A quasi-experimental investigation into the combination of the method of loci and the Dominic system in improving serial digit recall

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Abstract

The extant literature on a memory system known as the Method of Loci (MoL) has investigated its effectiveness in learning lists of highly imaginable concrete items (Legge, Madan, Ng, & Caplan, 2012). Individuals with expert memory ability have reported the use of MoL to learn record breaking strings of digits (Ericsson et al., 2017). However, scant research has looked at the technique's ability to improve recall for abstract content like digits among novice participants (Derwinger et al., 2003). This study sought to examine the effectiveness of a digit encoding system called the Dominic system (O'Brien, 2013) in improving serial digit recall when coupled with the Method of Loci.

Methods: Participants were randomly assigned to one of two groups; the method of loci and the Dominic system were implanted in the first group (MoLDS group). The method of loci on its own was implanted in the second group (MoL group). Both groups were tasked with learning a sequence of 40 digits in serial order at Time 1 (Pre-Intervention) and at Time 2 (Post-Intervention).

Results: Paired samples t-tests indicated a significant difference in Group 1 for pre-test (M=36.76, SD=14.91) to post-test (M=67.88, SD=29.47), p=.002 Cohen's d = 1.07

Independent samples t-test revealed a significant difference between post-test scores for the intervention group and the control group with the experimental group (M = 67.88, SD = 29.47) scoring higher than the control group (M = 38.73, SD = 16.59) p=.002 Cohen's d = 1.26

Discussion : The combination of the method of Loci and the Dominic system may be an effective mnemonic technique for serial digit learning.

Mnemonics are memory systems that associate new, to-be-learned information with previously learned information (Foer, 2011). Effective mnemonics assist memory recall by encoding and organising meaningless and unstructured information (Qureshi, Rizvi, Syed, Shahid & Manzoor, 2014). Up until Roediger's (1980) seminal research on the efficacy of four popular mnemonics (mental imagery, the peg-word method, the link method and the method of loci), the mnemonical discourse was largely philosophical (Cicero, Sutton & Rackham, 1942; Yates, 1966). Roediger's (1980) study investigated their effectiveness in comparison to a control group using a rehearsal technique. The method of loci yielded the greatest results in both the immediate recall task and the 24-hour delayed recall task (Roediger, 1980). Indeed, the method of loci (MoL) is widely considered to be a significantly effective strategy for improving memory recall (Amiryousefi & Ketabi, 2011; Harman, 2000; Legge, Madan, Ng, & Caplan, 2012; McCabe, 2015; Moe & De Beni, 2004; Qureshi et al., 2014). MoL is a visualisation mnemonic that requires one to imagine a familiar journey in one's mind, to create stages along that journey, and to store information at each stage (Foer, 2011). The technique is also known as the journey method (Qureshi, Rizvi, Syed, Shahid & Manzoor, 2014), the memory palace (Huttner & Robra-Bissantz, 2017) or the mental walk technique (Maguire, Valentine, Wilding and Kapur, 2002). MoL requires one to choose a journey through a familiar environment that can be clearly visualised. Experimenters regularly suggest the route from one's home to work (Foer, 2011). In sum, Moé and De Beni (2004) describe the three stages of visualisation necessary when using MoL, (1) one must visualise a familiar journey/route, (2) create salient loci/stages along that route, (3) picture images at each stage. The envisaged images should represent the to-be-learned information

(Moè & De Beni, 2004). The method of loci has been used successfully to memorise lists of words (Legge, Madan, Ng, & Caplan, 2012; McCabe, 2015; Huttner & Robra-Bissantz, 2017), long passages (Moè & De Beni, 2004; Qureshi et al., 2014) and to improve vocabulary (Amiryousefi & Ketabi, 2011). Ahour and Berenji (2015) found the method of loci to be more effective than rehearsal techniques in English vocab learning in a cohort of English language learners.

MoL may benefit, in part, from the self-reference effect (Wheeler & Gabbert, 2017) which purports that retrieval cues are more memorable when they are referred to one's self (Symons & Johnson, 1997; Conway, & Pleydell-Pearce, 2000). Indeed, Jund, Capobianco and Larue (2016) found greater recall in groups that used an egocentric frame of reference as opposed to an allocentric frame. McCabe and colleagues (2013) study found that college students are indifferent to the efficacy of mnemonics and that techniques such as MoL are infrequently used in college. Motivated to change this, McCabe (2015) taught psychology students MoL technique and participants were asked to use it to learn off grocery lists. Results showed that twice as many participants recalled the lists correctly after being taught the technique. Moreover, significant increases in MoL usage were reported upon follow-up. MoL has been analysed qualitatively in a number of studies (Qureshi et al., 2014; Legge, Madan, Ng, & Caplan, 2012) and findings show an improvement in overall student motivation and increases in metacognition interest after being taught the technique (Qureshi et al., 2014).

O'Hara and colleagues (2007) sought to address the scant longitudinal research with MoL among a cohort of community dwellers (n=122), aged 60 or older. Participants delayed recall was assessed before and after lessons on the MoL technique. Results showed significant increases in performance levels from pre- to post intervention. A follow up was carried out 5 years post intervention and results showed an overall decline bringing recall ability back to its pre- intervention standards. However, participants who reported continual use of the

technique after the study demonstrated significant increases in performance and the opposite effect was seen within participants who reported no use of the mnemonic post study. The paper reported that persistent use of the method of loci may have a positive impact on memory recall (O'Hara et al., 2007). In addition to this, results from a study which trained novice participants in the Method of Loci found positive changes at a neuronal level in the left parahippocampal gyrus and bilateral retrosplenial cortex after just six weeks of training (Dresler et al., 2017). Moreover, memory improvements remained at a 4-month follow-up (Dresler et al., 2017). Brain activation changes in these areas were also found in participants during the recall phase using MoL in a study carried out by Kondo and colleagues (2005).

