Investigating the effects of organisation on learning

Clive Newstead

Abstract

Background: Previous research suggests that the organisation of information is integral to its storage in and recall from memory. **Aim:** Differences with regard to the use of categorisation of information have been observed between cultures and age groups, so the aim is to find out the degree to which categorisation affects the learning of information in 16-18 year olds. **Method:** 20 participants aged 16-18 had 60 seconds to learn as many words as they could from a grid containing 24 words. The grid contained 6 words in 4 different semantic categories and was either categorised (control) or randomised (experimental). Participants then recalled as many of the words as they could. The amount of words that they recalled was observed. **Results:** The difference in the number of words remembered between the two conditions was found to be insignificant when put to the independent *t*-test and tested at the 0.05 level. In fact, participants in Condition B (randomised) recalled more words on average than those in Condition A (organised). However, participants in Condition B showed 68.83% categorisation upon recall, compared with 0.5% that would have been shown if participants recalled the words in the order that they appeared on the radomised grid. **Conclusion:** The results suggest that the degree of organisation of information upon presentation does not affect the amount of information remembered. However, the actual process of mentally organising the information may be a significant factor in the amount of information remembered. Individual differences may affect the way the information is organised, but this study found that categorical organisation was the most common form of this.

Introduction

Much evidence suggests that information in memory is highly organised, and that we remember large amounts of information by associating it with other similar pieces of information already stored. It may even be that the organisation of information is a prerequisite for information to be stored; for example, Mandler (1967) stated that *memory and organization are not only correlated, but organization is a necessary condition for memory.* From this viewpoint, it follows that, by definition, any information stored in the memory must be organised somehow. It may also be that the organisation of information upon presentation facilitates its storage, and that if information is not organised, people will attempt to create their own methods of organisation (Tulving, 1968).

Categorical clustering is a term coined by Bousfield (1953) in order to describe one type of organisation in learning. In his research, he presented participants with a list of 60 words (15 from 4 different categories: animals, anthroponyms, professions and vegetables) and asked participants to free-recall the list. He found that, despite not having been told what the categories were, participants tended to recall the words according to their category and thus demonstrated the phenomenon.

Bower *et al.* (1969) presented participants with words which were arranged into conceptual hierarchies. For one group, these were arranged in *hierarchical form*, and for the other they were listed randomly. The participants who were presented with the words in hierarchical form recalled almost 3½ times as many words as those to whom they were presented randomly, suggesting that the organisation of the words upon presentation facilitated their storage in memory.

A similar trait has also been observed with naturally occurring stimuli. Rubin and Olson (1980) asked students to recall the names of as many members of staff in their school as they could, and found that students showed a strong tendency for the members of staff's names to be recalled by their respective departments. This also shows evidence for categorical organisation. They further found that students who re-arranged word cards into more categories remembered more words on average than those who created less categories, and that those who were not told to actively remember the words, instead just sort them, remembered the same amount as those asked to remember them. These indicate that not only does categorisation increase the amount of information remembered, but the active process of organisation may even *cause* the information to be remembered.

More support that organisation and learning are intertwined comes from Kahana and Wingfield (2000), who found that the relation between organisation and learning remained the same even after significant differences between participants' mnemonic abilities had been taken into account.

One case study which suggests that memory is highly organised comes from Hart *et al.* (1985). Having almost made a complete recovery from a stroke two years previously, M.D. experienced no problems except that he was unable to name different types of fruit and vegetable or sort them into categories. However, he *was* able to name and sort types of food, for example, and vehicles, which suggests that his inability to carry out these tasks was limited to specific semantic categories.

Aims

The findings of this previous research suggest that organisation does play a large role in the storage, structuring and restructuring of information in memory. However, organisation does not necessarily imply categorisation, which is what will be tested here. Also, in a similar way that Gutchess *et al.* (2006) found that age and culture affected the way in which categorisation was used in memory, it may be that young people in turn use it differently.

So, the following experiment aims to investigate the effects of organisation on learning in 16-18 year-olds. More specifically, it will investigate the degree to which organisation of information upon presentation affects the storage and recall of words presented in a randomised grid. Following on from research by Bower *et al.* (1969) and Rubin and Olson (1980), two hypotheses have been drawn:

Experimental hypothesis

Participants will recall, on average, fewer words when the words given are listed randomly, than will the participants for whom the words are listed categorically.

Null hypothesis

There will be no difference in the average total amount of words recalled between participants to whom the words are listed categorically and those to whom they are presented randomly.

Method

The study was carried out using a controlled experiment with an independent measures design. The independent variable was the degree to which the word grid was categorised and took two values: categorised (control) or randomised (experimental). These respectively formed the two conditions, A and B respectively, of the experiment. The dependent variable was the amount of words recalled from the list.

