Relations between life difficulties, measures of working memory operation and examination performance in a student sample

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Abstract

This study investigated the hypothesis that the negative effect of life difficulties on examination performance in university students (Andrews and Wilding, 2004) can be explained by impairment of working memory efficiency. UK-based students were given an extensive interview covering recent life stressors and carried out a task testing working memory span, in which they had to judge the truth of arithmetic expressions while retaining words. Students reporting one or more life difficulties in the preceding 12 months recalled significantly fewer words than those reporting no such difficulties, but showed no difference in processing time on the task. However, while the number of words recalled was unrelated to examination performance at the end of the year, students who took longer on the task did significantly less well in the examination. This relation was more marked in Science than in Arts students. A number of possible explanations of this pattern of results are considered which need to be explored in further research. In particular it is suggested that the number of words retained in the working memory span task reflects current state and is reduced by intrusive thoughts provoked by current life difficulties, while time on the task reflects more permanent efficiency of the processing system and therefore efficiency in study and examinations.

Working memory has become an increasingly important construct in investigating individual differences in ability in a variety of contexts. The basic model of working memory incorporates a central executive control system that organises attentional focus and processing sequences, plus dedicated memory components, and the contribution to these components to a variety of aspects of cognitive development and performance has been assessed (Gathercole, Alloway, Willis & Adams, 2006; Gathercole, Pickering, Knight and Stegman, 2004; Jarrold & Towse, 2006; Pickering, 2006). The present study investigates relations between working memory efficiency and one such index of general cognitive ability, performance in university examinations. In particular it considers the way in which extraneous life difficulties experienced by students may impact on such relations.

Andrews and Wilding (2004) found that in a student population self-reported financial problems were associated with reduced examination performance at the end of the second year. The present study represents a development of the earlier study and is designed to test the hypothesis that the effects of financial and other life problems might be exerted through an impairment of working memory functioning, which would affect both learning over the university year and performance in the exam situation. Hence the study examined both relations between reported prior stressful life problems and working memory and between the latter and examination performance at the end of the second undergraduate year.

Klein and Boals (2001a) found that the self-reported impact of stressful life events reduced performance on a task designed to measure the capacity of working memory span (the operation span task). The task demands simultaneous processing to assess the truth of an arithmetic expression and retention of a word presented with the arithmetic expression. Memory for all the words is tested after a sequence of varying length comprising several such trials, and this test yields a measure of working memory span (though the precise measure taken varies between different studies). Klein and Boals did not find any relation between self-reported

anxiety and this measure but a number of other studies have reported that anxiety reduces working memory efficiency and explained this in terms of intrusive thoughts (e.g. MacLeod & Donnellan, 1993, Derakshan & Eysenck, 1998, Ashcraft & Kirk, 2001). It is plausible, therefore, that the effect of stressors in student life is to reduce working memory capacity and hence examination performance. The present study employed a direct and objective measure of difficulties at the time of the working memory span test, rather than the self-rating of the impact of difficulties used by Klein and Boals.

In a further study Klein and Boals (2001b) did not report any direct relation between operation span and college performance, but there is a variety of evidence that individual differences in working memory efficiency have implications for wider cognitive performance, especially in children (e.g. Gathercole et al, 2004, 2006). These authors found that measures of the functioning of the central executive of working memory were related to both English and mathematics performance in children at age 7 but only the relation with mathematics still held at age 14, when the two aspects of performance were less closely correlated with each other. This suggests that measures of working memory capacity may reflect specific aspects of cognitive function. More directly comparable with the current context is the study of Engle, Cantor and Carullo (1992), who found no relation between individual differences in span (i.e. number of words recalled) and scores obtained earlier on the verbal and quantitative Scholastic Aptitude Tests by young adults, but did find a significant relation between time taken on the operation span task and these measures of academic ability. The time and span measures were uncorrelated in their study, a result also reported by Towse, Hitch and Hutton (2000), and, it may be inferred, also found by Derakshan and Eysenck (1998), since groups differing in anxiety differed on span but not on time. These results suggest that different measures reflect different aspects of this task that are likely to be related to more complex aspects of cognitive performance in different ways.

