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Cognitive style, working memory and learning behaviour and attainment in school subjects

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Background. Both working memory capacity and cognitive style have independently been found to affect performance on school-type tasks, but their effects in interaction have not been considered.

Aims. The aims of this study were to consider the relationship between working memory, cognitive style and gender on (a) overall learning behaviour, and (b) performance on a range of school subjects.

Sample. The sample comprised 206 13-year-old secondary comprehensive school Year 8 pupils, being all pupils in that year who completed the principal assessments.

Method. The pupils did an assessment of working memory efficiency - the *Information Processing Index* (Riding, 2000a). They also completed the *Cognitive Styles Analysis* (Riding, 1991) to determine their positions on the two fundamental cognitive styles, which were indicated by two ratios: the Wholist-Analytic ratio and the Verbal-Imagery ratio. Overall learning behaviour was rated by the pupils' tutors. In addition, attainment in each of 10 subjects was rated by their subject teachers.

Results. For overall learning behaviour, there was an interaction between working memory capacity and cognitive style. With the Wholist-Analytic style dimension, memory made a marked difference for Analytics but had little effect for Wholists, and with the Verbal-Imagery dimension Verbalisers were affected but not Imagers. With the school subjects, these differed in terms of their sensitivity to gender, memory and style.

Conclusion. The results were discussed in terms of differences between the styles in terms of information-processing demands. Practical ways of improving learning performance were also considered.

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The intention of this study was to explore the effects of working memory capacity, cognitive style and gender on overall learning behaviour, and also the performance on a range of school subjects.

Working memory

Working memory refers to an active information-processing resource of limited capacity which is necessary for performing cognitive tasks such as comprehension, reasoning, and learning. Research on working memory has been reviewed by Baddeley (1999, 2000). Basically, new information is processed in working memory while its meaning is determined prior to the transfer of this to the more permanent long-term memory. A practical feature of working memory is its limited capacity and the vulnerability to loss of information in it from displacement by further incoming information.

Features of working memory

The working memory system comprises three components: the central executive, and two slave systems - the phonological loop and the visuo-spatial sketch pad (Baddeley, 1986; Baddeley & Hitch, 1974). Information is processed by either the phonological loop or the visuo-spatial sketch pad, or by both. The central executive is responsible for the control and integration of information from the phonological loop and visuo-spatial sketch pad.

The central executive

The central executive is considered to function as a control system. It is a limited capacity attentional system, responsible for co-ordinating the input and output of information to and from the subsidiary slave systems, and for selecting and operating control processes and strategies. The central executive is assisted by the operation of the two slave systems, the phonological loop and the visuo-spatial sketch pad.

The phonological loop

The articulatory or phonological loop is a system specialised for the storage of verbal information over short periods of time. According to Baddeley (1986, 1990a) and Gathercole and Baddeley (1993) the phonological loop has a limited capacity and is assumed to comprise two components: (a) a temporary store which holds information in phonological form and (b) an articulatory control process, which serves to maintain decaying representations in the phonological store.

It has been argued that the simple model of the phonological loop can account for a range of factors that affect memory span in terms of phonological similarity, word length, articulatory suppression, and irrelevant speech (e.g., Baddeley, 1986, 1990b; Baddeley, Gathercole, & Papagno, 1998; Gathercole & Baddeley, 1993).

The visuo-spatial sketch pad

The third component of the working memory system is the visuo-spatial sketch pad. It is 'a slave system specialised for the processing and storage of visual and spatial information, and of verbal material that is subsequently encoded in the form of imagery' (Gathercole & Baddeley, 1993, p. 17). However, the visuo-spatial sketch pad is in some

respects similar to the phonological loop, because it can handle more than one stimulus at a time and has the ability to rehearse information.

Individual differences in working memory capacity and performance

Since working memory has a limited capacity and is crucial in information processing, individual differences in memory capacity are likely to be reflected in performance.

Daneman and Carpenter (1980, 1983) have argued for the importance of individual differences in working memory processing efficiency for reading comprehension. They hypothesised that working memory is used to represent the strategies and skills used in a complex mental task such as reading, with the remaining capacity used to store the resulting products of the reading comprehension. They suggested that while information is being processed and the products of this processing stored, the two functions, processing and storage, would compete for the limited capacity available to working memory. They also argued that individual differences in reading comprehension are due to variability between readers in the efficiency of their processing.

As Daneman and Tardif (1987) have noted, there is the possibility that apparent working memory capacity may actually reflect differences in the efficiency of processing strategies or skills rather than differences in working memory capacity, as such. In practice it appears likely that there are differences both in capacity and in skill efficiency, although this is an ongoing issue (see for instance, Baddeley, 2000, pp. 86-87). For this reason in this article the term 'effective working memory capacity' will be used to denote the overall effect of working memory efficiency and/or capacity.

There is evidence that effective working memory capacity differs among individuals, and that this difference affects a wide range of cognitive tasks such as problem solving, reasoning, acquiring new vocabulary words, and reading comprehension (e.g., Cantor & Engle, 1993; Conway & Engle, 1994; Daneman & Carpenter, 1980, 1983; Engle, Cantor, & Carullo, 1992).

Working memory assessment

Efforts have been made by several researchers to measure effective working memory capacity, (e.g. Daneman and Carpenter, 1980; Daneman & Tardif, 1987; Turner & Engle, 1989; Shah & Miyake, 1996). Variations on the Daneman & Carpenter (1980) method have been widely used.

Working memory span

The Working Memory Span test (WMS) was devised by Daneman and Carpenter (1980) to measure working memory processing efficiency. In this task, subjects are asked to read aloud or listen to a series of unrelated sentences of moderate complexity and then to do two things: (a) to comprehend each sentence; (b) to remember the last word of each sentence. The task typically starts with two sentences and increases to a point at which subjects are no longer able to recall all the terminal words. Memory span is then measured by the number of sentences in the largest set of sentences for which a subject is able to remember the last word of each sentence.

