



What is SyncCalc?

A fast-growing number of researchers have become interested in quantifying the levels of synchronization of movements, EEGs, and autonomic arousal that can be observed between work team members, therapist-client relationships, and people engaged in simple social interactions (Delaherche et al., 2012; Elkins et al., 2009; Gipson, Gorman & Hessler, 2016; Guastello, 2016; Guastello, Marra et al., 2016; Marci et al., 2007; Orsucci et al., 2016; Ramseyer & Tschacher, 2016; Reuzel et al., 2014; Richardson, Garcia, Trank, Gergor & Marsh, 2012; Stevens & Galloway, 2016; Vink, Wijnants, Cilleson, & Bosman, in press). Several theoretical perspectives have been advanced with regard to the mathematical or statistical structure of synchronized time series, which include linear, oscillatory, and chaotic structures. Although the various options are workable for dyads, they do not capture a level of synchronization that describes an entire group of three or more people.

SyncCalc (Guastello & Peressini in press) is a response to the problem of measuring group-level synchronization. Its central algorithm starts with a data matrix that it provided by the user. The matrix indicates the amount of influence of each person in the group on every other person in the group. The person who has the strongest influences on the others is identified as the *driver*. The person who is most responsive to the others is the *empath*. The algorithm then proceeds to calculate single coefficient of synchronization, S_E . Instructions for preparing the starting data are given later in this manual, but first let's download the program.

PC Instructions for Downloading

Before actually downloading the program file **synccalc.exe** prepare the directory where you want it to land and where you will actually be using it. These instructions are meant for PC Windows and are followed by instructions for MAC.

1. Go to **Start | accessories | command prompt**. Note the directory name just before the command prompt itself. One of our computers says:
C:\documentsandsettings\HP_Administrator>
2. Using Windows Explorer, go to the folder shown in the command prompt above. Make a new folder, and call it **synccalc**. This is the folder into which you will download the program. It will also be where you will run any executions. Any data sets that you make to run with SyncCalc would go in this folder also.
3. Download **synccalc.zip** into your **synccalc** folder; you will need to unpack the file **synccalc.exe** from it.
4. Download the test data sets (optional): **demo8.txt**, **demo9.txt**, **subarcticData.zip**.

MAC Instructions for Downloading

Before actually downloading the program file **synccalc** (which is a Unix executable) prepare the folder where you want it to land and where you will actually be using it. These instructions are meant for Mac OS X.

1. Open a console window by clicking on **Console** from in your **Applications | Utilities** folder. At this point the current directory in the console window will be the current user's home folder. It may be show in the prompt which might say something like **macpro:~ tony** which indicates the home directory on the machine named MacPro is called "tony."
2. Next you will create a SyncCalc working folder in one of the following two ways. Option 1: use **Finder** to navigate to your home folder (in our example "Tony"), which usually has a shortcut to it on the side panel of the **Finder** window, and then click on the **File | New Folder** option at the top of the **Finder** window and create a new folder, and call it **synccalc**. Option 2: From within the console window type at the command prompt **mkdir synccalc** noting that there is a space between "mkdir" and "synccalc". This will create a subfolder called "synccalc" within your home folder. This is the folder into which you will download the SyncCalc program. It will also be where you will run it. Any data sets that you make to run with SyncCalc and its output would also go in this folder.
3. Download the **synccalc** program for Mac OS X and unpack the zip file into your **synccalc** folder.
4. Download the test data sets (optional): **demo8.txt** and **demo9.txt**, **subarcticData.zip**.

Run the Program

Once again we start with the PC instructions, which are followed by modifications for MAC.

PC Instructions

5. Go back to #1. Enter **cd synccalc** at the command prompt. The directory will change to your new orbital directory.
6. To the run the program itself, enter the following command at the prompt:

```
synccalc data1.txt > newout.txt
```

The command line argument **data1.txt** identifies the data set that you want analyzed. (There is a space between the command and each argument and the ">". The pipe > tells SyncCalc to make an output file instead of printing to the screen, and **newout.txt** is a sample name for an output file. The data and output files are text files and employing the extension **.txt** is highly recommended. When the computation is finished and the output file is created (beware – it will overwrite the file if it exists), and SyncCalc returns the DOS prompt.

