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The Ruff Figural Fluency Test: heightened right frontal lobe delta activity as a function of performance

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Abstract

Research has indicated that the Ruff Figural Fluency Test [RFFT; Ruff, R. M., Light, R. H., & Evans, R. W. (1987). The Ruff Figural Fluency Test: A normative study with adults. *Developmental Neuropsychology*, *3*, 37–51] is sensitive to right frontal lobe functioning. Indeed, research has differentiated between patients with left or right frontal lobe lesions using performance on the RFFT [Ruff, R. M., Allen, C. C., Farrow, C. E., Niemann, H., & Wylie, T. (1994). Figural fluency: Differential impairment in patients with left versus right frontal lobe lesions. *Archives of Clinical Neuropsychology*, *9*, 41–55]. The present investigation used quantitative electroencephalography to test further whether the RFFT was sensitive to right frontal lobe functioning among a group of individuals with no history of head injury. To meet this objective, the RFFT was administered to a group of 45 right-handed men with no history of significant head injury or cerebral dysfunction. Delta magnitude (μV) at three right frontal electrode sites (FP2, F4, F8) was then used to compare those who performed the best (High Fluency) with those who performed the worst (Low Fluency) on the RFFT. The findings indicated heightened right frontal delta magnitude for the Low Fluency group relative to the High Fluency group at the F2 and F8 right frontal electrode sites. Thus, the present findings provide further support for the contention that the RFFT is sensitive to right frontal lobe functioning, even among those with no history of head injury.

Keywords: Ruff Figural Fluency Test; Frontal lobe; Fluency

1. Introduction

Fluency has been defined as the ability to utilize one or more strategies that maximize response production while at the same time avoiding or minimizing response repetition (Ruff,

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Allen, Farrow, Niemann, & Wylie, 1994). Although some evidence exists that contradicts the hypothesis of double dissociation between verbal and figural fluency (Tucha, Smely, & Lange, 1999), research has generally supported that figural fluency is related to right frontal lobe functioning. For instance, based on performance on the Five-Point Test (Regard, Strauss, & Knapp, 1982), patients with right frontal lobe dysfunction are more correctly classified as defective than patients with dysfunction in other regions of the brain (Lee et al., 1997). Further, Jones-Gotman and Milner (1977) found that patients with right frontal lobe dysfunction exhibited significantly impaired performance on the Design Fluency Test (DFT) as compared to patients with dysfunction localized to the left frontal lobe as well as other areas of the brain.

The Ruff Figural Fluency Test (RFFT) was developed due to difficulties experienced in scoring the responses on the DLT and with the intent of developing a measure of nonverbal fluency based on psychometric techniques (Ruff, Light, & Evans, 1987). The RFFT has often been used as a measure of nonverbal fluency, has a demonstrated relationship with performance on the DFT (Demakis & Harrison, 1997), and good test-retest reliability (Ruff et al., 1987) and interrater reliability (Berning, Weed, & Aloia, 1998). Patients possessing severe head injuries have exhibited more impaired performance on the RFFT than those with moderate injuries (Ruff, Evans, & Marshall, 1986). Further, performance on the RFFT is specifically sensitive to right frontal lobe dysfunction (Ruff et al., 1994). Research has also found that patients with frontal lobe lesions exhibit more impaired performance on a measure based on the RFFT than a group of healthy control patients (Baldo, Shimamura, Delis, Kramer, & Kaplan, 2001).

Given that performance on the RFFT is sensitive to right frontal lobe dysfunction, variations in performance on the RFFT should be reflected in measures of cerebral activity, such as electroencephalography (EEG). Research has indicated that the EEG record of areas nearest to the site of brain lesions is characterized by increased slow wave or delta activity (Fernandez-Bouzas et al., 1999, 2001; Gotman et al., 1973; Harmony et al., 1993; Jackel & Harner, 1989; Logar & Boswell, 1991; Lukashevich et al., 1999; Murri et al., 1998). Additionally, experimentaly induced cerebral ischemia results in significant increases in delta and theta activity (Bo, Soragna, Spocchia, & Chimento, 2001). Brain tumors and cerebrovascular accidents are also associated with focal increases in delta activity (Tyner, Knott, & Mayer, 1989). Delta and theta activity are also known to increase as cerebral blood flow and metabolism decrease (Nagata, 1988). Indeed, localized increases in slow wave or delta activity in the record of an awake individual is generally considered a sign of brain dysfunction or abnormality (Hughes, 1994; Misulis, 1997). Thus, given the sensitivity of EEG to detect localized brain dysfunction, systematic differences in delta activity should be found at the right frontal lobe as a function of performance on the RFFT. The present investigation sought to test this hypothesis using quantitative electroencephalography (QEEG). Specifically, it was hypothesized that individuals who perform poorly on the RFFT would exhibit heightened delta magnitude at the right frontal electrode sites (F2, F4, F8) as compared to those who perform well. Although no specific hypotheses were generated regarding differences in delta magnitude between the three electrode sites, it was anticipated that the F2 and F8 sites were more likely to evidence significant group differences due to their closer proximity to the orbitofrontal region.

