FIXED VERSUS FREE CHUNK SIZES ON MNEMONIC EFFICIENCY

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B.A. (Hons) in Psychology

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Submission of Thesis and Dissertation

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First, I would like to thank my mother Alice, for everything she has done for me.

I would like to thank my two half-sisters, Liv and Hannah, for providing immeasurable happiness anywhere they go.

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Abstract

Previous research in short-term memory and working memory theories have long suggested average size limits on memory processes, from 7±2 and then to 4±1 individual pieces of information. Research into mnemonics and memory efficiency has looked for a way to further optimize the amount of individual raw data that can be stored, and arrived at between 3 and 4 as the most optimal chunks. This study used a between-groups study design with a digit span task in order to compare the success rate of participants memorizing a 15-digit number using the chunking mnemonic when told to use the optimal chunk size of 3 and when allowed to use their own, personally intuitive sizes. On average, participants using only chunks of 3 answered 1.73 more numbers correctly than the rest, with a significant effect. These findings may allow for improved interventions or training courses for mnemonics and working memory capacity, a metric associated with increased reading, language and attention skills.

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Ever since the transition from ‘short-term memory’ as outlined in Atkinson, & Shiffrin’s (1968) multistore model of memory to the working memory model proposed by Baddeley & Hitch (1974), a wealth of research within cognitive psychology has focused on exploring the capacity of human temporary memory as well strategies and techniques to optimize it, both for efficiency purposes and general quality of life. Using the knowledge discovered in this research, even attention, reading and language tasks see a better performance as a result of a stronger working memory (Haarmann, Davelaar & Usher, 2003; Unsworth & Engle, 2007), particularly within youth with disabilities (Wolgemuth, Cobb & Alwell.

We call these strategies ‘mnemonics’, a term which spans all learning techniques developed to aid in the retention or retrieval of information (McCabe, Osha, Roche & Susser, 2013). Many function by encoding the information into differently processed parts or utilizing cues to more efficiently retrieve it from pre-established memories. One such technique is chunking. Chunking, as a mnemonic strategy is described as a method to group together numbers or other pieces of information by processing them together as single concepts (Bellezza, 1981). For instance, one could memorise 2412 as the day and month of Christmas, joining up 24 and 12 as two separate chunks instead of the 4 individual components.

Originally it was proposed the average human could contain 7±2 individually processed pieces of information in their short-term memory (Miller, 1956), but time and expanded research has shown 4±1 to be more accurate, (Cowan, 2001) though varying heavily by age (Allen & Crozier, 1992) and other measures of working memory capacity (Gilchrist, Cowan, Naveh-Benjamin, 2008; Oberauer, 2005). However, these values do not account for nested chunks. Empirically, we believe chunk sizes range from 3-7 for a variety of tasks (Simon & Barenfeld, 1969; Simon, 1970), with the mathematically most efficient chunk size for any scale of nesting being either 3 or 4 (Dirlam, David, 1972; Mathy & Feldman, 2012).

By nesting 3 or 4 numbers at a time and memorising them as 1 individual chunk each, the average human can store a total of 9 to 20 individual numbers in their short-term memory rather than just 4±1 without any chunking at all – a significant increase compared to unrefined information. This demonstrates the usefulness of exploring mnemonic options for learning and memory optimisation, but still doesn't take into account any individual differences as defined by Cowan, Nelson, Zhijian & Jeffrey (2004) and measured through serial recall tasks. Studies have failed to draw any direct correlations between individual differences and preferred mnemonic style (Frensch & Miner, 1994; Lyon, 1977).

Gobet et al. (2001) distinguishes between conscious/deliberate and unconscious/automatic chunking. Deliberate chunking is described as specific, goal-oriented and under strategic control, while perceptual chunking is explained as automatic, continuous and linked to perceptual processes (Gobet, Lloyd-Kelly & Lane, 2016). In a task involving memorising and reciting a number sequence, if the participant has a specific goal and is explicitly dedicating all of their attention towards the task, they are considered to be using goal-oriented chunking. In a less controlled environment, such as on a football field, it could be argued players are employing perceptual chunking when memorising the opposition's formations and movement.

With this distinction of the two chunking types, we are able to explore more in-depth the limits and factors of each of the styles. In addition to defining the types, Gobet et al. (2001) suggested the practical use of further research into the goal-oriented style in particular, for use in academic settings. David Dirlam (1972), and more recently, Cowan (2001) placed numbers on what they considered empirically sound grouping quantities in chunking, and found links to some peoples' innate bias to skew towards the mathematically most efficient chunk sizes when chunking, which is between 3 and 4.