An alternative approach is the *Information Processing Index* (Riding, 2000a). This computer-presented assessment shows railway trains comprising carriages of different colours entering the left side of a station into which the whole train disappears from view and then reappears on the right side with some carriage colours changed. Under

the control of the person being assessed the train enters the left side of the station where it is totally obscured from view and then emerges from the right side of the station one carriage at a time. The colours of some of the carriages are different from that on entry. Seven colours are used. The task is to indicate by pressing one of two marked keys whether or not each carriage colour has changed. This is done as each carriage emerges from the station.

The assessee is able to view the train for as long as is wished before causing it to enter the station. While it is in the station and obscured from view the carriage colours have to be remembered. When the train is made to appear out of the station a decision has to be made as to whether there is a carriage colour change. While this is being done, the information about the remaining carriages which are still obscured has to be retained in working memory. Except in the case when there is only one carriage, both retention and information processing are required. Both the amount to be retained and the quantity of processing increases with the length of the train. Thus the total number of carriages correctly identified is taken as the indication of effective working memory efficiency.

The length of the trains range from one carriage to five carriages with four presentations of each train length in ascending order of length. There are thus a total of 60 carriages to be assessed. The score is the percentage of judgments that are correct.[1]

Cognitive style

Style and its assessment

Cognitive style is seen as an individual's preferred and habitual approach to organising and representing information (Riding & Rayner, 1998, p.11). The background to cognitive style has been extensively reviewed by Riding and Cheema (1991), and Riding and Rayner (1998, chapter 2). They concluded that the various style labels could be accommodated within two fundamental style dimensions – the Wholist-Analytic and the Verbal-Imagery – which may be summarised as follows.

(1) The *Wholist-Analytic* dimension of whether an individual tends to *organise* information in wholes or parts.
(2) The *Verbal-Imagery* dimension of whether an individual is inclined to *represent* information during thinking verbally or in mental pictures.

The two basic dimensions may be assessed using the computer-presented *Cognitive Styles Analysis*[2] (Riding, 1991). It directly assesses both ends of the Wholist-Analytic and Verbal-Imagery dimensions, and comprises three subtests. The first assesses the Verbal-Imagery dimension by presenting verbal statements one at a time to be judged true or false. Half of the statements contain information about conceptual categories while the rest describe the appearance of items. Half of the statements of each type are true. It is assumed that imagers respond more quickly to the appearance statements, because the objects can be readily represented as mental pictures and the information for the comparison can be obtained directly and rapidly from these images. In the case

[1] *In the published version of the Information Processing Index in order to raise the ceiling the train length has been increased to six carriages and the total number of carriages to 85.*

[2] *The Cognitive Styles Analysis is available in various languages: English versions for the Australasian, North Amercian, South African and UK contexts, and also in Arabic, Dutch, French, Germany, Malay and Spanish.*

of the conceptual category items, it is assumed that verbalisers have a shorter response time because the semantic conceptual category membership is verbally abstract in nature and cannot be represented in visual form. The computer records the response time to each statement and calculates the Verbal-Imagery Ratio. A low ratio corresponds to a Verbaliser and a high ratio to an Imager, with the intermediate position being described as Bimodal. It may be noted that in this approach individuals have to read both the verbal and the imagery items so that reading ability and reading speed are controlled for.

The second two subtests assess the Wholist-Analytic dimension. The first of these presents items containing pairs of complex geometrical figures which the individual is required to judge either the same or different. Since this task involves judgments about the overall similarity of the two figures, it is assumed that a relatively fast response to this task is possible by wholists. The second presents items each comprising a simple geometrical shape (e.g., a square or a triangle) and a complex geometrical figure, and the individual is asked to indicate whether or not the simple shape is contained in the complex one by pressing one of the two marked response keys. This task requires a degree of disembedding of the simple shape within the complex geometrical figure in order to establish that it is the same as the stimulus simple shape displayed, and it is assumed that Analytics are relatively quicker at this. Again the computer records the latency of the responses, and calculates the Wholist-Analytic Ratio. A low ratio corresponds to a Wholist and a high ratio to an Analytic. Ratios between these positions are labelled Intermediate. The background to the development of the *Cognitive Styles Analysis* is given in Riding and Cheema (1991).

Each of the cognitive style dimensions is a continuum, and labels are only attached to ranges on a dimension for descriptive convenience. The dimensions are independent of one another, in as much as position on one dimension does not influence position on the other. Cognitive style has been found to affect a wide range of behaviours, and this evidence for its construct validity has been considered by Riding and Rayner (1998, chapters 5-8). Further, style had been found to be independent of measured IQ (Riding & Pearson, 1994; Riding & Agrell, 1997), and also of common personality measures (Riding & Wigley, 1997). The present consideration will focus on aspects particularly relevant to cognitive learning and learning performance.

The action of style

It is useful to commence a consideration of the effects of style with a general model of the ways in which the two style dimensions may act.

Wholist-Analytic dimension

This dimension influences the structural way in which individuals think about, view and respond to information and situations. This affects the manner in which they organise information during learning, perceive their environment and relate to other people. Wholists tend to see a situation as a whole, are able to have an overall perspective, and to appreciate its total context. By contrast, Analytics will see a situation as a collection of parts and will often focus on one or two aspects of the situation at a time to the exclusion of the others.

The positive strength of the Wholists is that when considering information or a situation they see the whole 'picture'. They are 'big picture people'. Consequently they can have a balanced view, and can see situations in their overall context. This will make

it less likely that they will have extreme views or attitudes. The negative aspect of the style is that they find difficulty in separating out a situation into its parts. For the Analytics, their positive ability is that they can analyse a situation into the parts, and this allows them to come quickly to the heart of any problem. They are good at seeing similarities and detecting differences. However, their negative aspect is that they may not be able to get a balanced view of the whole, and they may focus on one aspect of a situation to the exclusion of the others and enlarge it out of its proper proportion.

Verbal-Imagery dimension

This style affects the way information is represented. It influences the characteristic mode in which people represent information during thinking: verbally or in images. For instance, when a person reads a novel they can represent the actions, happenings and scenes in terms of word associations or by constructing a mental picture of what they read. Just as it is possible to set down thoughts on paper in two possible ways - in words or in sketches - so they may also be represented during thinking in those two modes. People can think in words, or they can think in terms of mental pictures or images. On this dimension people may be categorised as Verbalisers or Imagers. *Verbalisers* consider the information they read, see, or listen to, in words or verbal associations. When *Imagers* consider information, they experience fluent, spontaneous and frequent mental pictures either of representations of the information itself or of associations with it.

