

**Working memory, style and behavioural predictors of GCSE exam success**

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### Abstract

This study investigates the interplay of working memory, cognitive style and behaviour. Year 8 (13 yrs) students (n=205) at a UK urban secondary school were tested to ascertain predictors of General Certificate of School Education (GCSE) achievement. Assessment included Riding's cognitive style dimensions, working memory capacity and a profile of school behaviour. A stepwise multiple regression analysis indicated that behaviour, working memory, verbal-imagery style by working memory, wholist-analytic style by working memory and verbal-imagery-style by wholist-analytic style predicted GCSE outcome accounting for 58% of the variance. Generally, poor GCSE grade points were predicted by low behaviour scores and analytics and verbalisers with low working memory capacity. The results are discussed in terms of possible interventions that may improve student GCSE performance.

*Keywords:* Cognitive style, working memory, school attainment, behaviour

The intention of this study was to examine a complex interplay of individual difference variables and their affect on GCSE (General Certificate of School Education) outcomes, a national examination at 16 years of age for most students in Great Britain.

Contemporary educational researchers have tended to turn their attention toward cognitive measures of working memory and its affect on educational outcome, rather than controversial and more heterogeneous intelligence measures (Gathercole, Pickering, Knight & Stegmann, 2004). However, the attainment of an individual student is dependent upon both environmental factors and cognitive factors, which will tend to interact, therefore both need to be considered simultaneously. In addition, it is useful if a practitioner can gain information that can be utilised early enough to intervene and make a difference. Therefore this study considers a mix of environmental and cognitive factors that are both high priority in schools and can be attended to early in a student's school life. In total six variables were explored; working memory capacity, wholist-analytic style, verbal-imagery style, conduct behaviour, emotional behaviour and learning behaviour.

### *Working Memory*

Working memory is a non-unitary model of short-term memory (Baddeley & Hitch, 1974) and constitutes the central executive that has control over the whole system; the phonological loop that is capable of holding speech based information and the visuo-spatial sketch pad that holds visual and spatial information. These components work together as a short-term processing system with the visuo-spatial sketchpad and articulatory loop as slave systems to the central executive. The model places an emphasis on active memory, which was lacking in Atkinson and Shiffrin's (1971) original multi-store model of memory. Therefore working memory can be seen as a complete information processing system rather than a passive store, storing information until it passes into long-term memory.

Recently, Baddeley (2000) has proposed a further addition to working memory, namely, the episodic buffer that explains a number of inconsistencies of the original model. The episodic buffer is a limited capacity store holding information that is multimodal (unlike the phonological

loop and visuo-spatial sketchpad) enabling information from other stores and from long term memory (LTM) to be synthesised and stored as an episodic representation (an episode integrated across space). This new element sits well with other research specifically intended to inform learning models. Mayer (1999, 2001) proffers the multimedia model of learning bringing together contemporary learning theories and working memory theories, this model is similar to Baddeley's original model but with the addition of something similar to the episodic buffer that brings together disparate information streams with prior experience or LTM. The model is very good at explaining how multimodal (multimedia) information is integrated into real world learning. (for a full description of this model see Mayer, 2001).

The efficiency of the central executive can be assessed by means of displacement tasks which determine how much processing an individual can do whilst retaining some presented information (e.g. Daneman & Carpenter, 1980). This approach has been found to indicate a strong relationship between working memory performance and comprehension (see, for instance, Mackintosh, 1999). In addition, recent research reveals links between working memory and educational outcome (Gathercole & Pickering, 2000) with children as young as 7years failing to achieve national standards at Key stage 1 when working memory capacity is low. Additionally, children (4- 15 years) identified with general special educational needs by their schools were also differentiated by the fact that they had poor working memories (Pickering & Gathercole, 2004). More specifically, studies indicate that the complex processing required in mathematics and science constrain the educational attainment for children with low working memory (Gathercole, Pickering, Knight & Stegmann, 2004). When performance on national curriculum assessments in english, mathematics and science were explored at 7years and 14years those children with low working memory were shown to under-perform in maths and science compared with those having normal to high working memory. Riding, Grimley, Dahraei and Banner (2003) illustrated that science, music, technology, art and geography were also particularly sensitive to working memory differences.

