Multitasking span measures and working memory capacity

The primary objective of this study was to examine whether verbal and spatial working memory capacity correlates with multitasking efficiency. Other studies have found a relationship between working memory and multi tasking such as Law (2006) whose findings suggested that the central executive and the phonological loop component of working memory were implicated by a test of multitasking.

To test this thirty two first year psychology student were used as participants.

Several cognitive tests were use to test the different aspects of the working memory. Verbal and spatial working memory was tested using computerised span measures. This consisted of two tests; the verbal working memory was tested by participants having to recall information verbally after processing sentences and spatial awareness was tested using manual response after making spatial judgements. Participants multitasking ability was assessed by using four subtasks with a limited time so they had to swap between tasks (multitask) to complete as much as they could. This test was a modification of a test which was originally used by Burgess et al (2000). The hypothesis was not supported as verbal and spatial working memory scores did not predict multitasking ability.

Introduction

Multitasking is the ability of an individual to perform more than one task at the same time by switching between tasks to complete all of the goals but not in a sequence. For the majority of people it is required in everyday life and for most jobs. Multitasking is required during anything from preparing a meal while keeping an eye on children or driving a car while speaking on the phone to more complex tasks such as operating heavy machinery while making sure your work colleagues are safe to performing surgery. It is an essential skill for anyone who lives a normal independent life.

Burgess and Simons (2005) described multitasking as: the creation, maintenance and execution of delayed intentions; the ability to recognise the need for self initiatives and carry out complex meta-strategies; dovetailing tasks to be time effective; prioritisation of tasks and deciding for oneself in the absence of feedback whether a result is satisfactory (pg 228).

This is a very complex description of multitasking, a more commonly used and accepted definition is the cognitive ability to perform " multiple task goals in the same time period by engaging in frequent switches between individual tasks" (Delbridge, 2000).

The term executive function describes the cognitive abilities that are concerned with our abilities to monitor behaviour as needed, start and stop actions and to plan for the future and therefore is the part of the brain that controls multitasking. It is located primarily within the frontal lobes of the brain and its function is thought to be supervisory or managerial.

During multitasking, different task are thought to interfere with one another (Broadbent, 1971). Some researchers such as Broadbent (1971) and Pashler & Johnson (1989) hold the view the interference happens as a result of some cognitive operations trying to be processed at the same time but only one can be serviced at a time so only one operation will be processed resulting in the bottleneck process.

Other researchers such as Kahneman (1973) and Wickens(1980) think that processing relies on graded resources meaning that resources can be of different sizes and the greater quantities are processed faster and more efficiently. They also believe that two tasks can be processed at the same time but they happen slower as there are fewer resources. Kahneman’s (1973) study of attention and effort found that a person’s mental resources are shared by different tasks during multitasking and tasks interfere with one another because mental resources are limited. A theory that best explains ‘ the bottleneck process’ has yet to be agreed on.

Working memory is a system used for the temporary storage and management of information. It is required to carry out complex tasks such as learning reason and comprehension. It is involved in the selection, initiation and termination of information processing functions such as encoding, storing and retrieving data.

There has been much debate as to whether memory should be regarded as a single unitary system or whether there are subsystems.

Research was done on brain damaged patients who appeared to have no ability to form new lasting memories but did however show some ability to use their short term memory. Findings opposite to this research showed that there were patients with limited ability to use their short term memory but appeared to have fully functional long term memory. This evidence pointed to the memory using the two subsystems but this model was dismissed shortly after as there were problems inherent in the neuropsychological evidence that originally appeared to support the model.

Atkinson and Shiffrin (1968) suggested that the short-term store within their model acted as a working memory, being necessary for learning, retrieving old material and for performance of many other cognitive tasks. This cannot be the case as it would mean that patients with defective short term memory stores would show other cognitive impairments such as long term memory defects but these patients appeared to have no impairments to long term memory capacity.

Baddley and Hitch's (1974) findings on short term memory store as well as other research encouraged the abandonment of the idea of a single unitary short term system that functions as short term memory. The tripartite system was proposed instead of the unitary system. Baddeley and Hitch (1974) introduced the multitcomponent model of the working memory which replaced Atkinson and Shiffrin's multistore memory model (1968).

The multicomponent model comprises of three components: the central executive, the phonological loop and the visuospatial sketch pad.

The central executive can be thought of as a supervisory system that control cognitive processes and coordinates the slave systems. It is also postulated to be responsible for selection, initiation and termination of processing routines. Baddeley reported basing his speculation regarding the central executive on Norman and Shallice's (1968) supervisory attentional system.