Using the information from these studies as well as a working memory digit span task derived from Daneman and Carpenter's (1980) original reading span task, an experimental study may be conducted in an attempt to measure the difference in efficacy between participants told to perform the task using the theoretically optimal chunk sizes and participants performing it without instruction of sizes to use. This could potentially provide us with new information on how best to use and teach the chunking mnemonic, or establish an emphasis on letting people use their current, intuitive chunk sizes.

The current study aims to explore how well humans remember number sequences using the chunking mnemonic when they can choose the chunk sizes themselves and when they are given set sizes to follow based on the mathematically most efficient ones. We hypothesize there will be a distinct difference in the accuracy of the digit span task between the unconscious, free choice of chunk sizes and the forced ones. In addition, we believe people might subconsciously default to using the chunk sizes closest to the mathematically optimal ones even without being asked, based on previous research by Simon (1974) as well as Jarrold and Howse (2005).

Methods

Participants

Due to a lack of time and funding, participants were primarily recruited from full-time and part-time psychology classes at the National College of Ireland as a form of convenience sampling, with extra participants gathered through snowball sampling via email sharing at the end of the test. A total of 50 participants were collected, of which 18 were female. The age of participants ranged from 19 to 60, $M = 26.3$, $SD = 9.8$. The sole exclusion criteria was in the case of non-answers, of which there were none.

Measures and Materials

Participants were shown simple presentation slides made in Microsoft PowerPoint via a projector within the college classrooms in which the study took place, containing the full, unbroken number sequences from the number lists (See Appendix A, B). All responses were written down by the participants themselves with pen or pencil on paper, and collected for later encoding into IBM SPSS Statistics 26 computer software. A stopwatch was used to keep track of the 30 seconds during which participants could memorize the numbers. Once encoded, size and quanity of chosen chunks for both fixed and free groups were manually counted, and submitted responses to the memory task were scored and added to the SPSS dataset.

Responses were scored by granting one cumulative point for each number submitted in the right place of the 15-digit number sequence. A correct number in for example position 7 would grant a point regardless of correct numbers before or after it. The scoring method of working memory span tasks is a neglected topic in the literature (Conway et al., 2005), as there is no universal measure. Our scoring method is one of the simpler ones, but allows for points to be earned on random guesses after participants without perfect scores have recited as much as they remember.

Research Design

Our research utilizes an experimental working memory digit span test based on the original reading span task by Daneman and Carpenter (1980). This task involves memorizing and reciting a long number list and is therefore categorized as a goal-oriented chunking style as distinguished by Gobet et al. (2001).

The number 3 as chosen for the fixed trials is based on empirically sound chunk sizes as well as mathematical formulas outlining the most efficient approach to chunking (Cowan, 2001). Two separate number lists are used to mitigate the risk of accidentally using patterned sequences in the task, as advised by previous studies on chunking tasks (Mathy & Feldman, 2012).

This is a quantitative study, as we want a numerical analysis on mathematical efficiency and definitive results of accuracy on a task. We will be using the framework for experimental design, as the procedure has been developed for this specific study in an attempt to measure one group of participants' accuracy of a memory-based task when performing it with fixed variables, as well as measuring another group to keep track of their naturally selected independent – or free- chunk sizes.

This study used a between-groups study design, meaning each participant will test only one condition and each of the conditions will be compared. Our primary dependent variable is the score; the amount of numbers participants recited in the correct place. A secondary dependent variable is which of the two number lists the participants are exposed to, A or B. The independent variables is the group the participants were assigned to, either Fixed or Free. While there are four groups in total, the two primary dependent variable groups will be merged and analyzed together should there be no significant difference in results based on the specific number lists.

Procedure

Prior to any participants entering the room at any of the scheduled appointments, or prior to the researcher entering the classroom in which the potential participants were already seated from previous obligations, they would collectively be assigned to one of four groups: Fixed A, Fixed B, Free A or Free B. The group name suffix would determine whether the experiment would expose them to Number List A (Appendix A) in either of the two A groups or Number List B (Appendix B), in either of the two B groups. It would also later determine whether they would be asked to memorize a 15-digit number using fixed chunk sizes of 3, or free chunk sizes, in which they could choose the size of their chunks themselves. The pre-emptive group selection was based on whichever group had the fewest total responses at the time, in order to keep all the groups as balanced as possible.