Frequent use of the method of loci requires the imagination of multiple environments that can be used as MoL journeys. However, individuals are generally familiar with a very finite amount of environments and eventually resort to reusing familiar MoL journeys (Massen & Vaterrodt-Plünnecke, 2006). Massen and Vaterrodt-Plünnecke (2006) found that repeated use of the same locations in one's visualisations caused interference upon recall. Hence, Harman (2001) sought to address this by assessing the efficacy of MoL when using environments created on a computer. Harman (2001) found positive results and developed a software for users to create their own memory palaces using a computer. However, technological advancements brought about the possibility of using the method of loci with virtual reality (VR; Krokos and Varshney, 2015; Huttner & Robra-Bissantz, 2017). Krokos and Varshney (2015) compared the effectiveness of MoL on a computer to VR and found VR to be significantly more effective. Two years later, Huttner and Robra-Bissantz, (2017) used an immersive virtual reality with head-mounted display and in accordance with previous research (Krokos & Varshney, 2015), immersive VR was reported to be more effective than MoL on a computer and as effective as traditional MoL usage.

One criticism of MoL is that the extant literature with novice mnemonists examines their ability to use MoL to improve recall for concrete, highly imaginable items. Indeed, some MoL research has used shopping list items e.g. "eggs", "milk", and "bread" (McCabe, 2015), other research has used word lists from categories of fruits or animals (Li et al., 2016) and passages of text, whereby cue words were highlighted in each sentence to facilitate retrieval of that sentence (Cornoldi & DeBeni, 1991). Concrete items generally require very little effort to elicit vivid imagery (Sabsevitz, Medler, Seidenberg & Binder, 2005). Consequently, the processing of concrete items requires significantly less effort than what is required for abstract data, which is associated with working memory and language brain areas (Lorusso et al., 2017; Sabsevitz et al., 2005). In addition to the above, visual imagery is a key component to the use of a visualisation technique like the method of loci (Dresler et al., 2013). Hence with the above arguments considered, it is reasonable to question whether a technique like the method of loci can be used to learn abstract data like digits (Derwinger et al., 2003).

Nevertheless, retrospective reports from expert memorisers indicate that MoL is widely used in the learning of abstract information like digits (Mallow et al., 2015). Maguire and colleagues (2003) initiated research on individuals who have expert ability to learn significant amounts of abstract items like digits. Maguire and her colleagues (2003) gathered participants from the World Memory Championships (N=10) and compared them to a control group matched for age and handedness (N=10). Participants were tasked with learning three types of information: digit sequences, faces and snowflake patterns. The expert memorisers outperformed the matched control group on all three tasks but most significantly on the digit learning task (Maguire et al., 2003). Maguire and colleagues (2003) then assessed general cognitive abilities and found no significant differences between the SMs and the controls in measures of verbal IQ, verbal recall, nonverbal fluid reasoning or general intellectual ability. Instead, it was reported that the use of mnemonic techniques like the method of loci

accounted for their superior results (Maguire et al., 2003). These unexpected results sparked interest into superior memorisers and today, studies into their techniques and cognitions abound in the literature (Ericsson et al., 2004; 2017; Hu et al., 2009; Mallow, Bernarding, Luchtmann, Bethmann & Brechmann, 2015; Raz et al., 2009; Takahashi, Shimizu, Saito & Tomoyori, 2006). Ericsson and colleagues (2017) studied a memorist named Feng Wang who was capable of recalling up to 300 digits presented at a digit a second. Another study examined a Japanese memorist named Tomoyori who once held a Guinness World Record for reciting the first 40,000 digits to the mathematical constant of pi, in 13 hours (Takahashi et al., 2006). An individual appropriately named "Subject Pi" recited pi to over 65,500 digits making less than 15 mistakes in the process (Raz et al., 2009). This achievement was even surpassed in 2005 by a world record set by a Chinese memorist named Chao Lu who recited pi to 67,890 digits (Hu & Ericsson, 2012). It is easy to marvel at these achievements and conclude that these abilities are due to savant syndrome (Treffert, 2009) or innate memory ability (Thompson, Cowen & Frieman, 1993). However, this deduction is unfounded and inconsistent with what is seen in the literature (Ericsson et al., 2017). Indeed, considerable examination in measures of intelligence, memory ability and structural and functional neuroimaging have depicted that when expert memorisers are forced to abandon their mnemonics, memory ability drops to equate that of a matched control group (Takahashi et al., 2006). Rajan was originally reported to be an exceptionally gifted memoriser due to his digit span of 15 and his ability to memorise lists of symbols and letters (Thompson, Cowan and Frieman, 1993) However, Ericsson and colleagues (2004) carried out further experimentation with Rajan which indicated that his superior abilities were consequences of learned encoding strategies (Ericsson et al., 2004). Indeed, this conclusion was also reported in Takahashi and colleagues' (2006) paper with Tomoyori. Despite his exceptional ability to recite digits of pi (up to 40,000 digits), Tomoyori's digit span wasn't impressive in comparison to that of the

