Do Riding's style dimensions have neural correlates?

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Abstract

Riding's cognitive style constructs have been recently criticised due to the poor performance of the CSA with regards reliability. This paper argues against premature abandonment of the constructs due to inefficiencies of the instrument and suggests that Neuro physiological measures may be a way forward. Sixteen participants (8 male, 8 female) were asked to listen to two different prose passages one highly concrete and descriptive the other highly semantically complex and acoustical (known previously to differentiate between verbalisers and imagers). Participants were attached to 19 electrodes via EEG recording equipment and overall power recordings were obtained for alpha, beta and theta frequency ranges. Results indicated that neural activity differentiated between verbalisers and imagers and wholists and analytics. Although this study implies neural correlates for the verbal imagery and wholist analytic dimensions this research is still in its early stages and needs further exploration and replication.

In this paper arguments are made for further research around Riding's style model despite recent criticism of its measurement instrument the CSA. It is important for any instrument used to measure a construct to be robust in terms of both its reliability and validity. Investigation into a better instrument is necessary and a viable option may be the use of neuro physiological measures. Evidence is presented in this paper to suggest neural activity correlates of Riding's style measures. However, the research is still in its early stages and needs further exploration and replication.

Style and its Measurement

Since the publication of Coffield, Moseley, Hall and Ecclestone (2004) there have been many heated discussions about the merits of cognitive style as a practical construct for educational and managerial intervention. There is a dire need to define cognitive style with appropriately valid and reliable instruments as the area is littered with style constructs and their associated instruments (e.g. Coffield et al., 2004 identifies 71). In addition, the area is complicated by the varied and inter-changeable labels given to these constructs (e.g. cognitive style, learning style, learning strategy), although style and strategy are often differentiated by habit and intention. This paper is more concerned with habitual processes and uses the term cognitive style as defined by Grigorenko and Sternberg (1995): "an individual's way of processing information and operates without individual awareness" (p205*).* Concentration on habitual processes allows me to argue that such processes may be reflected by distinct brain processes and as such it should be possible to identify brain correlates of particular constructs. This approach has been articulated by Riding and Rayner (1998) who state that cognitive style may be categorised as a fixed attribute of the individual with an underlying physiological basis. Work by Riding and Cheema (1991) attempted to rationalise the many different style dimensions into two dimensions namely the verbal imagery dimension and the wholist analytic dimension. However, the cognitive style analysis (CSA) has in recent years been criticised for its lack of reliability (Coffield et al. 2004; Peterson, Deary & Austin, 2003; Redmond, Mullally, & Parkinson, 2002) and in some cases lack of validity (Massa & Mayer, 2005).

CSA Reliability and Validity

A number of studies have brought the psychometric properties of the CSA into question. Peterson et al. (2003) reported a study showing poor test-retest and split half reliability for the verbal imagery dimension. Parkinson et al. (2004) also examined the test-retest reliability of the CSA and found the verbal imagery dimension to be low. Although both of these studies could be criticised for small and non representative samples, short time periods between test-retest and in the case of Peterson et al the fact that they did not use the actual CSA one cannot deny the failings of the CSA.

R. J. Riding (personal communication, October 1, 2005) contends that "with the CSA there is actually considerable evidence that, at least on its first presentation, it assesses style since many results are in directions that fit an expectation or explanation, as shown in the various reviews e.g. Riding & Rayner, 1998" (p. 2). Consequently one has to concede that Riding's style constructs show construct and predictive validity. In addition, the theoretical model is sound, but of course, the instruments' low reliability negates these findings. Although the instrument has its limitations the model and its underpinnings are sound suggesting that researchers should not yet abandon it. Even Coffield et al (2004) concede, "It is possible that the conceptual issues raised above can be resolved, and that the construct validity of Riding's model of cognitive styles may eventually prove more robust than the reliability of the CSA would suggest" (p. 42). Further investigation is needed and the consolidation of a reliable test. This study explores EEG neural activity in an attempt to find neural correlates for the verbal imagery dimension and the wholist analytic dimensions.

EEG and style measurements

Riding (1997) considered the nature of cognitive style to have a physiological basis and states:

> *In the case of the verbal imagery dimension, words and pictures are two different ways of representing information. This has the physical basis in terms of a shift of dominance from one hemisphere of the brain to another. For the wholist analytic dimension, it is possible to see a progression from the whole to the parts. The whole is in this sense, the opposite of the parts; the wood comprises the individual trees. In neurological terms, wholists are relatively more active towards the*

front of the brain and analytics towards the back (Riding,1996, pp. 11-12).