### *Cognitive Style*

Grigorenko and Sternberg (1995) define cognitive style as “an individual’s way of processing information and operates without individual awareness” (p205). In addition, Riding and Rayner (1998) describe it as “an individual’s preferred and habitual approach to organising and representing information” (p9).

The style concept has long been used in many areas of psychology including cognitive science, perception, motivation, learning and behaviour (Rayner & Riding, 1997). However, style is distinct from ability or intelligence in that it does not measure how well we do something but how we approach something. Grigorenko and Sternberg (1995) elaborate on this by stating:

styles are not abilities, but rather how these abilities (and the knowledge acquired through them) are used in day to day interactions with the environment. Simply put, styles are not how much intelligence we have, but how we use it (p205).

It may be that style is to do with the perceptual elements of learning e.g. structure, organisation, and assimilation of information (Grimley, 2002). Riding and Cheema (1991) reviewed the literature on cognitive style and concluded that the majority of ‘cognitive style’ dimensions can be grouped through two constructs; the wholist-analytic dimension and the verbal-imagery dimension. Riding (1991) developed the Cognitive Style Analysis (CSA) to assess the wholist-analytic and verbal-imagery constructs. The CSA is a computer presented assessment of two independent dimensions, the wholist-analytic style and the verbal-imagery style. The computer assessment is divided into three sections, the first of these assesses the verbal-imagery dimension the next two sections assess the wholist-analytic dimension. Riding and Cheema (1991) proposed that the verbal-imagery dimension was concerned with the way that information was represented. In other words concerned with whether information was represented by verbal constructs or images. Riding and Rayner (1998) suggested that individuals have the capacity to use both types of representation (verbal or visual), but generally they will have a preference for one or the other but will habitually use one type.

Riding and Rayner (1998) stated that the wholist-analytic style dimension was related to cognitive organisation and further expanded this by describing the wholist-analytic dimension as the way that individuals' process or structure information. Cognitive style has been shown to have an impact upon learning outcome and to interact with other variables (for a comprehensive review see Riding & Rayner, 1998).

### *Behaviour*

Anyone who has taught in mainstream schools will understand the importance of student behaviour in the classroom for learning. Conduct behaviour in the classroom is probably the variable at the forefront of most teachers' minds. However, it is also important to consider emotional stability and learning behaviour as these also impact on students' efforts in the classroom. A scale developed for the Qualifications and Curriculum Authority (QCA) (Grimley, Morris, Rayner & Riding, 2004) allows teachers to monitor children's conduct, emotional and learning behaviour, thus, allowing them to get a balance of appropriate behaviour management with appropriate meaningful programmes of instruction in the classroom. The scale asks teachers to rate conduct, emotional and learning behaviour on a 15 item 6-point scale. Each category is described as follows:

*Conduct behaviour* has to do with behaviours such as co-operation, lack of physical aggression, respect for property and the belongings of others, freedom from verbal aggression and inappropriate interruption, and regular attendance.

*Emotional behaviour* is concerned with frequently appearing miserable or contented, unhappy or happy, distressed or relaxed, and with respect to anxiety, freedom from unreasonable fear, a lack of unnecessary worry, and a reasonable level of self confidence.

*Learning behaviour* involves activity related to instruction and process skills, for example, a commitment to follow instructions and to complete tasks, making effort to participate in class discussions, concentration and extended attention span, persistence even with more difficult tasks, and an apparent interest in school work.

Evidence suggests that children with challenging behaviour are susceptible to low attainment. Cole, Visser and Upton (1998) report that about 50% of students labelled as having emotional

and behavioural difficulties (EBD) were significant under achievers in the core subjects, and of these, 30% were severe underachievers. In addition, the Elton Report (1989) indicated that students' at risk were generally under-achievers with learning support needs that were not being met. Whilst many students displaying behavioural problems have complex issues within the home environment others have stable home lives. It is important that in all cases the school implements appropriate educational strategies to lessen disaffection in the education environment and to improve the learning environment for students showing any degree of emotional and behavioural difficulty.

