


Subjective Organization Calculator for Free Recall

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Abstract

The free recall measure has an advantage over other memory measures because the free recall measure can provide organization measures, which can reveal the strategies participants used to maximize recall. For instance, even when a study list does not show a clear organizational scheme, recall outputs are often far from random, evidenced by participants recalling the same two or more items together repeatedly across multiple test trials. Unfortunately, computing organizational measures is laborious. The present article introduces a calculator to compute subjective organization (SO) measures. The calculator is based on a popular platform accessible to most researchers and is designed to compute commonly used SO measures for each participant.

Keywords

free recall, subjective organization

Ever since Ebbinghaus (1885/1913) began scientific investigations of human memory, researchers investigated numerous ways of measuring memory. Among these, free recall emerged as one of the dominant memory measures due, in part, to its simplicity. In free recall, participants are asked to recall as much as they can remember and report (orally or by writing down) what they remembered in any order. Although Hintzman (2011) indicated that the heyday of free recall has long since passed (peaked in 1970s), free recall is still called upon whenever one would want to know whether a given neurological disorder, such as Parkinson's disease, affects cognitive functions (e.g., Brønnick, Alves, Aarland, Tysnes, & Larsen, 2011). For instance, some standardized tests, such as California Verbal Learning Test–2 (CVLT-2; Delis, Kramer, Kaplan, & Ober, 2000), are based on a combination of free recall, cued recall, and recognition. Furthermore, as of September 16, 2015, a PsychINFO® database (<http://www.apa.org/pubs/databases/psycinfo/index.aspx>; American Psychological Association) search using *free recall* as a keyword resulted in 3,329 hits even when the search is limited to publications since year 2000, indicating that free recall continues to be a popular form of memory measure.

An advantage that free recall provides over other measures of memory is that participants are free to use whatever strategies to maximize recall. In fact, the main goal of studying free recall during the 1960s and 1970s was to find out the strategies participants would use to organize their recall outputs. Researchers discovered that participants organize recall outputs in one of two ways: clustering and subjective organization (SO). Clustering occurs when the to-be-remembered (TBR) materials have a clear organizational scheme, such as a list of words that consists of

conceptual categories (e.g., animal, fruit, weather, etc.); participants often output items that belong to the same category together (W. A. Bousfield, 1953). SO occurs when TBR materials do not have a clear organizational scheme. Tulving (1962) showed that even when a study list consists of unrelated words, recall outputs are far from random, evidenced by regular co-occurrence of the same two or more items across multiple recall trials. For instance, suppose a participant is presented with a list (e.g., *sheep, soldier, idea, coat, brush, sliver*), and after memorizing the list (Study Trial 1 or *s1*), the participant is asked to free recall (Test 1 or *t1*). The participant then is asked to repeat the procedure (*s2, t2*). When recall outputs from *t1* and *t2* are examined, it can be determined whether the same two or more items (e.g., *soldier* and *coat*) are recalled together across the test trials. Test trials can be repeated more than twice, but SO measures are computed between two test trials at a time (*t1* and *t2, t2* and *t3*, etc.).

Computing organization measures would potentially yield information regarding the nature of memory deficits experienced by patients of neurological disorders. For instance, a Patient Group A may show memory impairment because these patients are suffering from a condition that impairs their abilities to create organization. Unfortunately, these organization measures are not commonly used by researchers because computing these measures is laborious. In fact, there has been a hiatus in research on organization since the late 1970s, even though,

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Table 1. Parameters and Formula Used to Compute SO, DS', and ARC'.

M	=	Number of recalled items on Trial t
N	=	Number of recalled items on Trial $t + 1$
C	=	Number of common items recalled on Trial t and Trial $t + 1$
$O(ITR)$	=	Number of bidirectional pairs appeared on t and $t + 1$
R	=	Number of pairwise units on Trial t that show an item missing on Trial $t + 1$
Max	=	Maximum number of bidirectional pairs repeated on Trial t and Trial $t + 1$
$E(ITR)$	=	Expected number of bidirectional pairs repeated on Trial t and Trial $t + 1$
Max	=	$M - 1 - R$
$E(ITR)$	=	$2Max / N$
SO	=	$O(ITR) / (C + 1)$
DS'	=	$O(ITR) - E(ITR)$
ARC'	=	$[O(ITR) - E(ITR)] / [Max - E(ITR)]$

Note. The definitions and formula were adopted from Murphy and Puff (1982). SO = subjective organization; DS' = difference score of subjective organization; ARC' = adjusted ratio of clustering; ITR = intertrial repetition.

according to Hunt (2012), there is “no discernable reason” (p. 5) for this hiatus. We contend that the difficulty of computing organization measures is one of the reasons, even though there have been some efforts in the past to create computer programs to aid researchers and promote these measures (e.g., Kazen & Otani, 1996). However, due to the rapid advancement in computing technology, many of these programs became obsolete.