Riding, Glass, Butler and Pleydell- Pearce (1997) performed a study in which they presented words at varying word presentation rates and measured the Alpha EEG patterns of individuals of different cognitive styles. They found that there was a significant correlation (r = .5) between the verbal imager scale and hemisphere activation with imagers using the right side and verbalisers the left. As predicted they did not find any lateralisation effect for the wholist analytic dimension. However, differences were found for the wholist analytic dimension along the mid-line. Analytics showed decreased alpha activity all along the mid-line for this task but wholists showed decreased activity at anterior positions. As this was an analytic task and there was no wholist task comparison it is difficult to draw any clear conclusions. Analytics and wholists may differ in terms of anterior-posterior functioning along the mid-line location. In addition, a further paper from this study reported findings for delta, theta, alpha, gamma and beta bands. Results indicated increased alpha and theta powers for wholists along the midline and left-right differentials between verbalisers and imagers (Glass & Riding, 1999).

Alpha Rhythm

The alpha rhythm is a regular waveform with a frequency between 8 and 12 Hz and amplitude usually ranging between 10 and 150 microvolts. Historically Alpha waves were said to be typically blocked or desynchronised during cognitive activity. More recently Klimesch, Schack and Sauseng, (2005) suggest that Alpha is crucial for working memory processes.

Beta Rhythm

Beta has a frequency of 14Hz and above with a typical amplitude of under 25 micro-volts. Activity of beta occurs over most parts of the scalp with frontal predominance and sometimes-posterior dominance. Gevins and Schaffer (1980) suggested that all alpha and above frequency bands show a reduction in power with sustained cognitive function for all frequencies lower than alpha and reported beta suppression for increased cognitive functioning.

Theta Rhythm

Theta waves are generally between 4 and 7 Hz and have high amplitude. They can be distributed over the whole scalp, but this depends on the age and alertness of the subject. Normally theta localisation occurs more in posterior regions rather than anterior regions (Hugdahl, 1995). Theta power has a tendency to increase with increased attentional and cognitive demands e.g. theta becomes more synchronised thus increasing the power. This synchronisation of theta as opposed to desynchronisation seen for alpha for cognitive demands points to different neural generators for the two bands. Additionally, theta power has been recently linked with functional working memory tasks (Klimesch et al. 2005; Klimesch, Schimke & Scwaiger, 1994).

Proposed Aim

The purpose of the present study is to determine whether neural correlates of the verbal imager and wholist analytic dimensions of cognitive style are present using EEG recordings during a task known to show style differences, in particular the verbal imager dimension. The task used in the study is a task previously implemented by Riding and Calvey (1981) that showed distinct learning/comprehension differences between verbalisers and imagers. This study will examine EEG alpha, beta and theta powers exhibited for the task and investigate differences between groupings for the verbal imager and wholist analytic dimensions.

Methods

Participants

The sample was a self-selected opportunity sample and comprised 16 paid volunteers aged 16-27 (8 males, 8 females) recruited through advertisements offering a reward for participation in an EEG experiment. Volunteers under the age of 30 were selected to take part. The majority of the sample consisted of university students with the addition of some college students from a local sixth form college.

Cognitive Style Analysis

All participants were assessed individually for their cognitive style using the computer presented Cognitive Styles Analysis (CSA; Riding, 1991). Participants were tested individually using a personal computer with a colour monitor and scores on the verbal-imagery and wholist-analytic dimensions obtained.

The overall mean for the wholist-analytic dimension was 1.25 (SD = 0.34) and the mean for the verbal-imagery dimension was 1.05 (SD = 0.13). A one way analysis of variance of the two dimensions with gender as the independent variable gave no significance for either dimension, indicating that both dimensions were independent of gender. The two cognitive style dimensions were divided into two and were constructed to give similar numbers in each cell. The resulting divisions were:
wholist-analytic dimension: wholist, 0.87 - 1.15 (8); analytic. 1.16 - 2.08 (8): verbal-imagery dimension: verbaliser, 0.82 - 1.07 (9); imager, 1.08 - 1.26 (7).

Materials

Participants were attached to Bio-logic EEG recording equipment via 19 electrodes at scalp positions Fp1, Fp2, F7, F3, Fz, F4, F8, T3, C3, Cz, C4, T4,T5, P3, Pz, P4, T6, O1 and O2 (see Figure 1). A Fast Fourier Transform (FFT) was performed on the EEG data and Theta (4.0 - 7.5Hz), Alpha (8.0 - 11.5Hz) and Beta (12.0 - 15.5Hz) frequency absolute powers were obtained for every individual at each scalp position. Artefacts were rejected manually before FFT was carried out. A Sony tape recorder and headphones were used to play the passages to each participant. The apparatus was modified to split the signal from the tape so that the signal was received by both ears simultaneously.

