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Divided Attention and Students' Learning:

A Study on the Role of Prior-Knowledge and Short Term Memory

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Abstract

The level of attention deployed in a text-reading situation is said to be playing an important role latter. In this research, this study intended to find out how divided attention in adult students' learning situation can have an impact on their overall performance when controlling for their short-term memory, prior knowledge and their recall in long term memory. In a group of 100 Al-zahrā University students, aged between 18-49 years old, a computer program was designed to test learning from reading and a concurrent pictorial task on computer monitor in different settings. Exploring empirically how attention can be important in adult students' pattern of learning, it was found that involving the short term memory (STM) capacity together with prior knowledge (PK), the second variable more directly influences their later recall. In a divided attention situation, where most STM capacity would be expected to be involved in processing of text reading, recall was only better in more knowledgeable people. Paired t-test analyses were used to compare the high PK people versus the low ones among high and low capacity STM students in divided and undivided attention situations. It was found that the differences between recall of participants in a divided and undivided attention are only statistically significant when higher capacity STM participants were remembering the content. Other results indicated that while the higher PK groups remembered statistically more than the lower PK students, higher STM capacity groups did not remember significantly more than the lower ones. These results are indicating the role of PK in adult students' recall of text reading.

Keywords: Divided Attention; Short Term Memory; Prior Knowledge; Adult Students; Learning; Long Term Memory;

توجه تقسیم‌شده و یادگیری دانشجویان:

مطالعه‌ئی درباره‌ی نقش معرفت اولیه و حافظه‌ی کوتاه‌مدت

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چکیده

میزان توجهی که فراگیر در شرایط مطالعه از خود نشان می‌دهد در یادآوری‌های او نقش مهمی ایفا می‌کند. در این تحقیق، چگونگی تقسیم توجه در یادگیری فراگیران بزرگسال و نحوه‌ی تأثیر آن بر عملکرد مجموع یادآوری آنها، در شرایطی که حافظه‌ی کوتاه‌مدت و دانش قبلی آنها نسبت به موضوع، و یادآوری آنها از نظر حافظه‌ی بلندمدت تحت کنترل قرار گرفته‌بود، مورد مطالعه قرار گرفت.
برای یک گروه صدنفره‌ی دانشجویان دانشگاه الزهرا که سن آنها بین ۱۸ تا ۴۹ سال می‌رسید، یک برنامه‌ی کامپیوتری طراحی گردید تا یادگیری آنها را از خواندن یک متن مصور که بر صفحه‌ی کامپیوتری در شرایط مختلف و بطور همزمان ارائه می‌شده مورد آزمون قرار دهد.
یافته‌های تحقیق نشان داد که با توجه به میزان ظرفیت حافظه‌ی کوتاه‌مدت و متغیر دانش قبلی، متغیر دوم به طور مستقیم‌تری یادآوری‌های بعدی فراگیر را تحت تأثیر قرار می‌دهد. در شرایط تقسیم توجه که انتظار می‌رود بیشتر ظرفیت حافظه‌ی کوتاه‌مدت درگیر پردازش مطالعه شود. یادآوری در فراگیرانی بیشتر بود که دانش قبلی بیشتری داشتند. برای تحلیل آماری از آزمون T استفاده گردید تا افراد دارای دانش قبلی بالا را در مقایسه با افرادی که دانش قبلی آنها کمتر و ظرفیت حافظه‌ی کوتاه‌مدت آنها بالا و پایین بود، در شرایط تقسیم توجه و غیرتقسیم توجه مورد مقایسه قرار دهد. نتایج تحقیق نشان داد که تفاوت یادآوری میان شرکت‌کنندگان در تحقیق، در شرایط تقسیم توجه و غیرتقسیم توجه تنها در شرایطی تفاوت آماری معنی‌داری دارند که شرکت‌کنندگان دارای حافظه‌ی کوتاه‌مدت بالاتر، محتوای مطالب مورد مطالعه را به یاد آورند. نتایج دیگر تحقیق نشان داد در حالی که گروه دارای دانش قبلی بالا از لحاظ آماری بیشتر از دانشجویان دانش قبلی پایین مطالب مورد مطالعه را به یاد می‌آورند، گروهی که دارای ظرفیت حافظه‌ی کوتاه‌مدت بالاتری بودند از لحاظ آماری بیشتر از آنهایی که ظرفیت حافظه‌ی کوتاه‌مدت پایین‌تری بودند، مطالب خوانده‌شده را به یاد نمی‌آوردند. این نتایج نشان می‌دهد که نقش دانش قبلی در یادآوری مطالب خوانده‌شده در میان دانشجویان تا چه اندازه مطرح است.

