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Causal Analytics Toolkit

User Guide

Version 1.0.5

May 2016

System Requirements

Before installing the Causal Analytics Toolkit (CAT) on Microsoft Windows, the following must be installed:

- Microsoft Excel 2007 or later
- R version 3.2.2 or later.

In short, as long as you have Microsoft Windows, and you can run Excel 2007 or later (either 32-bits or 64-bits), then you can use CAT. The tested versions of R are 3.2.2, 3.2.3, 3.2.4, 3.2.5 and 3.3.0 patched. The unpatched version 3.3.0 of R does not work with CAT.

Install the "Causal Analytics Toolkit"

Download the latest CAT installation *CATkitSetup.exe*. Double-click, then follow the on-screen instructions. If you already have R installed, the installer will check whether the installed version can be used by CAT (32-bit R must be installed). If yes, then the option of installing R will not appear in Figure 1 below. If you have not installed R, then the installer will download and install R version 3.2.5 automatically.

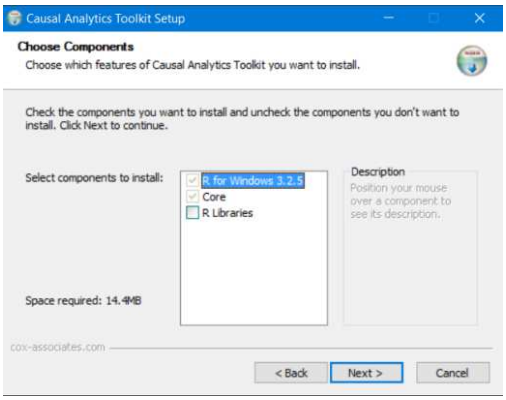
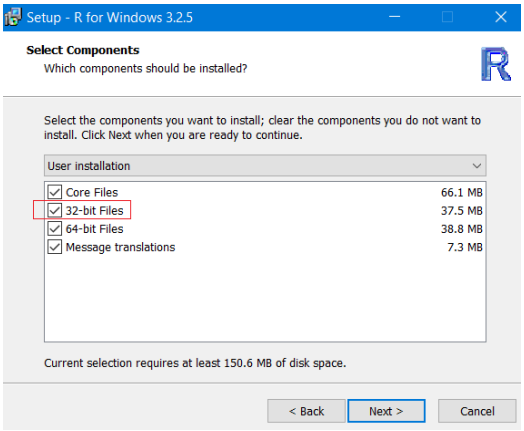
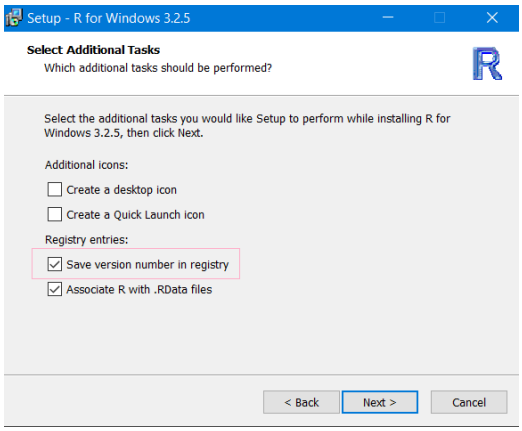


Figure 1. CAT installer options

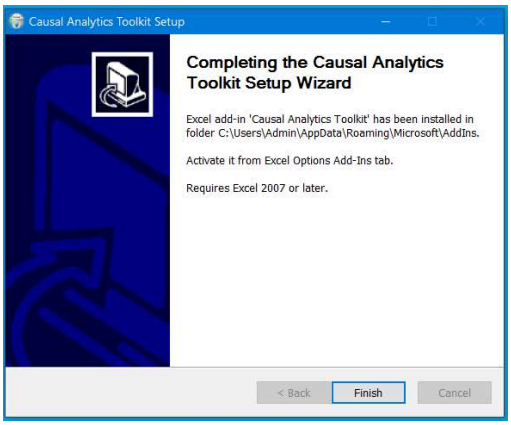
When installing R, options *32-bit Files* and *Save version number in the registry* are checked by default (see below). Do not uncheck these, otherwise CAT will not work.