Nevertheless, there has been a resurgence in researchers' interests in free recall protocol. For example, Kahana and his colleagues (e.g., Howard, Kahana, & Wingfield, 2006; Kahana, Howard, Zaromb, & Wingfield, 2002) decomposed free recall outputs into the probability of first recall (PFR) and the conditional response probability as a function of lag (lag-CRP). The PFR is the first response participants output when taking a free recall test, and lag-CRP is the responses participants output subsequent to the first response. The results showed that PFR often comes from the recency part of the study list, and the subsequent responses show a lag-recency effect, such that once a response is outputted, the next response is likely to come from nearby serial positions (but see Farrell & Lewandowsky, 2008). Based on this decomposition technique, Kahana et al. (2002) showed that the lag-recency effect is less pronounced among older adults relative to young adults, indicating that the memory difficulties older adults experience are due, in part, to their difficulty in forming associations among items that are temporally proximal. These results indicate that grouping items together is associated with good recall performance, even when a study list does not have an obvious organizational scheme. Accordingly, analyzing recall protocol, beyond the number of correctly recalled items, would greatly enhance the understanding of the nature of memory retrieval.

To promote the use of organizational measures, the goal of the present article is to introduce a simple accessible calculator that enables researchers to compute commonly used organizational measures, as suggested by Murphy and Puff (1982). These measures are A. K. Bousfield and Bousfield's (1966) difference score of SO for bidirectional pairs (DS'), Pellegrino's (1971) adjusted ratio of clustering (ARC') for bidirectional pairs, and Tulving's (1962) measure of SO for

bidirectional pairs (see Table 1 for the formula used to compute these measures, presented by Murphy & Puff, 1982). Note that *bidirectional* means that two items (e.g., *soldier* and *coat*) are considered as one unit regardless of the order in which these items are outputted. We present the calculator in both Microsoft Excel® and LibreOffice Calc spreadsheet versions to maximize the accessibility of this program.

The difference score of SO for bidirectional pairs (DS') is defined as a difference between the observed and the expected number of intertrial repetitions (ITR):

$$DS' = O(ITR) - E(ITR),$$

where the observed ITR is equal to the number of intertrial repetitions that occur for a given pair of trials, and the expected ITR is equal to the number of intertrial repetitions when items are randomly generated on these trials. The adjusted ratio of clustering (ARC') is defined by the following equation:

$$ARC' = \frac{O(ITR) - E(ITR)}{Max - E(ITR)},$$

$ARC' \approx 0$ means that the observed ITR is close to its randomly produced value $E(ITR)$, and positive values of ARC' indicate the above chance level of SO. The SO measure is defined as

$$SO = \frac{O(ITR)}{C + 1},$$

where $O(ITR)$ is the number of observed intertrial repetitions (for this measure, it includes repetitions with imaginary items at the beginning and the end of the words list) and C is the number of common items recalled on the Trials t and $t + 1$. The denominator $(C + 1)$ reflects the maximum number of repetitions one can construct from the C common items. The SO measure ranges from 0 to 1, with 0 indicating the absence of intertrial repetitions and 1 indicating that both t and $t + 1$ outputs show the same order.

According to Murphy and Puff (1982), computing SO measures based on bidirectionally scored pairwise units for adjacent

Table 2. Mock Data Sets Used to Verify the Accuracy.