All participants were sat down in a classroom or lecture hall. Consent forms (Appendix C) were handed out, and participants were given ample time to read and fill them out should they agree to participate in the study. A Powerpoint slide (Appendix D) was then projected in front of the participants to serve as an example during the explanation of chunking. They were told the chunking mnemonic to be used in the upcoming task functioned by grouping together connected items or words in order to memorise them as single units. In the example slide, “087” was shown as a common prefix to Irish phone numbers and therefore a possible chunk to use when memorizing such a phone number. “9191” was used as an example of either a potential chunk of 4 as it is two double-digit numbers repeated after one another, or two smaller, separate chunks of 91.

If the group of participants were assigned to either of the two Fixed groups, they were then told to exclusively chunk the upcoming number in groups of 3. Otherwise, they were told they could chunk the upcoming number in any size or combination of chunks that they wanted, but that they had to put a space, a dot, or in any way separate the chunks within their answer so that it would be possible for the researchers to later determine what kind of chunks were used.

Participants were explained that the task would involve a 15-digit number appearing on the projector for exactly 30 seconds, during which they were to memorise it as best as possible, using the chunk sizes previously explained. After the time was up, they were to recite it on the back of the consent form. They were informed there would first be a practice round, of 9 digits.

The practice number (Appendix E) was shown on the projector, and a stopwatch was set for 30 seconds. At the halfway point, the researcher quietly told the group: “Halfway”. Once the time was up, the slide was hidden and the participants recited the number on the back of the consent form. After everyone had recited the number, the practice number was shown again in case anyone was curious as to how well they performed.

Participants were informed that the next task was the large, 15-digit number and that they would once again have 30 seconds to remember it before reciting it on the back of the form. If the participants had been assigned to either of the A groups, they would be shown Number List A (Appendix A) on the projector, otherwise they would be shown Number List B (Appendix B). The timer was set to 30 seconds and the halfway point acknowledged exactly as done in the practice task. Once the time was up, the number was hidden and the participants began to write down what they remembered.

Finally, participants were informed that this marked the conclusion of the practical task, and that the researcher would explain the purpose of the study and the existence of the other groups to anyone who wished to remain and listen. All consent forms with results written on them were collected as soon as all participants were finished.

Results

Descriptive Statistics

There were 26 participants in total in the Fixed groups, of which 15 were exposed to Number List A, and 11 to Number List B. There were 24 participants in total in the Free groups, of which 12 were exposed to Number List A and 12 were exposed to Number List B.

There were 4 age groups:

18-25 with 38 participants and a mean score of 7.32.

26-35 with 4 participants and a mean score of 8.5.

36-45 with 4 participants and a mean score of 9.75

46+ with 4 participants and a mean score of 10.

Gender.

Descriptive Statistics Age

	N	Minimum	Maximum	Mean	Std. Deviation
Age	50	19	60	26.34	9.886
Valid N (listwise)	50				

Descriptive Statistics Gender

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	male	32	64.0	64.0	64.0
	female	18	36.0	36.0	100.0
	Total	50	100.0	100.0	

Inferential Statistics

Participants exposed to Number List A scored slightly higher (M = 8.11, SD = 3.66) than participants exposed to Number List B (M = 7.48, SD = 2.44), but to an insignificant effect, $t(48) = 0.7$, $p = 0.48$, two-tailed. We can now safely combine the four groups into two for analysis, separated only by chunking style rather than number list.

Group Statistics

	NL	N	Mean	Std. Deviation	Std. Error Mean
Correct Numbers	NLA	27	8.11	3.662	.705
	NLB	23	7.48	2.447	.510

Independent Samples Test

		Levene's Test		t-test for Equality of Means						
									95% CI	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Correct Numbers	EVs assumed	5.646	.022	.705	48	.484	.633	.898	-1.172	2.438
	EVs not assumed			.727	45.596	.471	.633	.870	-1.119	2.385