control group. His self-report analysis indicated that the speed of the digit presentation prevented him from using his learned digit mnemonics. Tomoyori's ability to learn digits of pi was achieved under self-paced time constraints (Takahashi et al., 2006). Moreover, his ability on memory tasks unrelated to digit memory like story recall and word list learning was insignificantly different to the controls (Takahashi et al., 2006). These findings were reflected with mnemonists ability to learn symbols and snowflake patterns (Ericsson et al., 2004; Maguire et al., 2003). Furthermore, a study on Chao Lu replicated the findings of the previous studies, Chao Lu's digit span (8.83) was lower than the average of the control group (9.27; Hu & Ericsson, 2012). Moreover, Chao Lu reported intensive training sessions in preparation for his attempt to break the world record in reciting pi digits. In the year leading up to breaking the World Record he practised memorising pi for 3 to 5 hours a day, up to 10 hours a day during holiday periods and even 13 hours in one day. So, although MoL has been investigated almost exclusively with concrete items, posteriori analysis of expert memorisers reveal the use of MoL in learning incredible amounts of digits Moreover, gifted memory ability does not appear to be a requirement to achieve these memory triumphs (Yin et al., 2015).

One theory which may help to explain how individuals of normal memory ability can perform outstanding feats of memory is the Skilled Memory Theory (Ericsson, 1985). This framework suggests three components to expert memory ability with abstract content like digits (Ericsson, 1985); (1) A retrieval mnemonic like the method of loci. (2) an encoding technique which converts abstract content into previously acquired knowledge systems. (3) practice focusing on efficient implementation of the two mnemonics. Ericsson (1985) developed the theory after carrying out longitudinal experiments with two runners of average memory ability (Chase & Ericsson, 1981; 1982) The two runners were instructed to create meaningful encodings from chunks of 2, 3 or 4 digits. The runners encoded digits into salient

running times (e.g. 3492 was 3 minutes and 49.2 seconds which, as of 1981, was a record running time), memorable dates (e.g 1944 "near the end of the war") and people's ages or birthdays (Chase & Ericsson, 1981;1982). To be able to retrieve the encoded information the runners created an ordered tree-like system. After about 270 1 hr sessions the two participants acquired expert memory with digit spans of 68 and 82 (Ericsson, 1985). From these studies, Ericsson formulated the *skilled memory theory* (Chase & Ericsson, 1981; 1982; Ericsson, 1985). The theory highlighted three aspects of acquiring expert memory ability; firstly, one must create meaning from to-be-learned information by relating it to knowledge already stored in the long-term memory. With digit learning, the runners encoded digits into personally meaningful numbers, e.g. record running times or birthdays (Chase & Ericsson 1981;1982). Secondly, one must use a mnemonic that facilitates long-term retrieval, in other words, a method that helps with the internal storage of encoded information e.g. the method of loci (Kliegl, Smith, Heckhausen, & Baltes, 1987). Finally, one must practise the above two aspects repeatedly to achieve efficient processing speed (Ericsson, 1985).

Kliegl, Smith, Heckhausen and Baltes (1987) sought to replicate Ericsson's study using the skilled memory framework. The study consisted of two participants (N=2). The first participant (participant SP) was instructed on the history/dates mnemonic modelled by participants in Chase and Ericssons experiments (1981; 1982) and the method of loci. The second participant (participant BB) carried out two mnemonics, a digit to phoneme encoding mnemonic (See procedure for participant BB; Kliegl, Smith, Heckhausen & Bates, 1987) and the method of loci. When the digits were presented at fast rates the history/dates mnemonic in combination with MoL was the most effective technique in improving digit span. However, this method requires one to make thousands of digit-to-date encodings. Therefore, when the digit sequences are completely random (unlike in this study) the method cannot be used (Kliegl, Smith, Heckhausen & Bates, 1987). The method practiced by participant BB

however only requires one to encode digits into pre- learned consonants and make words from pairs of consonants. A similar digit to consonant mnemonic is described in the retrospective self-reports of many of the expert memory champions (Takahashi et al., 2006; Mallow et al., 2015). An expert mnemonist names Johannes Mallow recounts how he encodes the digits "504" into the consonants "L, S and R" which to him, signify the word "laser". Tomoyori uses a similar technique in Japanese; "35" equals "sango" which in English means "a coral" (Takahashi et al., 2006). Additionally, Feng Wang's post experiment reporting reveal how he encodes the numbers "6389" to "Banana and Monk". These encodings mnemonics are used to create vivid images from the otherwise abstract digits (Ericsson et al., 2017) and are then coupled with a retrieval mnemonic like MoL (Yin et al., 2015). These encoding mnemonics have been poorly written about in the mnemonic literature (Mallow et al., 2015). Moreover, scant experimental research has investigated their efficacy with novice participants (Dresler et al., 2013). Indeed, only a few research papers have examined similar techniques (Higbee, 1997; Derwinger et al., 2003; Bellezza, Six & Phillips, 1992), and with very mixed results (Derwinger, Neely & Bäckman, 2005).