Standardised instructions (see Appendix 4) were given prior to participation to eliminate confusion as to the procedures of the experiment. In order to prevent participants from consciously grouping similar words in both conditions as a result of prior knowledge, the single-blind method was used. In addition, the experiment took place in an isolated environment so as to avoid distraction.

Ethical issues were also taken into consideration. Participants were required to read and sign a document (see Appendix 4) outlining their rights as participants. Due to the single-blind method, the document also informed the participants that the purpose of the experiment was not fully explained before participation, but in debriefing it was explained fully and the opportunity was given for any questions to be asked or comments to be given.

In conjunction with the aims of the study, the target population was people of both genders aged 16-18, and participants were gathered using an opportunity sample. The participants numbered 20 and were male and female sixth form students at St Aidan's Church of England High School. The youngest was 16 and the oldest 18. Conditions were allocated to participants by alternation, whereby odd-numbered participants (1st, 3rd, 5th, ...) were allocated to Condition A (categorised) and even-numbered participants (2nd, 4th, 6th, ...) were allocated to Condition B (randomised). Psychology students did not participate because they would be more likely to guess the aim of the experiment, which could lead to confounding variables

The materials used were as follows:

- Standardised instructions and agreement form (one per participant; see Appendix 4);
- Either categorised word grid or randomised word grid (one per participant; see Appendix 4);
- Lined paper (one A4 sheet per participant);
- Pen;
- Stopwatch.

Before carrying out the investigation, the word grids were prepared. Six words were chosen from each of the four different semantic categories: sports, animals, countries and colours. In the categorised word grid the words were arranged such that each category had its own line. For the randomised word grid, the words were arranged randomly, with the order determined by a custom PHP script (see Appendix 5) to eliminate any confounding variables that may have arisen from manual randomisation.

The materials were then prepared: 20 blank sheets of lined paper were gathered and 20 copies of the consent form were printed, along with one printout of each word grid.

An empty classroom was used to carry out the experiment, and no two participants were in the room simultaneously in order to avoid cheating or distraction of any sort. Once in the classroom each participant was given the standardised instructions and agreement form to read, understand and sign. When ready, the appropriate word list and blank sheet of paper were given to the participant and the stopwatch was set for 60 seconds. After this, the word list was taken away and covered, and the participant was allowed as much time as they required in order to recall the words that they remembered.

When each participant finished writing they were debriefed, and were told the aims of the experiment. Also, they were again given the opportunity to withdraw and the chance for any questions to be asked or comments to be given.

Results

The mean number of words recalled by participants in Condition A (categorised condition) was 14.6, compared to 15.6 in Condition B (randomised condition). This was unexpected, as it was hypothesised that those to whom information was presented randomly would remember less information than those to whom it was presented in categories. Figure 1 shows the median (14.5 for Condition A; 15 for Condition B), range (6 for Condition A, 10 for Condition B) and interquartile range (4 for Conditions A and B) of the results.

Figure 2 shows the mean and standard deviation of the number of words recalled by participants in the two conditions. It is evident that the distribution of results in Condition B is more widely spread than in Condition A, and that the mean number of words remembered in Condition B is higher than that of Condition A, despite being found to be statistically insignificant (see Appendix 2). The reason for this may be due to individual differences, see discussion.

The frequency with which each word was recalled was also recorded. Most frequent were *dog*, *Uganda* and *red* (each being recalled 18 times out of a possible 20), and least frequent were *swimming* and *cow* (each 8/20), *Australia* (6/20) and *China* (4/20). 303 words in total were recalled out of a possible 480, meaning that 177 were forgotten. The most-recalled group was colours (85/120) and the least-recalled group was countries (64/120). See Appendix 1 for each word's frequency of recollection individually.

The independent t-test (see Appendix 2) was used in order to measure the significance of the difference in results between the two conditions. A value of $t \geq 1.734$ was required for significance with $p \leq 0.05$ and 18 degrees of freedom. The value of t was found to be 1.188, meaning that the results are not significant.

All raw data and calculations can be found in Appendices 1-3.

Discussion

Unlike previous research such as that by Bower *et al.* (1969), who found organisation of information to increase recall, this experiment found that the degree of organisation to which the word grids were presented to participants had little effect on the amount of information they remembered, which would suggest that organisation of information upon presentation has little effect

upon how well a person remembers that information. This means that the experimental hypothesis for this study can be rejected and the null hypothesis retained.