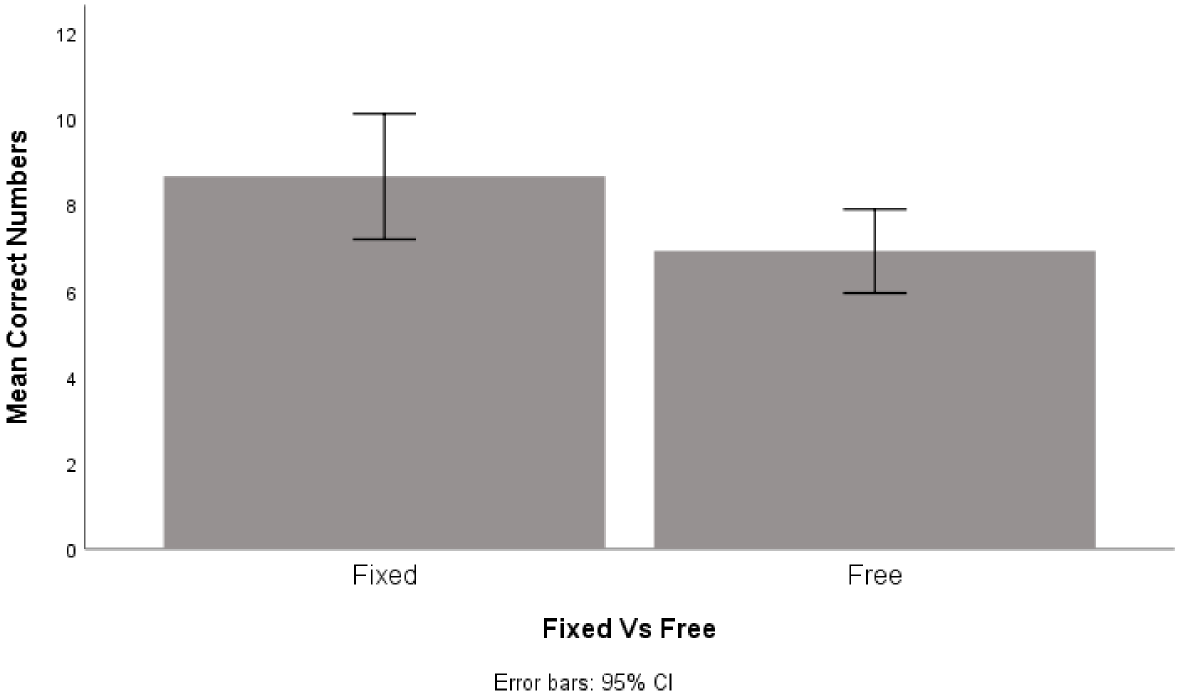
An independent samples *t*-test was conducted to compare difference in the mean scores between the Fixed versus Free groups. Levene's Test for Equality of Variance reported a significance of $p = 0.012$, indicating there had been a breach in the assumption of homogeneity of variance. The corrected equations for variance not assumed show there was a significant difference in results between chunking styles, whereas participants in the two Fixed chunking groups, 1 and 2, answered more numbers correctly ($M = 8.65$, $SD = 3.61$) than participants in the two Free chunking groups, 3 and 4 ($M = 6.92$, $SD = 2.3$), t(48) = 2.04, $p = 0.047$, two-tailed. The magnitude of the differences in the means (mean difference = 1.73, 95% CI: 0.023 to 3.451) was moderate (Cohen's d = 0.58). The *t*-test power was calculated to be 0.985 with an effect size of 0.58.

Group Statistics

	Fixed Vs Free	N	Mean	Std. Deviation	Std. Error Mean
Correct Numbers	Fixed	26	8.65	3.610	.708
	Free	24	6.92	2.302	.470

Independent Samples Test

		Levene's Test		t-test for Equality of Means						
									95% CI	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Correct Numbers	EVs assumed	6.855	.012	2.009	48	.050	1.737	.865	-.001	3.475
	EVs not assumed			2.044	42.833	.047	1.737	.850	.023	3.451



Female participants had a tendency to score higher (*M* = 8.78, *SD* = 3.49) than male participants (*M* = 7.28, *SD* = 2.85), t(48) = -1.55, *p* = 0.1, two-tailed. The magnitude of the differences in the means (mean difference = -1.49, 95% CI: -3.33 to 0.33) was small to moderate (Cohen's d = -0.47), but ultimately insignificant.

Group Statistics

	Gender	N	Mean	Std. Deviation	Std. Error Mean
Correct Numbers	male	32	7.28	2.854	.504
	female	18	8.78	3.490	.823

Independent Samples Test

		Levene's Test		t-test for Equality of Means					95% CI	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Correct Numbers	EVs assumed	1.175	.284	-1.642	48	.107	-1.497	.912	-3.330	.336
	EVs not assumed			-1.551	29.872	.132	-1.497	.965	-3.468	.475

The quantity and size of the chunks used by the 24 participants in the Free groups were counted manually. Primary chunk size indicates a participant having a specific size of chunk containing more or equal numbers in total than any other specific chunk size.