Therefore, the present study sought to introduce a novel digit-letter encoding mnemonic into the literature. This mnemonic was developed by an eight-time World Memory Champion named Dominic O'Brien and is known as the *Dominic System* (DS; O'Brien, 2013)

Dominic dominated the World Memory Championships from the early nineties to the early noughties winning the competition 6 years in a row (WorldMemoryStatistics.com, 2018). Since retiring from the competition in 2003, he has written a number of books including *"How to Develop a Brilliant Memory"* and *"The Amazing Memory Box"*. These books provide detailed descriptions of the techniques he uses to remember, numbers, dates, word lists, faces and playing cards. Of particular interest to the present study is a technique he calls

the "*Dominic System*" (DS). The Dominic System attempts to give numbers meaning by associating them with letters, which are then paired in twos to represent the initials of familiar people or characters. The following is an example of how the DS can be used; A = 1, B = 2, C = 3, 4 = D, 5 = E etc. thus, the number 15 could represent the initials AE and AE could then represent the initials of Albert Einstein. The idea is to encode number pairings in such a way that they elicit an image that can be visualised (O'Brien, 2013). A similar way of encoding digits was used in previous research by mnemonists to memorise record-breaking lengths of digits (Yin et al., 2015; Ericsson et al., 2017; Hu et al., 2009). Dominic asserts that his technique is an effective strategy for learning long strings of digits and moreover, that it is responsible for his memory achievements (O'Brien, 2013). However, the Dominic System is (as of 2018) yet to be evaluated under a scientific investigation with novice participants.

Research Aims

The present study is not the first to investigate the efficacy of the Method of Loci (MoL). However, it adds to the MoL literature in a number of respects. Firstly, it examines the effectiveness of a digit encoding system (The Dominic System) which appears to be novel in MoL literature. Additionally, it appears to be the first study that provides a detailed explanation of a digit encoding system. It is also novel in that it brings together an overview of the different techniques used by the world's greatest memorisers to achieve feats of memory. Moreover, it will add to the scant MoL literature that examines the effectiveness of MoL in learning abstract information among novice participants. Finally, this study will assess how quickly and effectively the method of loci and the Dominic system can be taught to naive participants. Previous studies teaching Mol to participants taught the technique over numerous sessions (Brehmer et al., 2007, Moè, & De Beni, 2004; Quereshi et al, 2014), For instance, Quereshi and colleagues (2014) taught the technique over three 60 to 90-minute

sessions and Moé and De Beni (2004) over three two-hour sessions. This study will leave no more than five minutes to teach both MoL and the Dominic System to participants.

The present study recognises the efficacy of the Method of Loci (MoL) in learning concrete information. However, it also acknowledges its shortcomings in learning abstract information. Therefore, if the Dominic system can withstand the scrutiny of scientific assessment and account for MoL's weaknesses thereby, the implications for future research are significant.

Pilot Study 1

The first pilot study had three main aims, (1) it sought to assess the efficacy of the proposed experiment, (2) to determine the length of time required for each intervention, (3) to examine levels of understanding, adherence or compliance rates for the two interventions (the Method of loci and the Dominic System). The pilot study did not make use of a control group nor did it investigate participants pre- intervention recall.

Participants

5 participants (N=5) took part in the pilot study, 3 were male and two were female. Ages ranged from 18 to 25. Participants were conveniently sampled from the National College of Ireland.

Materials

Materials for the first pilot study were a sheet of paper containing a string of 20 digits, a sheet of paper containing a distractor tasks (maths equations), an answer sheet, a stopwatch and a pen.

Procedure

Participants were assigned random participant numbers to ensure anonymity.

The Method of Loci

Training for the Method of Loci involved four stages: (1) A brief account of the history of the memory technique and its uses; (2) A description of the technique; (3) An example of it how it may be used to remember items of a grocery list; (4) Guided practice. All participants were students of the National College of Ireland and therefore the study used an experimenter-supplied MoL journey familiar to all participants. Participants were asked to close their eyes and to envisage the specific location as the experimenter brought them through each stage along the route. Following this, they were given 30 seconds to go through the MoL journey in their mind ensuring that the transitions from one stage to another are clear and memorable. This entire process took just under 3 minutes.

The Dominic System

Prior to a full description of the Dominic system, participants were presented with a list of 10 letter pairings (e.g. AE, BG). They were told to view the letter pairings as people's initials and were asked to try think of individuals for these letter pairings to represent. Participants were then given an example (e.g. "AE" could represent "Albert Einstein" and "BG" could represent "Bill Gates"). It took participants almost 8 minutes to think of individuals to represent all ten letter pairings. The Dominic System was then fully explained to participants (See introduction for description). Participants were encouraged to use one's imagination to envisage each of the ten images created at each of the ten loci along the MoL journey. The sequence of 20 digits was then presented to the participants and they were given 4 minutes to learn the digit sequence using Mol and DS. After this, the distractor task (maths equations)

was handed to the participants and they were given 1 minute to answer as many of the questions as they could. When the minute was up, participants attempted to recall the string of 20 digits in serial order. This study used strict serial and lenient serial scoring. This meant that two points were awarded for each correct digit in its correct serial order and one point was awarded for a digit that's in its wrong position but preceded by the correct digit.

Distraction Task

A distraction task was implemented in order to assess long-term memory more so than working memory (Higbee, 1997). The task contained two stages; (1) Maths equations (three); "4 x 13 - 7 =__", or "Count down from 1265 in 12s..". (2) Riddles (two); "What belongs to you but others use it more?". Participants were given one minute to answer as many questions as they could.

Results

Out of a possible 40 points; Participant 1 scored 32 points, participant 2 scored 28 points, participant 3 scored 4 points, participant 4 scored 25 points and participant 5 scored 34 points (Mean Score = 24.6). Analysis of a Likert scale (5-point scale) measuring compliance rates indicated that all participants bar participant 3 fully understood and implemented the techniques (scoring 5 on the Likert scale). Participant 3 reported a compliance rate of 0.