The phonological loop is the simplest and most extensively investigated component of WM. It consists of two parts which are a short term phonological store with auditory memory traces that are subject to rapid decay and an articulatory rehersal component that can revive the memory traces. The second component is an articulatory control process which severs several purposes. It can maintain material within the phonological store by sub vocal repetition and it can take visually presented materials such as words or nameable pictures and register them in the phonological store by subvocalization. The phonological similarity effect provides evidence for the phonological loop. The similarity effect is that similar sounds are more difficult to discriminate against while the semantic effect has comparatively no effect implying the notion of a temporary storage system for specifically verbal information.

The visuospatial sketchpad stores and manipulates visual information. It is used in the temporary storage and manipulation of visual and spatial information such as remembering shapes and colours or the location or speed of objects. If you are seeing something with the “ mind’s eye” or mentally manipulating an image you are using the visuospatial sketchpad.

Information in the phonological loop and the visuo-spatial sketch pad is encoded differently, while the central executive cannot store, only process. The episodic buffer is able to combine information from the three components into a single representation.

Concurrent storage and processing are one aspect of working memory but they are not the only one as Baddeley, Barnard and Schneider & Detweiler all suggested that the coordination of resources is the prime function of the working memory and the storage of information is only one of many potential demands.

Models of human memory commonly distinguish between previously learned knowledge which is stored in the LTM and the temporary activation of that knowledge which represents that content of current thought. The WM can be defined as that part of permanent LTM that is temporarily active above some critical threshold and that can be recognized and manipulated by ongoing cognitive processes. WM is where processing and storage interact within the information processing system.

Engle et al (1992) developed the general capacity model of WM to account for individual differences in WM. The model assumes a single WM capacity that transcends a variety of cognitive representations and is implicated whenever information must be temporarily maintained (Engle et al 1992, Engle, Nations, & Cantor, 1990. Shute (1991) demonstrated that quantitative, verbal and spatial WM tasks reflected a single cognitive factor and that this factor was a better predictor of learning than processing speed, general knowledge, or technical skill. There is also evidence for a common capacity that underlies auditory and visual WM spans (Daneman & Carptender, 1980) and for those that require problems solving, reasoning or reading (Kyllonen & Christal, 1990; Salthouse, Mitchell, Skovronek, & Babcock, 1989; Turner & Engle, 1989). According to the general capacity model these results indicate the WM is a single unitary resource. The model assumes that the content of WM is information that is in the LTM that has been stimulated or activated above some critical threshold.

There is a lot of evidence to support the claim that WM differs among people and this difference affects a wide range of cognitive tasks. Engle showed that problem solving, reasoning, reading comprehension, acquiring new vocabulary words, learning to spell, following directions and taking notes in the classroom are all influenced by individual differences in WM. Daneman and Carpenter's (1980) reading span task was the first measure to show important differences in WM. In their experiment subjects read a series of unrelated sentences while attempting to maintain the last word of each sentence. The span size was defined as the largest number of sentences from which at least 50% of the last words were recalled. The findings showed that these scores significantly predicted subject's performance on a variety of other reading related tasks and this indicated that individual differences in WM are driven by differences in processing skills. Good readers have fast and efficient reading process that require less WM capacity than those of poorer readers, so good readers have functionally more capacity in reading related tasks. This approach is known as task-specific view.

This view was challenged by Turner & Engle (1986, 1989) when they showed that performance on a non-reading WM span also predicted reading measures. They developed a task in which subjects solved simple maths problems while maintaining unrelated words. This operation word span predicted comprehension and verbal skills to the same extent as the reading span even when the maths skills were partialed out. This indicates the individual differences in WM are not driven by task specific processing skills.

The total amount of activation available to retrieve information from LTM differs from person to person and the difference is evident in any task that makes at least moderate demands for such activation. High and low capacity subjects differ in their activation limits and WM spans are thought to be a good measure of this limit as they are required to switch attention between reading or solving maths problems and maintaining words. The attention switching feature is a critical component of the WM spans. This attention switching characterizes all WM tasks and provides a way to measure the activation limits that constrain retrieval from LTM.

I expect to find that there will be a positive relationship between verbal and visual spatial working memory and multitasking efficiency and that verbal working memory will be positively related to participant's ability to learn the task rules. This investigation will build upon a study by Law (2004) in which she examined the effects of interruptions on multitasking in healthy adults and dysexecutive patients.