The style thus reflects the processing of information and the mode of representation and presentation that an individual will prefer, and this is likely to affect the types of task they will find easy or difficult. However, it is important to note that both groups can use either mode of representation if they make the conscious choice, e.g., Verbalisers can form images if they try, but it is not their normal, habitual mode.

Style and aspects of learning performance

The effect of style on learning in terms of the structure, mode of presentation, and type of content of the material will be considered.

The structure of the material

A number of studies have shown that an individual's position on the Wholist-Analytic dimension interacts with the way learning material is structured in its effect on performance. Basically, the findings appear to be as follows. When dealing with information, Analytics need a large 'viewing window' compared to Wholists (Riding & Grimley, 1999). In terms of locus of control the Analytics prefer to have control of their learning themselves rather than to be controlled, while the Wholists have no preference (Sadler-Smith & Riding, 1999). Individuals of complementary style (Wholist-Verbalisers and Analytic-Imagers) are influenced by the step size of the learning material and improve from large to small steps, while those of unitary style (Analytic-Verbalisers and Wholist-Imagers) are not affected (Riding & Sadler-Smith, 1992).

Content and mode of presentation

With the type of content of learning material, Imagers recall highly visually descriptive text better than acoustically complex and unfamiliar text, while the reverse holds for Verbalisers (Riding & Calvey, 1981; Riding & Dyer, 1980).

Two modes of presenting information are available: the verbal and the pictorial.

Taken overall, generally Imagers prefer and learn best from pictorial presentations, while Verbalisers learn best from verbal presentations (Riding & Ashmore, 1980; Riding & Douglas, 1993; Riding & Watts, 1997). Riding and Read (1996) with 12-year-old pupils found that the tendency by Imagers to use pictures, and Verbalisers writing, increased with ability. There was evidence that lower ability pupils were more constrained by the expected format of the subject than were those of higher ability.

Gender

With respect to academic achievement, there is the generally observed pattern of females out-performing males in most subjects but less so in mathematics and science, (see, for instance, Skaalvik & Rankin, 1994).

There is evidence of an interaction between gender and Wholist-Analytic style in the facilitating effect of structure in the form of both headings and overviews, such that these most help male Analytics and female Wholists (Riding & Al-Sanabani, 1998). It may be that male Wholists and female Analytics prefer to form their own structure of materials, and find difficulty in coping with externally imposed organisations (Riding & Read, 1996). More work is needed to clarify the gender and Wholist-Analytic interactions with structure.

Riding and Grimley (1999) compared learning from computer-presented multi-media presentations of Picture and Speech (P-S) with Picture and Text (P-T) by 11-year-old pupils. They found gender differences for P-S and P-T in which there was a *reversal* with gender which is related to whether the styles are complementary, as with Wholist-Verbaliser and Analytic-Imager, or unitary as with Analytic-Verbaliser and Wholist-Imager. P-S involves two modes and two senses, 'look and listen' (two channels), while P-T is two modes but 'look' only, (a single channel). For the Wholist-Verbalisers and Analytic-Imagers (the complementary groups), males do better on P-S than on P-T, while this is reversed for females. For the unitary groups, the Wholist-Imagers and Analytic-Verbalisers, the tendency is the other way round with the male Wholist-Imagers better on P-T, and the females on P-S. Basically with males, complementary groups are best on a *separation* of the channels of pictures and words received aurally, while the females are best on the *single channel* of picture and words. With the unitary groups, the males are best on a single channel, while the females are superior on separate channels. With P-S and P-T the effects are probably due to differences in gender susceptibility to interference between competing modes of representation and/or channels of input.

There is thus evidence of an interaction of mode and style with gender, and while the precise nature of this is not yet clear it is likely to be of practical importance. Basically with males, complementary groups are best on a separation of the channels of pictures and words, while the females are best on the single channel of pictures and words. With the unitary groups, the males are best on a single channel, while the females are superior on separate channels. This hints at a fundamental gender difference in information processing which also involves style.

In summary, cognitive style interacts with the structure of the material in influencing learning, and affects both performance and preference in terms of mode of presentation.

The aims of this study were to consider the relationship between working memory, cognitive style and gender on (a) overall learning behaviour, and (b) performance on a range of school subjects.

Method

Sample

The sample comprised 206 (118 males and 88 females) 13-year-old secondary comprehensive school pupils representing all Year 8 pupils in the school who completed the principal assessments.

Materials

Assessment of cognitive style

The computer-presented *Cognitive Styles Analysis* (Riding, 1991) was used to determine a pupil's position on the two fundamental cognitive styles, which was indicated by two ratios: the Wholist-Analytic ratio and the Verbal-Imagery ratio. The background to the development of the *Cognitive Styles Analysis* is given in Riding and Cheema (1991). The *Cognitive Styles Analysis* was individually administered in a computer room with approximately 14 pupils per session.

Assessment of effective working memory capacity

The computer-presented *Information Processing Index* (Riding, 2000a) was used. The score was the percentage of judgments that were correct. The *Information Processing Index* test was individually administered in a computer room with typically 14 pupils per session.

Learning behaviour measure

All pupils were allocated on entry to school to a tutor group and remained with the same tutor throughout. The tutors met regularly with the pupils in their group and knew them very well. Learning behaviour was rated by the pupils' tutors with items on a 6-point scale from 0 (very poor) to 5 (very good). The items were from the Learning Behaviour section of the *Emotional and Behavioural Development Scale* (QCA, 2000): 'Is attentive and has an interest in school work', 'good learning organisation', 'is an effective communicator', 'works efficiently in a group', 'seeks help where necessary'. The intention was to obtain a broad overall view of learning behaviour. The learning behaviour score was taken as the mean rating over the five items.