Current theories about the nature of the working memory system are moving toward a

consensus that this consists of a general purpose executive system controlling aspects of processing such as attentional focus, plus special storage systems for verbal and spatial information (e.g. Bayliss, Jarrold, Gunn, & Baddeley, 2003; Barrouillet, Bernardin, & Camos, 2004; Kane, Hambrick, Tuholski, Wilhelm, Payne, & Engle, 2004). While Towse and colleagues (Towse & Hitch, 1995; Towse, Hitch, & Hutton, 1998; Towse et al, 2000) have argued that the primary determinant of performance is the time that items have to be held in the memory store while carrying out other processing, rather than the capacity of the central executive system, Barrouillet et al (2004) present a convincing case for combining this viewpoint with the operations of the general purpose executive system in their time-based resource-sharing model. In this model, the time available for updating and rehearsing material in the memory stores is constrained by the processing load imposed on the executive system. More difficult processing operations, reduced time to carry these out and lower individual capacity will combine to restrict memory updating and hence reduce the final span.

At first sight it might seem that this theory predicts a relation between the processing and storage performance in the working memory span task (e.g. in time to make the judgement and the number of words recalled). However there is no reason to suppose that this will necessarily be the case when time is not constrained, unless more time is devoted to improving storage and rehearsal when processing is faster. If faster processing just results in earlier passage to the next trial, without any improvement in memory operations, no correlation would occur between the speed of carrying out the judgement aspect of the task and the memory span, which was the finding in the studies cited above.

The present study, therefore, examined relations between life difficulties, measures of working memory efficiency and examination marks in a student sample, in order to discover whether the effects of difficulties on examination performance might be explained in terms of a reduction in working memory efficiency when difficulties were experienced. Life difficulties and

their severity were assessed with an established semi-structured interview using investigator-based ratings, working memory span and processing speed were measured using the operation span task described above and second year examination marks were obtained, with permission, from college sources. It was predicted that difficulties would reduce working memory efficiency, which would in turn be related to examination performance. No specific predictions were made concerning the precise aspect or aspects of working memory that would be affected, since the existing results described above do not present a clear picture of the links between these constructs.

Method

The Sample

Ninety students were selected from those responding to a questionnaire sent to the whole of the UK domiciled undergraduate student population of a college of the University of London during the first half of the second year of study. Students indicated on the questionnaire if they were unwilling to be contacted for interview, and 15% did not wish to be contacted further. Of those approached, 61% (128/210) agreed to be interviewed. All those interviewed gave written informed consent. The final interview sample comprised 70 female and 20 male students with a mean age of 20.1 (SD = 3.1). Each respondent attended for a detailed interview before the end of the second term and carried out the operation span task at the end of the second term and 82 completed both parts of the study.

Measures

The Life Events and Difficulties Schedule (Brown & Harris, 1978) was modified for use with students. This semi-structured interview covered life events and difficulties for the 12 months prior to interview. The measure employs investigator-based ratings with reference to

examples and consensus meetings. Participants were also given the working memory span task used by Klein and Boals (2001a,b) and described above. This task was given before the interview in some cases and after the interview in others, but no differences were found due to this variable.

Life events and ongoing difficulties were rated according to the severity of threat that the average person would expect to experience. Ratings of severity were made on a 4-point scale ranging from none to marked. Following Brown & Harris (1978), ongoing difficulties rated on the top two points of the scale (moderate and marked) were defined as life difficulties for the purposes of the analysis. They were subsequently categorised as financial, relationship and other difficulties (illness, housing etc).

The measures taken from the working memory task were the total number of words recalled when the judgement of the truth/falsity of the arithmetic expression was correct (as advocated by Klein and Boals), henceforth referred to as span, and the mean time per trial (a measure not employed by those authors), henceforth referred to as processing time.