Output order	Participant															
	A	B	C	D	E	F	G	H								
1	5	2	1	3	10	4	1	2	16	16	1	10	5	5	8	3
2	2	1	7	4	9	1	2	1	15	15	3	11	2	8	7	4
3	6	4	11	5	3	3	7	3	17	10	2	9	3	10	3	5
4	4	3	4	2	4	2	8	5	10	17	8	7	4	19	1	7
5	1	5	6	1	5	6	5	4	1	7	9	6	1	17	2	9
6	3	7	5	6	6	5	6	9	2	12	6	5	17	11	10	11
7	7	9	2	14	1	9	3	7	3	14	7	8	19	14	12	8
8	8	8	8	13	8	8	4	6	8	1	5	12	20	20	9	1
9	9		9	12	7	7	9	8	9	3	4	1	9	3		10
10			14	8	2				7	2		3	10	6		2
11			3	9	11				11	5		4	11	2		6
12			12	7	14				12	4		2	14	1		
13			13	10					13	9			13	4		
14			10	15					14	6			16	7		
15			15	11					6	8			15	9		
16									4				12	12		
17									5				8	18		
18													18	16		
19													6	15		
20													7	13		

Note. For each participant, the first column shows coded output on the first trial, whereas the second column shows coded output on the second trial.

pairs of recall output (t and $t + 1$) would yield the optimal outcome. Furthermore, to achieve the optimal outcome, they recommended the use of Tulving’s (1962) SO measure and Pellegrino’s (1971) ARC’.

Based on these recommendations, the SO calculator is designed to compute SO measures for each participant based on two test trials at a time. Furthermore, the calculator is designed to analyze bidirectional pairs, even though it is possible that participants include more than two items in each organizational unit. To use the calculator, a unique number must be assigned to each recalled item on each test (e.g., *sheep* = 1, *soldier* = 2, *coat* = 3, etc.). These numbers can be arbitrary; however, the easiest way is to use the serial order of the study list. Then, these items are inputted in the columns B and C (for the first and second test trials correspondingly) of the calculator in the exact output order. Note that the calculator does not handle repeats (e.g., *sheep*, *soldier*, *coat*, *brush*, *soldier*, *silver*). In the case that the recall output includes repeated items, we recommend that the repeated occurrence be coded with a different number (e.g., *sheep*—1, *soldier*—2, *coat*—3, *brush*—4, *soldier*—22, *silver*—6). The rationale for this recommendation is that the pairs (*soldier*—*coat*) and (*soldier*—*silver*) are two separate organizational units. Furthermore, incorrectly recalled items should be included because these items can be a part of an organizational unit. The calculator is designed to handle 1,000 items, even though the number of items a participant can free recall is rather limited. The accuracy of the calculator was verified by using mock data sets (see Table 2) and comparing the values computed by the calculator and those computed by

Table 3. Measures Computed Based on Mock Data Sets.

Measures	Participants							
	A	B	C	D	E	F	G	H
M	9.00	15.00	12.00	9.00	17.00	9.00	20.00	8.00
N	8.00	15.00	9.00	9.00	15.00	12.00	20.00	11.00
C	8.00	15.00	9.00	9.00	15.00	9.00	20.00	7.00
O(ITR)	2.00	4.00	2.00	2.00	4.00	2.00	4.00	1.00
R	2.00	0.00	3.00	0.00	4.00	0.00	0.00	2.00
Maximum	6.00	14.00	8.00	8.00	12.00	8.00	19.00	5.00
E(ITR)	1.50	1.87	1.78	1.78	1.60	1.33	1.90	0.91
SO	0.22	0.25	0.20	0.20	0.25	0.20	0.19	0.13
DS’	0.50	2.13	0.22	0.22	2.40	0.67	2.10	0.09
ARC’	0.11	0.18	0.04	0.04	0.23	0.10	0.12	0.02

Note. ITR = intertrial repetition; SO = subjective organization; DS’ = difference score of subjective organization; ARC’ = adjusted ratio of clustering.

hand calculation (see Table 3). The calculator (cmsoc.xlsx, cmsoc.ods) and the scoring instructions can be obtained from the website listed in the author note or emailing a request to the corresponding author. A sample experiment and the scoring instructions for this experiment are provided in the Appendix. Note that the same website posts a calculator for category clustering; see Senkova and Otani (2012) for further information.

Appendix

Example Experiment and Scoring Instructions

An experiment was conducted using a list that consisted of 36 unrelated nouns, which were presented in a random order (see Table A1). After memorizing the list (Study Trial 1), participants were asked to recall as many words as possible in any order (Test Trial 1). The procedure was repeated once more (Study Trial 2 and Test Trial 2). The investigator is interested in (a) the number of correct responses on each test trial and (b) the degree of subjective organization (SO).

Table A1. Study List Consisted of 36 Unrelated Nouns.