2. Methods

2.1. Participants

A total of 45 right-handed men participated in exchange for extra credit in the undergraduate psychology course in which they were enrolled. Handedness was assessed using the Coren, Porac, and Duncan Laterality Questionnaire (CPD; Coren, Porac, & Duncan, 1979), a 13-item questionnaire that assesses lateral preference for the hand, foot, eye, and ear. To be considered for inclusion the participants had to score at least +5 on the CPD (range of scores possible is from −13 to +13, with positive scores indicating increased right-handedness) and identify both biological parents as being right-handed. Further inclusion criteria included having no history of significant head injury or brain dysfunction and no currently experienced psychological problems, as assessed by administering an inventory assessing history of head injury, stroke, seizures, paralysis, medical illness, psychological or psychiatric problems, sensory impairments, prescription medication use, and problems or pain related to movement.

Participants were assigned to either a Low or High Fluency group based on their performance on the RFFT, specifically, the total number of unique designs produced. The Low Fluency group, with an age range of 18–29 years ($M = 19.80$, S.D. = 2.76), consisted of the 15 participants that generated the fewest number of unique designs and the High Fluency group, with an age range of 18–24 years ($M = 20.29$, S.D. = 1.82), consisted of the 15 participants that generated the greatest number of designs. Those scoring in the middle third were not used in statistical analyses of group differences in delta magnitude.

2.2. Apparatus

2.2.1. Ruff Figural Fluency Test

The RFFT (Ruff, 1996; Ruff et al., 1987) is a measure of nonverbal fluency consisting of five individual parts, with each part consisting of a different stimulus pattern. The participants are instructed to draw as many unique designs as possible by connecting at least two of the dots comprising a 5-dot matrix. Nonverbal fluency is then considered as the total number of unique designs produced within a 1 min time frame.

2.2.2. Quantitative electroencephalography

QEEG was measured using a NeuroSearch-24 (Lexicor Medical Technology, Inc., Boulder, CO, USA). Monopolar QEEG recordings, with linked ear references, were obtained using a lycra electrode cap (Electro-Cap International, Inc., Eaton, OH, USA) containing 19 pure tin electrodes filled with EC2 electrode gel. The electrodes used to measure QEEG were arranged according to the International 10/20 System. Silver-silver chloride electrodes filled with conductive paste were used for ear references and for measuring electro-oculography. A Model 1089 mkII Checktrode Electrode Tester (Lexicor Medical Technology, Inc., Boulder, CO, USA) was used to check the impedance levels of the electrodes.

2.3. Procedure

The participants were initially screened by administering the RFFT, CPD, and the questionnaire assessing history of head injury and medical illness. Following the screening and group assignment, all participants were invited to return for the second phase of the investigation, which involved the collection of QEEG data. The participants were given a brief description of the experimental protocol and an opportunity to ask questions. The electrode cap was then attached to the participant's scalp using the appropriate anatomical landmarks, followed by the ear reference and electro-oculography electrodes. The impedance levels for all electrodes sites used to measure QEEG were less than 5 kΩ and in most instances below 3 kΩ. A sampling rate of 256 Hz was used and frequencies below 2 Hz were eliminated by a high pass filter. The QEEG bandwidth analyzed included high delta (2.0–4.0 Hz).

The participants were then seated in a padded chair located in a sound attenuated chamber and instructed to sit quietly with their eyes closed and to remain as still as possible throughout the remainder of the investigation. Approximately 2 min following these instructions a baseline measurement of QEEG activity was obtained. A total of 45 one-second epochs constituted the baseline QEEG measurement. The data obtained from this baseline measurement were then used for statistical comparisons of delta magnitude (μV) between the two groups of participants. Following the collection of baseline QEEG activity the participants were disconnected, thanked for their participation, and dismissed.