The CAT installer also provides an option to install R libraries (see Figure 1 above). It is recommended to check this box when you install CAT the first time. When checked, this will install all the libraries used by CAT in folder Documents/R/win-library/**3.x** where **3.x** represents the first two digits of the R version installed (currently 3.2 or 3.3). If you do not want to install packages this way, you need to manually install the required packages: a utility function is provided for this purpose (discussed below).

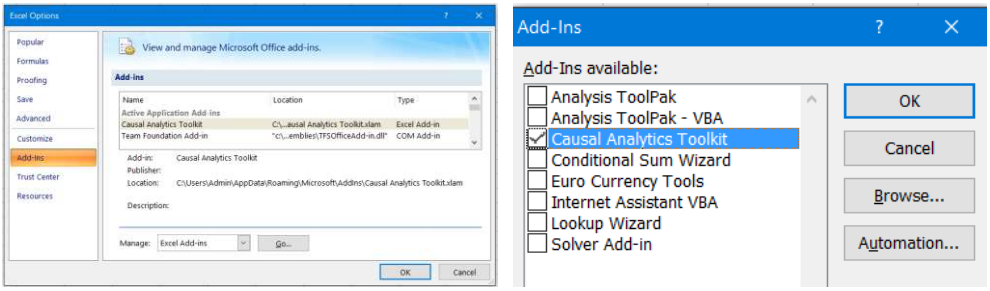
When installation is complete, an Excel add-in "*Causal Analytics Toolkit.xlam*" will be installed in the default Excel add-in folder. (The target folder can be changed during the installation process if desired). The final screen for the installation process should look as follows:



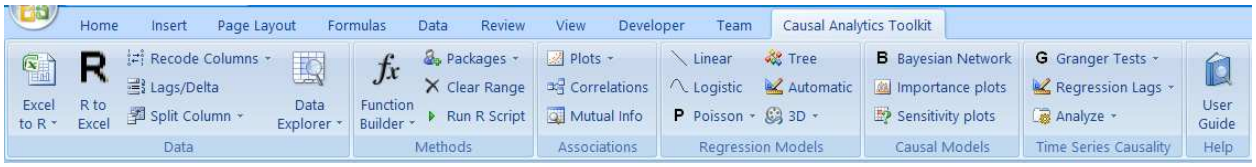
Note: If you manually changed R between version 3.2.* and 3.3.* *after* CAT is installed, then you *must* reinstall CAT again using *CATkitSetup.exe*.

Set up the "Causal Analytics Toolkit" Excel add in

Click the top left office icon in Excel (the "Office Button") then click the "Excel Options" button. Select "Add-ins", then click the "Go..." button next to Manage Excel Add-ins. Select (check) the "Causal Analytics Toolkit."

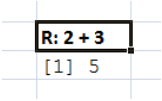


When the "Causal Analytics Toolkit" appears in the Excel ribbon as shown below, installation is complete.



The Causal Analytics Toolkit can be uninstalled at anytime using the standard Programs and Features in Windows' control panel.

To confirm that CAT is running at any time, double-click on any cell in an Excel workbook and enter a simple arithmetic command such as "R: 2 + 3**"** then hit the RETURN key. The *R:* prefix alerts CAT that what follows next is an R command. If CAT is running, it will return the R result "[1] 5" on the next line, and the cell with *R:* command should become **bold**. If CAT is not running, then closing Excel and reopening it will re-start CAT.

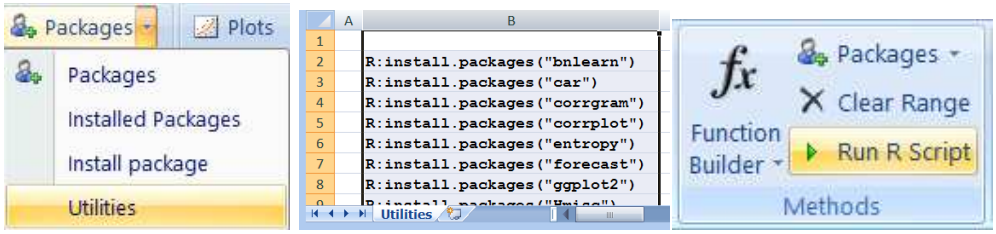


Install R Packages

CAT uses several dozen R packages; these must be installed while the computer is connected to the internet. It is recommended to use the CAT installer to install these packages. But if choose to install R packages manually, follow these steps:

- Start Excel and open a new workbook. (It is important that no existing worksheet named *Utilities* exists)
- From the CAT ribbon, select the *Packages* dropdown menu (in the *Methods* section of the CAT ribbon). Select *Utilities* from that menu. CAT will create a new worksheet called *Utilities*.
- In the *Utilities* worksheet, **select column B** (by clicking on the column heading to highlight the column), or select any subset of packages in column B, then click on *Run R script* (in the *Methods* section of the CAT ribbon).

