Keywords: Blink, short-term memory, Alzheimer's disease.

The appearance of eye-blinks during mental activity (Stern, Walreth & Goldstein, 1984; Simons et al., 1988) has been related to mental effort. Brezinova and Kendell (1977) found that mental arithmetic (serial subtraction) during a pendulum tracking task produced a significant increase in blink rate compared to the tracking task alone. Similarly, Karson (1983) showed an increase in blink rate when subjects were memorizing paragraphs. In contrast, Holland and Tarlow (1975) showed the rate of blinking to be significantly reduced when silent counting was performed. They proposed that focused internal mental activity decreased blinking as an adaptive mechanism to minimize changes in visual input which could interfere with information processing.

If blinking is indicative of cognitive states, then one would expect abnormal blink rates in certain brain disorders especially those marked by impaired cognitive abilities. Spontaneous blink rates are significantly elevated in schizophrenia and decreased in Parkinson's disease (Karson, 1983; Hall, 1945) and the use of blink rate as a clinical indicator of central dopaminergic activity has been suggested (Karson,

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1983, 1988; Shukla, 1985). A trend of an increased blink rate in Huntington's disease has also been reported (Karson et al., 1984; Davous, 1985; Starr, 1967). In Alzheimer's disease the latency of the blink reflex is increased (Tavy et al., 1986).

In all of the above studies, blinking was the dependent variable and was not inhibited by instructions. In contrast, subjects involved in cognitive activity while recording their event-related potentials (ERPs) are routinely instructed to avoid blinking. There is a resting potential between the cornea and the eye, and blinking, which is associated with a movement of the eye within the orbit, introduces a transient potential gradient over the scalp. Blinking occurs so frequently in certain patient groups (children, demented adults) that the ERPs are compromised. Various methods of compensating for the potentials associated with blinks have been described (e.g., Berg, 1986) but none are completely satisfactory. Thus, the blink is treated as an "artifact" with data systematically rejected from further analysis. In actuality, the inhibition of blinking is a secondary task built into the protocol of ERPs. Several studies (Donchin et al., 1986; Polich, 1986) have shown that the amplitude of one type of cognitive evoked potential components, the P300, is sensitive to the perceptual demands of additional tasks. While the perceptual demands of inhibiting blinking are considered negligible, they may be significant for particular populations such as those with cognitive impairment.

The failure to inhibit blinking is a clinical sign known as the glabellar reflex (Dejong, 1979). This sign is present when a patient is tapped repeatedly on the forehead or bridge of the nose and is unable to inhibit the evoked blinks whereas normal subjects stop blinking usually by the third tap. The presence of glabellar reflex is considered abnormal and has historically been referred to in the neurological literature as one of the "frontal release signs" or "primitive reflexes." Its localizing value to identify frontal lobe disease has been under increasing question (Benson & Stuss, 1982; Landau, 1989). This sign is seen with both Parkinson's and diffuse cerebral disease but can also be present in normal elderly patients (Jacobs & Grossman, 1980).

The purpose of this study was to examine blink frequency during the performance of short term memory tasks differing in difficulty and to determine factors which affected blinking. Factors studied included task type (stimulus modality, memorized set size), age, performance accuracy, mini-mental score and reaction time. Finally, the possible clinical significance of failing to inhibit blinking was examined by comparing high- and low-blinking subgroups of patients, all of whom presented with the chief complaint of memory impairment.

METHODS

Subjects

Twelve elderly patients (average age: 68 ± 8.9 yrs.) with complaints of memory impairment, 10 age-matched elderly controls (average age: 65 ± 11 yrs.), and 10 young normals (average age: 27 ± 7 yrs.) participated in this study. The patients all had a chief complaint of memory impairment and completed an extensive multidisciplinary evaluation. Each patient was evaluated by a clinical neurologist, psychiatrist and neuropsychologist. All patients had a neuroimaging study—either MRI or CT scan. Neuropsychological testing included a WAIS scale for verbal and performance IQ, Wechsler memory test, Rey-Osterrieth complex figure copy, Trails A and B, Rey Auditory Verbal Learning, Verbal Fluency (f, a, and s words), Boston Naming and Benton Visual Recognition testing. The mini-mental questionnaire (Folstein et al., 1975) was administered prior to the experimental sessions. Only one of

the normals scored below 29 out of a maximum 30 points (i.e., 27). The patients had mini-mental scores ranging from 13 to 29 (24 ± 5).