### *Interplay of Working Memory, Style and Behaviour*

Previous research indicates a complex interplay of the independent variables of working memory, cognitive style and behaviour in determining educational outcome. Riding, Dahraei, Grimley and Banner (2001) in a study of 12 – 13 year olds showed that cognitive style interacted with working memory when predicting educational outcome. Scores on the Cognitive Abilities Test (CAT) were predicted by an interaction between the wholist-analytic dimension and working memory capacity as measured by the Information Processing Index (IPI), with analytics performing well if they had good working memory capacity but poorly if they had poor working memory capacity, wholists were generally unaffected by their working memory capacity but showed average attainment throughout. In addition, further studies indicated that analytics and verbalisers were most affected by low working memory capacity with regards school attainment as measured by teacher ratings (Riding, Grimley, Dahraei & Banner, 2003). This high impact of working memory for verbalisers and analytics is explained in terms of the fact that both have relatively complex processing needs, thus, both verbaliser and analytic processing strategies are memory intensive. Studies of cognitive style have also shown a relationship between conduct behaviour and style, in particular it has been found that wholists are predisposed towards poor conduct behaviour thus being represented to greater proportions in EBD special schools than other style groupings (Riding & Craig, 1997; Riding & Rayner, 1998).

High anxiety individuals often show poor working memory and may be attributed to a decrement in processing efficiency, (e.g. Calvo & Eysenck, 1996; Elliman, Green, Rogers & Finch, 1997;

Eysenck, 1992; Hopko, Ashcraft & Gute, 1998). The general view is that some of the capacity of working memory is devoted to the objects of anxiety, and this reduces the resources available for general processing. If stress increases anxiety, which in turn reduces effective working memory capacity then there is the problem that this reduction causes misunderstanding, confusion and uncertainty when processing information. This in turn may cause further stress and hence increase anxiety even further. It is inevitable that this reduction in working memory is going to impair students' academic attainment in the short term and if stress continues it will also jeopardise long-term attainment. Additionally, students high in trait anxiety may suffer from impaired working memory that will inevitably cause problems with schoolwork unless addressed early in their schooling. Riding, Dahraei, Grimley and Banner (unpublished) found that students rated as being high in anxiety by their teachers tended to be low in working memory measures. Thus, cognitive style in interaction with working memory may be a good predictor of cognitive dysfunction, which in turn may be exacerbated by stress/anxiety levels within the student. This interaction between anxiety, working memory and cognitive style may be a key factor for low attaining students as the majority of those with behavioural problems will be high in anxiety and stress. Therefore it is important that the interplay of working memory, cognitive style and behavioural measures are further explored, especially in relation to learning outcome. To date no study has considered the interplay of working memory, cognitive style and behaviour measures on GCSE outcome. Thus, the aim of this study is to explore how these variables together and separately describe GCSE outcome and to inform early intervention to improve outcome.

## Methods

### *Sample*

The sample participants comprised 205 students (115 males, 90 females) who were all Year 8 (13 years-old) at an urban secondary school in the West Midlands, UK. No Year 8 students were excluded from the sample.

## *Materials*

### *Assessment of Working Memory*

The computer presented Information Processing Index (IPI; Riding, 2000) was administered by the same teacher to students in groups of approximately 14 in a school computer room. Riding's (2000) IPI shows children a train comprising different numbers of coloured carriages (1 – 5) entering a station and then emerging out of the other side one carriage at a time. The carriage moves into the station and completely out of sight under the control of the student, it then emerges one carriage at a time still under the control of the student. The student is required to make a key press to decide whether each carriage that emerges has stayed the same or changed colour. This process continues until all carriages have been revealed. The train length ranged from one to five carriages and each length was repeated four times in a pseudo random order, thus, giving a total of 60 carriages for the students to respond to. The score is given as a percentage of responses correct. Subsequently, students were required to both retain information and simultaneously process information for a response. This assessment is a variation on the Daneman and Carpenter Working Memory Span Test (Daneman & Carpenter, 1980) and is similar in nature to the listening span test (Pickering & Gathercole, 2001). The test measures central executive functioning and has been shown to be correlated with listening span (Riding, Dahraei, Grimley & Banner, 2001).

### *Assessment of Cognitive Style*

The cognitive style of all participants was assessed using the Cognitive Styles Assessment task (CSA; Riding, 1991). This is a computer-administered task. Each participant was tested individually using a PC with a colour monitor. Scores were obtained for their position on the verbal - imagery scale and the wholist-analytic scale. For a comprehensive description of the background to the CSA see Riding and Cheema (1991).