Note: *Installing packages may take several minutes, depending on your computer and internet connection speed.*



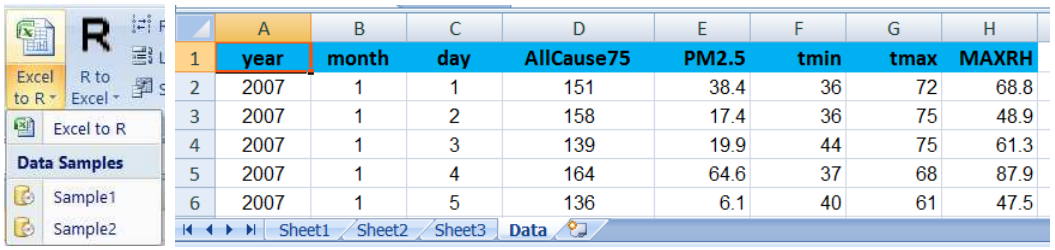
***Note**: During package installation, dialog boxes may pop up to prompt user input. Some dialog boxes may be hidden behind the Excel window, so watch the Windows' taskbar for flashing icons that need attention. Click on "Yes" or "Next" or "Ok" as needed to install all packages.*

Using CAT

The CAT Excel add-in provides relatively simple, powerful commands and a point-and-click interface for doing advanced analytics from Excel using R packages, even if the user does not know R. It can be used in many ways, from push-button, fully automated analyses to programming in R, depending on the level of user experience and familiarity with statistics and with R. For users who have no knowledge of R, a few mouse clicks will display results from advanced R packages without the need to learn R or to know about the packages being used.

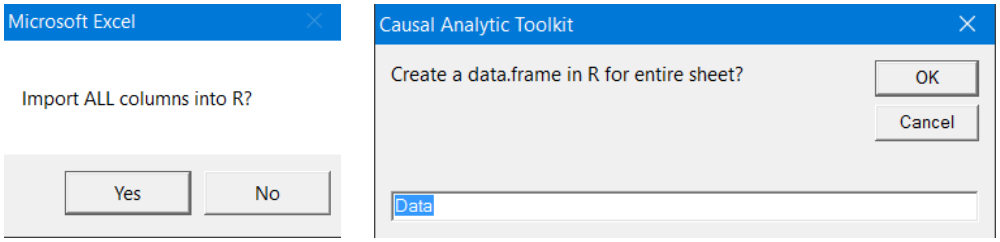
Example: Push-Button Regression Modeling and Bayesian Network Modeling in CAT

To illustrate CAT's push-button analytics, open a new Excel workbook and select Sample1 from the *Excel to R* drop-down menu at the far left of the CAT ribbon. A new worksheet named *Data* will be created that looks like this:

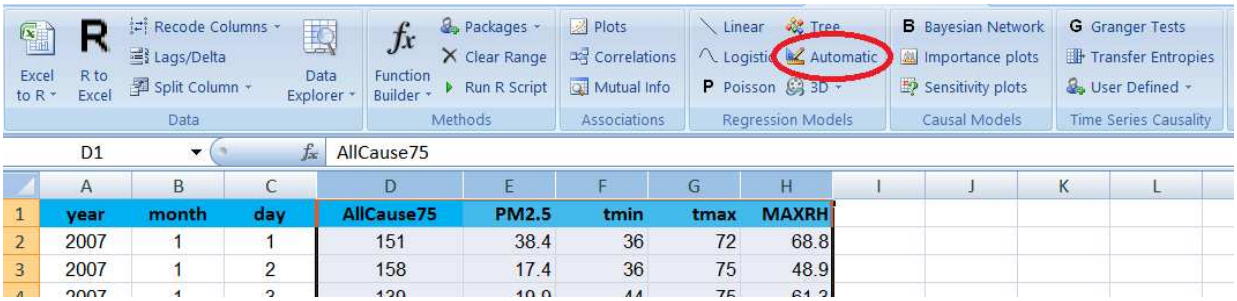


	A	B	C	D	E	F	G	H
1	year	month	day	AllCause75	PM2.5	tmin	tmax	MAXRH
2	2007	1	1	151	38.4	36	72	68.8
3	2007	1	2	158	17.4	36	75	48.9
4	2007	1	3	139	19.9	44	75	61.3
5	2007	1	4	164	64.6	37	68	87.9
6	2007	1	5	136	6.1	40	61	47.5