Nonetheless, organisation cannot be rejected as a key factor in remembering information. A trend was noticed in the participants assigned to Condition B to group together the words into the same categories that were listed in Condition A. Indeed, this appears to be the same phenomenon that Bousfield (1953) describes as *categorical clustering*. This trend having been noted, it was analysed by measuring the degree of categorisation (as a percentage; see Appendix 3) for each of the participants and for the two word lists themselves.

Had the word grids been recalled word-for-word, participants in Conditions A and B would have produced results with 100% and 0.5% categorisation, respectively. The actual average for each condition was 85.1% and 68.83%, respectively, which indicates that a significant amount of categorical organisation of the information presented was undertaken by participants; and particularly those in Condition B. This further suggests that organisation as a cognitive process is very important for the encoding of information, supporting Mandler's (1967) claim that organisation is a necessary condition for memory. The reason why the average degree of categorical clustering for Condition B was lower than that of Condition A may be because the categories were not obvious, allowing for more freedom in terms of choice of the method of organisation to be used.

However, if semantic categorisation was the only way of storing information, it would follow that all of the participants would have an average degree of categorisation of 100% for each condition. This may be accounted for by individual differences. For example, one participant (**B01**, see Appendix 1) said that she remembered the words by associating colours with animals, which does itself suggest a degree of categorisation, but not one in which the categories are clustered in blocks. An example of a method of organisation which did not involve categorisation was shown by participant **B08** who commented that she used rhyming strings of words to remember more easily. This was a form of acoustic organisation, not one which relied on semantic categories. However, even though categorical clustering was not evident in all of the participants' recalls, each participant organised the data in their own way (rhymes, mental images, the order that they occurred on the list, etc.). This also supports Tulving's (1968) claim that people presented with randomly sorted information will attempt to organise it in some manner.

In Condition A, the categorisation of the words was very evident through the layout of the word grid and this might account for the higher average degree of categorisation. This held for participants who had forgotten words. For example, participant **A04** said he knew that he had failed to recall an entire category, but couldn't remember what the category was. Upon being told what the category was he successfully recalled all six words (the countries) without further prompting. Participant **A05** similarly commented that she knew how many words of each category she had forgotten. Other participants in Condition A also commented that they counted how many words they had forgotten. This shows that, even without categories being explicitly demonstrated, participants in Condition A had the ability to notice patterns in the categories of the words and, alongside the given information that there were 24 words, they were able to decipher how many words in each category remained.

This indicates that when memories of this nature are stored and categorically organised, what might be called a *domino effect* is seen upon recall: the knowledge of what the semantic category is acts as a recognition cue for one of the words, and then that word for each word thereafter. A demonstration of this became evident in debriefing: many of the participants requested to see the word list again, and of those, each one made remarks similar to "I *knew* I'd forgotten a colour." A more commonplace example of this domino effect may be seen when reciting the alphabet. Most people can say it from A to Z without hesitation. However, asking a person to recite it from the letter T, for example, may cause hesitation as no previous letters preceded and therefore nothing could act as a recognition cue, as opposed to if the sequence R, S, T was given.

Returning to the original finding that there was no significant difference in the number of words recalled in either condition, the reason for the discrepancy between this study and previous research, which did find significant differences, may be that participants were given 60 seconds to remember the word list and an unlimited amount of time to write down the words that they remembered. This gave an average of 2.5 seconds to remember each word, which may have given participants in Condition B the opportunity to recognise that there were four distinct groups of words. A way round this for future research may be to either increase the number of words, increase the number of categories, decrease the amount of time given to remember the words or limit the time given to recall the words. In other words, it may be that if the obviousness of the categorisation is reduced, a significant difference between the two conditions may become evident as the semantic domino effect may not develop.

Another interesting finding was the distribution with which the words were recalled. For example, the most commonly-recalled country (18/20) was *Uganda*, compared with *Germany* second (14/20) and *England* third (13/20). Similarly, the most common animals to be recalled were *dog* (18/20), *cat* (17/20) and *chimpanzee* (16/20). Conversely, words such as *China* (4/20) and *cow* (8/20) were very infrequently recalled. The patterns observed here indicate that the words most often recalled fall into one of two groups:

- Words very common in usage and typical to their category in the word grid; or
- Infrequently-used words which stand out.

This would explain the large quantity of participants remembering *Uganda* and *chimpanzee*, for example, as they are very infrequently used and may have stood out from the more generic words in the table. This may also account for why words like *China*, *cow* and *swimming* were frequently forgotten: they are neither very common nor uncommon in their usage in everyday life, nor are they stereotypical of their respective categories. What is meant by this is if the question was asked *name a sport*, it is unlikely that the answer *swimming* would be given, whereas *football* would be a more likely answer, despite swimming being a relatively common word to encounter. This builds on the idea of categories acting as recognition cues for subsequent words.