کلیدواژه‌ها: تقسیم توجه؛ حافظه‌ی کوتاه‌مدت؛ دانش قبلی؛ دانشجویان بزرگسال؛ یادگیری؛ حافظه‌ی بلندمدت؛

Introduction

Psychophysiologically and neuropsychologically, memory attributes are known to be related to different parts of the brain, specifically, to the frontal, pre-frontal, and Hippocampal sections (Andrews, 2001; McLeod, Plunkett, & Rolls, 1998). The interplay of processing input information and storage is said to be mediated by selective attention to the subset of elements in Working Memory (WM) that must be manipulated at any stage (Oberauer, 2002). *Moscovitch* and *Umiltà* (1990; 1991) and *Moscovitch* (1992; 1994) proposed a neuropsychological account of the effects of attention on memory. *Afzalnia* (2000) and *Cowan* (1995; 1999) distinguished between the activated part of LTM and the focus of attention. It is believed that both STM and the focus of attention have a limited capacity (Mousavi, Low, & Sweller, 1995; Cohen, Sparling-Cohen, & O'Donnell, 1993). This proposition can suggest a component-process model, where performance can be mediated by several mechanisms (Cohen, Sparling-Cohen, & O'Donnell, 1993; Cohen, Johnston, & Plunkett, 2000) under voluntary control. This systematic interplay between different parts provides an on-line processing of the inputs (Logie, 1999).

The literature on memory from various presentation modes (e.g. Afzalnia, 2000; Afzalnia & Foster, 2003), shows the relative value of reading to be controversial (De Vega, 1995; Jorm, 1983; O'Brien, 1995; O'Brien et al, 1998; Perfetti, 1985). Reading activity involves eye processing data in the occipital, links with Working Memory (WM) and Prior Knowledge (PK) in Long Term Memory (LTM), along with symbol and icon recognition (Lund, 2001), as well as encoding and decoding activities, (Logie, 1995; Conway, 1997). Recall of ideas central to a text reading is believed to be improved as a result of the organisation of the encoded content (Mayer, 1983). It has also been suggested that background information encourages the function of organized representation, improves accessibility of the reading content, and produces a better subsequent memory (Rawson & Kintsch, 2002). If a representation obtained from the reading is considered in terms of a network consisting of weighted nodes and links (McLeod, Plunkett, & Rolls, 2002; Kintsch, 1998), an organisational effect implies differences in the links established between nodes, where a node is a context-independent representation. These nodes are linked by connections of differing associative strengths carrying pre-existing semantic associations. The recall of semantic information proceeds through the activation of these nodes (Burgess & Shallice, 1997:260-261). This means that PK can preactivate relevant concepts and evoke potential nodes that facilitate subsequent processing and encoding activities, or it could encourage more active rehearsals of the reading (Afzalnia & Foster, 2003). PK, therefore, can influence the effectiveness of all processing activities and the interplay between different parts of the brain (Kintsh, 1998). Many recent studies have stressed the role of factual background knowledge and informational outlines in the later recall of a text reading (Corkill, 1992; Dunlosky, Rawson, & Hacker, 2002; Glynn, Britton, & Muth, 1985; Mannes & Kintsch, 1987; Rawson & Kintsch, 2002; Slater, Graves, & Piche, 1985).

On the attentional side, the Central Executive (CE) component of WM can play an important role in pattern recognition and in shaping episodic memory (Baddeley, Conway, & Aggleton, 2002; Lund, 2001) for both composing an on-line memory in WM (Logie, 1999) and in producing quantitative organization in conjunction with PK at LTM (Rawson & Kintsch, 2002), affecting both immediate and later retrieval (Kane & Engle, 2000). This subject is currently the focus of theoretical and empirical interest in memory studies (Afzalnia, 2000; Baddeley, Conway, & Aggleton, 2002; Kane & Engle, 2000). The

CE part of the WM model, which still remains mysterious despite intensive research (Logie, 1995; Zeki, 1993), is proposed to be equivalent to the Supervisory Attentional System (SAS) described by the *Shallice* group (e.g. Norman & Shallice, 1986; Shallice & Burgess, 1993). *Baddeley* and *Logie* (1999) proposed that the CE, as the system responsible for coordinating the operations of the other parts as subsidiary 'Slave' systems (Logie, 1995; Baddeley, Conway, & Aggleton, 2002).