Conduct behaviour measure

Conduct behaviour was also rated by the tutors with items on a 6-point scale from 0 (very poor) to 5 (very good). The items were from the Conduct Behaviour section of the *Emotional and Behavioural Development Scale* (QCA, 2000): 'behaves respectfully towards teachers', 'shows respect to other pupils', 'only interrupts and seeks attention appropriately', 'is physically peaceable', 'respects property'. The intention was to obtain a broad overall view of conduct behaviour. The conduct behaviour score was taken as the mean rating over the five items.

For both the learning and the conduct behaviour measures the teachers were also given the descriptive amplifications, that are provided with the *scale* and which for each item gave positive and negative examples of the behaviours.

Subject attainment measures

Teachers of the 10 following subjects, art, English, geography, history, languages (half of the pupils did French and the rest German), mathematics, music, religious education,

science and technology, each rated the attainment of their pupils in their subject on a 6-point scale from 0 (very poor) to 5 (very good). It is recognised that the ratings of behaviour by the tutors and of attainment by the subject teachers had a degree of subjectivity. However, they were the only available indicators of performance across the school Year group.

Procedure

The style, memory, behaviour and attainment ratings were collected during the last (Summer) term of the school Year 8.

Results

The independent variables

The school reported conduct behaviour, as rated by the tutors on a 6-point scale from 0 (very poor) to 5 (very good), as being between the categories of '4 - good' and '5 - very good', with a mean of 4.23. Thus the following results apply to the type of school where generally the pupils have a high standard of behaviour.

The independent variables were gender, Wholist-Analytic ratio, Verbal-Imagery ratio and effective working memory capacity (IPI). The correlation between the independent variables were all low and non-significant (all r's were <0.09; P>0.050) A principal components factor analysis with varimax rotation was performed with the variables of Wholist-Analytic ratio, Verbal-Imagery ratio, WMS and IPI. Three factors had an eigenvalue greater than approximately unity (0.9 and above) accounting for 100% of the variance, and these are shown in Table 1. The factor analysis suggests that the style dimensions are independent of one another and of the effective working memory capacity measure.

In order to consider the relationship between the independent variables and school performance indicators, each dimension was divided into two approximately equal groups. The cognitive style dimensions were divided on the basis of the style ratios according to the secondary school standardisation sample (see Riding 2000b) as follows: Wholists, 0.20-1.02 (N=90); Analytics 1.03-4.41 (N=116); Verbalisers 0.65-1.07 (N=109); Imagers 1.08-3.95 (N=97). The IPI measure of effective working memory capacity was divided at the median into two groups: low, 40.0-85.0 (N=100); high, 85.1-98.3 (N=106).

The study considered both the overall rating of learning behaviour by the tutors and

Table 1. Rotated factor matrix

	Factor 1 Wholist-Analytic style	Factor 2 Working memory	Factor 3 Verbal-Imagery style
Wholist-Analytic ratio	**1.00**	.01	−.03
Verbal-Imagery ratio	−.03	−.04	**1.00**
IPI	.01	**1.00**	−.04

the rating by teachers of attainment on a range of school subjects by the subject teachers. These will be reported in turn.

Tutor ratings of pupil learning behaviour

The tutors rated the overall learning behaviour of the pupils. An analysis of variance of gender (2), Wholist-Analytic style (2), Verbal-Imagery style (2) and memory (2) with the dependent variable of overall learning behaviour rating was performed on the data. Females had a slightly higher mean rating (3.90) than males (3.65), but the gender difference in overall learning behaviour was not significant.

Wholist-Analytic style, memory and learning behaviour

There was a significant effect of memory (F=5.58; df 1,188; p=.019), and an interaction between Wholist-Analytic style and memory (F=3.00; df 1,188; p=.013), and this is shown in Table 2 and Figure 1.

Table 2. Wholist-Analytic style, memory and learning behaviour

Wholist-Analytic style	Mean learning behavoiur rating for IPI level (with *SD*s in brackets)	
	Low	High
Wholist	3.74 (1.15)	3.66 (1.14)
Analytic	3.42 (1.00)	4.16 (0.92)

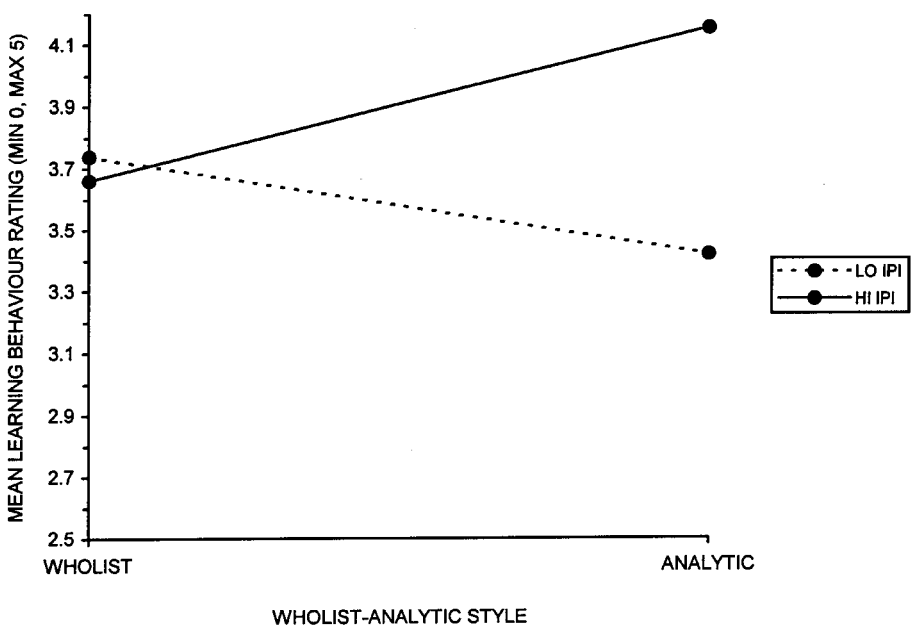

Figure 1. Learning behaviour, memory and Wholist-Analytic style

Inspection of Figure 1 shows that working memory capacity has little effect for Wholists but a large effect for Analytics. This is reasonable since Analytics are likely to have an elaborated approach to processing information which would involve examining all aspects and considering the full range of options. Such an approach is likely to result in good performance but to be successful requires the availability of sufficient processing capacity. Consequently when effective capacity is low, the Analytics are unable to complete the processing and performance is depressed. However, when effective memory capacity is high it is possible to complete the elaborated processing with resulting superior performance. The Wholist approach is probably more impressionistic and requires less processing capacity and presumably effective memory capacity is in most cases sufficient, and this approach results in average performance irrespective of effective memory capacity.