Results

Though measures of anxiety and depression were available from the Hospital Anxiety and Depression Scale (Zigmund & Snaith, 1983) completed with the original questionnaire, this questionnaire had been completed between two and three months previously, so these measures were not regarded as relevant to the present investigation (and were in fact unrelated to the variables of interest). Hence they will not be discussed further.

In this relatively small sample the incidence of financial difficulties was low, so for analysis all difficulties have been pooled (cf Klein & Boals, 2001a).

- Table 1 -

Table 1 gives means and standard deviations for relevant variables. For reasons that will emerge, separate scores are also given for students from the Arts and History/Economics Faculties combined (henceforth referred to as "Arts" for short) and for students from the Science Faculty. There were no significant differences between these two groups on any of these measures. Overall 46 participants reported no life difficulty, 25 reported one difficulty and only 11 reported more than one. Of the 36 participants reporting one or more difficulties, in 19 cases these were all reported to be moderate and in 17 cases at least one was a marked difficulty. The span scores were very similar to those reported by Klein and Boals (given as percentages correct at different list lengths in their paper, but recalculated for comparison).

Those reporting no life difficulties achieved a span (with the arithmetic judgment correct) of 44.5 (s.d.. 6.6), whereas those reporting at least one such difficulty had a span of 39.3 (8.1); the difference was significant ($t(80) = 3.22$, $p = 0.002$). This result held for both Arts and Science students (t values were 2.13 and 2.68 respectively). One-way Analyses of Variance comparing span scores across the number of difficulties or the severity of difficulties (at all levels) confirmed this relation; however inspection of the means showed that the difference lay principally between those not having and those having a difficulty, with increased number or severity of difficulties having no consistent additional effect. Separate examination of different types of difficulty (financial, relationship and other) confirmed that the relation held in all cases, though occurrences of each type of difficulty taken separately were too few to make formal analysis appropriate. This finding of a relation between ongoing life difficulties and span confirms the result of Klein and Boals (2001a).

There were no significant relations between the existence of life difficulties and processing time in the working memory span task, either overall ($t = .41$) or in the Arts and Science students separately (t values were .65 and .14 respectively). Processing time was also

unrelated to the number or severity of life difficulties.

Table 2 shows the correlations between the two working memory measures and second year examination performance for the whole sample and for the Arts and Science sub-samples. In the total sample, as in the studies of Engle et al (1992) and Towse et al (2000), there was no indication of a significant correlation between span and processing time, and, as in the Engle et al study, processing time, but not span, was related to the measure of general cognitive performance (SAT in Engle et al's study and examination performance in the current study). Only in the present study, however, is this a predictive relationship, since Engle et al employed already existing SAT scores, while in the present study examinations were taken after the working memory span task had been administered.

- Table 3 about here -

However further examination of the data uncovered a complication when Arts and Science students were examined separately. These two groups demonstrated different patterns of relations. The Science students were the main source of the overall negative correlation between processing time and examination performance and there was only a weak relation in the same direction in the Arts group (the difference between the two correlations bordered on significance with $p = .06$, so the separate analyses have been retained). The correlations between span and examination performance were not significant in either group.

Discussion

The study has shown that life difficulties affect working memory span, supporting the finding of Klein and Boals (2001a), but using a more objective measure of the difficulties that students were experiencing. However, contrary to the hypothesis being tested, low span was not

associated with poor examination performance, since the relevant correlation was close to zero. This parallels the finding of Engle et al (1992) that span was unrelated to SAT score.

The pattern of results for processing time was a mirror image of the above results. Processing time was unrelated to life difficulties but was significantly associated with examination performance, with longer times predicting worse performance. This was true overall and particularly strongly apparent in the Science faculty students. It also conforms to the results found by Engle et al (1992) with SAT results.

These results do not unambiguously support the hypothesis being tested that the effect of difficulties on examination performance may be due to reduced efficiency in working memory. Difficulties affected span but span was unrelated to examination performance. And difficulties did not affect processing time which was related to the latter measure. How can these contradictions be explained? There are a number of possibilities, which can only be resolved by further experimentation. We consider three questions raised by our findings and offer possible explanations that are not mutually incompatible.