### *Assessment of Behaviour*

The Emotional and Behavioural Development scale (EBDS) is a 15 question checklist (Grimley, Morris, Rayner & Riding, 2004) used to assess student's emotional, conduct and learning

behaviour. The EBDS 15-item checklist is divided into three sections (emotional, conduct and learning behaviour) each with five questions (see list below). It is completed by teachers who rate each question using a 6-point scale from 0 to 5 thus giving a score for emotional, conduct and learning behaviour out of 25. These scales were developed in order to assess a student's behavioural and emotional stability within each behaviour area (emotion, conduct, learning) and to reflect the students' behaviour in school. The scales were completed by the student's form teacher who had a good knowledge of each student.

<b>Conduct</b>	<b>Emotion</b>	<b>Learning</b>
1. Respect towards teachers	1. Empathy	1. Attentiveness for school work
2. Respect towards other students	2. Social awareness	2. Learning organization
3. Attention seeking behaviour	3. Happiness	3. Communication
4. Physically peaceable behaviour	4. Confidence	4. Working in a group
5. Respect for property	5. Emotional stability and self control	5. Help/support seeking behaviour

### *School Achievement Measures*

Data regarding each of the sample students' GCSE results were gathered. These results were then converted to a score by giving each GCSE grade a point score as follows: A\*=7, A=6, B=5, C=4, D=3, E=2, F=1, G=0. Some students took GNVQ, however, for practicality these results were not taken into account. In order to get an achievement score it was necessary to sum the total number of points scored for each individual.

### *Procedure*

The same teacher assessed students' during the last term of the school year in groups of approximately 14, in a school computer room, on a cluster of PC's. The CSA and the IPI were administered during different sessions to avoid fatigue. Tutors for Year 8 were asked to assess each of their students on the EBDS. GCSE grades were obtained for each student from school records.

### Results and Discussion

A correlation matrix of independent variables (Table 1) showed wholist analytic style (WA), verbal imagery style (VI) and working memory (IPI) to be unrelated. Conduct (Cond), emotion (Emot) and learning (Learn) were highly correlated. In addition, working memory was correlated with emotion and learning behaviour. One would expect conduct, emotion and learning behaviour measures to be correlated as each will impact on the other. For instance one would expect a student who has poor conduct to also have poor learning behaviour, or a student with poor emotional adjustment to have poor conduct or poor learning behaviour. Also, working memory has been shown to be related to anxiety measures (Calvo & Eysenck, 1996) which were included in the range of assessed behaviours under the emotion scale. In light of the correlations for the individual behaviour measures (conduct, emotion and learning) it was decided to combine these measures into an overall behaviour measure (Beh). The combined behaviour score is therefore included in the correlation matrix (see Table 1) and indicates a small significant correlation with working memory and no other significant correlations.

### TABLE 1 ABOUT HERE

Data was analysed using stepwise multiple regression analysis with total GCSE score as the dependant variable. The predictor variables included in the multiple regression analysis were wholist-analytic style, verbal-imagery-style, working memory, behaviour score and the products (interactions) of each of the four main variables. Each of the independent variables were centred with reference to the mean giving adjusted scores, thus allowing for multi-collinearity commonly

associated with cross products. Summary statistics for the independent variables are given in Table 2.

#### TABLE 2 ABOUT HERE

The regression analysis generated a model that included 5 significant variables, namely, behaviour, working memory, verbal-imagery style by working memory, verbal imagery by wholist-analytic style and wholist analytic style by working memory. Table 3 summarises the results of the stepwise multiple regression. It shows that the model was a good fit accounting for 58% of the variance in GCSE score. From the beta weights of the main effects it can be seen that behaviour ( $B = .76$ ) is approximately twice the size of working memory ( $B = .41$ ) indicating about twice the effect on GCSE performance. However, it is difficult to interpret the interaction effects from raw beta. Therefore, in order to interpret these results further each predictor is described in terms of its effect on GCSE score below and median splits are performed on each independent variable to indicate the difference in GCSE score for low and high predictors and their interactions.

