Comparison of Checkerboard P300 Speller vs. Row-Column Speller in Normal Elderly and Aphasic Stroke Population

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Abstract. This study evaluates the ability of aphasic stroke patients to use two different P300 visual spellers to communicate. Nine normal elderly subjects and eight aphasic stroke patients used the checkerboard (CBP) and row-column (RCP) paradigms on a 6x6 alphanumeric matrix. We used a stepwise linear discriminant analysis for online classification of training data. Stroke subjects achieved a spelling accuracy of 60-65%. Normals achieved a higher accuracy than stroke subjects with the CBP (89% vs. 65%). CBP was also preferred over the RCP by normals, had a higher accuracy rate and was judged to be easier to perform. Our results indicate that in the elderly population, CBP is a superior paradigm compared to RCP. Our study also demonstrates that aphasic stroke patients can use a P300 visual speller to communicate.

Keywords: Electroencephalogram (EEG), P300 Speller, aphasia, stroke, checkerboard paradigm

1. Introduction

One major goal of current P300 visual speller research is to develop paradigms that significantly improve communication in patients suffering from severe neurologic disorders impairing speech and motor function. Most of the past clinical research subjects were patients with ALS or locked-in syndrome. A group of patients that has not been well-studied is aphasic stroke patients. Stroke is the leading cause of neurologic disease in the United States and those causing aphasias or language dysfunction are some of the most disabling. Restoring effective communication for stroke patients, especially for patients with expressive aphasia, is a potential application for BCI. Another area not well studied is how age may affect performance in BCI tasks, as most studies recruited young adult volunteers. Many of the anticipated clinical applications for BCI would apply to a much older population. Therefore, we studied the performance of aphasic stroke patients compared to an age-matched control group in controlling a P300 visual speller.

2. Material and Methods

2.1. Subjects and Data Acquisition

Nine normal elderly subjects and eight aphasic stroke patients were tested for the ability to control the P300 Speller using both the row-column paradigm (RCP) and checkerboard paradigm (CBP). All stroke subjects had Broca's aphasia and a NIH stroke scale language subscore of 2 or greater, indicative of severe aphasia. All subjects signed a Mayo Clinic IRB-approved consent form. EEG was recorded using a standard 32-channel electrode cap, amplified, band pass filtered 0.5-500 Hz and digitized at 1200 Hz using g.USB amplifiers (Guger Technologies). Stimulus presentation and data recording were controlled by BCI2000. Subjects viewed a 6x6 matrix on a computer screen and P300 Speller accuracy was based on a linear classifer and testing protocol previously described (Krusienski et al., 2008; Townsend et al., 2010; Krusienski and Shih, 2011). At the completion of testing, all subjects completed a testing preference questionnaire and visual analogue scale of paradigm difficulty (1-easiest, 10-most difficult).

Table 1. *Subject Information.*

Subject Number	Age	Gender	Starting Paradigm	Flash Number		Accuracy (%)		Paradigm	Visual Analogue Score	
~	~	~	~	RCP	CBP	RCP	CBP	Preference	RCP	CBP
C01	70	M	RCP	14	10	57	91	CBP	9.0	3.0
C02	58	F	RCP	12	10	93	93	CBP	7.0	4.0

C03	69	M	CBP	8	8	86	100	CBP	8.0	3.5
C04	72	F	RCP	14	10	95	91	No Preference	5.5	5.5
C05	67	F	CBP	12	10	86	86	No Preference	7.0	5.25
C06	78	M	CBP	14	14	75	98	CBP	5.5	2.5
C07	74	F	RCP	12	16	43	98	CBP	6.5	2.5
C08	72	M	CBP	14	10	64	86	CBP	3.0	2.25
C09	64	M	RCP	18	10	73	55	CBP	8.5	3.0
Average:	***69***	***~***	***~***	***13***	***11***	***75***	***89***	***~***	***6.7***	***3.5***

Subject	**Age**	**Gender**	**Starting**	**Flash Number**		**Accuracy (%)**		**Paradigm**	**Visual Analogue Score**	
Number	**~**	**~**	**Paradigm**	**RCP**	**CBP**	**RCP**	**CBP**	**Preference**	**RCP**	**CBP**
S01	80	M	CBP	12	20	36	73	CBP	5.5	6.75
S02	68	M	RCP	14	24	18	55	CBP	8.5	2.0
S03	66	M	RCP	24	12	68	66	CBP	5.0	7.0
S04	60	M	CBP	28	24	75	66	RCP	7.0	5.25
S05	54	M	RCP	12	12	61	68	No Preference	4.0	4.0
S06	54	M	CBP	12	12	77	36	No Preference	8.0	5.0
S07	60	M	RCP	24	8	86	98	No Preference	6.0	6.0
S08	75	F	CBP	Inc.	20	Inc.	55	Inc.	Inc.	Inc.
Average	***65***	***~***	***~***	***18***	***17***	***60***	***65***	***~***	***6.3***	***5.1***

2.2. Data Analysis

The data were analyzed using two-tailed paired t-tests to assess performance differences in flash number, accuracy and visual scale of difficulty between RCP and CBP for normal subjects. Because S08 did not complete the RCP portion of testing, two-tailed unpaired t-tests were used to analyze the data within the stroke group, and to assess for differences between the control and stroke group.

3. Results

Normal elderly using CBP were able to achieve a significantly higher average spelling accuracy (89%) than subjects using the RCP (75%) ($p < 0.01$), and found CBP easier than RCP ($p < 0.005$). Classification flash number was not different. Within the stroke group, there were no differences in test performance when using the RCP and CBP. In comparing normal elderly to stroke subjects, normals had higher accuracy using CBP ($p < 0.01$), but were not significantly different when tested with RCP. Normals needed less flashes with CBP to make a classifier ($p < 0.05$).

4. Discussion

The results indicate that CBP was superior to RCP as a P300 visual speller paradigm, when evaluated in terms of spelling accuracy, subject preference, and ease of use. This study also demonstrates that aphasic stroke patients can use a scalp-based P300 visual speller to communicate. While stroke subjects did not achieve the character selection accuracy attained by normals, their ability to use a BCI visual speller points to another potential clinical application in this fast moving research field.

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