Another important part of the role that attention can play in learning is to use the PK to enhance memory from learning (Afzalnia, 2000; Rawson & Kintsch, 2002). Indeed, *Sakata* (2001) has reported that a person's knowledge can direct selective attention. According to her, attention appears to produce different strategies, which influence the ability to solve the task. Others have shown that the direction of attention depends on memory accessibility (Courage & Howe, 2001). But the focus of attention is different from the activated portion of LTM (Afzalnia, 2000; Oberauer, 2002). *Cantor* and *Engle* (1993) explaining the correlation that is often observed between WM spans and reading comprehension, maintain that individuals differ in the level of activation that is available for LTM units. They suggest that the relationship between WM and LTM is so high that "WM is often defined as that part of permanent LTM that is temporarily active above some critical threshold and that can be recognized and manipulated by on-going cognitive processes. Within the information-processing system, WM is the arena where processing and storage interact" (Ibid:1101).

The cognitive functions required for learning, thus includes: attention, perception, pattern recognition, categorization (producing a quantitative organisation), motor control, decision-making, thinking, memory, and retrieval (Foster & Jelicic, 1999). Many of theses activities demand attention. Attention can, therefore, play a critical role in learning tasks from feature selection (Afzalnia, 2000; Baddeley, 1999; Lund, 2001) to feature binding and retrieval (Franklin & Tversky, 1990). It has also been suggested that memory for surface features is characteristic of processing with less attentional consumption (Baddeley, 1999). For example, according to *Anderson* and *Burns* (1991), *Anderson* and *Collins* (1988), and *Calvert, Huston,* and *Wright* (1987), both attention and comprehension are guided by the viewer's seeing TV surface and formal features, which provide more information than is available in a verbal mode. These formal features resemble the surface features in reading condition (i.e. the form that represents the content/message). Recent evidence, suggest that the visual system does not just construct a global image of a scene by integrating sensory information from separate fixation (Wade & Swanston, 2001; Zeki, 1993). The visual representation of a scene is local and transient, limited to currently or recently attended objects and, therefore, involves both attentional and WM capacity. Reports indicate that the visual information is retained in memory from previously attended objects in natural scenes (Hollingworth, Williams, & Henderson, 2001). This evidence is indicative that attentional resources, WM capacity, and PK are influencing the retrieval system. Although the function of CE is yet to be specified clearly (e.g. Baddeley, 1996; Baddeley & Logie, 1999; Engle, Kane, & Tuholski, 1999) the other parts of the WM has been much studied (Conway, 1997; Miyake & Shah, 1999). Ecologically, however, the nature of their relationship so far is less well understood in the real life memory situation (Cohen, 1996). Here Divided Attention (DA) exists with many distracting factors that can affect learning from reading text in student life (Cohen, 1996; Rawson & Kintsch; 2002).

The literature review on divided attention indicates that performing concurrent activity decrements in subsequent recall (Afzalnia, 2000; Baddeley et al, 1984; Craik, et al, 1996; Fernandes & Moscovitch, 2000). In addition, researches in this area have suggested a link between WM construct and capacity to interfere. It has also been suggested that there is significant difference between respondents with high and low working memory spans. *Conway* and *Engle* (1994), for example tested high and low WM span students with a modification of Sternberg probe-recognition task. It was found that low spans recognition times were significantly longer in the non-interferences condition, but high spans' were not. Low spans, therefore, appeared more vulnerable to interference than the high spans. More recent studies are indicative that under a divided attention situation both high and low spans show equivalent interference (Kane & Engle, 2000). It is theorised that in a divided attention situation, CE is responsible for deciding on inference making when the environment triggers conflicting action schema. The nature of his relationship, however, is not well understood.

Studies exploring the focus of attention and its role in accessing information in WM (e.g. Oberauer, 2002) indicate that focus of attention can have a major impact on the states of representations. These studies, however, do not show whether other influencing variables like PK can act as an important covariant. The present study addressed the question of whether individual differences in background information affect susceptibility to divided attention among high and low working memory spans. We examined whether individuals differ in their use of controlled attention in the interfering presence of a secondary task. *Rosen* and *Engle* (1997), and *Kane* and *Engle* (2000), testing high and low WM span respondents, indicated that low spans showed greater susceptibility to interference caused by divided attention than did the high spans group. In the *Rosen* and *Engle* experiment, high spans recalled more animals than did the low spans (through reading about them). The results of the *Kane* and *Engle*'s study (2000) have shown that attentional processing has a central role in learning and recall. The present study explores how the relationship between WM capacity, divided attention, and Prior Knowledge can influence later memory. Memory theories assume that divided attention, especially with low knowledge about the subject, requires more controlled processing either at learning or at retrieval (Anderson & Bjork, 1994; Anderson & Neely, 1996; Foster & Jelicic, 1999; Hasher & Zacks, 1988). But there are other concerns in the interplay between prior knowledge, WM activities, and performance that can influence the focus of attention. It was hypothesized that the impact of DA would be greater on the high PK students than on the low ones. Evidence for this prediction comes from studies showing that the interactions between variables such PK and DA can have detrimental effects on later recall (Afzalnia, 2000; Fernandes & Moscovitch, 2000; Kane and Engle, 2000). This implies that those with higher span WM may use more attentional resource at encoding in order to combat the interference caused in a DA condition.