MAC Instructions

The execution command is **./synccalc_**. All other subcommands and syntax are the same as for PC. Once again the data and output files are text and so the extension **.txt** is helpful in keeping things straight and also ensure that the proper program (a text editor) will automatically open them when you click on them from a **Finder** window. When the computation is finished and the output file is created (beware – it will overwrite the file if it exists), and SyncCalc returns the command prompt.

Making Data Sets

Instructions for the PC version are described first and are followed by modifications for MAC systems.

PC Instructions

SyncCalc processes data files that are made as text only. You can make text files using the Windows Notepad program or equivalent. File names will end with the **.txt** extension automatically for Notepad. The sample data set `demo8.txt` appears in Table 1:

Table 1. Data set `demo8.txt`.

```
GRP45_Session2_Game1 Linear Sync Matrix
8
    0.6338 0.4521 0.4527 0.4757 0.5221 0.3633 0.4692 0.4823
-0.0058 0.5068 0.3151 0.3640 0.2745 0.3214 0.3759 0.3352
    0.0574 0.2243 0.4527 0.3221 0.2732 0.3109 0.3556 0.3504
-0.0343 0.1311 0.1622 0.3742 0.1702 0.2316 0.2999 0.2303
    0.0321 0.2036 0.2957 0.3193 0.4981 0.3060 0.3492 0.2877
    0.0483 0.1650 0.2271 0.2448 0.1549 0.3381 0.2676 0.1769
-0.0150 0.0973 0.1648 0.2881 0.1542 0.2336 0.4271 0.1541
    0.0956 0.2459 0.2732 0.3516 0.2676 0.3364 0.3653 0.4943
```

The first line is simply a title that identifies the data set. The second line consists of a number ranging from [3 to 20] that specifies the matrix size, which is the number of people or time series that are going to be synchronized. The matrix itself appears on the next 8 lines (for this 8-person group). There can be either a tab or a space between row entries.

MAC Instructions

SyncCalc processes data files saved as text only. You can make text files using the Mac OS X TextEdit program or equivalent. File names will end with the **.txt** extension automatically with TextEdit. Some versions of OS X hide the extensions to file names, so, depending on your version of the software, the text data file will appear in your **Finder** window as the name with or without the extension, e.g.

data1. You can type **ls** at the console command prompt and see what file names and extensions are really there and rename files as necessary. The MAC instructions for matrix size and data content are the same as those for the PC version above.

Matrix Composition

Although SyncCalc was derived with the usual properties of biometric data in mind, it is not confined to GSR or EEG data. For the sake of discussion, however, let's assume the raw data are GSR (galvanic skin response, or electrodermal response) time series which measures autonomic arousal. The SyncCalc user would need to perform some statistical analyses on the raw data to produce an autocorrelation for each person and a semipartial correlation that quantifies the amount of influence of a second person on the target that is not explained by the autocorrelation of the target person's time series.

SyncCalc is not confined to specific linear or nonlinear models, so long as the numbers in the matrix range from -1.0 to +1.0. For the sake of discussion, however, let's consider the simple linear pairwise case. Two equations are involved:

$$X_n = \beta_0 + \beta_1 X_{n-j}, \quad (1)$$

$$X_n = \beta_0 + \beta_1 X_{n-j} + \beta_2 P_{n-j}. \quad (2)$$

Equation 1 is the autocorrelation function for a target person. The autocorrelations, r (or AR in Table 2), are placed on the diagonals. The remainder of the matrix and contributing analyses from Equation 2 are formatted as shown in Table 2 (gray cells only). Thus, for a target person X , β_2 would be the semipartial correlation associated with a second person. The resulting matrix is not symmetric.

Table 2. Prototype Matrix of Synchronization Coefficients for a Group with Four Members.

		<i>TO</i>				Driver Score
		P_1	P_2	P_3	$\dots P_n$	
Matrix P:	<i>FROM</i> P_1	AR_1	R_{12}	R_{13}	R_{1n}	ΣR^2_1
	P_2	R_{21}	AR_2	R_{23}	R_{2n}	ΣR^2_2
	P_3	R_{31}	R_{32}	AR_3	R_{3n}	ΣR^2_3
	P_n	R_{n1}	R_{n2}	R_{n3}	AR_n	ΣR^2_n
Empath Score		ΣR^2_1	ΣR^2_2	ΣR^2_3	ΣR^2_n	

The data in table 1, which lists the data set demo8lin.txt, was produced by a group of eight people who were playing a board game while wearing GSR sensors. The GSR data were originally sampled at 120 observations per second and then downsampled to 1 observation per second. The regression analyses that contributed to the data file were calculated at a lag of 1 second. There were eight autoregression coefficients and 56 multiple regression analyses formatted according to Equation 2. The influence of each person on each other person would correspond to the row of values labelled β_2 in Table 3. So for Player 1, the row of values β_2 would correspond to the column entries for P_1 in Table 1.