Also interesting was the distribution of recalls by category: colours were recalled the most frequently (85/120), compared with sports and animals (both 77/120) and, least frequently, countries (64/120). There could be several explanations for this, but it ap-

pears to constitute primarily of two factors: the frequency of usage, and the size of the categories' domains. For example, colours are frequently used words and there are relatively few words that fall under that category; sports and animals are also categories from which often-used words are drawn, but there are many more words that fit into them than there are for colours; and countries are less frequently-used words. Therefore, a decrease in common usage and an increase in size may lead to proactive interference, causing more confusion and, occasionally, incorrect words to be recalled. This is demonstrated, for example, in that the word *America* was recalled three times despite it not being on any of the lists (see Appendix 1).

In the results from Condition B, there is also evidence that primacy and recency may have occurred. Respectively, *green* and *dog* are the first and last words on the grid, and they were recalled by 10 and 9, respectively, of the 10 participants in that condition. No such effect was found, however, in Condition A, suggesting that the order in which words are sequenced has little effect if there is a more significant method of organisation present (in this case, categories).

These patterns indicate that organisation is the key factor in remembering information, but at any one time there may be several methods of organisation occurring simultaneously, such as the words' semantic categories, the order that the words are written down, and the frequency of the words' usage, among others.

This study did, however, have limitations; the most prominent of which is the potential lack of population validity as a result of the relatively small sample size used and the highly restricted age group from which participants were drawn. This could be overcome in future research by widening the target population and using a larger sample in order to identify trends in more detail. In terms of ecological validity, the study uses artificial stimuli to test memory, and naturally occurring stimuli could be used instead in order to observe the effects of organisation on learning in a natural setting and thus improve the ecological validity.

There are implications of this study for many aspects of life which involve learning, but particularly education. It has shown that information is better learnt when organised, either upon presentation or as a mental process. The implication of this is that pupils and students may learn information more efficiently through teaching methods involving organising information into structures and providing tasks to do so if the information is not already organised. The former would provide explicit organisation, and the latter would allow individual pupils and students to find their own ways to learn greater amounts of information.

Future research might aim to investigate further into the effects of categorisation. This could be done by using a larger list of words or by drawing words from more distinct categories, and observing if, how and how much participants categorise these words; and relating this to the amount of information they remember. A wider target population would also be beneficial. It is often cited that children learn information more efficiently than older adults, and giving participants from the two age groups the same task and comparing the results would provide insight into how the process of learning is different between them, if indeed it is different.

To conclude, this study has found no significant effect of organisation of information upon the learning of this information, but organisation cannot be ruled out as a significant factor. It may be the case that organisation upon encoding, rather than presentation, is the factor that determines the storage of the information. This organisation may be in the form of categorisation, but individual differences exist with regard to how this information is organised. Other factors may be how commonly the information is experienced in the given context, and how many recognition cues are available for the information to be recalled.

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Appendix 1: Raw data

The participant identification numbers are in the form **A*nn*** or **B*nn***, where **A** refers to the categorised condition, **B** refers to the randomised condition, and ***nn*** is a two-digit number rendering the full ID unique to each participant.

The numbers in the following table refer to the order in which the words were recalled, and the numbers in bold show the last word recalled (and thus the total number of words recalled by each participant). Words not recalled are marked by a dot. A key to other symbols used is shown at the bottom of the page.