Method

The present study investigated the effects of divided attention during reading. In so far as interference of DA would matter when the secondary task is dealing with the same modality (i.e. seeing), we only dealt with a secondary load, which was expected to disrupt the primary task more when it was in the same mode. The primary task was to read a text shown on a computer screen. The secondary task involved 20 familiar pictures shown dispersed outside the text lines every few seconds. The pictures were introduced on the computer screen along with the reading text. Participants were instructed to remember the pictures for a later quiz.

We tested 100 high and low span (Kane & Engle, 2000) adult students, with high and low Prior Knowledge groups (Rawson & Kintsch, 2002; Sakata, 2001) producing two main high and low PK group of 50 participants. We then divided each of these two groups into two sub-groups based on their WM span, producing four main groups. Therefore, the experiment shaped four groups; with two having text reading only and the other two having the same text plus the distraction of 20 pictures presented along with the text. These conditions with half the participants being tested under DA and high and low PK produced eight final groups.

Participants

A group of 100 university students of both graduate and undergraduate students aged between 18-49 years old were asked to participate in this study. These participants were identified from a larger pool that had originally participated in the PK test (105 people). They all spoke Persian (Fārsi) and everything was provided in the Persian language. They were randomly selected from a total university population.

Condition and Procedures

We selected a text of 5 minutes 22 seconds long. An average reading speed of three pilot participants was taken for showing up the text over a 15 inches monitor line by line so that the indiscriminate eye movement of participants all over the text could be controlled. Amongst several topics that we thought would not have much direct relevance to our participants' background, the selected final text was about a subject in management. This text covered a scope of area in that topic. We also developed a twenty-question PK test based on the content of the reading text. Multiple-choice in this test was not directly about the subject of the text, but about the topic of the reading. 105 students took part in this pre-test. The maximum score they could get in this test was 20 (one mark for each correct answer). Because the skewness of the mean was marginally negative we selectively dropped 5 participants to bring the shape of the distribution closer to a normal distribution and retained the rest of the 100 participants. 50 of the top half of the curve were selected as high prior knowledge (HPK) and the lower half were taken as low prior knowledge (LPK).

We also screened all of the participants for WM capacity using a listening and writing verbal span task in which they had to write down, one sentence at a time from what was read to them orally. In addition, they also had to solve five series of 5 mathematical operations. To do this, they had to keep all of the operations on their WM while thinking of the final result. For example, $8 - 2 \times 3 + 5 = ?$ This is a sample of the sequence of their mental operation. Participants listened to the sentence (listening/writing practice) and did the math exercise (mathematical operation series) one at a time. They were group tested. Both verbal and mathematical tests were marked individually. The sum of both tests was considered as the scale of their WM span.

Each sentence that was recalled correctly scored 5. For each missed word (up to 5 words) or mistakes shown in the ordering of sentences, one point was taken off their total score. Because there were 5 sentences like this, the maximum score they could get was 25. On the mathematical part, participants had a score of 5 if the answer they gave regarding the final equation was correct. Otherwise they gained no score if the final answer was wrong. Therefore, the maximum they could get on this part was also 25. We anticipated a range of 0 to 50 for the aggregate of both test scores. The upper half of the scores were taken as the high WM spans, known as HWMSs and the lower half ones were taken as the low WM spans or LWMSs.

For the learning (reading text comprehension), participants were asked to be sitting individually at the most comfortable viewing distance from a 15 inches computer screen with a SVGA graphics card and were tested individually after their viewing task. They were instructed to read their task very clearly on a written A4 size sheet beforehand. No extra ordinary action was allowed after the instructions were given and they started the actual reading in two conditions. One group comprising 50% of the entire participants read the text only as the control group and the other half read the text along with a secondary task. The text was presented line by line on face of the computer monitor at an average reading speed as was explained before. Their secondary task was remembering the distracting 20 pictures for producing a DA situation. The second group had an additional instruction about their secondary concurrent task. After doing their tasks, the control group was asked to do a written memory test in a multiple-choice format. There were 20 questions each with one score. The second group was asked to try to remember and write down as many pictures as they could remember in addition to their reading task. The reading task was tested by a cued recall test. The tests asked about what they read. This test was carried out in both groups.