Final diagnoses were: Alzheimer's disease (6 patients), amnesia of unknown etiology (1), Parkinson's disease with dementia (1), communicating hydrocephalus following subarachnoid hemorrhage (1), basilar artery insufficiency (1), and depression without dementia (2).

The diagnosis of probable Alzheimer's disease was made for the six patients who had histories of progressive cognitive decline and whose neuropsychological examinations showed deficits in memory and one or more other cognitive areas (generally with features of a cortical-type dementia with language impairments such as anomia and/or visuospatial deficits) in the absence of any focal neurological features such as hemiparesis, gait disturbance or visual field deficit. These patients all had neuroimaging studies (MRI or CT) without focal lesions. This method of diagnosing probable Alzheimer's disease has been shown to correlate with high accuracy to histopathological diagnosis (Sulkava et al., 1983; Katzman, 1986). One patient was diagnosed as amnesic syndrome of unknown etiology because with the exception of an abnormal Weschler memory score of 85, there was no significant deficit in any other cognitive area on neuropsychological testing. Also, there was no progression of memory or cognitive impairment after a two-year period of follow-up. There was no history for likely etiologies such as alcohol abuse, epilepsy or past encephalitis. The patient diagnosed with basilar artery insufficiency had multiple episodes of confusion and dizziness associated with amnesia. Between these episodes, memory and other neuropsychological tests were normal. The two patients diagnosed with depression by psychiatric evaluation presented with complaints of poor memory along with depressed mood. The mini-mental score for both of these patients was 28 and neuropsychological testing showed only mild cognitive deficits (mostly poor attention) consistent with those seen with depression (Glass et al., 1981; Miller, 1975; Silberman, 1983).

Procedures

We wished to determine the effect of a specific short term memory task on the incidence of blinking. Since spontaneous blinking varies between subjects (Greene, 1986) and may increase nonspecifically under the stress of experimental conditions, we compared blinking in two tasks: (A) a short term memory task modified (Starr & Barrett, 1987) from that used by Sternberg (1966), and (B) a relatively simple target detection task, initially described by Sutton et al. (1965) and colloquially referred to as the "odd-ball task." In the short term memory task the subject is presented with a set of items to be remembered, followed shortly (2 s) by a probe item which the subject must identify as being, or not being, a member of the memorized set by an appropriate button press. A three-second pause then follows before the start of the next trial. Three types of stimuli were used: digits presented acoustically, digits presented visually and musical notes, all produced by a computer. For details see Pratt et al. (1989). Memorized set sizes of 1, 3, and 5 items were employed for each stimulus type (i.e., auditory digits, visual digits, notes). All subjects had 2 blocks of 20 trials for each stimulus type-memorized set size combination except for the young controls who had 4 blocks of 20 trials for each stimulus type with memorized set sizes of 1 or 5. With four of the memory patients, these procedures were modified as they had difficulty performing some of the memory scanning tasks. Two of these patients were tested only with a memorized set size of 1 item for each stimulus type and another two patients were tested only on the 1 and 3 item tasks.

TABLE 1

Behavioral measures (accuracy (%C) and RT in ms) in two types of short term memory tasks: memory scanning and target detection. The percentage of trials with blinks (%BLINK) and the normalized blink inhibition ratio (NBIR) are included. The table includes patients, age-matched controls, and young normals. The order of the subjects in each group is a function of the incidence of blinking in the memory scanning tasks. The diagnoses of the memory impaired patients are listed in the column headed with "Dx." The diagnoses code is as follows: ALZ = Alzheimer's disease, PD = Parkinson's Dementia, HC = Hydrocephalus, DEP = Depression, BAI = basilar artery insufficiency, AMN = amnesia of unknown etiology.