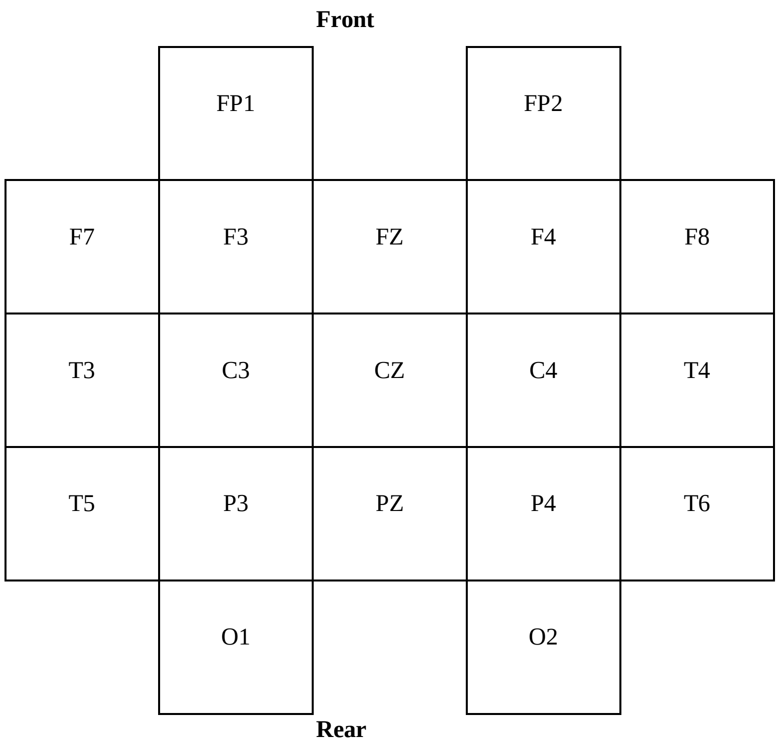


Figure 1 Schematic diagram of electrodes positioned on the scalp.

Passage 1 (Concrete Passage)

Passage 1 was a passage containing complex imagery and was 217 words long. The passage was recorded onto tape using a slow speech rate of 96 words per minute; normal speech rate is about 150wpm. Someone other than the experimenter recorded the speech. The spoken voice was female. The passage was taken from Riding and Calvey (1981).

Passage 2 (Abstract Passage)

Passage 2 was a passage containing complex acoustic and semantic information and was 216 words long. The same person recorded this passage at the same speech rate as passage 1. Passage 2 was again taken from Riding and Calvey (1981).

Design

EEG activity was recorded for each of the 16 participants in the following three conditions:

Baseline in which EEG was recorded whilst participants were at rest with eyes closed for 2 minutes.

Passage 1 in which EEG was recorded for the duration of the passage played to the participant via headphones. Participants listened with eyes closed.

Passage 2 in which EEG was recorded for the duration of the passage played under the same conditions as for passage 1 (eyes closed).

Both passages were of the same length and recorded by the same person using the same speech rate. The order in which passages were presented was counterbalanced to avoid order bias. It was explained to participants that recall for each passage would be tested with ten questions after each passage presentation. This ensured that participants listened to each passage actively. Following the extraction of artefacts a FFT transform was applied to the EEG data and the remaining recording was averaged across the length of the passage and alpha, beta and theta frequencies extracted.

Procedure

Prior to commencement of the experiment participants were informed that EEG recording would take place and this procedure was fully explained. On arrival participants were shown to the laboratory area and asked to complete the computerised version of the Cognitive Style Analysis (CSA).

Participants were then escorted to the area of the lab containing the EEG recording equipment and the procedure was explained to them in detail. They were given the opportunity to withdraw from the experiment at this point and informed that they could withdraw at any time during the procedure if they so wished. Participants were seated in a chair facing away from the EEG equipment and 19 silver –silver chloride electrodes were attached to the scalp using electrode gel. An impedance test was performed to check that all electrodes were correctly attached. They were informed that a baseline recording was about to be taken and that they should sit still in a relaxed position with eyes closed for two minutes whilst recording took place. Following baseline recording participants were informed that they were about to be played a passage lasting approximately two and a half minutes and that they should listen carefully as they would be tested on the content of the passage immediately afterwards. They were also informed that it was important for them to keep as still as possible and to stay relaxed with eyes closed for the duration of the passage. The passage was played to the participant via headphones connected to a tape recorder. EEG activity was recorded. On completion they were asked to open their eyes and the experimenter asked them ten questions about the content of the passage. Participants responded verbally to the experimenter who wrote down the answers. This procedure was then repeated for the second passage.

Statistical Analysis

The data obtained from this study is particularly complex and extensive it is derived from EEG measures taken over 19 electrode positions for 3 different conditions and 3 different frequency bands over a measurement period of approximately 2 minutes. The data was initially analysed using MANOVA with topographically clustered lines of electrodes. However, results were typically complex and difficult to interpret. Consequently, the analysis was simplified in favour of determining general trends rather than specific results and complex interactions. A discriminant function analysis was chosen as the tool for achieving this because it enabled the exploration of potential EEG variables which could discriminate between different cognitive style groupings.