3. Results

The total number of unique designs generated by the Low Fluency group ranged from 47 to 85 ($M = 69.87$, S.D. = 10.47), which as a group placed them at about the second percentile as compared to the normative sample. The total number of unique designs generated by the High Fluency group, in contrast, ranged from 103 to 133 ($M = 115.40$, S.D. = 10.35), placing them at about the 66th percentile as compared to the normative sample. A between-group AVOVA indicated that the difference in number of designs generated between the Low and High Fluency groups was statistically significant, $F(1, 28) = 143.54$, $P < .0001$.

For the sake of comparison, the total number of perseverative errors and the perseverative error ratios for each group were also calculated and compared. The number of perseverative errors committed by Low Fluency group ranged from 0 to 8 ($M = 2.47$, S.D. = 2.10) and from 1 to 8 ($M = 4.14$, S.D. = 2.14) for the High Fluency group. This difference in the number of perseverative errors between the Low and High Fluency groups reached statistical significance, $F(1, 28) = 5.46$, $P = .027$. The perseverative error ratio ranged from 0.000 to 0.094 ($M = 0.035$, S.D. = 0.024) for the Low Fluency group and from 0.009 to 0.072 ($M = 0.036$, S.D. = 0.018) for the High Fluency group, this difference was not statistically significant, $F(1, 28) = 0.045$, $P = .833$.

Prior to conducting the statistical analyses on delta magnitude, all epochs resulting from the baseline measurement of QEEG were individually artifacted to remove epochs contaminated by muscle and eye movements as well as other contaminants. To determine whether the Low and High Fluency groups differed in delta magnitude at the right frontal electrode sites, a mixed factorial ANOVA was conducted with a between-subject factor of Group (Low and High Fluency) and a repeated factor of Site (F2, F4, F8). The results indicated that the interaction between Group and Site was not statistically significant, $F(2, 56) = 0.64$, $P = .533$. However, the main effect for Group was statistically significant, $F(1, 28) = 5.44$, $P = .027$, with the Low Fluency group ($M = 4.83$, S.D. = 1.27) exhibiting greater delta magnitude than the High Fluency group ($M = 4.05$, S.D. = 0.70). Further, the main effect for Site reached statistical significance, $F(2, 56) = 19.10$, $P < .0001$, with the F4 electrode site ($M = 4.91$, S.D. = 0.95) exhibiting significantly greater delta magnitude than the F2 ($M = 4.47$, S.D. = 0.84) and the F8 ($M = 3.92$, S.D. = 1.18) electrode sites. The F2 electrode site was also associated with heightened delta magnitude relative to the F8 electrode site. Due to the large difference in standard deviation between the Low and High Fluency groups, and the potential effects this heterogeneity of variance may have on the findings, the data were also analyzed using a transformation for heterogeneity variance suggested by Winer (1971). However, this transformation did not significantly alter the findings.

The data were also subjected to separate one-way between-group ANOVAs between the Low and High Fluency groups at each of the electrode sites so that a more complete understanding of the data could be obtained. The resulted indicated that a significant difference existed in high delta magnitude, $F(1, 28) = 4.71$, $P = .039$, between the Low ($M = 4.82$, S.D. = 1.09) and High Fluency ($M = 4.17$, S.D. = 0.58) groups at the F2 electrode site. A significant difference, $F(1, 28) = 4.56$, $P = .042$, was also noted between the Low ($M = 4.42$, S.D. = 1.64) and High Fluency ($M = 3.43$, S.D. = 0.71) groups at the F8 electrode site. No significant difference between the Low ($M = 5.24$, S.D. = 1.08) and High Fluency ($M = 4.58$, S.D. = 0.82) groups emerged at the F4 electrode site, $F(1, 28) = 3.57$, $P = .069$ (see Fig. 1).

Although not included in the hypothesis, correlational analyses were also conducted using the entire sample to obtain a more complete understanding of the relationship between right frontal lobe delta magnitude and performance on the RFFT. The results indicated significant negative correlations between the total number of unique designs produced and delta magnitude at the F2 ($r = -.33$, $P = .013$), F4 ($r = -.34$, $P = .012$), and F8 ($r = -.37$, $P = .006$) electrode sites (see Fig. 2).