Chunk sizes (X)	**Number of participants using at least one instance of X**	**Number of participants using X as primary chunk size**
1	3	0
2	11	5
3	12	5
4	7	7
5	4	3
6+	7	4

Discussion

Although at the violation of a statistical assumption and barely at the p-value threshold, a significant difference was found in the mean score of participants using Fixed chunk sizes of 3 and participants choosing their own chunk sizes. On average, participants in the Fixed groups scored 1.73 higher on a scale of 0-15 than the Free groups. Only two participants correctly reported all 15 numbers, and they were both in the Fixed groups.

Not enough data was gathered for more detailed analysis of default chunk sizes for the Free group, however at least one instance of chunk size 3 was spotted in 12 out of 24 participants, followed closely by 2 at 11 participants. 7 out of 24 participants used 4 as their primary chunk size, and chunk sizes 2 and 3 were tied second for primary chunk size at 5 participants each.

No significant findings were found between the number lists and score, meaning both numbers were at relatively equal difficulty. The study found no significant link between gender and scoring. A wider range of age demographics is required for valid analysis on age and score.

Implications

The findings support a large amount of research suggesting 3 is the most efficient chunk size (Cowan, 2001; Dirlam, David, 1972; Mathy & Feldman, 2012), however this study lacked the data to find any indication of people’s innate bias to skew towards this size, unlike in other studies (Chen & Cowan, 2005). If indeed the mathematically most efficient chunk size of 3 is superior to whichever other chunk sizes people default to like we found in our study, this could be taught in interventions or practices of memory techniques in order to ensure as many people as possible are using the best possible method for goal-oriented chunking they can.

Strengths and Limitations

As a result of lack of time, funding and research assistance, a large majority of participants were gathered from full-time and part-time psychology courses within the same college within Dublin city. The sample size is barely adequate for the types of analysis we would like to conduct.

One major flaw in the procedure that was not discovered in time was that participants were not informed on whether to stop reciting numbers after they had written down as many as they remembered, or if they were to randomly guess the rest of the numbers until they had reached 15. As a result, some participants only submitted a handful of numbers and thereby placed a soft cap on their potential score, while others submitted the full 15 regardless of how many they managed to memorize and had a reasonably high chance to earn more points just by guessing correctly. This may have skewed the results.

As an experimental study, there is no prior research that can corroborate the efficiency and accuracy of our scoring methods and procedure for this particular task, however the very simple instructions and structure of the actual task allows for wide alterations to be made in the case of future research.

Future research

A larger scale study focusing on efficiency of chunk size and with other measurements may be warranted, as there are still not enough studies looking into this particular subtopic of mnemonic efficiency, and we believe there is still insight to be gained from optimizing manual goal-oriented chunking. A longitudinal study could be conducted comparing digit span test results in individuals told to use optimal chunking in everyday life versus a control group. This way we could effectively determine whether preferred mnemonic style interventions have any actual merit.

While this study fits in with research on mnemonic efficiency in goal-oriented chunking, research on unconscious, automatic chunking should not be ignored. While it is very difficult to research due to its subconscious and personal nature, it may be the next step towards improving working memory capacity in individuals.

Conclusion

Significant results were found in relation to chunk size and numbers memorized within the chunking mnemonic, in that participants asked to only use chunk sizes of 3 outperformed participants allowed to use any size they preferred. Findings of 3 as an optimal or near-optimal size for chunking in the average population supports previous literature, but the challenging of the optimal size against individuals' intuitive chunking methods has not been done in a similar manner before, opening small windows for new, focused research.