Prior to statistical analysis the data was transformed by taking the ratio; baseline power:active power. This allowed for baseline comparisons to be made rather than relying on data that included individual power fluctuations. Thus, if the baseline is taken to be a stable value with the active value changing according to the task then the ratio value will increase as the active value decreases and decrease as the active value increases.

Six stepwise discriminant analyses were performed on the data for verbal imager and wholist analytic dimensions across 3 frequency bands (alpha, beta, theta). This was achieved by taking alpha, beta and theta values separately for each independent variable and running the analysis for each of the 19 electrode positions over both conditions (passage 1 and passage 2), thus allowing 38 regressors to be entered into each analysis. All power units are arbitrary and means, standard deviations and effect sizes (Cohen's *d*) are calculated for each significant electrode position (small = .2, medium = .5, large = .8; Cohen, 1988).

Results

Verbal Imager Style

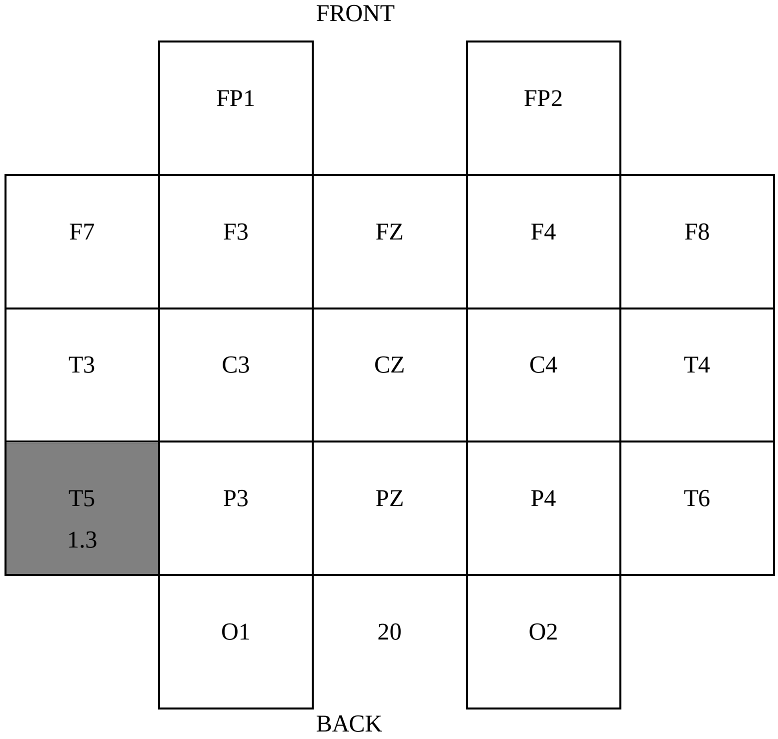
Two analyses returned significant results for the verbal imager dimension. These were for alpha and theta frequency ranges, each range will be considered separately below.

Alpha Band Results

Alpha suppression is associated with increased cognitive activity (Klimesch et al, 1994; 1996). Consequently, alpha ratio values will indicate *alpha suppression* in the active condition and therefore *increased cognitive activity*.

Two variables were significant in predicting membership of the verbaliser and imager groupings; (F[2,13] = 7.42, p = .007) and correctly classified 87.5% of originally grouped cases. EEG activity for electrode position T5 during passage 2 indicated alpha suppression (cognitive activity) for verbalisers for passage 2 (verbaliser mean: 1.26, SD 0.25; imager mean: 0.98, SD 0.18) with an effect size of 1.3 (*d*). In addition, EEG activity for electrode position F8 during passage 2 indicated increased cognitive activity for imagers during passage 2 (verbaliser mean: 0.95, SD 0.28; imager mean: 1.06, SD 0.21) with an effect size of 0.45(*d*). These results are shown graphically below (figure 2) with increased cognitive activity being shaded on the positional representation diagrams for both verbalisers and imagers.