Dx	Subject #	Memory Scanning				Target Detection			
		%BL-INK	%C	RT	%BLINK	%C	RT	NBIR	
	Patients								
ALZ	1	89	61	1240	100	100	359	NA	
ALZ	2	82	74	1394	70	100	621	.60	
HC	3	67	81	1502	22	100	451	.42	
DEP	4	53	87	1145	21	100	333	.59	
ALZ	5	43	73	1444	8	100	536	.62	
ALZ	6	42	57	1063	5	98	278	.61	
ALZ	7	35	92	1137	18	100	403	.79	
ALZ	8	30	88	1051	2	100	463	.71	
DEP	9	27	85	1013	30	100	292	1.04	
BAI	10	25	95	1177	5	100	335	.79	
PD	11	22	83	1493	25	100	416	1.04	
AMN	12	19	95	1197	23	100	310	1.05	

Age-Matched Controls									
13	97	85	1082	65	100	302	.09		
14	56	87	1095	3	100	363	.45		
15	50	90	1029	26	97	402	.68		
16	47	93	1125	27	100	436	.73		
17	38	92	1075	48	100	325	1.19		
18	26	96	991	40	100	318	1.23		
19	25	88	1054	3	100	538	.77		
20	20	87	1107	7	100	365	.86		
21	16	91	833	13	100	683	.97		
22	15	92	1116	15	100	373	1.00		
Young Normals									
23	48	89	754	43	100	286	.91		
24	47	92	902	28	100	310	.74		
25	39	86	719	22	100	634	.78		
26	36	93	659	31	98	363	.93		
27	22	96	683	7	100	310	.84		
28	17	96	755	5	100	326	.87		
29	14	95	577	8	100	348	.93		
30	10	90	733	32	100	264	1.32		
31	7	93	523	14	98	371	1.08		
32	4	96	708	5	100	395	1.01		

The second task, a target detection task, consisted of the presentation of 300 musical notes, 80% of which were "Middle C" and 20% of which were "D," an octave higher. The subject's task was to press a button in response to the high "D" note ("target"). The target detection task was performed first followed by the memory scanning tasks.

Subjects were instructed both to perform the tasks and not to blink during stimulus presentation and task performance. Blinks could be made beginning "at least one second after the button press response but before the start of the following trial as well as in the rest periods between blocks." Practice runs were provided before each condition and if blinking recurred in the forbidden zones, subjects were chided and reminded of the need not to blink during the performance of the task. If blinking occurred frequently during the test procedures, the experiment was temporarily halted and the subject reminded once again of the importance of not blinking.

Electroencephalogram (EEG) and electrooculogram (EOG) [derived from electrodes placed above and below the eye] were recorded. Performance accuracy (percentage correct, %C) and reaction times (RTs) were also measured. Our experience of correlating video monitoring of eye movements in 11 of the subjects with EOG evidence of eye movements is in agreement with Stern et al. (1984). We found the vertical EOG to be a reliable indicator of blinking. When blinks occurred within 1.28 seconds after a probe stimulus in the memory tasks and 1.00 second after a target stimulus, those trials were counted as containing blinks. The percentage of trials with blinks was calculated.

A response was incorrect if an inappropriate response button was pressed or if an appropriate response button was not pressed within two seconds of the probe. Each subject's performance was quantified in terms of accuracy (%C) and average reaction time (RT).

Analysis

The percentage of trials with blinks was averaged across memory scanning tasks (%BLINK MEM) and the target detection task (%BLINK TARG). Reaction Times (RT MEM or RT TARG) and accuracy (%C MEM or %C TARG) were calculated analogously. Another measure of blinking was also calculated relating the incidence of blinking during each of the memory scanning tasks to the incidence of blinking during target detection. This ratio was termed NORMALIZED BLINK INHIBITION RATIO (NBIR) and is a numerical index of the change in blinking during memory scanning tasks compared to the simpler target detection task. The normalized blink inhibition ratio equals the percentage of trials with successful inhibition of blinking on the memory scanning tasks ($= 100 - \%BLINK\ MEM$) divided by this same indice on the "oddball" target detection task ($= 100 - \%BLINK\ TARG$). If blinking occurs linearly as a function of time and independent of task difficulty, one would expect an average NBIR of .781 ($= 1\ sec./1.28\ s$) for our paradigms. A lower value than this reflects more blinking on the memory scanning tasks than expected for a given patient's baseline blinking frequency on the oddball task. One patient (#1 in Table 1) had 100% blinking on the oddball task (which yields a denominator of zero in the NBIR) and was thus excluded from the group NBIR analysis. This seems most appropriate as this patient had excessively high blinking rates on both the memory scanning and target detection tasks and therefore the relative change in blinking is of very doubtful significance for this "outlying" data point. With the above exception, the NORMALIZED BLINK INHIBITION RATIO was calculated for each subject.