Click anywhere in the spreadsheet to make sure only a single cell is selected, then click on the big *Excel to R* icon to send all columns to R; click on "Yes" when the message box appears, and click on "OK" to have CAT create an R data frame.



Highlight columns D-H (by clicking and swiping on the Excel column letters D-H). Click on the *Automatic* button in the Regression Models area of the CAT ribbon, as shown below:



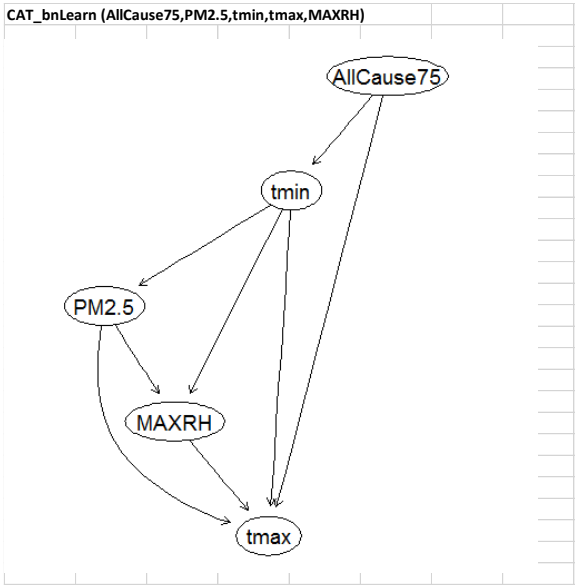
	A	B	C	D	E	F	G	H	I	J	K	L
1	year	month	day	AllCause75	PM2.5	tmin	tmax	MAXRH				
2	2007	1	1	151	38.4	36	72	68.8				
3	2007	1	2	158	17.4	36	75	48.9				

CAT will then automatically select appropriate families of regression models, fit the models to the data, and display the results. The first column selected, column D (AllCause75) is treated as the dependent variable and the remaining variables highlighted are treated as candidate predictors (i.e., independent variables). CAT generates a new Regression tab with extensive output from the regression modeling, beginning with the following display:

CAT_regression (AllCause75,PM2.5,tmin,tmax,MAXRH)

```
Estimated Coefficients

Call:
glm(formula = fm, family = quasipoisson())

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-3.7078  -0.9241  -0.0240   0.8433   5.0138

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept)  5.3466312  0.0279479 191.307  < 2e-16 ***
PM2.5        0.0005926  0.0002652   2.235   0.0256 *
tmin        -0.0047077  0.0006500  -7.243 7.10e-13 ***
tmax        -0.0018344  0.0004668  -3.930 8.90e-05 ***
MAXRH       -0.0009451  0.0002420  -3.905 9.85e-05 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for quasipoisson family taken to be 1.611213)
```

This shows the regression coefficients for a quasi-Poison regression model fit to the data. Additional outputs include 95% confidence intervals, Added-Variable plots showing how the dependent variable is predicted to change as each predictor is varied (i.e., assigned a range of counterfactual values, while holding all other variables at their actual values), importance measures, results from non-parametric (Random Forest) and linear regression modeling, and a plot showing which variables are used in linear regression models of increasing size that explain increasing proportions of the variance in the dependent variable. These outputs are generated by appropriate R packages and use the same format as these packages; thus, the modeling and interpretation of results can be studied in detail by using the extensive existing documentation on R packages. (To see which specific R packages are used by each CAT function, select *View CAT Functions* under the *Function Builder* drop-down menu in the Methods section of the CAT ribbon.) To generate a Bayesian Network for the same data, simply click on the *Bayesian Network* button (under the Causal Models section of the CAT ribbon). CAT will then generate a new tab called *Bayesian* that shows a Bayesian network (BN) structure for the data. (In such a BN diagram, nodes represent variables and arrows between nodes show that they are not statistically independent of each other, i.e., observing the value of one variable provides information about the value of the other.) CAT does not teach the user how to read and interpret its outputs, leaving this for the R package documentation. But it does enable users to generate a rich set of advanced statistical outputs with minimal effort, and with no knowledge of R or R packages, by selecting columns in an Excel spreadsheet and clicking on analytics buttons.