Verbaliser



Imager

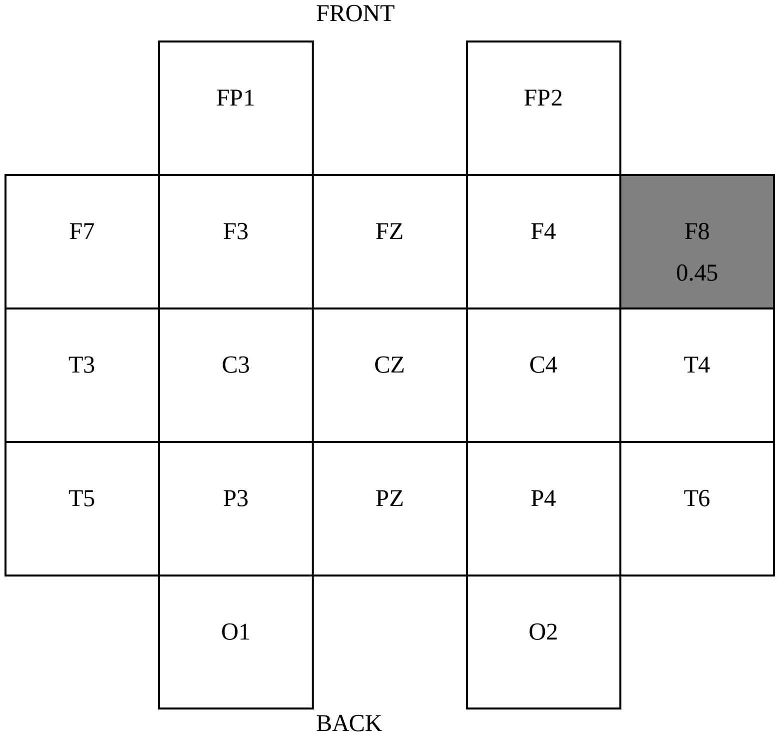


Figure 2. Schematic diagram of the scalp showing increases in cognitive activity for both verbalisers and imagers for passage 2, including effect size (d)

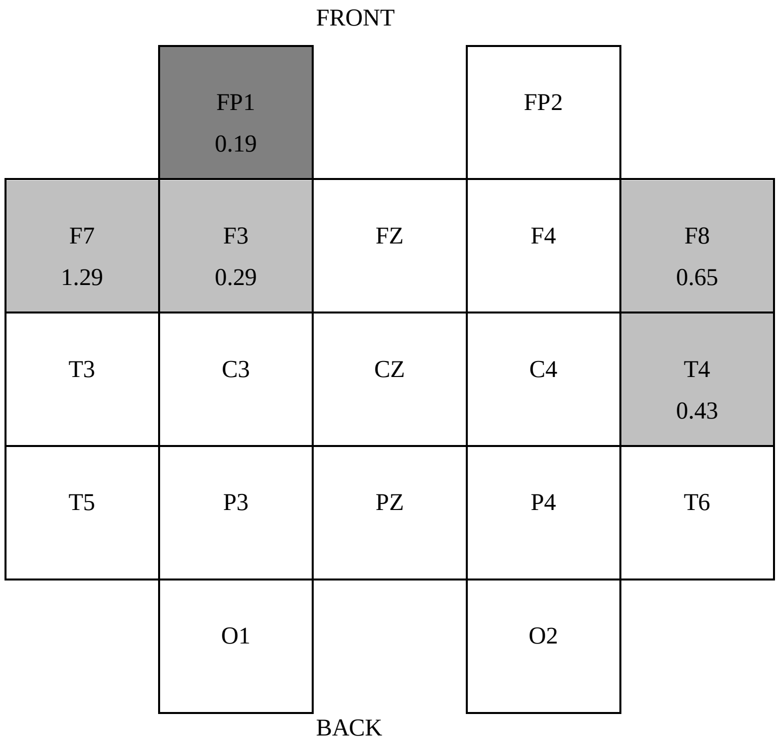
Theta Band Results

Theta power has a tendency to increase with increased attentional and cognitive demands. This synchronisation of theta as opposed to desynchronisation of alpha for cognitive demands points to different neural generators for the two bands (Klimesch et al, 1994). Consequently, *decreases* in theta ratio power will show *increases* in theta activity for the active conditions. Five variables were significant in predicting membership of the verbal imager dimension for the theta frequency range these were FP1 for passage 2, F7 for passage 1, F3 for passage 1, F8 for passage 1 and T4 for passage 1 ($F[5,10] = 12.05$, $p = .001$) and correctly classified 100% of originally grouped cases. Means standard deviations and effect sizes are shown below in table 1 and the cognitive activity profile is depicted in figure 3 below. Increased cognitive activity as indicated by increased theta power is only evident for verbalisers.

Table 1. Showing means, standard deviations and effect sizes for theta power across electrode position and verbal imager style

Electrode Position	**Verbaliser**	**Imager**	**Effect Size (*d*)**
FP1 (Passage 2)	0.87 (0.32)	0.81 (0.30)	0.19
F7 (Passage 1)	0.87 (0.17)	1.07 (0.14)	1.29
F3 (Passage 1)	0.90 (0.16)	0.95 (0.18)	0.29
F8 (Passage 1)	0.87 (0.21)	1.01 (0.22)	0.65
T4 (Passage 1)	0.96 (0.26)	1.06 (0.21)	0.43