The scores ranged from 0 to 20 in both reading comprehension and remembering each picture shown on the screen. The aggregate score was 40. In the divided attention situation, unlike *Kane* and *Engle* (2000) experiment, participants in this study were doing both tasks concurrently. Furthermore, unlike *Daneman* and *Carpenter*'s (1980) earlier experiment, in which participants started with the smallest sized lists and progress to the larger sized lists, here, the number of pictures and the text length was in a random relationship to the subjects shown concomitantly on the computer face. Therefore, participants of this study could not know the number of words or the number of mathematical operations in any way and no such thing could influence their performance.

Therefore, in general, different groups were shaped which are shown in the **Chart 1**.

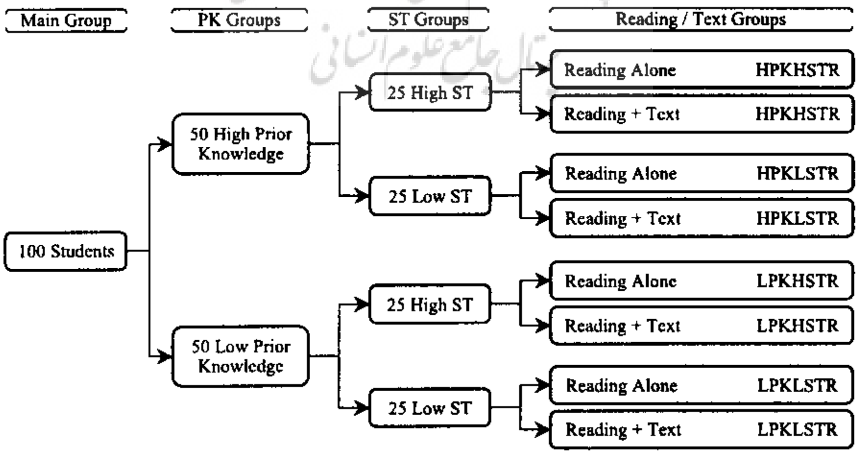

Chart 1. Participants in Different Groups Studied

Design

The experiment produced eight final sub-groups; with knowledge (high and low) being divided into four groups of WM span group (high & low) each being tested in two conditions of reading text only and reading + picture. Concerning the LPK, HPK, LWMS, HWMS, and the DA conditions in terms of reading alone condition versus reading and pictures, the results produced eight paired-comparisons and a paired *t*-test was used for the final data analyses.

Results

The descriptive statistics obtained from this study are shown in **Table 1**. As can be seen, albeit distinct differences obtained between the first pair of the high and low PK, the obtained differences in the four subsequent groups are not showing a meaningful trend when comparing them pair wise. But the mean difference between the high and low PK groups (groups marked with *) shows a statistically significant difference [$t = 11.45$; $df = 49$; $P < 0.000$]. The same-paired *t*-test statistics for the high and low WM spans (groups marked with **) in the high and low PK groups does indicate a statistically meaningful difference. These *t*-test analyses for the respective groups are shown in the **Table 2**.

Table 1. Descriptive Statistics: Means and STD

Variables	N	Mean	STD
High PK*	50	15.06	1.41
Low PK*	50	10.70	2.04
High PK High Span**	25	15.20	2.98
High PK High Span Text	13	15.77	1.74
High PK High Span Text + Picture	12	12.50	3.18
High PK Low Span**	25	14.64	2.08
High PK Low Span Text	13	15.77	1.64
High PK Low Span Text + Picture	12	13.42	1.83
Low PK High Span**	25	13.76	2.59
Low PK High Span Text	13	13.62	1.71
Low PK High Span Text + Picture	12	12.25	3.41
Low PK Low Span**	25	13.96	1.90
Low PK Low Span Text	11	14.00	2.41
Low PK Low Span Text + Picture	14	13.93	1.49
Secondary Task	50	12.48	3.15

* **The main two groups of high and low Prior Knowledge**

** **The main four groups based on PK and WM span**

On the issue of the main four groups obtained from the high and low PK groups versus the high and low WM span groups, a *t*-test analysis was run to see the statistical interactions, results of the six paired comparisons are shown in the **Table 2**. As the table shows, in the six comparisons made, there are no statistically meaningful differences among any paired comparison. However, the aggregate HWMS mean average in both single and dual task performance was 14.58, and the same aggregate for the Low spans mean average was 14.30. This shows a higher memory outcome for the HWMS group. This latter data show that higher spans in general had a better overall performance than the lower spans but not significantly

[$t = 0.54$; $df = 24$; $P > 0.05$]. But when the aggregate mean average for the overall high PK group was 14.90, and for the low PK group was 13.94, the difference showed a statistically significant difference [$t = 2.11$; $df = 24$; $P < 0.05$].