TABLE 2

Regression analyses of the incidence of blinking in the memory scanning tasks and four other parameters; accuracy (%C), age, mini-mental score (MM) and reaction time (RT). Correlation coefficient = r , intercept = a , slope = b , tail probability for T-test = prob. Probabilities of $<.05$ are indicated by asterisks (*).

	r	a	b	t -value	prob.
%C	-.573	159.8	-1.41	3.83	.001*
RT	.489	-7.5	.044	3.07	.005*
Age	.455	8.6	.51	2.79	.009*
MM	-.439	103.9	-2.44	2.68	.012*

Correlations between the percentage of trials with blinks and performance accuracy, RT, age and mini-mental score (MM) were assessed using bivariate statistical analysis. The relative, independent contributions of the various parameters upon the percentage of trials with blinks were determined using multivariate regression analysis. In order not to combine accuracy, mini-mental score and RT, which are likely to be related, blinking was analyzed as a function of age and only one of these measures at a time. The difference in performance measures between memory patient subgroups and age-matched controls was determined using the Mann-Whitney Two Sample Test. Probabilities below .05 were considered significant.

The 6 patients with the highest blink rate in the memory scanning tasks were placed in a "high-blink" subgroup (high) and the other 6 patients were placed in a "low-blink" group (low). The diagnoses of the high-blink patient group were: Alzheimer's disease (4), hydrocephalus (1), and depression (1). The low-blink group consisted of Alzheimer's disease (2), amnesia of unknown etiology (1), basilar artery insufficiency (1), Parkinson's dementia (1) and depression (1).

RESULTS

Blinking and performance measures (accuracy and RT) during the memory tasks and clinical diagnoses for each subject are in Table 1. Blinking varied widely among the subjects within each of the three groups; from 19 to 89% in the patients, from 15-97% in the age-matched elderly controls and from 4-48% in the young subjects. In contrast, RTs were consistently longer in both patients and age-matched controls compared to the young normals. Performance accuracy was nearly identical (close to 100%) in all groups in the target detection task whereas four of the patients had difficulty in performing all of the short term memory tasks and even in those they were able to complete, their accuracy was less than 80%, slightly above the 50% level achieved with chance performance. Blinking in the memory scanning tasks was significantly related to performance accuracy, RT, age and mini mental score (Table 2, all subjects are included in this analysis). In contrast, none of these same correlations was significant in the target detection task. Note that in the memory scanning task, all four of these parameters were significantly correlated with blink frequency ($p < .05$), with the strongest correlation being between performance accuracy (%C) and blink rate (%BLINK): $r = -.57$. Figure 1 is a scatterplot showing this correlation between blinking and performance accuracy (with each point representing one subject's overall performance on all memory scanning tasks completed). This correlation remains similar when one analyzes each of the subgroups separately with