Verbaliser



Imager

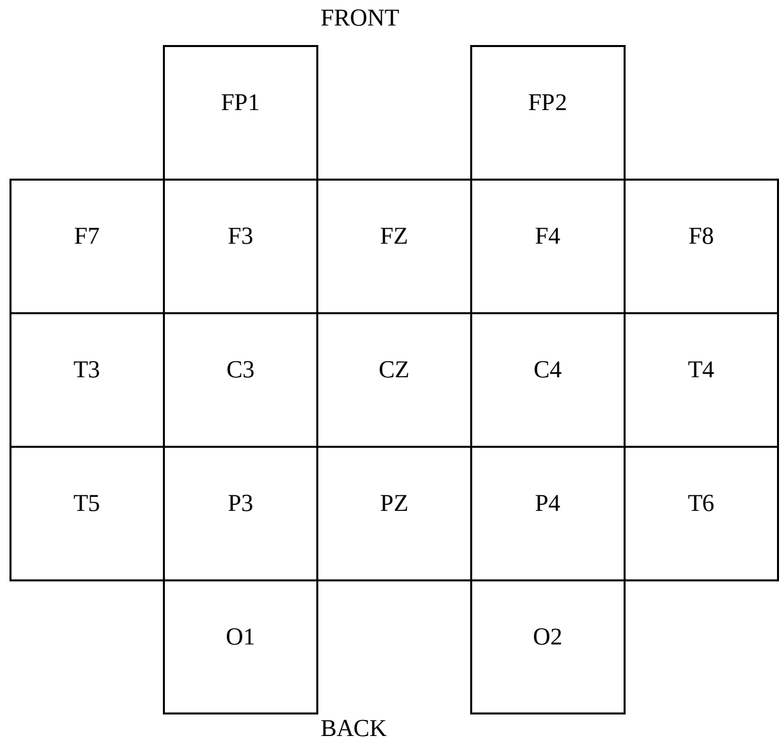


Figure 3 Schematic diagram of the scalp showing increased cognitive activity for both verbalisers and imagers for passage 2 (dark shading) and passage 1 (light shading), including effect size (*d*)

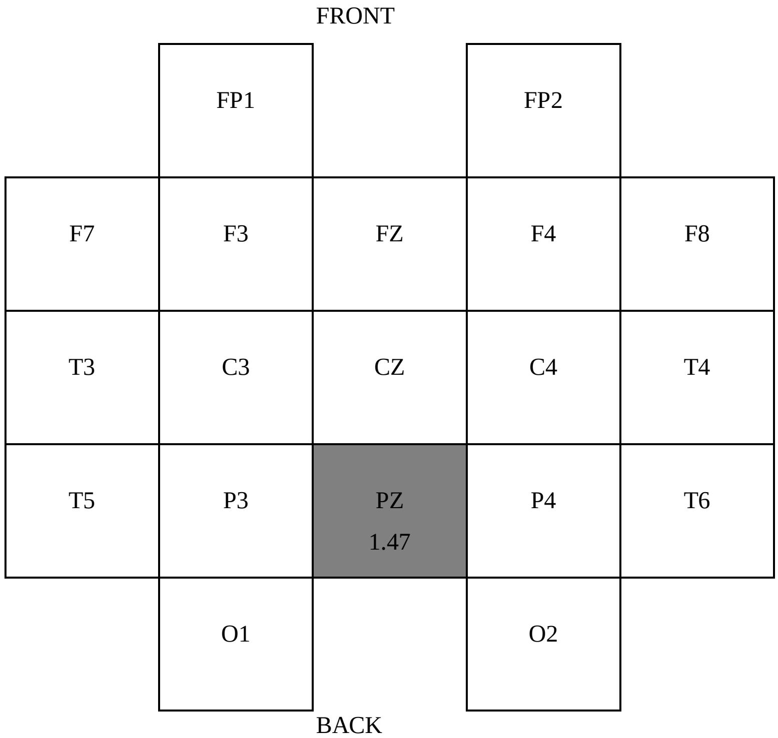
Wholist Analytic Style

Two analyses returned significant results for the wholist analytic dimension. These were for beta and theta frequency ranges each range is considered separately below.

Beta Band Results

Reductions in beta power are associated with increased cognitive activity (Gevins & Schaffer, 1980). Consequently, in the following results section *increased* ratio values will indicate *beta reductions* in the active condition and therefore *increased cognitive effort*. One variable was significant in predicting membership of the wholist analytic range and this was PZ for passage 2 ($F[1,14] = 8.52$, $p = .011$) and correctly classifyied 75% of originally grouped cases. The means and standard deviations are as follows: wholist mean 0.91 (SD 0.09); analytic mean 0.77 (SD 0.10), indicate increased cognitive activity for wholists at PZ with an effect size of 1.47 (*d*). These results are depicted graphically in figure 4 below.