Discussion

The present pilot study was exploratory and its primary aim was to see if the interventions can be implemented successfully and within reasonable time periods. Additionally, the pilot study sought to identify different adherence or compliance rates among participants. Results showed that 4 out of the 5 participants understood the techniques and were able use them effectively. One participant failed to understand and implement the techniques. Individual

self-reports indicated that this participant's low compliance rate related to the MoL intervention. The participant understood the DS but was not able to implement it in combination with MoL. This may be partially due to retroactive interference as the Dominic System was taught directly after MoL training (Sosic-Vasic, Hille, Kröner, Spitzer, & Kornmeier, 2018). Recent research indicates that retroactive interference leads to forgetting in some individuals more so than others (Sosic-Vasic et al., 2018). The method of loci was successfully implemented within the desired time frame (3 minutes) however the Dominic System was not (9 minutes and 20 seconds). In order to reduce the time spent for the Dominic System training period future studies may suggest individuals or imagery to use for the letter pairings (e.g. HH could stand for Hugh Hefner/Hulk Hogan). Prior to implementation of DS participants could be presented with a sheet with all the suggested names and to rate familiarity levels on a Likert scale (Likert, 1932). This should dramatically reduce the time spent for the DS training period as participants spent almost 8 or the 9 minutes and 20 seconds thinking of individuals to use for the letter pairings. A similar system was implemented by Higbee (1997; Experiment 1) in an experiment using a phonetic mnemonic.

Pilot Study 2

Participants

In total there were four participants in the second pilot study, three were in the MoL and DS intervention group (MoLDS group; N=3), and one was in the MoL only intervention group (N=1). Participants were all male and 23 years of age (M=23). Participants were right handed and had no known cognitive impairments.

Materials

Materials for the present pilot study were two sheets of paper each containing a string of 20 digits, two sheets of paper containing distractor tasks (maths equations), two answer sheets, a stopwatch and a pen.

Procedure

Participants were asked to attempt to learn a string of 20 digits in serial order from left to right. They were informed that they would have 4 minutes to do so. Once the 4 minutes were up the digit sequence was taken away from them and they were handed a distractor task (See: Distractor Task) which they were given 1 minute to carry out. Following this they had 4 minutes to attempt to recall as many of the 20 digits as they could and in serial order from left to right. Upon completion they were allowed a few seconds to rest before the intervention began.

The Method of Loci

The training for the Method of Loci in the present pilot study followed the same process as in the first pilot study (See: Pilot Study 1). However, this study suggested a MoL journey from one's home to their place of work/study. The entire process took a total of 2 minutes and 30 seconds.

The Dominic System

The Dominic System carried out the same procedure as the first pilot study, however suggestions were supplied for the letter pairings.

Distractor Task

See Pilot Study 1

Results

MoLDS group - Means Time 1 (M = 40.5) and Means Time 2 (M = 58)

MoL only group – Mean Time 1 (M = 35) and Mean Time 2 (M = 36.5)

Discussion

For the Method of Loci intervention, participants were suggested to use their journey from home to work/college as the journey for MoL. Moè and De Beni (2004) posit that experimenter supplied Self-report analysis following the study revealed that all four participants used vastly different MoL journeys. Participant no.1 created four stages from his house to the bus stop, which was only 50 metres away, and then the next stage was where he got off the bus (3km away). The other participants had no issues with MoL.

Retrospective Reports & Discussion

Results from two participants from Time 1 to Time 2 did not show a significant difference. Both participants scored very highly at each timepoint. Self-report analysis revealed that Participant no.2 used a visualisation technique which involved two steps. He first separated the string of 20 digits into five groups of four digits (Chunking). He then pictured himself entering each grouped digit sequence into a machine he uses in work that is similar to the front of an old phone. He reported that this technique was effective for the first 3 to 4 groups but "blurry at times" and involved some guess work. The other participant used mnemonic techniques very similar to those used in Ericsson's (1981; 1982) work with the runners who used salient running times to remember the digit sequences. He remembered the digits by encoding them as meaningful numbers or famous sporting dates e.g. "'96' represented the 96 victims of the Hillsborough disaster". This technique was effective for the first 14 of the 20 digits but the participant reported an element of luck in finding meaning from the digit

sequences. Moreover, the participant reported that the meaningful dates did not provide much assistance to the serial order of the digit sequence. Future research will assist participants in creating their MoL journey in order to avoid confusion (as seen with participant no.1). Moreover, the number of digits to-be-learned will increase from 20 to 40 as participants in the MoLDS group seemed to find the tasks relatively easy after the intervention (M = 58).

Method

Participants

32 (N=32) participants took part in the present study, all participants were undergraduate psychology students attending the National College of Ireland, in Dublin, Ireland. Of the 35 participants 12 were male and 20 were female. Ages ranged from 18 to 29 years of age and the mean age was 21.63 (M = 21.63) with a standard deviation of 2.06 (SD = 2.06). The inclusion criteria for this study was English as first language and the exclusion criteria was no known cognitive disabilities. All participants were right handed. Participants initially signed-up for the experiment after receiving a brief description of the study during a lecture. Of those who provided their email addresses 40 were selected for participation. These 40 individuals were then contacted via email and half of the participants were randomly assigned to the experimental group and the other half to the control group. Participants assigned to the experimental group were taught both the method of loci and the Dominic system (MoLD group) and participants in the control group were only taught the method of loci (MoL group). Three subjects from the MoLDS group and five from the MoL group cancelled with short notice and were unable to be replaced.