Verbal-Imagery style, memory and learning behaviour

There was an interactive effect of Verbal-Imagery Style and memory which approached significance, (F=3.78; df 1,188; p=.053), and this is shown in Table 3 and Figure 2.

Table 3. Verbal-Imagery style, memory and learning behaviour

Verbal-Imager style	Meaning learning behaviour rating for IPI level (with *SD*s in brackets)	
	Low	High
Verbaliser	3.37 (1.08)	4.01 (1.07)
Imager	3.80 (1.04)	3.86 (1.03)

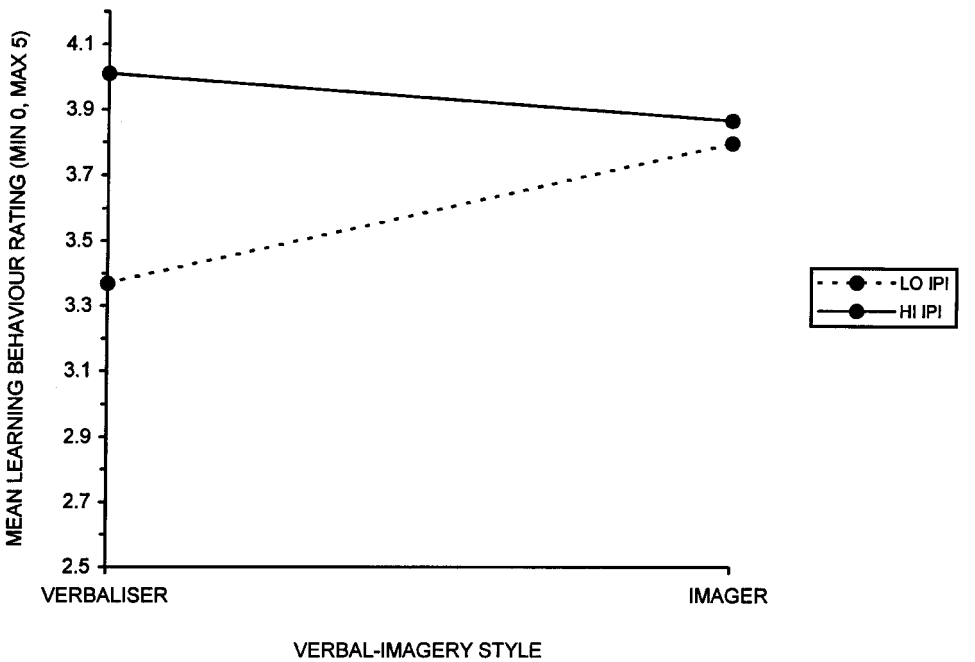

Figure 2. Learning behaviour, memory and Verbal-Imagery style

Consideration of Figure 2 shows that with the Verbal-Imagery dimension of style, it is the Verbalisers who are most affected by effective working memory capacity. Verbalisation is a more elaborated process than imaging and is likely to require more processing capacity. Again, superior performance is possible when there are adequate processing resources available for the Verbalisers, while for the Imagers the performance is more average irrespective of the processing capacity.

Teacher rating of attainment on subjects

Subject teachers rated performance on the subjects they taught again on a 6-point scale. An analysis of variance of gender (2), Wholist-Analytic style (2), Verbal-Imagery style (2), memory (2) for the school subject attainment was performed for each of the 10 subjects. The degrees of freedom were generally 1,200. The subjects will be grouped into three in terms of the effects. All significant effects for the subjects are shown in Table 4, including those approaching significance ($p<.070$). Where there are main effects and interactions, the highest order effect (in bold) will be considered. The

Table 4. Summary of ANOVAs significant effects for subjects

Subject	Significant Effects (*F* ratio and probability)						
	Gend	Gend by VI style	Gend by WA style by VI style	MEM	WA style	WA style by MEM	VI style by MEM
Music	**$F=24.28$**			**$F=19.52$**			
	$p<.001$			**$p<.001$**			
Art	**$F=9.86$**			**$F=9.62$**			
	$p<.002$			**$p<.002$**			
Technology	**$F=4.68$**			**$F=7.96$**			
	$p<.032$			**$p<.005$**			
English	**$F=5.17$**			$F=21.46$		**$F=7.14$**	
	$p<.024$			$p<.001$		**$p=.008$**	
History	**$F=5.20$**			$F=8.58$		**$F=3.70$**	
	$p<.024$			$p<.004$		**$p=.056$**	
Maths				$F=24.59$		**$F=7.48$**	
				$p<.001$		**$p=.007$**	
Science				**$F=21.65$**	**$F=4.36$**		
				$p<.001$	**$p=.038$**		
Languages	**$F=6.47$**			$F=19.90$			**$F=4.61$**
	$p<.012$			$p<.001$			**$p=.033$**
Religious	$F=14.13$		**$F=4.55$**	$F=8.43$		**$F=4.17$**	**$F=3.34$**
Education	$p<.001$		**$p<.034$**	$p=.004$		**$p=.043$**	**$p=.069$**
Geography			**$F=3.41$**	**$F=10.68$**			
			$p<.067$	**$p<.001$**			

Note. The highest order significant effects are shown in bold font.

effects will be considered in terms of gender and memory, in turn. Within individual subjects there were no gender by memory interactions.

Gender and gender interactions

Gender. Gender as a main effect without interaction with other variables was found for the subjects, music, art, languages, English, history and technology, and these are shown in Table 5. For all subjects listed in Table 5 the means for the females were above those for the males. There were no gender differences for mathematics and science, either as a main effect or in interaction with other variables. With respect to academic achievement, there is the generally observed pattern of females out-performing males in most subjects but less so in mathematics and science, (see, for instance Skaalvik & Rankin, 1994).