For intermediate users who wish to learn or extend their knowledge of R or CAT commands, CAT also automatically generates and displays the relevant commands (e.g., *CAT_regression (AllCause75, PM2.5, tmin, tmax, MAXRH)* for the above regression modeling, or *CAT_bnLearn (AllCause75, PM2.5, tmin, tmax, MAXRH)* to generate the Bayesian network). Typing such commands directly into Excel (prefixed by *R:* as in *R: CAT_regression(AllCause75,PM2.5,tmin,tmax,MAXRH)*) provides another way to run them without using the CAT ribbon interface. For advanced R users, any R or CAT formula can be entered into an Excel cell and then run as if the Excel cell were an R console. (Thus, typing *R: mean(tmin)* into an empty cell in the above example will return 50.3525 as the mean of the variable *tmin*.) In addition, CAT provides a Function Builder (the left-most option in the Methods section of the CAT ribbon) that guides users in selecting R package and CAT functions and populating them with appropriate argument values. Advanced users can also write an R script (a sequence of commands) in any Excel range, highlight the script, and then run it using CAT's *Run R script* command from the CAT ribbon (at the bottom of the *Methods* section) to see results directly in the Excel spreadsheet.

Basic Use Cases

Step 1. Create Data

Although not strictly required, it is recommended practice to use *one data set per Excel workbook*, and to name that data sheet *Data*. (If you already have a data set open in a worksheet named *Data*, then skip this step and go to Step 2.)

Two sample data sets, Sample1 and Sample2, are included with the base CAT installation. These can be loaded from the *Excel to R* drop-down menu at the upper left of the CAT ribbon. Sample1 is a time series data set for daily fine particulate matter (PM2.5) concentrations, mortality counts among people at least 75 years old (AllCause75), and meteorological variables (daily minimum and maximum temperatures and maximum relative humidity) for the Los Angeles air basin. These data were kindly provided by Dr. Stan Young. Sample2 is a larger cross-sectional data set assembled from EPA and CDC (BRFSS survey) data in the public domain. To load a sample data set, simply click on it in the *Data Samples* menu.

Upon clicking Sample1 or Sample2, if an open *Data* sheet already exists, then it will be just activated, and no further changes will be made. Otherwise, a new worksheet *Data* will be created.

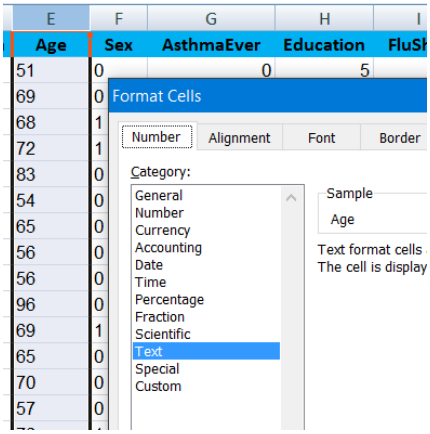
To apply CAT to a new data set, open a new workbook in Excel and create an Excel spreadsheet named *Data* that contains the data set. Variable names should be in the first (top) row. Data should start from the first column, and fill a range without any blank columns in middle.

Note: *The current base version of CAT does not allow missing data. If needed, click on* Clean Rows *under the* Split Column *drop-down menu in the Data section of the CAT ribbon to delete all rows with missing data. Most R packages and CAT functions can be configured to work with missing data, e.g., using various imputation options, but the current base version of CAT assumes no missing data. If there are many missing data values and they are not missing at random, then the missing data may bias results.*

Step 2. Export Data to R

Select some or all columns of the *Data* sheet (by clicking on the letter that Excel provides at the top of a column; click-and-dragging across multiple contiguous columns to multi-select them; and using Ctrl-Left-Click to select additional columns as desired, and Ctrl-Right-Click to deselect a column). Then, click the *Excel to R* button at the far left of the CAT ribbon to export the selected data columns into R. If no columns are selected, and only a *single* cell is selected, then ***all*** columns in the *Data* sheet will be export to R by default.