In Law's investigation two experiments were used to assess the impact of interruptions on a novel test of multitasking. The first experiment used four groups, the first was not interrupted during the test, the second was interrupted early in the test, the third group late and the forth group was interrupted both early and late. These findings showed that no differences in multitasking performance between the groups. The second experiment used seven dysexecutive patients and fourteen aged matched controls. It used a repeated measures approach to assess the impact of both groups an early and late interruption. They found that both groups are not affected by the by the interruptions even though their multitasking performance was still impaired. The results show that the ability to deal with interruptions is separate from the ability to organise and execute a number of tasks within a limited period of time. In my experiment I will use the same test for multitasking as Law did in her study. It involves four subtasks which include block construction, bead threading, alphabetical searching in a phonebook and folding paper and putting it into envelopes. The participants must switch between the tasks over a 10 minute period to get the highest score that they can.

A recent study by Colom et al (2010) investigated the simultaneous relationship between intelligence, working memory and multitasking performance. Their participants were three hundred and two applicants for air traffic control training course. They assessed intelligence, working memory and multitasking by making participants complete a set of computerized tests, one for each of the variables. The findings that intelligence and working memory capacity are both related to multitasking when the intelligence relationship was removed. The processing and storage components of working memory capacity also predicted multitasking. These results are similar to the findings I expect to find when I complete my experiments. Although I am not using the same experiments to test for working memory capacity and multitasking span measures I expect that the results will show a similar relationship between the two.

The purpose of this study is to investigate the relationship between both verbal and visual spatial working memory and multitasking efficiency. I will attempt to find whether the scores from the visual spatial and verbal working memory tests correlate with the multitasking test scores.

A study by Konig, Buhner and Murling (2005) can provide some rational for the present research as they showed that WM is an important predictor of one type of multitasking test so the research will investigate whether it will be for the test used in this research.

Method

Participants

The participants were 32 first year psychology students at Liverpool John Moores University, who received course credits for taking part in the study. There were 13 males and 19 females and they ranged in age from 19 to 24, with a mean age of 20. 61 years (SD = 1. 43).

Design

This study had a correlational cross sectional design.

Material and tasks

Participants’ multitasking ability was assessed in a test that consisted of four sub-tasks. The study used the same tasks as were used in a study by Law (2004) who modified tasks originally used by Burgess et al (2000).

The participants were given general instructions on how to complete the test. They were as follows “ You have ten minutes to complete the four sub tasks, your aim is to complete as many red items as possible across the four sub tasks, you must make an attempt at all the sub tasks however there is not enough time to complete all of the tasks, You can perform the tasks in any order that you please and you may switch tasks at any point. Red items are worth ten points and all others are worth only one point, you must aim to accumulate as many points as possible from all the tasks. You will lose all points accumulated in a task if you break the rules and lose one hundred points if you miss out a task entirely.

The general instructions were given to participants on a sheet along with the rules for the four sub-tasks at the beginning. The four sub-tasks were as follows:

Telephone task: For the telephone task participants had to look through the residential section of a phonebook to find names from a list of 20. A label indicated the beginning of the residential section of the phonebook. Five of the names from the list were in red indicating that they were worth more points. Participants had to find the names on the list in the phonebook and write down the corresponding phone numbers. Participants were informed at the beginning that they could look up the names in any order and so could concentrate on the names in red to get a higher score.

Brick construction task: For the brick construction tasks the participants were presented with an example of the structure they had to replicate. It comprised of 13 layers of eight 2×4 bricks in each layer. All of the bricks were the same colour for each layer with no two consecutive layers having the same colour. The 2nd, 6th and 11th layer of the construction had red bricks indicating that they were worth more points. There was a container of bricks with a sufficient amount to replicate the structure. Participants were informed before the beginning that points were awarded for every layer not every brick so completing red layers before moving to another task was the best way to achieve the highest score possible.

Envelopes task: The envelope task used 25 sheets of A4 paper which were placed in one pile with five red sheets and five sheets of yellow, blue, green and orange. There were also a sufficient amount of envelopes. Participants were informed to fold the sheets into three and place them in the envelopes and the sheets could be selected in any order so again concentrating on red was the best strategy to achieve a high score. They were also instructed not to seal the envelopes.

Beads task: For the beads test participants were presented with a series of beads threaded onto a string which they had to replicate. There were 26 sections of colour with each section containing three beads. The 2nd, 6th, 12th and 19th sections were red and there was a box containing a sufficient amount of beads to complete the task. The beads were Galt toys threading beads (0. 9cm in diameter with a 0. 4cm hole and the string was approximately 55cm long. The best approach was to complete the red sections before moving to another task. Participants were instructed that they must only take one bead out of the box at a time or they would lose points.