Table 5. Mean attainment rating for subject for females and males

Subject	Females	Males	Sig Level (*p*)	Diff F-M
Music	4.07	3.49	<0.001	0.58
Language	3.41	3.03	0.012	0.38
Art	3.56	3.20	0.002	0.36
History	3.71	3.40	0.024	0.31
English	3.67	3.37	0.024	0.30
Technology	3.68	3.38	0.032	0.30

Music and languages were particularly gender sensitive in terms of performance. This could be due to a combination of social and information-processing influences. Languages and music may not be perceived as having significant instrumental importance. Traditionally these subjects are regarded as 'accomplishments' as opposed to valuable tools for life. Current modern language courses may also not provide intensiveness in information processing. School-related factors affecting gender differences have been reviewed by Sukhnandan, Lee, and Kelleher (2000, pp. 8-10 88-90), although as they point out more research is needed to clarify the situation.

Gender, Wholist-Analytic style and Verbal-Imagery style

There was a significant interaction between gender, Wholist-Analytic style and Verbal-Imagery style in their effect on performance in religious education (p=.034) and

Table 6. Cognitive style, gender and attainment in RE and geography

Cognitive style	Mean attainment rating for subject and gender (with *SD*s in brackets)			
	Religious Education		Geography	
	Male	Female	Male	Female
Wholist-Verbaliser	3.43 (0.97)	3.84 (0.76)	3.65 (0.84)	3.63 (0.76)
Wholist-Imager	3.14 (0.85)	4.05 (0.71)	3.43 (0.75)	4.00 (0.82)
Analytic-Verbaliser	3.21 (0.99)	3.86 (0.99)	3.71 (0.85)	3.90 (0.65)
Analytic-Imager	3.66 (0.91)	3.89 (1.10)	3.66 (0.81)	3.78 (0.65)

geography (p=.067), and this is shown in Table 6 and Figure 3 where the style groups are Wholist-Verbaliser (WV), Wholist-Imager (WI), Analytic-Verbaliser (AV) and Analytic-Imager (AI).

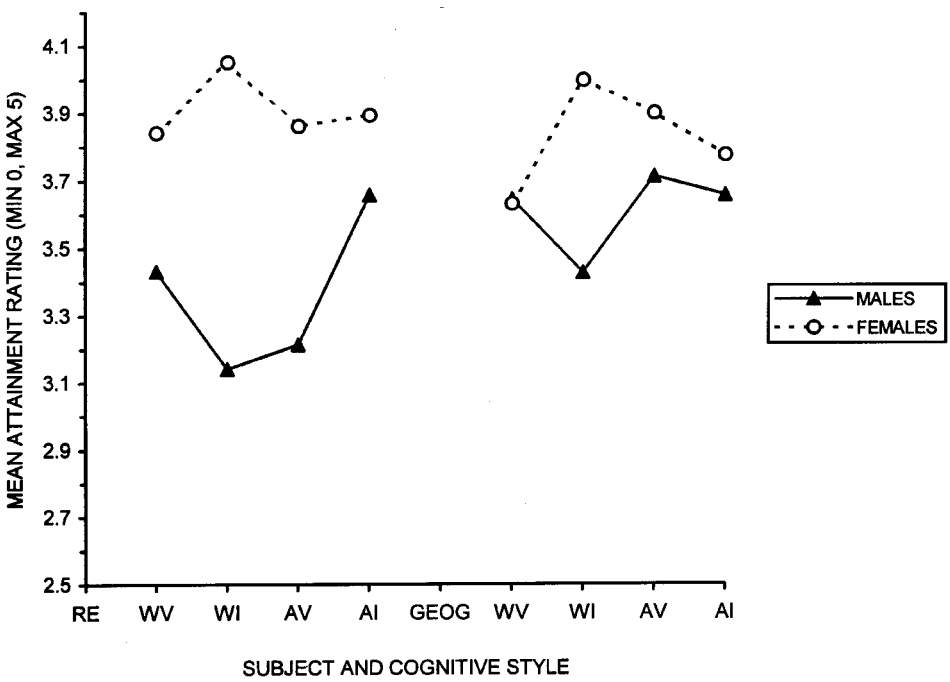

Figure 3. RE and geography attainment, gender and cognitive style

Figure 3 shows that there is a reversal effect such that the styles which do best for females do worst for males. This may be due to the different processing systems of males and females. This interaction did not appear to apply to languages (p=.436), which are a similar type of subject but lack the verbal-spatial contrast of religious education and geography. In terms of the difference of female minus male, the unitary style groups show a bigger difference than the complementary style groups for these two subjects. For the present data there were particularly large gender differences for Wholist-Imagers for both religious education and geography, (respectively, 0.91 and 0.57). Further research is needed to unravel the reasons for gender by style interactions, which probably reflect fundamental differences in information processing.

Cognitive style and working memory interactions

Working memory

Working Memory as a main effect without interaction with other variables was found for science, music, geography, art and technology, as shown in Table 7. Science and music are particularly sensitive to working memory capacity.

Table 7. Mean attainment rating for subject for memory levels

Subject	Lo MEM	Hi MEM	Sig level (p)	Diff Hi-Lo MEM
Science	3.16	3.88	<0.001	0.72
Music	3.51	3.95	<0.001	0.44
Art	3.16	3.54	0.002	0.38
Geography	3.54	3.89	0.001	0.35
Technology	3.33	3.67	0.005	0.34

Wholist-Analytic style

For science there was a main effect of Wholist-Analytic style (p=0.038) in which the Wholists did less well than the Analytics, means respectively, 3.36 (*SD* 1.11), 3.66 (0.98).

Wholist-Analytic style by memory

The significantly affected subjects were mathematics (p=0.007), English p=(0.008), religious education (p=0.043), and history (p=0.056), and the interactions are shown in Table 8 and Figure 4.