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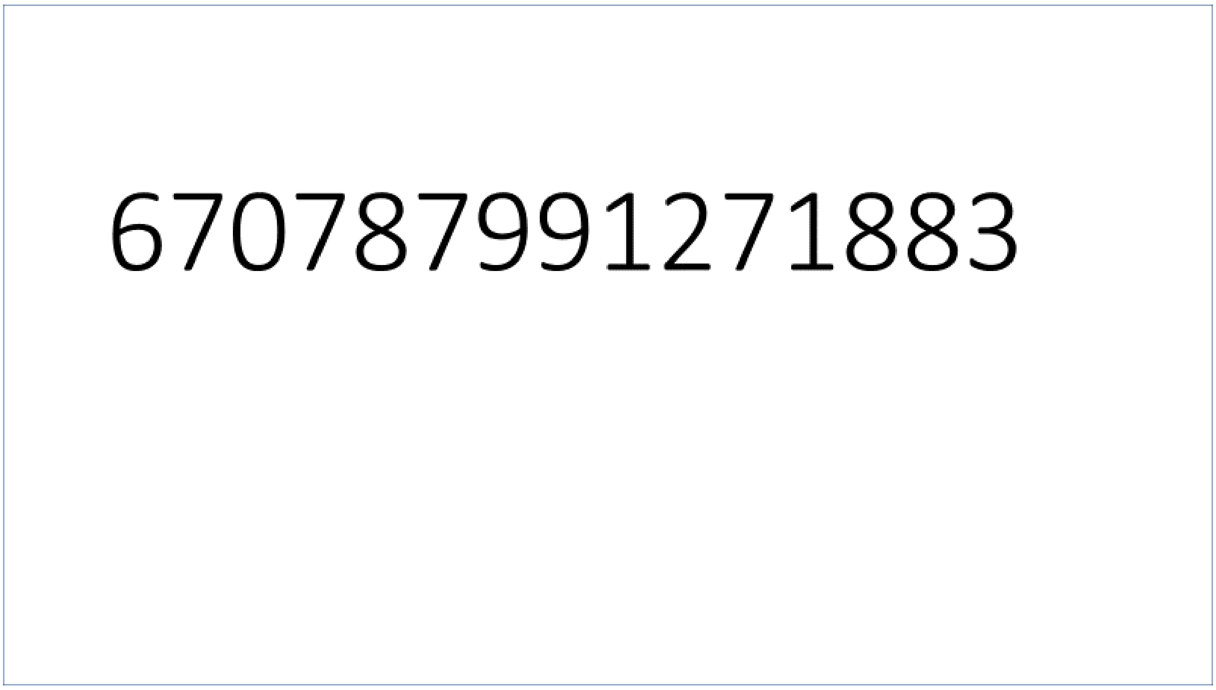
Appendix