#### TABLE 3 ABOUT HERE

##### *Behaviour*

An examination of behaviour scores indicates that increased behaviour leads to improved GCSE performance ( $r = .66$ ). A median split of behaviour into high and low groupings showed the high group to have a GCSE mean value of 47.9 ( $SD = 11.2$ ) and the low group a mean value of 31.1 ( $SD = 12.4$ ). This is an average increase in grade points of just under 17 and represents a percentage increase of 54%. This is not unexpected as students with low conduct, emotional and learning behaviour will generally be less academically inclined and be 'off-task' for larger proportions of their time at school. Consequently, they are more likely to do poorer in the final GCSE assessments. This is corroborated by work reported by other researchers (Cole, Visser and Upton, 1998; Elton, 1989).

### *Working Memory*

Working memory also shows that increased working memory leads to increased GCSE performance ( $r = .45$ ). A median split of working memory into high and low groups showed that the high working memory group achieved a GCSE mean of 44.4 ( $SD = 13.5$ ) and the low group a GCSE mean of 34.3 ( $SD = 13.8$ ). Thus, students with high working memory achieve better GCSE grades than those students with low working memory. This is an average increase of just over 10 grade points and equates to an increase of 29%. This has previously been documented by other researchers (Gathercole & Pickering, 2000; Gathercole, Pickering, Knight & Stegmann, 2004; Pickering & Gathercole, 2004; Riding, Grimley, Dahraei and Banner, 2003) who have indicated low working memory as a significant factor in academic performance.

### *Verbal Imagery Style by Working Memory*

The interaction between verbal imagery style and working memory is shown in Table 4. The interaction encompasses the working memory effect previously described showing better GCSE grades for students with high working memory. However, it also shows that verbalisers are more affected by poor working memory than imagers suggesting that working memory deficits may be more of a disadvantage for verbalisers than for imagers. This result supports Riding et al (2003) assertion of verbalisers being more susceptible to low working memory than imagers. This may be explained by the more verbally elaborate processing engaged in by verbalisers who expend more processing capacity (working memory capacity), thus leaving fewer resources available for 'school work'.

TABLE 4 ABOUT HERE

### *Wholist-Analytic Style by Working Memory*

The interaction between wholist-analytic style and working memory is shown in Table 5. This interaction is similar to that shown for the verbal-imagery by working memory interaction. However, in this case, analytics are more affected by poor working memory than wholists. Thus, working memory deficits are more of a disadvantage for analytics than for wholists. Again, this result supports Riding et al (2003) assertion of analytics being more susceptible to low working memory than wholists and can be explained by analytics being more elaborate in their processing

and thus expending more processing capacity (working memory capacity), leaving fewer resources available for ‘school work’.

#### TABLE 5 ABOUT HERE

##### *Verbal-Imagery Style by Wholist-Analytic Style*

Table 6 shows the interaction between wholist-analytic style and verbal imagery style. Analytic-verbalisers have the best GCSE performance overall followed by analytic-imagers, wholist-imagers and finally wholist-verbalisers. It is somewhat ironic that although verbaliser and analytic styles in combination are probably beneficial for enhancing GCSE performance as shown by the superior results of analytic-verbalisers, it can also be detrimental if the individual student has low working memory.

#### TABLE 6 ABOUT HERE

#### Overall Discussion

The results of this study clearly show the importance of improving conduct, learning and emotional behaviour in schools with the aim of increasing GCSE performance. However, such improvements are not easy and probably need to be addressed by the whole school community rather than individual teachers. The instrument used to measure behaviour in this study is an instrument available to all UK schools and is provided by the Qualifications and Curriculum Authority (QCA). Therefore this instrument would be a good starting point for schools wishing to improve behaviour. Schools may then use the instrument to encourage strategic discourse in schools around the area of behaviour improvement (see Grimley, Morris, Rayner & Riding, 2004).