Working memory span was assessed using the E-Prime Version 1. 0 program that consisted of two tasks. The test was taken from a study by Law, Logie and Trawley (2010) in their study of working memory and multitasking in a virtual environment. The first task that testes the verbal recall and the participants had to sit at a computer and a random sentence would appear on screen (e. g. Salmons are carpenters tools or Moscow houses many people). They had to press 1 or 2 on the keypad to indicate if the sentence was true or false (1= true, 2= false). Before they began the test participant had a practice trial that ensured that they understood exactly how to do the test. Each sentence would be followed by another with approximately 6 seconds between each sentence and at the end of each stage a blue screen would appear and participants would recall the last word in each sentence and this would be recorded by the experimenter. As the stages progressed there would be one additional sentence at each stage so as the test progressed it was more difficult to recall all of the words with each stage. At the first stage there were 2 sentences and by the sixth and final stage there were 6 sentences.

The second task assessed the spatial recall of the participants. This trial was called the letter R task and similar to the test of verbal recall the participants would sit at a computer and a letter would sit at a computer and a letter would appear before them either as a normal image or as a mirror image. As it appeared they pressed either 1 or 2 (1= normal image, 2= mirror image). The letter would also be at a different angle of orientation and there were seven different possible angles: 45, 90, 135, 180, 225 and 325. When the blue screen appeared at the end of each stage the participants had to mark on a page provided which indicated the seven possible orientations what angle the letters were at. They marked the first letter that appeared 1 and the second 2 and so on. Similar to the verbal recall test there were 2 letters for the first and finally 5 letters at the last stage of the test.

Procedure

The four sub-tasks were spread out across a large desk and participants were given the instruction sheet and informed that they had two minutes to learn the rules of the test and the rules of the four sub-tasks. After two minutes the instructions were taken away from them and they were asked to recall everything they could. The results were recorded and then they were given the instruction sheet back until they were happy they understood it. They were then asked twelve cued questions which covered the most important points and told the correct answers to anything that they got wrong. Participants then began the sub-tasks during which a stop clock was in view but the participants had to turn their head to view the elapsed time. When the 10 minutes were up the participants were again tested with both free and cued recall of the task instructions with the results being recorded.

The experimenter recorded the tasks attempted, the number of switches, number of items completed on each sub-task, clock watches and rule breaks.

2. 6 Results

The results of this investigation did not find a significant relationship between verbal and spatial working memory and multitasking efficiency. Verbal: mean= 51. 63 (SD= 5. 49), spatial: mean= 21. 25 (SD= 4. 70), multitasking average: mean= 0. 61 (SD= 0. 11).

The Kolmogrov-Smirnov test showed that the data for multitasking average and verbal working memory was not normally distributed: multitasking average (D(32)= 0. 24, p <0. 05), spatial (D(32)= 0. 09, p <0. 05). However the data for verbal working memory scores was normally distributed (D(32)= 0. 19, p> 0. 05).

Spearman’s Rho showed that there was a negative trend between spatial working memory and the amount of task switches, rho = -0. 29, p= 0. 103, N (32), although this was not a significant finding. Spearman’s Rho did however find a marginal positive relationship between spatial WM and multitasking average, rho = 0. 35, p= 0. 53, N (32).

A multiple regression was conducted with number of task switches as the outcome variable and verbal and spatial working memory as the predictor variables.

The overall model does however predict significance amount of in task switching, F(2, 31) = 6. 342, p = 0. 05.

The model summary shows that 25. 6% of variability is accounted for by the predictor as adjusted R2= 0. 256, p> 0. 001.

The part correlations and betas indicate that spatial WM is the most important predictor, (B = -0. 44, p= 0. 08), but verbal working memory is also significant, (B = 0. 379, p = 0. 021).

Discussion

The aim of this investigation was to show a relationship between multi-tasking spam measures and working memory capacity. Focusing on how results from verbal and spatial working memory tests could predict multitasking efficiency. The findings from the investigation did not support the hypothesis that verbal and spatial WM scores would predict multitasking efficiency. However, verbal and spatial WM did predict a significant amount of variance in the number of times that participants switched between sub-tasks.

Nothing measured predicted the participant's ability to multitask efficiently, by targeting high-value red items within the sub-tasks. There was also no relationship between verbal WM and spatial WM.