Table 8. Wholist-Analytic style, memory and subject attainment

Wholist-Analytic style	Mean attainment for Wholist-Analytic style and subject and IPI level (with *SD*s in brackets)							
	Maths		English		Religious Education		History	
	Lo IPI	Hi IPI	Lo IPI	Hi IPI	Lo IPI	Hi IPI	Lo IPI	Hi IPI
Wholist	2.95 (1.33)	3.41 (1.13)	3.30 (0.99)	3.48 (0.96)	3.56 (0.91)	3.61 (0.91)	3.41 (0.95)	3.50 (0.81)
Analytic	2.55 (1.09)	4.00 (1.19)	3.05 (0.87)	4.08 (0.93)	3.31 (0.93)	3.93 (0.99)	3.30 (0.97)	3.86 (0.80)

In Figure 4, a pattern of divergence from Wholist to Analytic was observed, such that with low memory the Analytics did least well, with high memory the Analytics did best. Thus, capacity has its strongest effect with Analytics. As noted in the case of overall learning behaviour, this is reasonable since Analytics might be expected to have an elaborated approach to processing information. Such an approach is likely to result in good performance but to be successful requires the availability of sufficient processing capacity. Wholists probably employ a more impressionistic, intuitive overall method which is less demanding of capacity and hence less affected.

Wholist-Analytic style, alone or interaction, is likely to apply to subjects where structure is important.

Verbal-Imagery style and memory

There was an interaction between Verbal-Imagery style and memory affecting performance for languages (p=0.033) and religious education (p=0.069), and this is shown in Table 9 and Figure 5. For subjects like languages it would be expected that Verbalisers would do best. This was so with high effective memory capacity, but for low

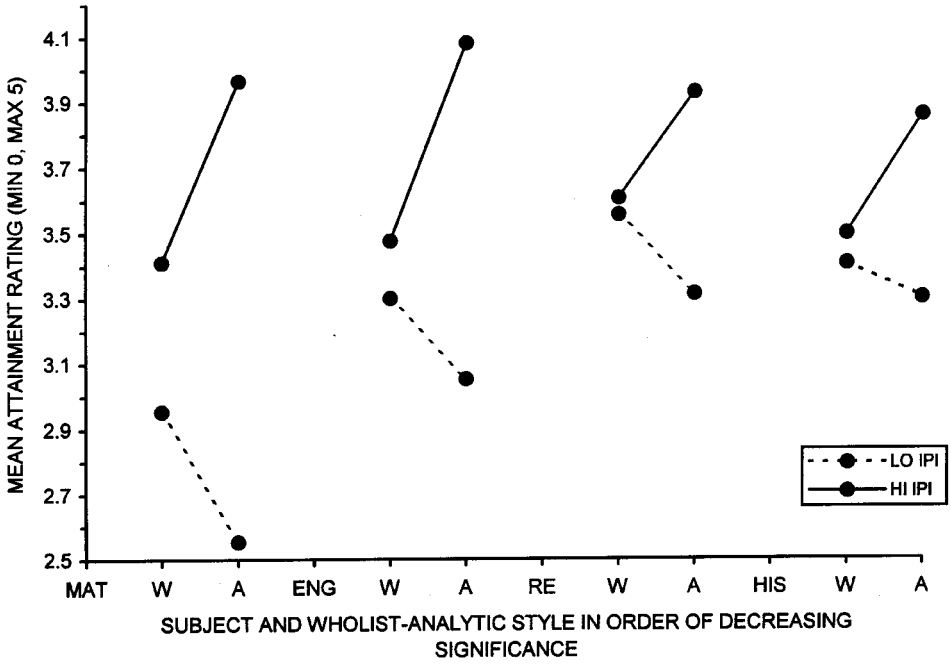

Figure 4. Subject attainment, memory and Wholist-Analytic style

effective memory capacity the Imagers were superior perhaps because imagery is less memory intensive than verbalisation. The same pattern of means was also observed for geography but not to the level of significance (p=.093).This is likely to apply to subjects which have a verbal bias, and where relationships or patterns between the elements are important, as in the grouping of words into phrases.

Table 9. Verbal-Imagery style, memory and subject attainment

Verbal- Imagery style	Mean attainment for Verbal-Imagery style and subject and IPI level (with *SD*s in brackets)			
	Languages		Religious Education	
	Lo IPI	Hi IPI	Lo IPI	Hi IPI
Verbaliser	2.70 (0.95)	3.64 (1.02)	3.26 (0.96)	3.87 (0.90)
Imager	3.05 (1.10)	3.40 (1.04)	3.61 (0.84)	3.72 (1.03)

Discussion

Overall learning behaviour, memory and style

In terms of learning behaviour, the present data indicate that effective working memory capacity has its major influence on the performance of Analytics and of Verbalisers. It may be speculated that this is probably so because both of these style groups use a

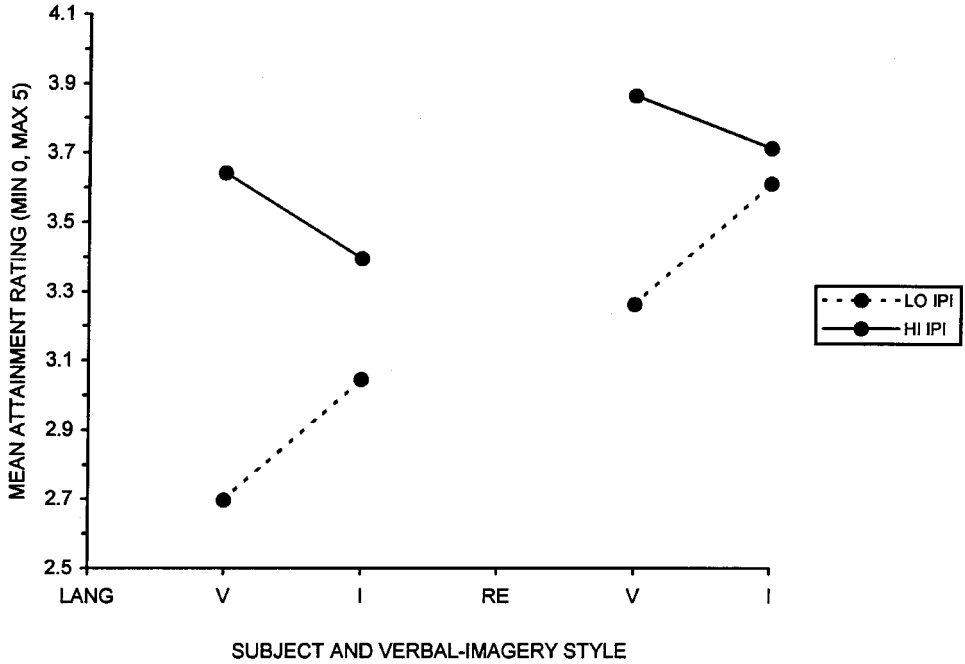

Figure 5. Languages and RE attainment, memory and Verbal-Imagery style

relatively elaborated method of processing information during understanding and learning. This elaborated approach produces good results provided that there is sufficient processing-effective capacity available to complete it. If effective capacity is inadequate then the processing is incomplete and learning performance is reduced.