Table 2. Results of the Paired 2-tailed t-test Analyses for the Six Combinations of High and Low PK and WM Span Groups

Paired-Group Combination	t	df	P
High PK High Span - High PK Low Span	-0.84	24	0.41
Low PK High Span - Low PK Low Span	-1.65	24	0.11
High PK High Span - Low PK Low Span	1.98	24	0.59
High PK High Span - Low PK Low Span	0.30	24	0.77
High PK Low Span - Low PK High Span	1.36	24	0.19
High PK Low Span - Low PK Low Span	1.19	24	0.25

Examining more further paired *t*-test analyses on the final 8 groups are shown in the **Table 3**.

Table 3. Results of the Paired 2-tailed t-test Analyses for the Four Pairs of Single and Dual Tasks Groups in High & Low WM Spans across High & Low PKs Paired Samples Test

Paired comparison of DA Groups	t	df	p
High Pk High Span Text - High PK High Span Text+ Picture	2.79	11	0.02
High Pk Low Span Text - High PK Low Span Text+ Picture	2.73	11	0.02
Low Pk High Span Text - Low PK High Span Text+ Picture	1.14	11	0.28
Low Pk Low Span Text - Low PK Low Span Text+ Picture	0.51	10	0.62

As the above results indicate, while the differences in higher PK groups are showing statistically significant differences in high and low WM spans, in divided attention condition, the lower PK group did not show such meaningful difference comparatively. Results show that high and low spans varied in dual task susceptibility. It appeared that PK variable is influencing the outcomes. Under single task condition, this pattern of results indicated that in the higher PK participants showed a dual-task cost on cued recall memory test.

With respect to the data related to the secondary task, **Table 4** shows the descriptive mean and standard deviations.

Table 4. Mean and Standard Deviations of the Secondary Task Results

Group	N	Mean	STD
HPKHS	12	13.17	2.5
HPKLS	12	10.92	3.34
LPKHS	12	14.33	3.75
LPKLS	14	11.57	2.44
H SPANS in HPK&LPK (Mean)	12	13.75	1.63
L SPANS in HPK&LPK (Mean)	12	11.21	2.57

Table 4 shows that in terms of the performance of the secondary task, paired comparisons indicate that high WM spans showed considerable superiority to low spans. This can be interpreted for higher cortical activity during the DA condition.

Nevertheless these differences perhaps due to the small sample size are not statistically significant. However as the following table of statistical data (**Table 5**) represents the overall performance of the high spans in both high and low PK groups. Further statistical analyses show a meaningful difference among the means.

Table 5. Results of the Paired 2-tailed t-test Analyses for the Following Combinations of High and Low Span Groups in High and Low PKs

Paired-Group Combination	t	df	P (2-tailed)
HPKHS -HPKLS	1.96	11	0.08
HPKHS -LPKHS	-0.74	11	0.48
HPKHS -LPKLS	1.80	11	1.00
LPKHS – LPKLS	1.90	11	0.08
HPKLS – LPKHS	-2.00	11	0.07
HPKLS – LPKLS	-0.65	11	0.53
HSPANS – LSPANS	2.60	11	0.03*

* **Significant Statistics**

The above data illustrate that in terms of WM spans in the secondary task the differences obtained in the high and low WM participants mean for both high and low PK groups are statistically different. But comparing them in any other combination, there is no statistically significant difference.

Discussion

High and low PK and WM spans showed differences in close-to-real life situation when a distracting divided attention task was introduced. Results showed that high span participants with high PK were more susceptible to DA in their primary task than were high spans with low PK. Under an additional load of the secondary task, however, the high spans performed better than the low spans. This pattern of data perhaps could be interpreted as when the general reliance on the PK variable is taken for granted in high PK participants, during the processing episode of the inputs, the attention of high PK readers appears to be more directed and focused on the secondary task. The findings of this study also suggest that due to the interplay between STM and LTM and CE, there were differences in the high and low span memory among participants with high PK in the subject of the text. There was increased DA interference in respondents' recall of the same content of reading when their PK was higher.