Participant	football	rugby	tennis	badminton	golf	swimming	bird	cat	dog	horse	cow	chimpanzee
A01	1	4	3	5	-	2	-	-	-	6	7	8
A02	-	-	**14**	-	13	-	-	10	9	-	12	11
A03	14	15	16	13	-	-	-	6	7	-	8	5
A04	1	2	3	4	6	5	-	8	7	9	-	10
A05	**15**	-	-	14	3	4	-	2	1	-	-	6
A06	1	2	4	5	-	3	8	7	6	-	-	9
A07	1	6	2	3	4	5	-	8	7	-	-	-
A08	1	16	3	2	4	5	13	17	**18**	12	-	11
A09	1	-	10	**12**	-	-	-	8	6	7	-	5
A10	8	-	-	-	-	-	11	9	10	-	-	**12**
B01	-	10	11	5	12	-	8‡	-	-	-	13	2
B02	-	-	3	-	-	-	-	-	12	2	10	-
B03	-	12	13	4	-	-	-	**15**	14	-	11	-
B04	-	17	16	**18**	-	-	7	9	6	-	8	5
B05	13	12	14	15	11	-	4	3	5	2	6	1
B06	12	11	-	13	-	-	4	2	1	8	-	3
B07	17	**18**	15	-	14	16	9	8	7	-	-	10
B08	**18**	9	3	-	7	15	-	5	6	2	-	10
B09	7	-	-	-	-	-	3	1	2	-	-	-
B10	1	4	-	3	2	*	-	6	7	8	-	5
Participant	**England**	**Germany**	**China**	**Uganda**	**Australia**	**Finland**	**red**	**green**	**blue**	**purple**	**yellow**	**white**
A01	9	10	-	**12**	-	11	-	-	-	-	-	-
A02	*	8	-	7	6	-	1	4	5	3	2	-
A03	10	9	-	12	-	11	1	3	2	**18**	17	4
A04	-	-	-	-	-	-	11	-	-	**14**	12	13
A05	10	11	-	12	-	13	9	-	5	-	7	8
A06	11	12	-	10	-	-	15	13	14	-	**16**	-
A07	10	-	9	12‡	11	-	13	14	**15**	-	-	-
A08	6	8	-	10	14	-	7	-	9	-	-	15
A09	-	-	-	9	-	-	2	3	4	11	-	-
A10	6	7	-	-	-	-	5	3	4	-	1	2
B01	-	-	6	**14**	-	-	3	1	4	7	-	9
B02	-	8	**14**	11	7	9	5	1†	6	4	13	-
B03	5	8	-	7	9	6	3	2	1	10	-	-
B04	4	2	-	1	-	3	12	14	11	15	13	10
B05	7	8	-	9	-	10	19	17	16	18	**20**	-
B06	-	9	-	10	**14**‡	-	-	5	-	6	4	7
B07	11	-	-	12	-	13	2	1	6	5	3†	4
B08	-	13	14	4	-	8	12	1	16	17	11	-
B09	8	9	-	**10**	-	-	5	4	6	-	-	-
B10	10	-	-	9	-	-	11	13	12	-	-	**14**

* Word recalled similar in meaning but different to original.
† Word recalled more than once.
‡ Word misspelt but accepted.

The following set of tables shows the amount of correct words recalled by each participant (shown in bold in the table above).

Participant	Words recalled (x_a)
A01	12
A02	14
A03	18
A04	14
A05	15
A06	16
A07	15
A08	18
A09	12
A10	12
$\bar{x}_a$	**14.6**

Participant	Words recalled (x_b)
B01	14
B02	14
B03	15
B04	18
B05	20
B06	15
B07	18
B08	18
B09	10
B10	14
$\bar{x}_b$	**15.6**

The following table shows words recalled by participants which were not on the word grid. If a participant is not listed, they only recalled words which were on the grid.

Participant	Words recalled not on list
A02	orange, UK*, America
A05	hockey
A09	Italy
B01	America
B04	field
B05	France, cricket
B07	fish
B10	diving, America

* Word similar in meaning but different to a word on the grid

During debriefing, there was the opportunity for participants to ask any questions or give feedback. Any significant comments and questions were noted and are listed in the table below.

Participant	Notes
A04	The participant commented that he knew he had forgotten a category. Upon telling him what the category was (countries), he recalled all six from the category without hesitation.
A05	The participant commented that she had counted how many of each category she had forgotten.
B01	The participant commented that she remembered some of the words by grouping colours with animals, for example "green chimpanzee".
B08	The participant commented that she learnt the words by attempting to make rhymes out of them in the order that they appeared in the grid.

The words, ordered first by their frequency (out of 20), then by their category, then alphabetically, are shown in the table below.

Word	Recalls
dog	18

Word	Recalls
green	16

Word	Recalls
England	13

Word	Recalls
horse	9

Uganda	18
red	18
cat	17
blue	17
chimpanzee	16

football	15
rugby	15
tennis	15
badminton	14
Germany	14

purple	12
yellow	12
golf	10
white	10
bird	9

Finland	9
swimming	8
cow	8
Australia	6
China	4

Appendix 2: Central tendency, spread and significance

Central tendency and spread

The following set of tables show the amount of correct words recalled by each participant, the mean, standard deviation and other values required for calculating the significance of the results.