1	Sheep	9	Failure	17	Moment	25	Advice	33	Pressure
2	Soldier	10	Sigh	18	Space	26	Storm	34	Teeth
3	Idea	11	Minute	19	Lord	27	Bird	35	Silk
4	Coat	12	Fortune	20	Wage	28	Nature	36	Party
5	Brush	13	Cake	21	Thought	29	Blame		
6	Silver	14	Dinner	22	Book	30	Gold		
7	Fashion	15	Brick	23	Career	31	Flesh		
8	Weight	16	Tide	24	Meaning	32	Page		

Tables A2 and A3 show the recall output of Participant A on Test Trials 1 and 2.

Table A2. Recall Output of Participant A on Test Trial 1.

Silver	Failure	Moment
Gold	Blame	Career
Cake	Brick	Soldier
Dinner	Weight	Coat
Thought	Storm	

Table A3. Recall Output of Participant A on Test Trial 2.

Gold	Brick	Soldier	Teeth
Silver	Weight	Flesh	Table
Failure	Dinner	Minute	
Blame	Storm	Moment	
Storm	Career	Bird	

Note. "Storm" was repeated twice, and "Table" was an incorrect item.

The first step in scoring the output for this participant is to assign a unique number to each recalled item. Any convenient coding system can be used for this purpose; however, the simplest would be to use the serial positions of the study list from Table A1. Tables A4 and A5 show such coding example for the first and second test trials.

Table A4. Coded Recall Output of Participant A on Test Trial 1.

No.	Item	Code No.	Item	Code No.	Item	Code No.	Item	Code No.
1	Silver	6	6 Failure	9	11 Moment	17		
2	Gold	30	7 Blame	29	12 Career	23		
3	Cake	13	8 Brick	15	13 Soldier	2		
4	Dinner	14	9 Weight	8	14 Coat	4		
5	Thought	21	10 Storm	26				

Table A5. Coded Recall Output of Participant A on Test Trial 2.

No.	Item	Code No.	Item	Code No.	Item	Code No.	Item	Code No.
1	Gold	30	6 Brick	15	11 Soldier	2	16 Teeth	34
2	Silver	6	7 Weight	8	12 Flesh	31	17 Table	67
3	Failure	9	8 Dinner	14	13 Minute	11		
4	Blame	29	9 Storm	66	14 Moment	17		
5	Storm	26	10 Career	23	15 Bird	27		

Note. The output orders are indicated by column "No." For Item No. 9 "storm," the code "26," which was assigned to Item No. 5, cannot be used because this item is a repeated item. The researcher can eliminate this item or assign another number (like "66" in this example). Also, Item No. 17 "table" is an incorrect item which was not on the study list. However, this item can be a part of a bidirectional pair, and therefore, the researcher can either exclude this item or assign a unique code such as "67."

The next step is to input the scored output into the SO calculator. Input the third, sixth, and ninth columns of Table A4 (labeled *Code*) to the column labeled *Trial_t* (column B) in the calculator. Input the third, sixth, ninth, and 12th columns of Table A5 (labeled *Code*) to the column labeled *Trial_{t+1}* (column C) in the calculator. Be sure to maintain the output order of the recalled items.

The calculator will compute the following SO measures for this participant: SO (Tulving, 1962), DS' (difference score of SO; A. K. Bousfield & Bousfield, 1966), ARC' (Pellegrino's, 1971, measure of SO), along with *M* (number of items recalled on Trial *t*), *N* (number of items recalled on Trial *t + 1*), *C* (number of common items recalled on Trials *t* and *t + 1*), O(ITR) (number of observed pairwise bidirectional repetitions), *R* (number of units from Trial *t* that have one or more items not recalled on

Trial *t + 1*), *Max* (maximum number of bidirectional repetitions), and E(ITR) (expected number of bidirectional repetitions).

To make the calculator error-proof, we implemented two fail-safe mechanisms. All the cells which are responsible for the data evaluation are protected and cannot be changed without entering a password (the password is "cmsoc," be careful when modify the calculator), at the same time the user area (columns B and C) remains unprotected. In addition, to reduce the number of possible errors/misprints during the input of experimental data, the calculator performs simple data check and prints the results of this check in Table 2. The calculator checks for Repeats (there should be no repeats), for Spaces (there should be no spaces in the coding system), and for Empty Rows (there should be no empty cells in between the data). Proceed when Table 2 indicates "No error found."

Authors' Note

The subjective organization calculator can be downloaded from the following website: <http://otanicognitionlab.weebly.com/resources.html>

Declaration of Conflicting Interests

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