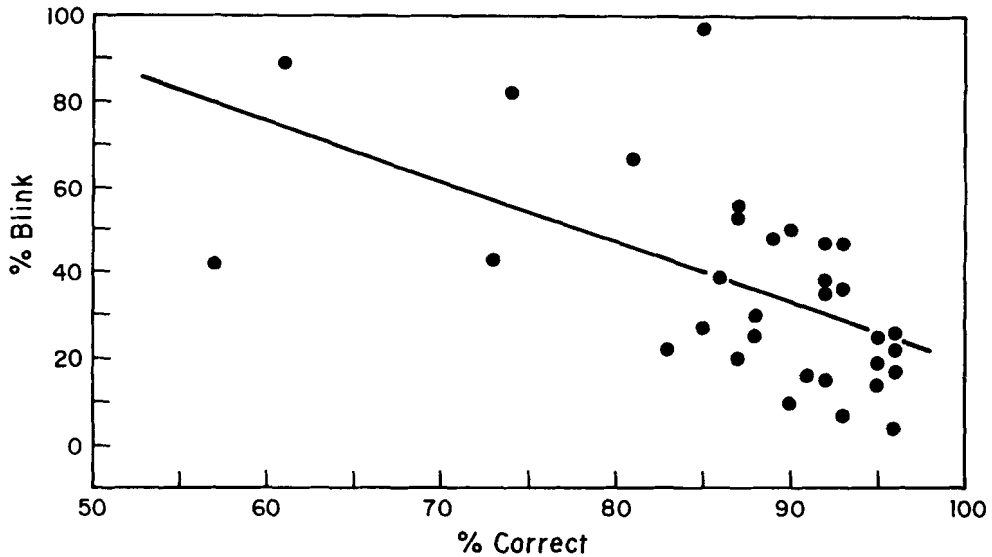


FIGURE 1 Scatter plot of the percentage of trials in which a blink occurred (% Blink) and performance accuracy (% Correct) on auditory and visual short-term memory tasks for all subjects. Bivariate analysis showed the slope to be $m = -1.41$ with a y-intercept of 89.5% at 50% correct (chance performance). The correlation coefficient was $r = -.57$.

$r = -.61$ for the memory patients, $r = -.51$ for the aged-matched controls and $r = -.56$ for the young normal subjects.

A multivariate regression analysis was performed to assess the relative independent contributions of the three behavioral variables (RT, accuracy, and mini-mental score) and age upon blinking. There was no consistent pattern of significance for the different stimulus types (Tables 3A–3C). For instance, with auditory digits blinking was correlated with both accuracy, and mini-mental score, but not with RT. In contrast, with visual digits only RT was correlated with blinking rate. When all stimulus types were combined (Table 3D) only performance accuracy correlated with blinking.

There was a significant difference in performance accuracy in the memory scanning tasks between the patients and the normal age-matched controls ($p = .04$). However, several of the patients performed quite well with 8 patients scoring over 80% correct and 3 of these scored over 90% correct (see Table 1). The patients were then divided into two equal sized groups according to their blinking. The high-blinking and low-blinking groups were compared to each other and to the normal age-matched controls using the Mann-Whitney test. The results (Table 4) show significant differences ($p < .05$) in performance accuracy (%Correct), mini-mental score (MM) and reaction time (RT) between the high-blinking and age-matched control groups. Note also that only accuracy was significantly different between the high- and low-blinking patient groups. A trend of the high-blinking patients to have lower mini-mental scores than the low-blinking group can be seen but did not reach statistical significance. Note that the patients with low blinking performed as accurately as did the age-matched normals. The measure relating blinking in the memory scanning tasks to that during the target detection task (NORMALIZED BLINK INHIBITION RATIO) proved to have a statistically significant correlation with perfor-

TABLES 3A-3D

Regression analyses and significance levels of the relative contributions of age and one behavioral parameter (i.e., accuracy, %C, mini-mental score, MM, or reaction time, RT) upon the incidence of blinking (%BLINK) in the various memory scanning tasks. The results from all 32 of the subjects are included. Asterisks (*) indicate statistical significance with probability <.05.

Table 3A—Auditory memory-scanning tasks (1, 3 and 5 item).

	%C & Age		MM & Age		RT & Age	
simple <i>r</i>	-.35	.38	-.41	.38	.29	.38
partial <i>r</i>	-.25	.28	-.28	.23	.07	.25
simple <i>R</i> 2	.13	.14	.17	.14	.09	.14
overall <i>R</i> 2	.205		.217		.146	
<i>t</i> -value (<i>b</i> = 0)	-2.69	3.01	-2.95	2.43	.71	2.53
prob. (<i>b</i> = 0)	.009*	.003*	.004*	.017*	.480	.013*

Table 3B—Visual memory-scanning tasks (1, 3 and 5 item).