Table 3. Summary of Regression Results for Demonstration Group

Player 1 Results Summary							
Autoregression = 0.633							
Linear Sync							
	ER1w/2	ER1w/3	ER1w/4	ER1w/5	ER1w/6	ER1w/7	ER1w/8
$R^2 =$	0.402	0.403	0.402	0.402	0.403	0.402	0.406
$\beta_1 =$	0.634	0.591	0.658	0.608	0.604	0.644	0.563
$\beta_2 =$	-0.006	0.057	-0.034	0.032	0.048	-0.015	0.096
Player 2 Results Summary							
Autoregression = 0.507							
Linear Sync							
	ER2w/1	ER2w/3	ER2w/4	ER2w/5	ER2w/6	ER2w/7	ER2w/8
$R^2 =$	0.326	0.280	0.266	0.275	0.273	0.262	0.287
$\beta_1 =$	0.139	0.343	0.417	0.355	0.403	0.445	0.333
$\beta_2 =$	0.452	0.224	0.131	0.204	0.165	0.097	0.246
Player 3 Results Summary							
Autoregression = 0.453							
Linear Sync							
	ER3w/1	ER3w/2	ER3w/4	ER3w/5	E32w/6	ER3w/7	ER3w/8

$R^2 =$	0.295	0.252	0.220	0.250	0.239	0.223	0.245
$\beta_1 =$	0.114	0.223	0.347	0.247	0.320	0.356	0.268
$\beta_2 =$	0.453	0.315	0.162	0.296	0.227	0.165	0.273

Player 4 Results Summary

Autoregression = 0.374

Linear Sync

	ER4w/1	ER4w/2	ER4w/3	ER4w/5	ER4w/6	ER4w/7	ER4w/8
$R^2 =$	0.254	0.211	0.200	0.200	0.179	0.192	0.213
$\beta_1 =$	0.038	0.125	0.165	0.170	0.230	0.198	0.149
$\beta_2 =$	0.476	0.364	0.322	0.319	0.245	0.288	0.352

Player 5 Results Summary

Autoregression = 0.498

Linear Sync

	ER5w/1	ER5w/2	ER5w/3	ER5w/4	ER5w/6	ER5w/7	ER5w/8
$R^2 =$	0.347	0.282	0.287	0.265	0.263	0.261	0.284
$\beta_1 =$	0.079	0.293	0.307	0.388	0.400	0.394	0.308
$\beta_2 =$	0.522	0.275	0.273	0.170	0.155	0.154	0.268

Player 6 Results Summary

Autoregression = 0.338

Linear Sync

	ER6w/1	ER6w/2	ER6w/3	ER6w/4	ER6w/5	ER6w/7	ER6w/8
$R^2 =$	0.195	0.177	0.178	0.149	0.171	0.152	0.177
$\beta_1 =$	0.110	0.136	0.156	0.202	0.146	0.209	0.113
$\beta_2 =$	0.363	0.321	0.311	0.232	0.306	0.234	0.336

Player 7 Results Summary

Autoregression = 0.427

Linear Sync

	ER7w/1	ER7w/2	ER7w/3	ER7w/4	ER7w/5	ER7w/6	ER7w/8
$R^2 =$	0.305	0.266	0.265	0.238	0.250	0.232	0.255
$\beta_1 =$	0.114	0.188	0.218	0.243	0.193	0.279	0.180
$\beta_2 =$	0.469	0.376	0.355	0.300	0.349	0.268	0.365

Player 8 Results Summary

Autoregression = 0.244

Linear Sync

	ER8w/1	ER8w/2	ER8w/3	ER8w/4	ER8w/5	ER8w/6	ER8w/7
$R^2 =$	0.350	0.301	0.311	0.276	0.286	0.262	0.257
$\beta_1 =$	0.138	0.258	0.257	0.347	0.291	0.376	0.390
$\beta_2 =$	0.482	0.335	0.350	0.230	0.288	0.177	0.154

Output

Your output lands in the **synccalc** folder that you made in Step 2. The file name will be the one you gave it on the command in Step 6 (**newout.txt** in the example). A sample output from **demo8.txt** appears on the next page.