Materials

Materials included a sheet of paper containing a random sequence of 40 digits, generated by a random sequence generator (Random.org), two distractor tasks (Appedix A), a sheet containing an experimenter-generated explanation of MoL and of the Dominic system (Appendix B), two answer sheets (Appendix C), a stopwatch and a pen.

Measurements

Design

The present paper used a quantitative quasi-experimental design. Participants were randomly assigned to either the experimental group or the control group. The first group received training in the Method of Loci and the Dominic System. The second group received training in the Method of Loci but not in the Dominic System.

Procedure

Method of Loci

MoL was implemented in the same manner as in the two pilot studies, However, all participants in the present study were students of the National College of Ireland and were all familiar with its campus, therefore it was feasible to use a common location for MoL. All participants reported being familiar with the specific route chosen by the experimenter (From the college's main entrance to the canteen exit).

Dominic System

See Pilot Study 2/Appendix B

Distractor Task

See Pilot Study 1

Measuring serial recall differs depending on the nature of the experiment, some papers have measured errors of omission and commission (Anderson & Matessa, 1997) others have looked at omission errors, commission errors and transpositional errors (Jurden, 1993), while other research used algorithms that account for deletion, substitution, translocation, and insertion errors (Mathy & Varré, 2013). Previous studies with the Method of Loci have assigned a point for an item being in the right position (strict serial score). A point for an item having the correct antecedent regardless of position e.g. if "popsicles" was in 9th position instead of 8th but "chips" preceded it (lenient serial score) and a point for each list item recalled irrespective of position (non-serial recall score; McCabe, 2015). In contrast to the present study, McCabe (2015) examined word list recall as opposed to digit recall. Non-serial recall of listed items was important to the above study as it demonstrated that participants remembered the item just not where it belonged. The present study however, examined serial digit recall and therefore, each digit (from 0 to 9) is likely to have appeared a number of times in the string of 40 digits. In other words, using non-serial recall would result in participants being rewarded for random number guesses. Hence, this paper used a system similar to all of the above but that is more applicable to the current study. It assigned 3 points to the correct number in its correct position, 2 points for the correct number 1 place (+/-) away from its correct position and 1 point for the correct number 2 places (+/-) away from its correct position.

Results

The first paired samples t-tests was conducted to evaluate the impact of intervention on the pretest and posttest scores for Group 1 (MoLDS Group). There was a significant increase in

scores for Time 1 (Pretest; M = 36.76, SD = 14.91) to Time 2 (Posttest; M = 67.88, SD = 29.47), t(16) = 3.65, p < .002 (two-tailed). The mean increase in scores from Time 1 to Time 2 was 31.11 (95% confidence interval ranging from 13.07 to 49.15). The magnitude of the effect was large (d = 1.07).

The second paired samples t-test was conducted to evaluate the impact of intervention on the pretest and posttest scores for Group 2 (MoL only Group). There was an insignificant difference in scores for Time 1 (Pretest; M = 37.67, SD = 22.75) and Time 2 (Posttest; M = 38.73, SD = 16.59), t(14) = 0.34, p < .737 (two-tailed). The mean increase in scores from Time 1 to Time 2 was 1.06 (95% confidence interval ranging from -5.61 to 7.75). The magnitude of the effect was small (d = 0.09).

Two independent samples t-test were conducted to compare pretest and posttest scores for the two groups. The first independent samples t-test compared pretest scores for the two groups. There was no significant difference in scores between the pre-test scores of the MoLDS group (M = 36.76, SD = 14.91) and the pretest scores of the MoL only group (M = 37.67, SD = 22.75; t(30) = -.13, p = .89, two-tailed). The magnitude of the differences in the means (mean difference = -.90, 95% CI: -14.63 to 12.83) was small (Cohen's d = 0.04).

The second independent samples t-test was conducted to compare the post-test scores for the MoLDS group and the MoL only group. There was a significant difference in scores between the two groups, t(25.76) = 3.49, p = .002, two-tailed with the MoLDS group (M = 67.88, SD = 29.47) scoring higher than the MoL only group (M = 38.73, SD = 16.59). The magnitude of the differences in the means (mean difference = 29.14, 95% CI: 12.01 to 46.28) was large (Cohen's d = 1.26).

Discussion

A profusion of studies has examined individuals with superior memory ability who have achieved incredible feats of memory in the World Memory Championship (Maguire et al., 2003; Raz et al., 2009). These memory achievements include learning tens of thousands of digits to the mathematical constant of pi (Takahashi et al., 2006). Some researchers report that superior innate memory ability mediates these achievements (Thompson, Cowan & Frieman, 1993; Wilding & Valentine, 1997). However, more recent research credits the use of mnemonic techniques (Ericsson et al., 2017; Takahashi et al., 2006) In spite of this, scant literature has examined the techniques used by these World Memory Champions (WMC) amongst novice participants (Mallow et al., 2015). As a result, the present paper proposed a novel mnemonic that is reported to be used by some of the WMC (O'Brien, 2013). The current study coupled the Dominic system with the method of loci in following with the skilled memory framework (Ericsson, 1985). The method of loci is suggested to be effective in facilitating the retrieval of concrete items (Hu, Yang, Lu & Ericsson, 2009). However, scant research has investigated its ability to learn abstract data. The present study will therefore assess the efficacy of MoL with the learning of abstract data in a task of serial digit recall.