	%C & Age		MM & Age		RT & Age	
simple <i>r</i>	-.25	.37	-.33	.37	.38	.37
partial <i>r</i>	-.14	.31	-.18	.26	.21	.20
simple <i>R</i> 2	.06	.14	.11	.14	.15	.14
overall <i>R</i> 2	.160		.174		.184	
<i>t</i> -value (<i>b</i> = 0)	-1.47	3.30	-1.95	2.72	2.23	2.09
prob. (<i>b</i> = 0)	.145	.001*	.054	.008*	.028	.039*

Table 3C—Musical note memory-scanning tasks (1, 3 and 5 item).

	%C & Age		MM & Age		RT & Age	
simple <i>r</i>	-.42	.33	-.24	.33	.37	.33
partial <i>r</i>	-.33	.19	-.12	.25	.24	.18
simple <i>R</i> 2	.18	.11	.06	.11	.14	.11
overall <i>R</i> 2	.215		.121		.166	
<i>t</i> -value (<i>b</i> = 0)	-3.50	2.06	-1.20	2.49	2.50	1.82
prob. (<i>b</i> = 0)	.001*	.042*	.234	.015*	.014*	.072

Table 3D—All modalities of memory scanning tasks (auditory, visual and tonal tasks combined).

	Ave %C & Age		MM & Age		RT & Age	
simple <i>r</i>	-.57	.45	-.44	.45	.49	.45
partial <i>r</i>	-.40	.20	-.26	.29	.22	.13
simple <i>R</i> 2	.33	.21	.19	.21	.24	.21
overall <i>R</i> 2	.367		.276		.255	
<i>t</i> -value (<i>b</i> = 0)	-2.71	1.33	-1.67	1.83	1.37	0.79
prob. (<i>b</i> = 0)	.011*	.195	.105	.078	.180	.438

mance accuracy (% Correct) ($r = .45$; $p = .011$). Note this correlation is independent of absolute baseline blinking frequencies as defined on the "oddball" task for each subject.

DISCUSSION

The results of this study show that blinking during the performance of short term memory tasks is inversely related to performance accuracy. This is not surprising if one views the inhibition of blinking as a secondary task. Thus, an impairment of

TABLE 4A

Behavioral parameters (%C, MM, RT), age and incidence of blinking on the memory scanning and target detection tasks combined for all patients (All), high-blinking patients (Hi), low-blinking patients (Lo) and age-matched elderly controls (Con).

	All	Hi	Lo	Con
%Correct	80.9 ± 12.4	72.2 ± 11.3	89.6 ± 5.1	90.1 ± 3.5
Mini-mental	24.2 ± 5.3	21.3 ± 6.0	27.0 ± 2.4	29.7 ± .5
RT (ms)	1239 ± 176	1300 ± 173	1178 ± 170	1051 ± 87
Age (yrs)	68.4 ± 8.6	72.0 ± 6.1	64.8 ± 9.7	64.5 ± 11.3
%BLINK	44.5 ± 23.7	62.7 ± 20.1	26.3 ± 5.8	39.2 ± 25.3

TABLE 4B

Significance of differences between populations using the Mann-Whitney procedure; significant differences, $p < .05$, are indicated by asterisks (*).

	Hi & Lo $p <$	Hi & Con $p <$	Lo & Con $p <$	All & Con $p <$
%Correct	.010*	.002*	.828	.041*
mini-mental	.078	.001*	.003*	.0002*
RT (ms)	.200	.009*	.448	.010*
Age (yrs)	.262	.255	.871	.429
%BLINK	.004*	.065	.448	.509

performance (decreased accuracy) occurs in concert in both tasks, i.e., short term memory and inhibition of blinking. Furthermore, other correlates of performance, i.e., reaction time, mini-mental scores, and subject age, each were also significantly correlated with blinking, with the latter two measures being relatively strong predictors of blinking. This is to be expected, since the mini-mental score and age are constant for each subject and therefore are statistically more robust than measures such as accuracy and reaction time, which may vary for each task. Reaction times were confounded by an age effect since in the age-matched elderly controls this measure was almost 350 ms longer than those of the young group (703 ± 106 ms vs 1051 ± 87 ms; $p < .05$). In contrast, performance accuracies were indistinguishable ($92.6 \pm 3.4\%$ vs $90.1 \pm 3.5\%$ respectively). In comparison, the patients' performance accuracy and reaction times differed from their age-matched controls ($80.9 \pm 12.4\%$ and 1239 ± 176 ms respectively).