Participant	xa	x^2a
A01	12	144
A02	14	196
A03	18	324
A04	14	196
A05	15	225
A06	16	256
A07	15	225
A08	18	324
A09	12	144
A10	12	144
	$\Sigma xa = 146$	**$\bar{x}a = 14.6$**
	$(\Sigma xa)^2 = 21316$	**$\sigma a = 2.15$**
	$\Sigma x^2a = 2178$	**$Na = 10$**

Participant	xb	x^2b
B01	14	196
B02	14	196
B03	15	225
B04	18	324
B05	20	400
B06	15	225
B07	18	324
B08	18	324
B09	10	100
B10	14	196
	$\Sigma xb = 156$	**$\bar{x}b = 15.6$**
	$(\Sigma xb)^2 = 24336$	**$\sigma b = 5.21$**
	$\Sigma x^2b = 2706$	**$Nb = 10$**

In summary:

- The **mean** number of words recalled in **Condition A** is **14.6**, and the mean for **Condition B** is **15.6**.
- The **median** for **Condition A** is **14.5**, and that for **Condition B** is **15**.
- The **range** for **Condition A** is **6**, and that for **Condition B** is **10**.
- The **standard deviation** for **Condition A** is **2.15**, and that for **Condition B** is **5.21**.

Significance

The *t*-test for unrelated data was used to test the significance of the difference between the results. This was calculated using the following equation with the values from the tables above.

$$t = \frac{|\bar{x}_a - \bar{x}_b|}{\left[\sqrt{\frac{\left(\sum x_a^2 - \frac{(\sum x_a)^2}{N_a}\right) + \left(\sum x_b^2 - \frac{(\sum x_b)^2}{N_b}\right)}{(N_a + N_b - 2)}} \times \left[\frac{N_a + N_b}{N_a N_b}\right]\right]}$$

A value of $t \geq 1.734$ was required for significance with $p \leq 0.05$. Putting in the values from the table above:

The value of t was thus found to be 1.188, which is below the threshold for statistical significance.

$$t = \frac{|14.6 - 15.6|}{\left[\sqrt{\frac{\left(2178 - \frac{21316}{10}\right) + \left(2706 - \frac{24336}{10}\right)}{20 - 2}}\right] \times \left[\frac{20}{100}\right]}$$

Appendix 3: Measure of categorisation in recall

The categorisation of recall was done by first replacing recalled words with letters that represent their respective categories.

S = sports; A = animals; X = countries; C = colours;

This leaves a string of letters. A *block* is defined as a series of one or more of the same letters joined together, e.g. [CCC] or [X]. The

$$C = \frac{6\sum_{i=1}^{a}\left(\frac{w_i}{b_i}\right) - n}{5n}$$

degree of categorical clustering was calculated by using the following equation.

C is the degree of categorical clustering, a is the number of categories recalled, n is the total number of words recalled, w_i is the number of words in each category i, and b_i is the number of blocks encompassed by that category. It is done in this way because Σw_i will always be equal to n. This means that if all words are grouped together in their various categories, then b_i will be 1 in each case, meaning that the numerator and denominator of the fraction will be equal, so $C = 1$. It also means that for any other values of bi, $C < 1$, then the increased proximity to 0 will indicate a decrease in categorisation. A value of $C = 0$ indicates a complete lack of categorical clustering, i.e. no adjacent words which are in the same category.

C when referring to the degree of categorisation of a participant's results will be represented with a percentage, so $C = 1$ refers to 100% categorisation and $C = 0.3819$ refers to 38.19% categorisation, and so on.

Using the data from participant **A09** as an example:

football	**red**	**green**	**blue**	**chimpanzee**	**dog**	**horse**	**cat**	**Uganda**	**~~Italy~~***	**tennis**	**purple**	**badminton**
S	C	C	C	A	A	A	A	X	X*	S	C	S
1	2			3				4		5	6	7

All **4 categories** were used → $a = 4$;
12 words* were recalled → $n = 12$;
There are **3 words** in S in **3 blocks** → $w_1 = 3, b_1 = 3$;
There are **4 words** in C in **2 blocks** → $w_2 = 4, b_2 = 2$;
There are **4 words** in A in **1 block** → $w_3 = 4, b_3 = 1$;
There is **1 word*** in X in **1 block** → $w_4 = 1, b_4 = 1$.

* Words not on the original word grid are omitted.

Putting these into the equation gives $C = 0.8000$, or 80%, which is the degree of categorisation for participant **A09**.

The degree of categorisation to four decimal places for each participant is shown below:

Participant	***Ca***
A01	100%
A02	100%
A03	80%
A04	100%
A05	56%
A06	100%
A07	100%
A08	55%
A09	80%
A10	100%
C□a	**85.1%**

Participant	***Cb***
B01	25%
B02	19.29%
B03	60%
B04	100%
B05	100%
B06	64%
B07	100%
B08	20%
B09	100%
B10	100%
C□b	**68.83%**

If words were recalled in the order that they appear on the grids, then:

For the **categorised** grid, $C = 100\%$;
For the **randomised** grid, $C = 0.5\%$.