Wholist



Analytic

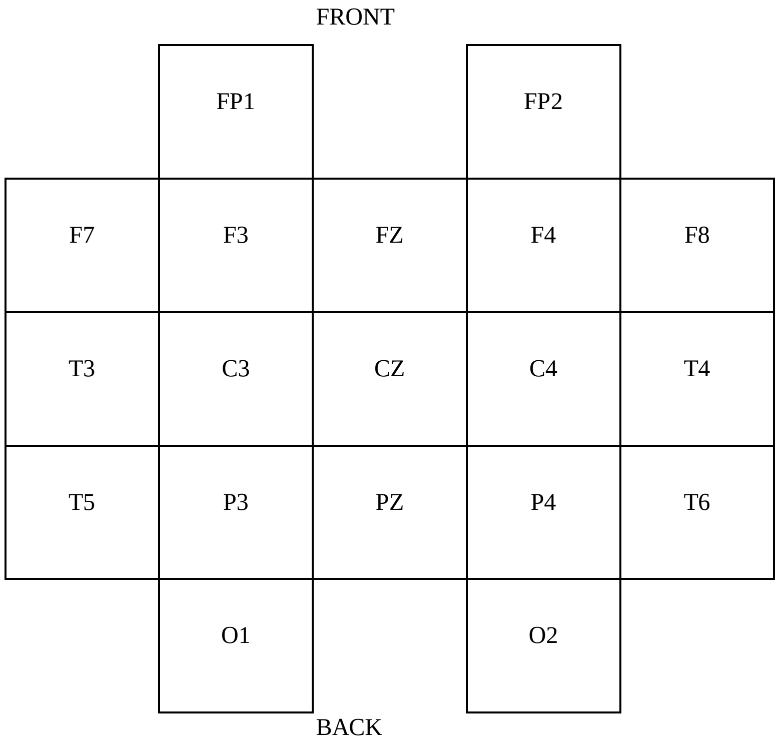
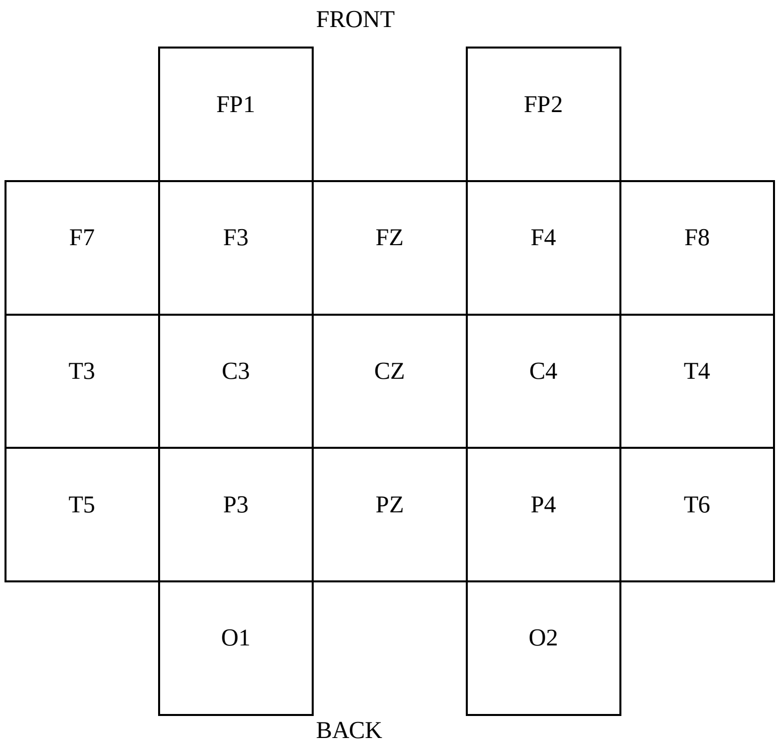


Figure 4 Schematic diagram of the scalp showing increased cognitive activity (shaded) for both wholists and analytics for passage 2, including effect size (*d*)

Theta Band Results

Two variables were significant in predicting membership of the wholist analytic dimension for the theta frequency range these were C3 for passage 1 and P4 for passage 2; (*F*[2,13] = 5.84, p = .015) and correctly classified 81.3% of originally grouped cases. Means for C3 were: wholists = 1.26 (SD 0.92); analytics = 0.99 (SD 0.23) with an effect size of 0.47 (*d*). Means for P4 were: wholists = 1.40 (SD 0.92); analytics = 0.92 (SD 0.23) with an effect size of 0.83 (*d*), indicating increased cognitive activity at C3 and P4 for analytics. This profile is shown in figure 5 below.