In addition, working memory has been shown to be an important factor in predicting GCSE performance with students of low working memory capacity being vulnerable to poor GCSE results. Further, students with an analytic or verbaliser style combined with low working memory are even more vulnerable to poor performance. It would be wise for schools to identify these groups and to offer support in terms of study strategies and meta-cognitive strategies that may

ameliorate their tendency to ‘over process.’ Therefore in light of these results the following recommendations can be made:

- Schools should implement a behaviour plan to improve behaviour throughout the school
- Schools should, concentrate on verbalisers and analytics with a low working memory to support their processing needs

More exploration is warranted into the ways in which working memory, learning behaviour, emotional behaviour and conduct can be enhanced so that effective interventions can be implemented. In addition, the measurement of working memory used in this study was relatively crude, although quick, efficient and practical for administration in a school environment. It would be beneficial to refine this measure to include different aspects of working memory to establish whether different subject areas are affected by different working memory profiles and how they interact with style variables as different subjects differ substantially in terms of their modes of presentation. Finally, more exploration of the relationships between the different behaviour subgroups (conduct, emotion, learning) would be pertinent.

It is extremely important that school teachers are given the information about how individual differences affect a child’s journey through school and their ultimate achievement that either equips them for a life or doesn’t. However, from the perspective of the teacher this needs to be in a manageable form e.g. not different for every single child, and it needs to be achievable through manageable interventions.

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Table 1 Correlation matrix of independent variables

	1	2	3	4	5	6	7
1. WA	--	.01	-.03	.06	.05	.02	.047
2. VI		--	-.02	.03	.01	.03	.027
3. IPI			--	.05	.23**	.21**	.18*
4. Cond				--	.68**	.79**	.89**
5. Emot					--	.86**	.92**
6. Learn						--	.96**
7. Beh							--

\*P<.05,\*\* p<.01

Table 2 Independent Variable Descriptive Statistics

<b>Variable</b>	<b>Mean</b>	<b>SD</b>	<b>Range</b>	<b>N</b>
Wholist-Analytic	1.13	.40	4.21	198
Verbal-Imagery	1.11	.26	3.30	198
Working Memory	83.39	11.35	50.00	198
Behaviour	58.72	11.26	58.83	174

Table 3 Summary of Stepwise Regression Analysis for Variables Predicting GCSE Outcome (N = 206)

Variable	Model 1			Model 2			Model 3			Model 4			Model 5		
	B	SE B	$\beta$	B	SE B	$\beta$	B	SE B	$\beta$	B	SE B	$\beta$	B	SE B	$\beta$
Behaviour	.85	.08	.65**	.76	.70	.59**	.77	.07	.59**	.77	.07	.59**	.76	.07	.59**
IPI				.44	.07	.34**	.44	.07	.34**	.44	.07	.35**	.41	.07	.32**
VI x IPI							-.70	.30	-.12*	-1.01	.34	-.18**	-1.0	.33	-.17**
VI x WA										-22.57	10.97	-.12*	-24.30	10.88	-.13*
WA x IPI													.19	.09	.11*
$R^2$		.48			.54			.55			.56			.58	
F for change in $R^2$		121.99**			95.**			66.79**			52.15**			43.53**	

*Note:* Behaviour and working memory were centred at their means.

Table 4 Mean GCSE scores for the interaction between verbal-imagery style and working memory, standard deviations given in brackets

Variable	Low Working memory	High Working Memory
Verbaliser	33.5 (13.5) n=45	47.0 (12.6) n=51
Imager	36.0 (14.2) n=45	42.6 (13.9) n=50

Table 5 Mean GCSE scores for the interaction between wholist-analytic style and working memory, standard deviations given in brackets

Variable	Low Working memory	High Working Memory
Wholist	37.5 (13.0) n=40	40.3 (13.2) n=46
Analytic	32.5 (14.2) n=50	48.6 (12.5) n=55

Table 6 Mean GCSE scores for the interaction between wholist-analytic style and verbal-imagery style, standard deviations shown in brackets

Wholist-Verbalisers	Wholist-Imagers	Analytic-Imagers	Analytic-Verbalisers
39.2 (13.2) n=44	39.5 (13.2) n=46	40 (15.9) n=53	41.5 (15.2) n=55

Table 2 Correlation matrix of independent variables

Table 2 Independent Variable Descriptive Statistics

Table 3 Summary of Stepwise Regression Analysis for Variables Predicting GCSE Outcome (N = 206)

Table 4 Mean GCSE scores for the interaction between verbal-imagery style and working memory, standard deviations given in brackets

Table 5 Mean GCSE scores for the interaction between wholist-analytic style and working memory, standard deviations given in brackets

Table 6 Mean GCSE scores for the interaction between wholist-analytic style and verbal-imagery style, standard deviations shown in brackets