Appendix 4: Original materials

Standardised instructions and agreement form

This is the form used to ensure that participants understood the procedures of the investigation, and that they understood their rights as participants, for example, to withdraw.

What this experiment is

The experiment that you are taking part in explores the nature of human memory and our ability to remember and recall information. You will be shown a list of 24 words, and you will have 60 seconds to remember as many of them as you can. Then, you will be asked to write down the words that you remember. This entire process should take around 2-3 minutes and should be done in isolation.

Your agreement

By signing below, you understand:

- ...that you may withdraw from the experiment at any time, including after the experiment has taken place, and that in such cases all information regarding you will be destroyed;
- ...that, by default, your name is the only piece of personal information which is asked for, but you can request to be anonymous;
- ...that all personal information will be kept confidential, and upon request you will be presented with all information about you which has been collected for this research;
- ...that only limited information regarding the research will be given prior to participation, because giving detail about the nature of the research would compromise the validity of the results. Further information will be given during debriefing which will take place after participation.

Also, by signing below you agree that:

- ...you consent to participate in this experiment;
- ...you consent to have the results derived from your participation used for the purposes of psychological research;
- ...you have a clear understanding of the procedures required for the experiment.

Name *(If you wish to be anonymous, write "N/A")*:

Date:

Signature:

Word grids

The following 6×4 word grids are identical to those presented to participants. Both grids contain the same 24 words. The words are split into 4 categories each of 6 words. The categories are, respectively: sports, animals, countries, colours.

Categorised grid (Condition A)

Each category is listed on its own line.

football	**rugby**	**tennis**	**badminton**	**golf**	**swimming**
bird	**cat**	**dog**	**horse**	**cow**	**chimpanzee**
England	**Germany**	**China**	**Uganda**	**Australia**	**Finland**
red	**green**	**blue**	**purple**	**yellow**	**white**

Randomised grid (Condition B)

The order of the words in this list was randomised using a PHP script (see Appendix 5), working horizontally from the top-left to the bottom-right. This eliminated any patterns, specifically semantic patterns, that may have arisen through manual randomisation.

green	**horse**	**tennis**	**Uganda**	**cow**	**bird**
chimpanzee	**England**	**cat**	**China**	**golf**	**Finland**
red	**swimming**	**white**	**yellow**	**badminton**	**purple**
blue	**Germany**	**football**	**Australia**	**rugby**	**dog**

Appendix 5: Random word order script source code

This script, whose source code is shown in a monospace font, was used in order to eliminate any chance of a pattern occurring accidentally as a result of human error. Line numbers are shown on the left. The script is written in PHP and can therefore be executed by embedding it in a HTML page on a PHP-compatible server, or otherwise by using a PHP compiler.

```
 1:    $wordid = array();
 2:    $output = array();
```

Lines 3-12 put all integers from 1 to 24 in a random order in the array `$output`.

```
 3:    for($i = 1; $i <= 24; $i++) {
 4:        $wordid[] = $i;
 5:    }
 6:
 7:    for($j = 1; $j <= 24; $j++) {
 8:        $key = mt_rand(0, count($wordid)  - 1);
 9:        $output[] = $wordid[$key];
10:        unset($wordid[$key]);
11:        sort($wordid);
12:    }
```

Lines 13-33 convert the numbers in `$output` to words. Line 15 avoids ambiguity between, for example [14] and [1][4]. E.g. [3] becomes [03]. Line 31 replaces the numerical values from `$rep_num` with the corresponding words in `$rep_word` and adds them to the final word list.

```
13:    foreach($output as $num) {
14:
15:        if($num <= 9) { $num = "0" . $num; }
16:
17:        $rep_num = array(
18:            "01", "02", "03", "04", "05", "06",
19:            "07", "08", "09", "10",  "11", "12",
20:            "13", "14", "15", "16", "17", "18",
21:            "19", "20", "21", "22", "23", "24"
22:        );
23:
24:        $rep_word = array(
25:            "football", "rugby",   "tennis", "badminton", "golf",      "swimming",
26:            "bird",     "cat",     "dog",    "horse",     "cow",       "chimpanzee",
27:            "England",  "Germany", "China",  "Uganda",    "Australia", "Finland",
28:            "red",      "green",   "blue",   "purple",    "yellow",    "white"
29:        );
30:
31:        $wordlist .= str_replace($rep_num, $rep_word, $num) . "   \n";
32:
33:    }
```