4. Discussion

As hypothesized, performance on the RFFT was reflected on the QEEG with low fluency individuals exhibiting increased delta activity across right frontal electrode sites in comparison to high fluency individuals, thereby providing support for the use of the RFFT to distinguish right anterior cerebral functionality. The present findings not only provide objective neurophysiological validation for the RFFT as a measure of right frontal lobe functioning but also lend support for the integration of neurophysiological measures into neuropsychological assessment. QEEG has been successfully implemented in demonstrating localization and verification in studies concerning right and left cerebral dysfunction (Demaree, Crews, & Harrison, 1995; Duffy, 1994; Everhart & Harrison, 1995).

However, several problems exist that limit the usefulness of the findings. For instance, no information was gathered regarding the intellectual functioning of the participants. The

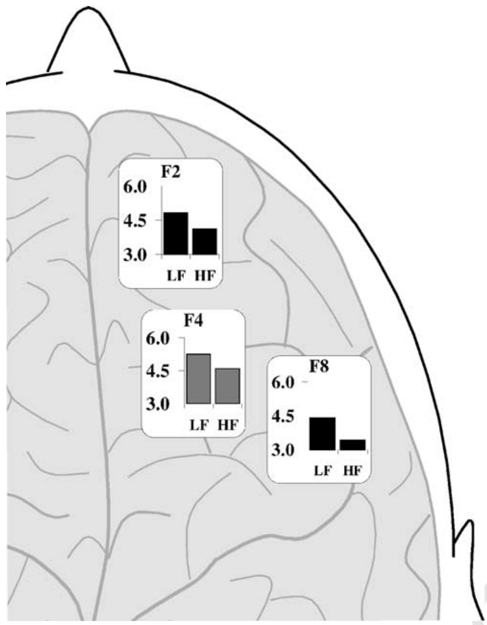

Fig. 1. Delta magnitude (μV) at the right frontal lobe as a function of performance on the RFFT. Note: Microvolts (μV) presented on *y*-axis. LF represents the Low Fluency group and HF represents the High Fluency group. Graphs presented in black represent statistically significant differences between the Low and High Fluency groups (i.e. $P < .05$).

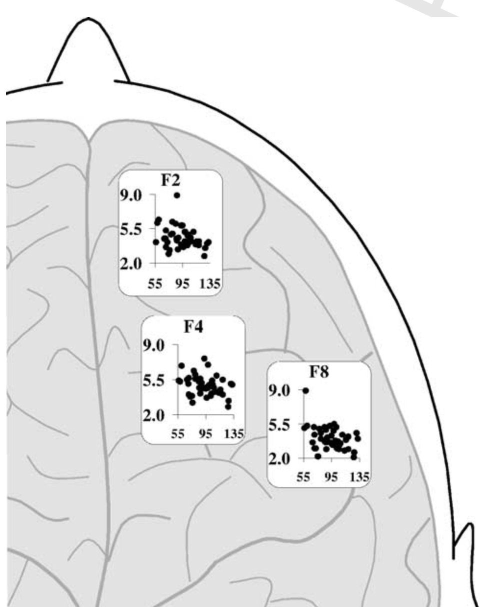

Fig. 2. Relationship between right frontal delta magnitude (μV) and performance on the RFFT. Note: Microvolts (μV) presented on *y*-axis and RFFT scores on the *x*-axis.

possibility exists that systematic variability in intellectual functioning between the groups may have affected the data and findings. Perhaps, though, the largest limitation is the use of a single association as opposed to a double dissociation paradigm. The findings would have provided stronger support for the hypothesis that the RFFT is sensitive to right frontal lobe functioning if left frontal lobe delta magnitude was measured and found to be unrelated to performance on the RFFT. Indeed, the interpretative value of the findings would have been increased had delta magnitude at other electrode sites, such as the temporal and other posterior sites, been measured. Even stronger support would have been provided had a measure of verbal fluency been included and found to be related to left frontal but not right frontal lobe delta magnitude.

Clearly, given these limitations, the present investigation should be followed by a study using a double dissociation design incorporating measures of both verbal and nonverbal or figural fluency. Nevertheless, the findings do provide support for the contention that the RFFT is sensitive to right frontal lobe functioning. Another important implication of the present findings, though, is the use of an objective physiological measure to provide validation of a neuropsychological test. Hopefully, the present investigation will stimulate additional studies seeking to validate other neuropsychological tests using QEEG or other physiological measures.

Uncited reference

Williamson et al. (2003).

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