Furthermore, the results show the general impact of DA load on remembering encoded materials. Based on the detailed results obtained above, the impact of additional charge, perhaps inhibitory in nature, at encoding with respect to theories of WM capacity and prefrontal cortex function can be inferred. Probably, this would be mainly because the costing effect in high and low spans is only showing up when person's background knowledge is high rather than low. Considering that the high PK group did better in the secondary task, in general, with respect to text reading as a primary activity, the current results suggest that the more knowledgeable students about a subject combat more in general with dual task interference in a divided attention situation but rely more on their PK in their primary task. Probably because at encoding level more effort is needed to use of PK about the subject and therefore capturing secondary issues appears to become an easier task.

If we consider the impact of PK variable in producing the differences, the present finding upgrades, *Kane* and *Engle*'s (2000:336, 340) report that "the low spans showed a greater proactive interference than did high spans under no load and that load increased proactive interference only for high spans". The importance of the present finding is that if according to the existing knowledge, the high spans would have less problem in divided attention than did the low spans, and then this might show itself in the overall performance of both tasks. While the high span participants did considerably better in the secondary task, their performance in the primary task was more disturbed by the DA interference than the comparable group. Therefore, participants' background knowledge about the subject seems to have various interactions with their capacity of WM. In addition, whether the same modality is used or not, might have an influence on cortical functioning. What *Kane* and *Engle*'s (2000) comparative study indicated was the effect of encoding or retrieving of a word list on concurrent secondary task of tapping. Their study, improving on the ecological aspect of the more real-life situation, also indicated that DA can hurt high and low spans equally perhaps because participants' primary task could be performed only through controlled processing. *Kane* and *Engle*'s results however, failed to indicate any causal relationship and did not make any clear reference to any underlying interaction or relationship. Therefore, the nature of this relationship remained unclear. Their study being purely an empirical research and under laboratory condition can be challenged for its ecological validity. Empirical condition can affect the situation where more real life state of affairs may apply. Whereas in the present study we considered a more realistic studying situation in students' lives, where reading from a text was accompanied by a concurrent distracting secondary task.

Neurophysiologically, this attentional demand of the secondary task being involved in picture and spatial information by the same receptive sense has little surface similarity to the primary comprehension of a text that has to do a lot with semantic reading and lexical processing (Andrewes, 2001). The present findings of WM span and differences that was shown up in the dual task situations and DA susceptibility are consistent with the idea that CE processes are particularly reliant on prefrontal and frontal cortex functioning (e.g. Baddeley, 1996; 1986; Shallice & Burgess, 1993). It also relates to the idea that the initial data from each section of WM are saved temporarily in respect to STM dispensation and wait for further processing, which occurs as a result of further inputs that help their linkage with LTM (Afzalnia & Foster, 2003). CE on its part also obtains and saves a record of all of these events in temporary storage at the intelligent side of the WM to produce a source for the episodic memory storage at a later point (Baddeley, Conway, & Aggleton, 2002). All these activities of WM are only possible with the leading co-operation of the CE (Logie, 1995). Many short-term memory tasks (e.g. listing, naming, spelling, etc.) clearly do have a long-term component with the direction of CE part and the provision of the evoked potentials in LTM traces which inevitably make theoretical interpretation difficult (Cantor & Engle, 1993). For example, someone hearing a word, can visualise the appearance of the given word, can silently articulate the word or spell it out, and can imagine writing the word or forming it in sign language.

According to *Brandimonte*, *Hitch*, and *Bishop* (1992a & 1992b), each STM system is connected to the other so that, for instance, visual material can be encoded into phonological format, and vice versa. Supporting the above, in a study carried out by *Martin*, *Shelton*, & *Yaffee* (1994), two brain-damaged patients were investigated with measures for short-term memory and for sentence processing abilities. The results of the study support the idea that there are separate capacities for phonological and semantic retention as was later confirmed by *Logie* (1995) and *Baddeley* (1999). But how do these separate STMs make sense as a whole from the input message? It is suggested that pattern recognition part of the CE (Afzalnia, 2000; Lund, 2001) using CE resources, is also responsible for integration of these separate streams into one general coherent flow of inputs. Retention of this requires a separate storage for keeping track of the respective functions. This situation, therefore, suggests that connections between different modular perceptual STM activities take place by something like the multi-functional CE (at frontal cortex) in the final integration stage, where cohesion of the perceptual analyses derived from the analysed inputs is necessary for comprehension. The capacity of WM would thus depend on the amount of CE in maintaining elements from the inputs that would help both comprehension and recall, and this is exactly where the DA situation meets with this costing effect.