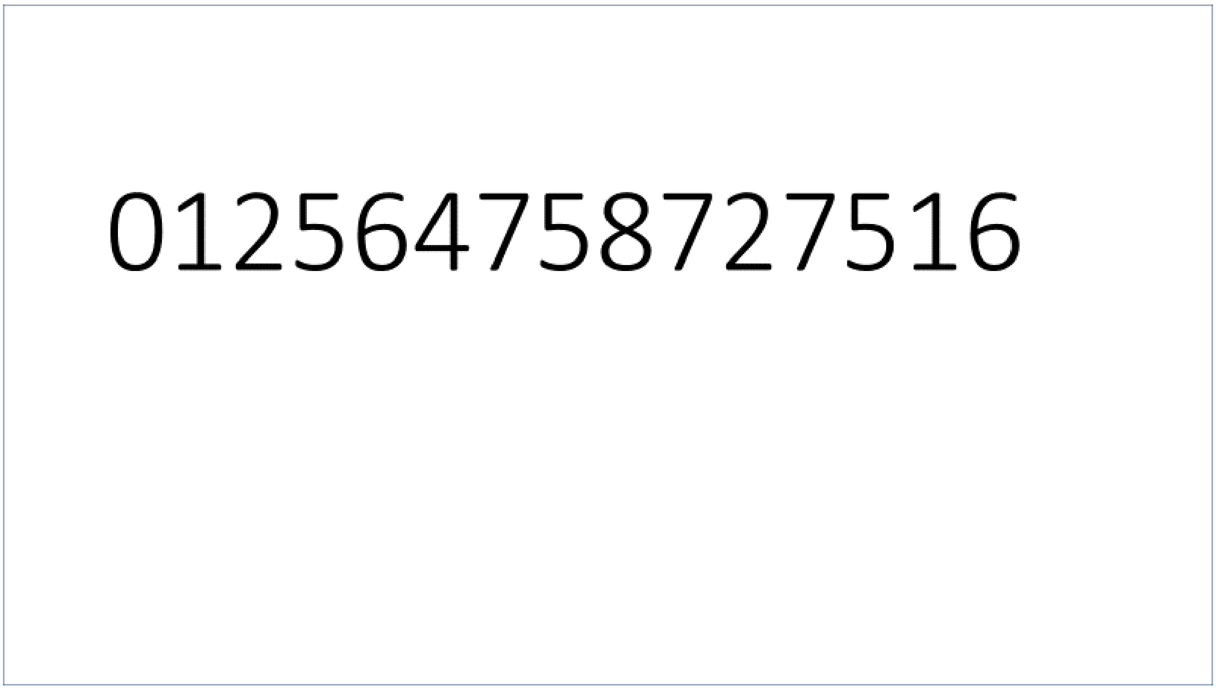
Appendix A

Number List A = 670787991271883



Appendix B

Number List B = 012564758727516



Appendix C

Consent form

This research is being conducted by Vaughan Andrew Bjørn Lund, an undergraduate student at the School of Business, National College of Ireland.

This task will involve reading, memorising and reciting a 15-digit number.

The method proposed for this research project has been approved in principle by the Departmental Ethics Committee, which means that the Committee does not have concerns about the procedure itself as detailed by the student. It is, however, the above-named student's responsibility to adhere to ethical guidelines in their dealings with participants and the collection and handling of data.

I have been informed as to the general nature of the study and agree voluntarily to participate.

There are no known expected discomforts or risks associated with participation.

All data from the study will be treated confidentially. The data from all participants will be compiled, analysed, and submitted in a report to the Psychology Department in the School of Business.

Data is at all times de-identified and will never be traceable to the participants.

Data will be stored and used to determine differences within fixed and free chunk sizes in mnemonic efficiency.

Data may be stored and used for future research different than the one outlined.

At the conclusion of my participation, any extra questions or concerns I have will be fully addressed.