The primary aim of this study was to see if an encoding mnemonic called the Dominic System could be coupled with MoL to improve memory recall for digits. The secondary aim was to examine the use of MoL on its own in learning digit sequences. Results from the combined intervention of the Method of Loci and the Dominic System revealed improvements in serial digit recall scores. Although the present study did not examine processing speed, its findings lend support to the skilled memory framework which suggests that superior memory ability results from the use of an encoding mnemonic (DS) and a retrieval mnemonic (MoL; Ericsson, 1985). Maguire and colleagues' (2003) reported that the expert memorisers in their study use mnemonic techniques to learn digit sequences. This

study demonstrated how novice participants can use similar techniques to those described by the experts (Raz el al., 2009; Ericsson et al., 2017) to achieve significantly greater results than can be achieved without the use of a memory technique. Roediger's (1980) early research on the method of loci reported it to be an effective mnemonic technique for recall on tasks of serial order. This finding paved the way for further investigation into the mnemonic (Legge, Madan, Ng, & Caplan, 2012; McCabe, 2015). The extant literature is consistent with the early work of Roediger (1980) as MoL interventions have reflected improved memory recall scores in a profusion of studies (Huttner & Robra-Bissantz, 2017; Legge, Madan, Ng, & Caplan, 2012; McCabe, 2015). However, the literature has mostly investigated MoL's efficacy with concrete information (Dresler et al, 2013). Prior to this research, scant papers have examined MoLs use with abstract data (Derwinger et al., 2003). It was hypothesised that this may be because MoL requires the creation of vivid imagery and without it the technique is of no benefit (Dresler et al., 2017). This hypothesis was supported by the findings of the current study.

Implications

With regards to implications among mnemonical literature, this study highlights the efficacy and potential for combining two mnemonic techniques for the learning of abstract content. Moreover, the present study introduced a novel mnemonic to the literature, this will hopefully add to the extant mnemonical literature which has seen scant developments in the previous decade (Dresler et al., 2013).

This paper has implications in educational research. Mnemonics have been found to assist memory recall in many cohorts of college students (Legge, Madan, Ng, & Caplan, 2012; Bass & Oswald, 2013). Moreover, Scruggs and Mastropieri (2000) report that mnemonic techniques like those examined in the present study are specifically useful with children of learning and behaviour related issues. Inability to learn school work at the same rate as other

students is a main cause of frustration for these children (Scruggs & Mastropieri, 2000) and focused training with MoL and DS may help to mediate this issue. Additionally, MoL interventions have been described as an enjoyable method of learning (Qureshi et al., 2014).

The findings of the present study may also have implications in cognitive interventions for individuals with mild cognitive impair. The research of O'Hara and colleagues (2007) indicates that older adults can benefit from training with mnemonics like the method of loci. Indeed, functional brain changes have been observed in older adults following long-term training with the method of loci (Dresler, et al., 2017). Improvements in mnemonic research like those of the current paper may also add to the memory related aspects of Cognitive training (Kelly et al., 2014) and cognitive rehabilitation (Kelly, Lawlor, Coen, Robertson, & Brennan, 2017).

Strengths and limitations

A significant strength of the present study was that it was the first paper to subject the Dominic System to the scrutiny of scientific investigation. Additionally, it adds to the paucity of modern research combining a retrieval mnemonic and an encoding mnemonic among novice participants (Ericsson, 1985). However, there were some limitations to the present study, the MoLDS group was carried out on one occasion whereas the MoL only group was carried out on two. Therefore, in spite of the relatively equal sample sizes (N=17 & N=15) there were significantly more participants in the MoLDS group than in the two MoL only groups. With this came a couple of limitations; There was more noise and distraction in the MoLDS group and it was significantly more difficult for the researcher to teach the intervention while ensuring that everyone understood.

Another notable strength of this study is that it adds to a dearth of research investigating the efficacy of MoL with abstract content like digits (Winding & Valentine, 1997). Results

showed that MoL was an ineffective strategy for learning abstract data unless it is coupled with an encoding technique. This finding is consistent with the literature (Derwinger, 2003). A noteworthy limitation of the current experiment was that levels of compliance with the mnemonics were not gathered from participants following the interventions. As a result, it could not be determined if poor understanding or misuse of the techniques accounted for poor performance scores. In addition to the above, the training periods for this experiment were vastly shorter than in similar studies were mnemonics have been implemented to improve recall (Mallow, 2015).

It ought to be noted that the measurements of memory used in the present study lack reliability and validity. The present study used a technique whereby 3 points were assigned for the correct number in its correct position, 2 points if the correct number was one position away from its correct position and 1 point if the correct number was two positions away from its correct position. Many studies use similar scoring systems (McCabe, 2015), however, for reasons specific to this study the current paper could not utilise these systems.

It is also important to note that due to limited time and resources the present study did not ask subjects in the MoLDS group to learn the specific encodings from the Dominic system (e.g. 1 = A, 2 = B). Other research using similar digit encoding mnemonics has asked participants to learn the encodings the night before the experiment (Higbee, 1997). However, in many cases, low post-intervention test scores in these studies were not indicative of an ineffective mnemonic. Instead, they reflected subjects' inability to properly use the mnemonic. Hence, the present study chose to supply the digit-to-letter encodings meaning that post intervention test scores reflect the mnemonic's efficacy in ideal conditions (Higbee, 1997).