The first part of the output displays the original data matrix with the calculations for communality and eigenvectors, which correspond to the driver score and the empath score respectively. The calculations are shown as part of Table 2 above. Below the matrix the output identifies the empath and the driver of the group.

Sometimes the output contains a warning that two or more people have very close driver or empath scores. The program will, nonetheless, select the nominally larger empath score for continuing the calculations.

In “Reduced Vector **V**” the column entries for the empath have been isolated with the diagonal entry removed. The remaining matrix entries are condensed into “Reduced Matrix **M**.” “Vector of weights **Q**” is the degree of influence on the empath from all other group members, such that:

$$\mathbf{Q} = \mathbf{M}^{-1}\mathbf{V}' \quad (3)$$

The last item is the synchronization coefficient, or synchronization with the empath, S_E :

$$S_E = \mathbf{V}' \mathbf{Q}. \quad (4)$$

For further information about the properties of S_E and the rationale for the calculations, see Guastello & Peressini (in press).

Other Input Options

As mentioned previously, SyncCalc is indifferent to the source of the elements that comprise the starting matrix input. The foregoing example is based on the linear models in Eqs. 1 and 2. One can also extract matrix elements from nonlinear models that are calculated through nonlinear regression. At the time of this writing, it is an empirical question as to whether synchronization coefficients based on linear or nonlinear analyses produce better results for explaining other measures or behaviors within an experiment. It has been shown, however, that there are occasions where nonlinear analyses of the dyads capture information that is not produced with linear analyses and vice-versa (Guastello, 2016; Guastello, Marra et al., 2016; Guastello, Peressini et al., 2016). The data file **demo8.txt** was composed from nonlinear coefficients that were calculated from the same set of GSR time series.

Table 4. Sample output from demo8.txt

Original Matrix

	To1	To2	To3	To4	To5	To6	To7	To8	Communality
From1	0.6338	0.4521	0.4527	0.4757	0.5221	0.3633	0.4692	0.4823	1.8947
From2	-0.0058	0.5068	0.3151	0.3640	0.2745	0.3214	0.3759	0.3352	0.9210
From3	0.0574	0.2243	0.4527	0.3221	0.2732	0.3109	0.3556	0.3504	0.7828
From4	-0.0343	0.1311	0.1622	0.3742	0.1702	0.2316	0.2999	0.2303	0.4103
From5	0.0321	0.2036	0.2957	0.3193	0.4981	0.3060	0.3492	0.2877	0.7783
From6	0.0483	0.1650	0.2271	0.2448	0.1549	0.3381	0.2676	0.1769	0.3823
From7	-0.0150	0.0973	0.1648	0.2881	0.1542	0.2336	0.4271	0.1541	0.4044
From8	0.0956	0.2459	0.2732	0.3516	0.2676	0.3364	0.3653	0.4943	0.8304
Eigenvector	0.4189	0.6674	0.7763	0.9711	0.8190	0.7613	1.0872	0.9029	

The empath is P7.

The driver is P1.

Reduced Vector V'

0.4692
0.3759
0.3556
0.2999
0.3492
0.2676
0.3653

Reduced Matrix M

0.6338	0.4521	0.4527	0.4757	0.5221	0.3633	0.4823
-0.0058	0.5068	0.3151	0.3640	0.2745	0.3214	0.3352
0.0574	0.2243	0.4527	0.3221	0.2732	0.3109	0.3504
-0.0343	0.1311	0.1622	0.3742	0.1702	0.2316	0.2303
0.0321	0.2036	0.2957	0.3193	0.4981	0.3060	0.2877
0.0483	0.1650	0.2271	0.2448	0.1549	0.3381	0.1769
0.0956	0.2459	0.2732	0.3516	0.2676	0.3364	0.4943

The vector of weights Q is:

-0.0341
0.0521
0.1275
0.4664
0.0982
0.2552
0.0907

The synchronization coefficient S_E is: 0.3245

Exiting: SyncCalc ver. 2.1 (Group Synchronization Calculation).

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