Firstly, why was no relation found between span and examination performance? Our findings and those of Klein & Boals (2001a) demonstrate that span is likely to be unstable, being affected by current circumstances. Therefore an effect found at one point in time has little implication for performance at a different time when circumstances affecting span might have changed. Were span to be measured close in time to an examination a relation might well emerge.

Secondly, if this is the case, the question still needs to be addressed of how difficulties have long-range effects on examination performance, as shown by Andrews and Wilding (2004). One likely explanation is that difficulties, particularly those of a financial nature, may have a range of other practical implications for study; coping with them may take time away from completion of course assignments, field trips and lecture attendance, and resources may be

reduced, such as ability to buy books and so forth.

Thirdly, there is also the question of why no relation was found between difficulties and processing time in working memory. One possibility is that processing time is a relatively stable measure of individual working memory efficiency that is relatively immune to interference and is an independent determinant of academic performance. In this case we would have to conclude that life difficulties do not exert their effects on academic performance through impairing processing speed in working memory. Alternatively it is possible that the version of the working memory span task used here enabled processing time to be maintained at the expense of reduced rehearsal. The model of Barrouillet et al (2004) discussed above envisages a general purpose executive system that shares time between processing new inputs and rehearsing material in memory. The separation between the arithmetic problems to be judged and the words to be memorised (unlike the requirements of academic study, where the same material has to be understood and retained) readily permits this strategy. However, other variations on the span task may be less conducive to such a strategy and may impair processing time (e.g. Macleod & Donnellan, 1993; Derakshan & Eysenck, 1998), leaving open the possibility that the link between difficulties and examination performance may lie in working memory, but did not emerge clearly in the task used in the present study.

An explanation is also needed as to why the relation between processing time and examination mark was stronger in the Science than the Arts students. The most plausible suggestion would seem to be that the element of the task that engaged the executive attention system (the arithmetic judgement) was closer to the demands imposed by the examination and coursework system in the Science students. This suggestion could be tested by changing this element of the task to verbal demands or by devising some more neutral task such as shape matching.

In conclusion, the results of this study confirm the pattern of relations between

difficulties, working memory measures and wider cognitive performance that was apparent in the earlier studies of Klein and Boals (2001a,b) and Engle et al (1992), namely that difficulties reduce working memory span, while only working memory processing speed is related to wider cognitive performance. Hence there was no clear link apparent between difficulties and examination performance via working memory operation. However, before it can be concluded that the effects of difficulties on examination performance must depend on other factors, further research is necessary to establish whether difficulties may in some situations affect the speed of processing in working memory and thereby impact on examination performance. The effects of such factors as individual expertise specific to the task and variations in strategy in modulating these processes also needs clarification. The model of Barrouillet et al (2004), with its emphasis on the role of the central executive as a flexible control system, seems well adapted to handle the present results and any variations to the pattern that further studies may suggest.

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Table 1

Means for the measures taken over the whole group and for the Arts and Science students separately (s.d.s in parentheses)

Measure	All n = 82	Arts n=42	Science n=40
Percent. female	76	81	70
Age in years	20.1 (3.2)	20.0 (1.6)	20.3 (4.3)
2nd yr exam mark	61.2 (7.4)	60.7 (6.4)	61.7 (8.4)
Percent. with difficulty	44	50	38
No. of difficulties	0.67 (0.91)	0.81 (1.02)	0.48 (0.78)
Severity of difficulties	0.69 (0.83)	0.79 (0.87)	0.50 (0.71)
Working memory span	42.2 (7.7)	43.1 (7.2)	41.3 (8.2)
Processing time (secs)	6.5 (2.5)	6.8 (2.0)	6.2 (2.9)

Table 2

Correlations between working memory measures and second year examination performance for the whole group and for the Arts and Science students separately

	Processing Time			Span		
	All	Arts	Science	All	Arts	Science
Span	.10	.24	-.01			
Examination mark	-.37*	-.11	-.50*	.06	.13	.03

* $p < .001$