Wholist



Analytic

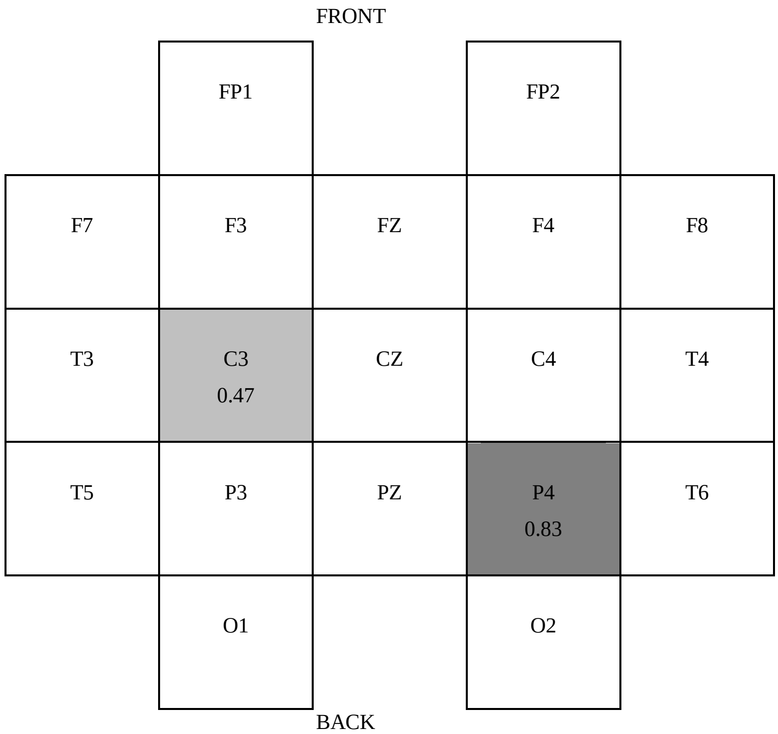


Figure 5 Schematic diagram of the scalp showing increased cognitive activity for both wholists and analytics for passage 1 (light shading) and passage 2 (dark shading), including effect size (*d*)

Discussion

The results from the analyses of this task appear to indicate that verbalisers and imagers can be differentiated by activity at electrode positions T5 and F8 for alpha activity. Verbalisers show increased cognitive activity at the left sided position T5 which is a position that may show activity from Wernickes area, often associated with language comprehension (Jasper, 1958). Imagers however show increased cognitive activity from the right sided position of F8. This distinction is seen in response to passage 2 which was the semantically complex and acoustical passage. Typically verbalisers will excel for this type of passage as oppose to highly concrete imagery style passages. Is it that predisposition for verbalisers to use appropriate (Wernicke’s area) neural processes with this sort of passage causes improved learning and comprehension? It should also be noted that the effect size for T5 is particularly large at 1.3. This result also accords with Riding et al. (1997) in which they found a predisposition for imagers to use right sided processing and verbalisers to use left sided processing.

Theta power also differentiates between verbalisers and imagers. The pattern of increased cognitive activity is present for verbalisers but is much more diffuse appearing over frontal and temporal areas on both the left and right sides. The most prominent activity however, if we examine effect sizes, is over F7 which is often associated with Broca's language area (Gevins & Schaffer, 1980). It should be noted that all activity except over FP1 occurs in response to passage 1, the highly concrete and descriptive passage. This may explain why activity is more diffuse with the integration of right sided areas and the use of Broca's language area.

Results for wholists and analytics were differentiated by beta and theta frequency bands. Wholists showed increased cognitive activity at PZ for beta in response to passage 2. The effect size for this position was extremely large at 1.47. Previous EEG research has also indicated differences along the midline for wholists and analytics (Glass & Riding, 1998; Riding et al., 1997). In addition, theta activity was prominent at C3 and P4 with P4 being the largest of these with an effect size of 0.83. The significance of this may be that P4 is at a posterior position adjacent to PZ.

These results appear to show that it may be possible to differentiate between verbalisers and imagers and wholists and analytics using neural power values and they seem to accord with previous results reported by Riding et al. (1997) and Glass and Riding (1998). However, there is a need to be cautious as this study needs to be replicated using a larger and more representative sample than the present. It should be noted that the current study should be viewed as exploratory and that statistical results viewed with caution due to small sample size. In addition, consideration of the poor reliability of the CSA needs to be considered and alternative means of identifying different style categories should be adopted in future studies. If sample sizes were larger it may be possible to use tasks known to reliably differentiate between styles as the indices for assigning groupings. This would also enable specific tasks to be used to correspond with the different style dimensions. The task in this study was more suited to differentiating between verbalisers and imagers rather than wholists and analytics.

Finally other style measures should be incorporated in an attempt to bring together disparate style dimensions. Use of a range of advanced imaging techniques such as fMRi, ERP, MEG should also be investigated as a means of triangulating the data to establish robust conclusions.

Conclusions

Researchers should be cautious before abandoning Riding's style dimensions. Although the CSA is a poor instrument in terms of reliability other means of measuring these constructs should be pursued. This study is an indication that neuro physiological measures are one route forward in untangling the style web. Consideration should be given to simple style measures using EEG recordings given the recent advancements in EEG scull caps and advanced computing techniques. Alternatively, the use of EEG techniques to consolidate individual style dimensions should be pursued.

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