I may refuse to participate and withdraw from this study at any time

I, the voluntary participant, have read, understood and accepted the above

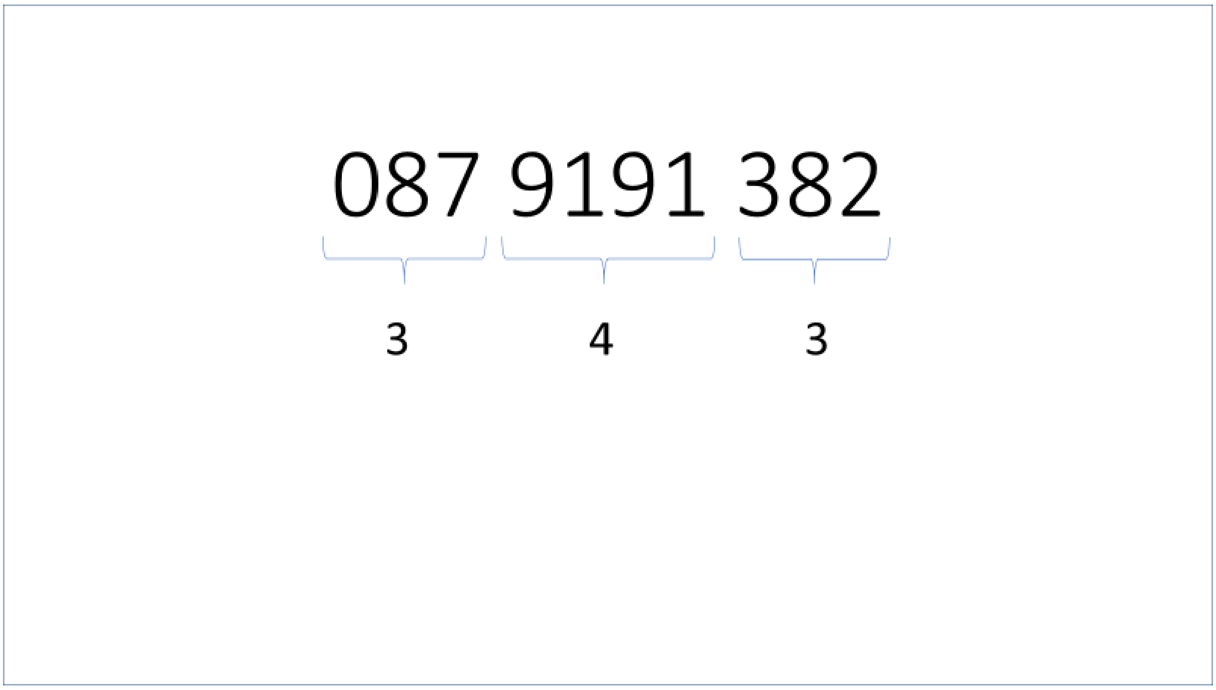
Participant age:________________

Participant gender:______________

Researcher ___________________ Date _______________________

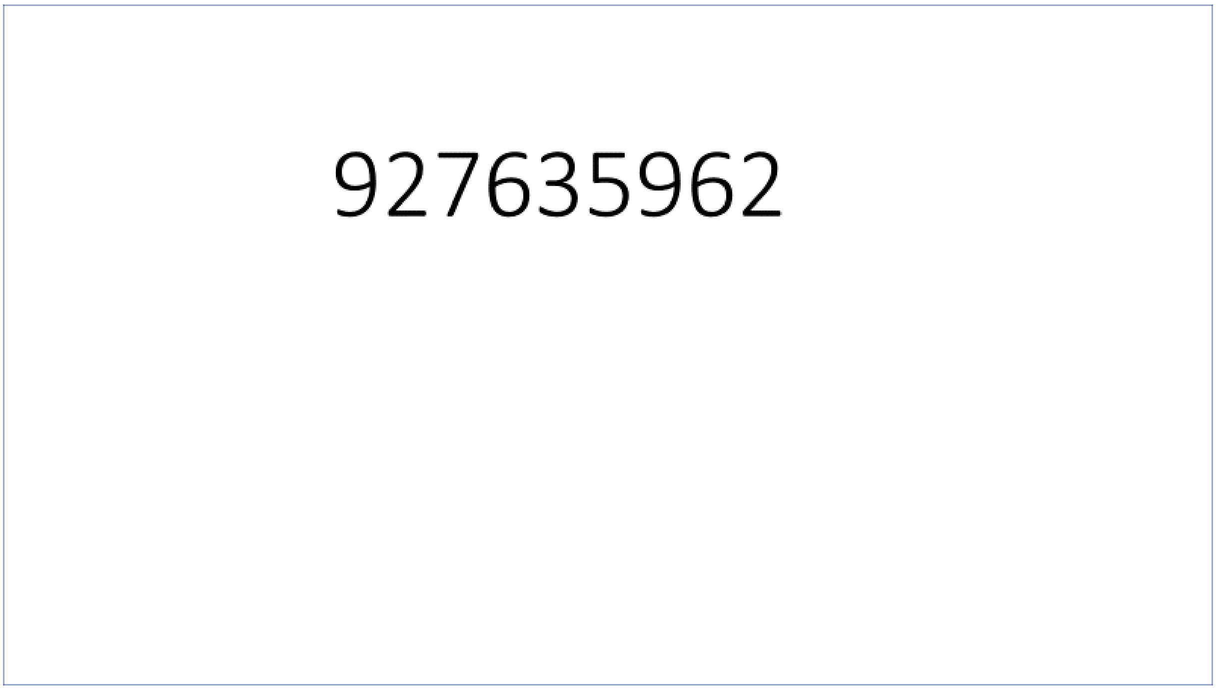
Appendix D

Powerpoint slide demonstrating chunking



Appendix E

Practice number Powerpoint slide



Appendix F

Screenshot of SPSS dataset – Proof of evidence

	ID	Numbers_Response	Numbers_Correct	Age	Gender	Group	Group_Combined	Number_List
1	1	670787991271883	15	21	2	1	1	1
2	2	670787991271883	15	50	2	1	1	1
3	3	670787991271	12	38	2	1	1	1
4	4	670787991272780	12	34	2	1	1	1
5	5	670787991832	9	20	2	1	1	1
6	6	670787991283691	10	20	1	1	1	1
7	7	670787991371831	12	22	2	1	1	1
8	8	670787991683	9	43	1	1	1	1
9	9	670771991697883	10	21	1	1	1	1
10	10	680787	5	21	2	1	1	1
11	11	6708701297803	3	23	1	1	1	1
12	12	670708	4	23	1	1	1	1
13	13	670887991277283	12	20	2	1	1	1
14	14	6709957788813	4	50	2	1	1	1
15	15	607781991	6	20	1	1	1	1
16	16	012564754727916	13	21	1	2	1	2
17	17	012564718727026	12	60	1	2	1	2
18	18	012564758	9	38	2	2	1	2
19	19	012564758	9	54	2	2	1	2
20	20	012564778	8	19	1	2	1	2
21	21	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Full dataset may be supplied upon request.