Line 34 displays the randomised word list.

```
34:    echo $wordlist;
```

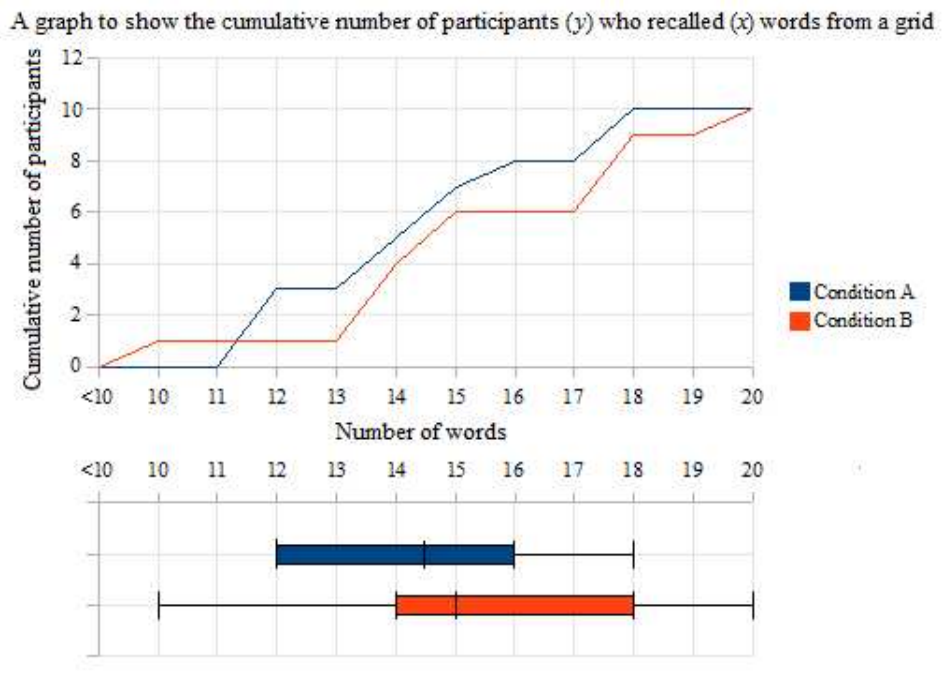

Figure 1: *Participants in Condition A recalled on average less words than those in Condition B, but the recall of words in Condition B was more widely spread. This may be due to individual differences in how participants recalled the words in Condition B (see discussion).*

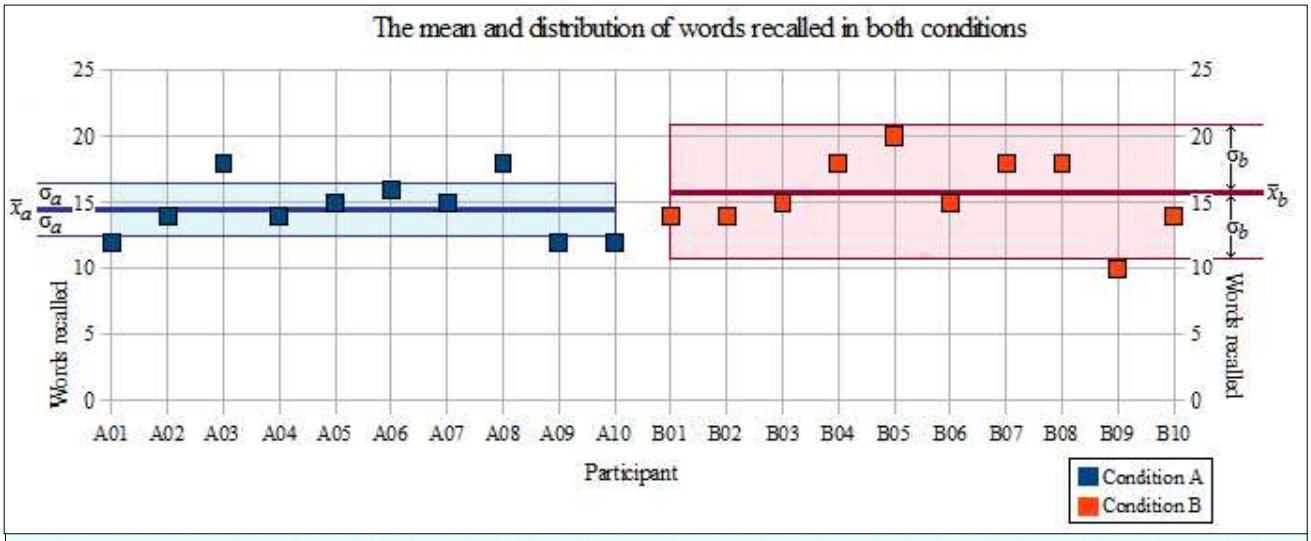

Figure 2: *The means (x□) of the two conditions are similar, but the standard deviations (σ) differ to a far greater extent. See discussion for more information.*