Future Research

If future research wished to replicate the findings of this paper, it could introduce two groups to the study, an intervention group receiving training on the Dominic System on its own and a control group receiving no interventions. Moreover, the present study was not a randomised control trial as there were differences between the two intervention groups. Future research could implement the two groups in the exact same experimental conditions and with larger sample sizes. Moreover, an interesting addition to the current paper would be to add longitudinal data to effects of MoL and DS training. Some studies have found long-term performance related benefits of MoL use (Dresler et al., 2017) and even long-term changes in brain activity (Kondo et al., 2005). A future paper could look at the effect continued use and practice with MoL with DS has on one's recall, general memory ability and functional or structural brain changes. Moreover, there is a profusion of research papers looking at the brain activity of expert mnemonists as they encode, learn and recall abstract information using a combination of mnemonics similar to the ones used in this study (Maguire et al., 2003; Mallow et al., 2015; Ericsson et al., 2017). It would make interesting reading to see if brain activity of individuals using the techniques of the current study differ to those in the aforementioned studies.

Considering some of the procedural limitations of the current project, a future study with less time and resource restrictions could implement the method of loci and the Dominic system over a few training sessions. Then, participants could be tested on their ability to use the techniques prior to engaging in the study. The researcher in this study supplied a specific method of loci journey with pre-prepared stages, provided suggestions for letter combinations (See Appendix B) and supplied the digit to letter encodings for the Dominic system. Therefore, the results of this study are a reflection of results from ideal conditions. Hence, a future paper providing extensive training and testing with MoL and DS could produce more generalisable results.

Another procedural limitation of the current study was that the characters/individuals supplied by the experimenter (Appendix B) were supposed household names to the cohort of participants. However, participants were not asked to verify this presupposition. A future replication of this study could provide images of each of the supplied characters/individuals (Appendix B) and ask participants to rate their familiarity with each of them. This study may be then able to determine if poor familiarity mediates poor results.

Furthermore, in order to achieve truly skilled memory ability according to Ericsson (1985) individuals not only need to be proficient with an encoding mnemonic (DS) and a retrieval mnemonic (MoL) but also must have efficient processing speed. Future research with individuals extensively trained on the two mnemonics could attempt to increase their processing speed to improve digit span (Kiegl et al., 1987).

Conclusion

In conclusion, this paper adds to the extant literature by being the first paper to investigate the combination of the method of loci and the Dominic system in a task of serial order recall. Moreover, it extends the literature by introducing a novel memory system (the Dominic System) to mnemonical literature. Furthermore, this paper adds to the dearth of research investigating MoL's efficacy with digit learning. The results showed that MoL in combination with DS may be an effective strategy for improving serial digit recall. Despite some imperfect experimental conditions, and the short intervention time (5 minutes) significant increases in mean scores were observed following the MoLDS intervention. The significance of these mean changes was further strengthened by the insignificant increases in mean scores seen in the MoL only group. Finally, implications for the findings of the current study were discussed in relation to the extant literature on mnemonics and for education or cognitive intervention.

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Appendix A (Distractor Task)

Participant No.

Maths Equations	$19 + 87 - 38 =$
	$8 \times 14 =$
	Count down from 999 in 14s.. 985 ___ 957 ___ ___

Riddles

What comes once in a minute, twice in a moment, but never in a thousand years?

If the day after tomorrow is three days before Wednesday, what day is today?

Appendix B (The Dominic System Intervention)

1 = A	**6 = S**
2 = B	**7 = G**
3 = C	**8 = H**
4 = D	**9 = N**

5 = E   **0 = O**

LOCI 1 - (NCI ENTRANCE) - SANTA GOING "**HO, HO, HO**", HOLDING A **B**IG **D**IAMOND
(**HO** = 80; **BD** = 24)

LOCI 2 - (WHEELCHAIR RAMP) - **E**D **S**HEERAN/**ES**COBAR DRESSED AS **GA**NDHI
(**ES** = 56; **GA** = 71)

LOCI 3 - (SEATING AREA) - **H**UGH **H**EFNER/**H**ULK **H**OGAN FIGHTING **BA**TMAN
(**HH** = 88; **BA** = 21)

LOCI 4 - (FOUNTAIN BESIDE TOILET) - **OB**AMA DANCING WITH **S**NOOP **D**OGG
(**OB** = 02; **SD** = 64)

LOCI 5 - (BESIDE TROPHY CABINET) - **G**RAHAM **N**ORTON HOLDING A GIANT **CD**
(**GN** = 79; **CD** = 34)

LOCI 6 - (RECEPTION) - **N**I**D**G**E**/**N**OEL **G**ALLAGHER/**N**U**G**GET FIGHTING **D**ONALD
DUCK
(**NG** = 97; **DD** = 44)

LOCI 7 - (MIDDLE OF ATRIUM)- **S**IDESHOW **B**OB/**S**A**B**RINA DRESSED AS **HA**RRY
POTTER
(**SB** = 62; **HA** = 81)

LOCI 8 - (CANTEEN ENTRANCE) - **D**OU**G**AL/**DO**G RUNNING FROM **B**ART **S**IMPSON
(**DG** = 47; **BS** = 26)

LOCI 9 - (CANTEEN EXIT)- **A**LBERT **E**INSTEIN TEACHING **D**AVID **B**ECKHAM/**D**AVID
BOWIE
(**AE** = 15; **DB** = 42)

LOCI 10 (SMOKING AREA)- **G**OD THROWING **S**TEPHEN **H**AWKING OFF HIS
WHEELCHAIR
(**GD** = 74; **SH** = 68)

Appendix C (Answer Sheet)

Attempt to recall the digit sequence in serial order (from left to right)