Further research referrals on this taxing effect of DA indicate that the spatial processing of pictures presented to half of the participants in comparative dual task groups to produce a divided attention condition is endogenously driven and may put a premium on efficient functioning of the prefrontal cortex (see Cohen, Sparling-Cohen, & O'Donnell, 1993; Cohen, Johnston, & Plunkett, 2000). Some pre-existing exercises of this approach have been implemented to patients with prefrontal cortex damage in order to stimulate their cognitive performance (e.g. Moscovitch, 1992, 1994; Martin, Wiggs, Lalonde, & Mack, 1994). Furthermore, the existing literature of cognitive Neuropsychology is suggesting that the executive functions of WM have been associated with and rely on the prefrontal cortex (e.g. Cohen, Sparling-Cohen, & O'Donnell, 1993; Cohen, Johnston, & Plunkett, 2000; Eysenck, 2000). The authors, like *Kane* and *Engle* (2000), found that high and low spans differed in DA conditions; this finding is sensitive and somewhat selective to prefrontal injury and activation. Our findings thus support the idea that encoding and retrieval under certain episodic retrieval from LTM (prior knowledge) and the interference effect, rely on PFC circuits (Moscovitch, 1992). *Conway* (1997) and *Baddeley* (1997; 1999) have suggested that encoding of language inputs semantically at the WM level involves LTM activities along with WM. *Baddeley* (1997), *Garnham* (1997), and *Gathercole* (1996), have argued that semantic decoding can be due to retrieval traces that activate the background network in LTM. All of these debates suggest that information flows between the permanent and the temporary systems in the form of sensory inputs and ideas (Garnham, 1997). On the other hand, in respect to the secondary visual task, empirical studies of memory for sentences, models of psycholinguistic processing, and models of memory such as schema theory, have confirmed that memory for surface features is characteristic of processing with less attentional consumption (Baddeley, 1999). This type of superficial learning can very rapidly get lost in the cognitive system. What is stored in memory is an abstract representation of the meaning rather than a clear image of the dialogue (Afzalnia, 1988; Cohen, 1996) that would affect the retrieval procedures. Both the visual and the verbal components of the inputs draw on prior knowledge (the LTM resources) and on the products of moment-to-moment perception that may be interrupted and complemented via the knowledge base. This system paves the way for the WM system that provides a two-way on-line interaction between the outside world and our LTM resources.

In this view, the prediction that the impact of DA would be more on the high PK students than the low ones in the present study can be supported. We reject the previous report by *Kane* and *Engle* (2000) that the high spans would have fewer problems in divided attention than the low spans in the primary task. It is possible that the difference Kane and Engle reported between the high and low span groups could have been affected by the way participants' background knowledge would have influenced their memory, and this is indeed what is recently been reported by *Rawson* and *Kintsch* (2002). Complementing on the impact of DA on later recall in terms of encoding rather than retrieval factor, *Fernandes* and *Moscovitch* (2000) reported that regardless of the type of distracting task, DA produced uniformly large interference effects during the encoding procedures because DA's impact on the retrieval process can be only organisational relating mostly to the PK variable. However, the finding that was reported by *Fernandes* and *Moscovitch* could have been related to the empirical word-listing situation that needs to be established in a more real life situation of text reading. The findings of present research contribute to the growing body of work suggesting that normal adult student differences in WM capacity may serve as a human model for level of PFC functioning (Engle, Kane, & Tuholski, 1999). However to produce yet clearer picture of attentional role in STM and LTM functioning, one other possible variable that needs to be followed up would be a further control on the pace of presentation. With the current results and the consideration of the *Kane* and *Engle* (2000) report, it can be anticipated that the self-paced group would have less distractions in the presence of a secondary task than when the pace of presentation cannot be controlled. Finding out more about pace variable further, can complement more on the current literature and would thus be plausible.

Conclusions and suggestions

The more knowledgeable group would feel more distorted in performing the primary task while doing the other learning activity probably because of the PK role in the evoked potential traces of LTM that interplays between LTM and CE. This would neuropsychologically indicate a connection between Hippocampal section and the frontal cortex that is well evidenced in the literature. The higher reactions of higher WM span participants to DA condition that was reported by *Kane* and *Engle* (2000) could have been due to their prior knowledge and compensated in their secondary task. The relatively high and low reactions to the primary task of the high and low span participants to DA situation can be attributed to PK variable rather than to WM span; and should be considered in conjunction with the performance on the secondary task. With this consideration, we retain further hypotheses for conflicting modality in the secondary task situation that would also be much more plausible in the follow-up study. In addition, and in continuing efforts further to *Fernandes* and *Moscovitch* (2000), we need to establish whether the interferences caused in the divided attention situation is related to and occurs at an initial learning or at the retrieval process. This experience would elaborate on the existing knowledge of attentional role in LTM.

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