None of these findings support previous literature which was unexpected as a lot of research has been done in this area and the majority found similar results. Although a study by Konig& Buhner found that working memory was a predictor of multitasking but attention and fluid intelligence did not to a significant level however they did contribute significantly to explaining the variance. Siklos & Kerns (2003) investigated whether children with Attention Deficit Hyperactivity Disorder demonstrated a deficit in multitasking. They found that ADHTD children appeared to have a specific deficit in monitoring their behaviours and useful generating strategies for task completion. Their results also showed that the number of tasks tried in the test they administered to examine multitasking correlated significantly with a measure of verbal working memory.

The measures of how many times participants switched between tasks and there score on the spatial WM test interestingly found a negative correlation but no previous research can support this finding. Silkos & Kerns (2003) also found a significant positive correlation between the numbers of tasks attempted with their scores on the working memory test which showed that children with better verbal working memory also attempted more tasks.

The working memory has been found to be the most important predictor of multitasking in other studies so finding no relationship between the two was a surprise. Konig, Buhner & Murling (2005) found that a multiple regression analysis showed that the working memory was the most important predictor in addition to attention and fluid intelligence. Working memory explained incremental variance that could not be accounted for by the other two predictors. They thought that this could be explained by the individual differences in controlling attention rather than differences in attention itself. They believe higher cognitive processes are so important that simple perceptual speed might be marginal.

Buhner et al (2006) extended the work of Konig and Murling which can be criticized for using only one latent WM variable and so did not account for the multidimensional nature of the WM. They investigated working memory dimensions as predictors of multitasking. They found as expected that WM was the best predictor of multitasking. The WM components showed a differential validity when predicting multitasking speed and error and a differential WM model with three dimensions contribute to our understanding of multitasking. They reported that WM dimensions and attention explained as much of multitasking speed variance that reasoning added nothing. The study was based on the three dimensional model proposed by Oberauer et al (2003).

Law (2006) found similar results in her study on the impact of secondary tasks on multitasking in a virtual environment. She examined the involvement of WM in the Virtual Errands test and assessed executive functions using a virtual environment. The test used 42 participants who completed the test twice and the test required them to multitask efficiently if they were to complete it as the time was limited. On the first attempt they were asked to perform a concurrent test throughout and for the second test the group was split and the first group had to randomly say months of the year aloud in the dual task condition while the second group were asked to repeat the word December aloud. The results showed a drop in performance when participants were under the dual task conditions and the drop was greater for the second group who repeated the word December. The data suggested that the central executive and the phonological loop components of the WM are implicated in the test of multitasking. One explanation that Law stated was the participants rely heavily on executive resources in WM on their first attempt on the Virtual Errands test but they learned strategies that reduced WM load when performing the test on its own.

I believe that there were several reasons why the results of this investigation did not show any significant relationships between visual and spatial working memory and multitasking efficiency. Firstly only thirty two participants were used and this number of people may not be able to give sufficient statistical power to detect relationships with working memory. As well as this all the participants were first year psychology students so it might be that they had similar levels of cognitive abilities.

If a larger random sample was taken with a range of people at different ages and occupations the results may have agreed with previous research.

A problem that a significant number of participants actually reported without being asked was the difficulty of the E-Prime test for spatial recall. There was too much information being absorbed by participants and it was obvious that after the first stage people were being forced to guess the answers. In addition to this there was not a practice trial for the “ letter R task” unlike the test for verbal recall which may have resulted in the participants being overloaded with information before they fully understood what they were meant to be doing.

Any future research on multitasking should address this problem so multitasking span measures can be assessed more effectively. There are also other areas that need to be addressed if multitasking ability is to be better understood. A possible investigation for future research could be whether practicing and improving multitasking ability results in improved WM capacity. There have been a lot of studies that have shown a relationship between the two but most investigate how WM can predict multitasking ability or relationships with cognitive impairments and multitasking. This would take the research in a different direction with positive implications if the study was to prove that WM capacity could be improved by multitasking ability.

In conclusion the results did not prove the hypothesis that there would be a positive relationship between verbal and visual spatial working memory and multitasking efficiency or that verbal working memory would be positively related to participant's ability to learn the task rules. The study did however show that verbal and spatial WM did predict a significant amount of variance in the number times that participants switched between sub tasks, although nothing predicted participants ability to multitask efficiently. These findings are more likely a result of not using enough participants or that the tests used were not as successful as they have been in other studies whether than the investigation finding that there is no relationship between the WM and multitasking as many studies have shown a positive relationship between the two.