By contrast, Wholists and Imagers probably employ a more economical method of processing, which may be more intuitive or impressionistic, that arrives at decisions without fully and exhaustively analysing all information, but by a process of sampling the incoming information. This approach produces reasonable performance, but at a level which is inferior to the approach used by Analytics and Verbalisers with adequate memory. However, since it is much less processing capacity intensive, it is much less affected by effective working memory capacity.

If this interpretation is correct then the method used by Analytics and Verbalisers is inadequate if there is insufficient capacity since information would be lost or the final conclusion not reached resulting in poor performance. The poorer performance of Analytics and Verbalisers with low memory suggests that style is fairly fixed and is used even when it is not the best approach. From a practical point of view, individuals with low memory capacity, and particularly those who are also Analytics or Verbalisers, could improve their performance by means of the load being reduced or the effective capacity enhanced.

In conclusion, it might be that the Wholist and the Imagery operations are less demanding of memory than those of Analytics and Verbalisers. However, these former styles are generally less good at academic performance, and where there is adequate memory, the Analytics and the Verbalisers are superior. This interpretation needs further investigation.

Memory, style, gender and subject effects

When performance on individual school subjects is considered, differences are observed between subjects in terms of the variables that most affect them, and the nature of such interactions.

Many school subjects at this level have much in common in that they have a variety of content, use a range of modes of presentation, and several types of learning task. For instance, a subject like geography might deal with topics on human geography and during the same term consider the interpretation of maps; thus predominantly verbal concepts are considered alongside spatial information. While this blurs the differences between subjects, consideration needs to be given to discover what it is about particular subjects which causes them to be affected by certain individual difference variables while others are not. The following speculation will attempt to group subjects.

In general terms it might be expected that some subjects would be more processing intensive in their nature and therefore more dependent for successful performance on there being sufficient effective working memory capacity. Such subjects appear to be science and music.

Subjects will also differ in the extent to which their content is hierarchically structured. In the case of hierarchical structure there is likely to be an interaction between effective memory capacity and Wholist-Analytic style, where high memory Analytics do best. This is the case particularly for mathematics, English, religious education and history. Other subjects will be more relational and have patterns of use, and be verbal in nature as is the situation with second languages like French and German.

Some subjects will employ different channels or modes of representation, and these may compete or interfere with one another resulting in gender effects, particularly in interaction with style. This may apply to religious education and geography.

Improving learning performance

Two general possible practical approaches may emerge from the present study to improve learning performance: (1) reduce the information processing load, and (2) adapt the presentation structure and mode to suit the pupil's cognitive style. The investigation of these may further clarify the interactive effects of cognitive style and effective working memory capacity.

(1) Information processing load reduction

The processing load can be reduced by several methods. This particularly applies to memory load sensitive subjects such as science, music, technology, art, and geography, and to Analytics in subjects such as mathematics, English and history, and Verbalisers in languages and religious education.

(a) Use of external representation

External representation is where notes or jottings are used as an 'external memory' into which information is concisely placed for ready retrieval at a glance, thus reducing the load on working memory, during activities such as learning and problem solving.

(b) Reducing processing load

(i) *Slowing presentation*. Reducing the rate of presentation of speech, for instance,

allows more time for processing. Slowing can be either by speaking more slowly or putting pauses after sentences or paragraphs. This improves listening comprehension (for instance, Woodcock & Clark, 1968, found that slowing speech presentation rate improved comprehension by lower ability pupils).

(ii) *Using revision*. Frequent revision may be employed so that the necessary concepts for giving meaning to the new work are readily available in long-term memory and primed for retrieval. This makes retrieval quicker and reduces processing load. Riding (1982) showed that individuals respond more quickly to previously judged statements for some time after the initial presentation, perhaps because those areas of semantic memory are in some way activated and the pathways faster.

(iii) *Sequence design*. The subject matter being presented can be made more logical for the individual and hence easier to process. A comparison may be made between learning a list of items in the correct order with learning a list that has to be re-ordered at the same time as learning.

(2) Presentation structure and mode

Since there is less effect of effective memory capacity on the performance of Wholists and of Imagers in several subjects, these can be helped in other ways. Wholists can be helped by modifying the structure of the material to be learned by the use of Overviews and Organisers. Imagers can be aided by the adjustment of the mode of presentation from verbal to pictorial.

Conclusion

The present study has shown clear interactions between working memory capacity and cognitive style in affecting school learning. This adds evidence for the validity of both constructs. In the past, studies of style effects have often either not shown clear results or have shown relatively little effect. It seems likely that only when the individual differences variables are taken in interaction will a clearer picture emerge. Further, this will enable individualised instruction to be more effectively planned.

The present results justify further research, particularly with a sample large enough to allow three levels of the Wholist-Analytic dimension and the Verbal-Imagery dimension. This may show more effects – in the present study music, art and technology for instance did not show style effects, but these are likely to be present.

There were two limitations of the present study. The first is that no direct measure of achievement was available, but only teacher ratings. Secondly, these results were from a comprehensive school where the conduct behaviour was rated by the tutors as good or very good for 70% of the pupils, and less than 4% were rated 'poor' or 'very poor'. Consequently, the pupils were generally attentive and so the results reflect a situation where pupils were trying to learn, and memory and style were influencing the efficiency of learning. This is in contrast to schools where conduct behaviour is more generally poor, and style might affect the type of misbehaviour rather than the learning process. In the latter case the Wholists and Verbalisers are likely to be more disruptive (see Riding & Rayner, 1998, pp. 170–176).

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