Two considerations could account for these results. First, inhibition of blinking is specific for tasks that emphasize short-term memory functions (contrast blinking in short-term memory versus target detection). Secondly, inhibition of blinking is related to task difficulty as reflected in RT measures which were longer in the short-term memory tasks than the target-detection task. The present results can not distinguish between these two alternatives.

The possibility that subjects with memory deficits had an increased blink rate because they forgot to perform the secondary blink-inhibition task was addressed by normalizing each subject's blink rate in the memory scanning task relative to that subject's blink rate in the target-detection task (defined as the NBIR, see Methods). The normalized blink inhibition ratio (NBIR) reflects the blink rate with the more demanding memory-scanning task, corrected for possible differences in baseline blink rate or forgetting to inhibit blinking during the performance of tasks. Thus, the results of our study are very unlikely to result from the subjects forgetting to inhibit blinking or from increased baseline blinking rates. In fact, dividing the patients into

two groups (high and low blinking) on the basis of blinking frequency on the *oddball* task revealed no difference in performance accuracy on the short term memory tasks ($79.8 \pm 11.5\%$ and $82.0 \pm 14.4\%$ respectively, $p = .63$).

The possibility that subject "fatigue" may have contributed to the results needs to be considered. The memory tasks were performed in the same order: auditory, then visual, and finally musical notes, and within each task 1-item, then 3-items and finally 5-items; the only possible significant effect on performance was with musical notes, where performance decreased on the 3- and 5-item tasks. This latter decrement of performance could reflect effects of "fatigue." However, Brezinova et al. (1977) found no change in blink rate over an hour period in which subjects continuously observed a swinging pendulum. In contrast, Simonov and Frolov (1985) found that during a visual tracking task, increased blinking frequency corresponded to decreased quality of performance. In visual tasks blinking could clearly cause decreased quality of performance. Other factors such as "anxiety" have also been considered as variables affecting blink rate but there has been no consistent association of these variables with blink rate (Stern et al., 1984).

Correlates of the incidence of blinking during memory tasks were also assessed by dividing the patients into high- and low-blinking subgroups (Table 4). Accuracy was significantly different between the high- and low-blinking patient groups ($p = .01$) while mini-mental scores, RT and age were not significantly different. This finding indicates that the failure to inhibit blinking is related to poor performance on the primary memory-scanning tasks and not to the overall cognitive state as measured by mini-mental score. This conclusion is further supported by the finding that the low-blinking patients (who overall were quite accurate on the memory-scanning tasks ($89.6 \pm 5.1\%$)) significantly differed from the age-matched control group with respect to mini-mental scores ($p = .003$) but not with respect to performance accuracy ($p = .83$) or blink rate ($p = .45$). The ability to use the inhibition of blinking as a diagnostic guide for individual subjects at risk for memory disorder is limited since some of the age-matched controls blinked as frequently as did the patients. However, indices such as normalized blink inhibition ratio likely adds specificity to detecting difficulty with certain tasks. For example, all subjects with normalized blink inhibition ratios less than .63 (subjects # 2, 3, 4, 5, 6, 13 and 14; see table 1) had relatively poor performance on the short term memory tasks (accuracies < 87%).

Accuracy, but not mini-mental score or reaction times, was significantly different between the high- and low-blinking groups. In contrast, all three parameters were significantly different between the high-blinking and normal age-matched controls (see Table 4). Thus, the failure to inhibit blinking during the performance of memory tasks may be a clinical indicator of cognitive disorders. The generality of this relationship requires further study but at least we have found this relationship to be significant during ERP testing in which blink inhibition is an implicit secondary task and appears sensitive to task difficulty.

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