Note for R users: Each column is exported as a vector or factor depending on whether it is numeric or text. When numbers are stored as text in Excel (e.g, zip codes), CAT will export such text columns into R as factor. When columns with numbers only need to be treated as factor in R, e.g., Year or Age, format the column as text (see below): Excel will automatically set the column alignment to the left.



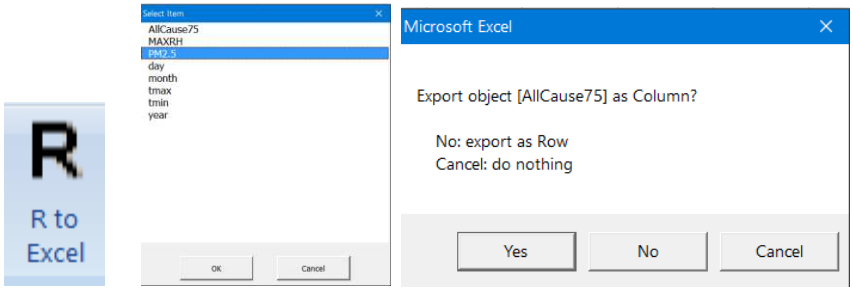
After the selected columns have been exported to R, CAT will prompt the user about whether to also export the entire collection of columns as an R data frame. It is recommended to select *Yes* and to keep the R data frame named *Data*. Accepting these defaults will create a named array of data (the data frame, named *Data*) that can be used by R programmers and by R and CAT. (For example, the data frame with name *Data* is used by the Data Explorer tool, discussed later, to display summaries of data in

the *Data* sheet.) If your data set is very large, and you do not plan to use data frame in your R functions, there is no need to create a data frame from the columns.

When a column of data is exported into R, the column header will be used as the name of the R vector or factor. Special characters in the column header are replaced by _ in the R name. For example, column header "*Test Header*" results in "*Test_Header*" in R.

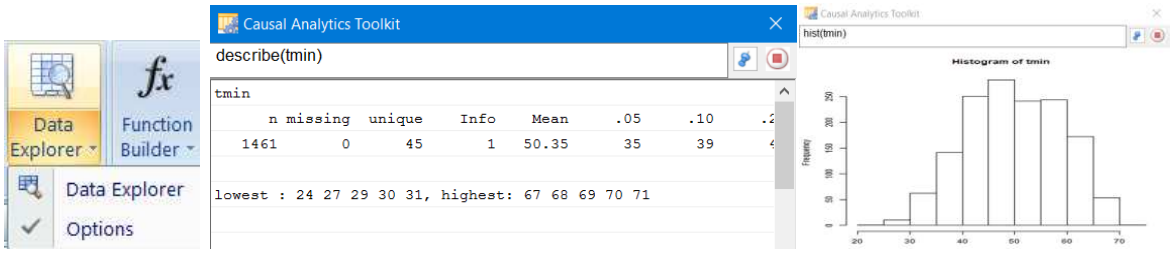
Step 3. Verify R Data

To verify that all/selected columns are exported into R, use the *R to Excel* menu. If a column header is shown in the list, then the column has been successfully exported to R. Any variable in the list can be imported back into Excel. (If the R variable is a vector or factor, there is an option to export it as a row or column.)



Step 4. Viewing Statistical Patterns with Data Explorer

CAT provides a unique *Data Explorer* feature that lets users view many statistical characterizations of the data simply by mousing over columns of data (or, for some more sophisticated analyses, by selecting one or more columns and then mousing over others). To activate it, just click on the *Data Explorer* icon (at the right of the Data section of the CAT ribbon). A new window will pop up (possibly after a brief pause). By default, this Data Explorer window will move with the mouse. As it moves, different results are displayed. The motion of the window can be controlled using the pin icon at the upper right corner of the window, which looks like this:  . To stop the explorer window from moving, double-click on any cell of Excel worksheet so the pin icon becomes down  . Clicking on the pin icon itself will also toggle window movement on or off.



While the data explorer window is active, it will show results for the column under the mouse cursor. To freeze contents in the explorer widow, click this icon in the upper right corner of the explorer window, or right-click on any Excel worksheet cell that is *not* empty: the icon will be changed to .

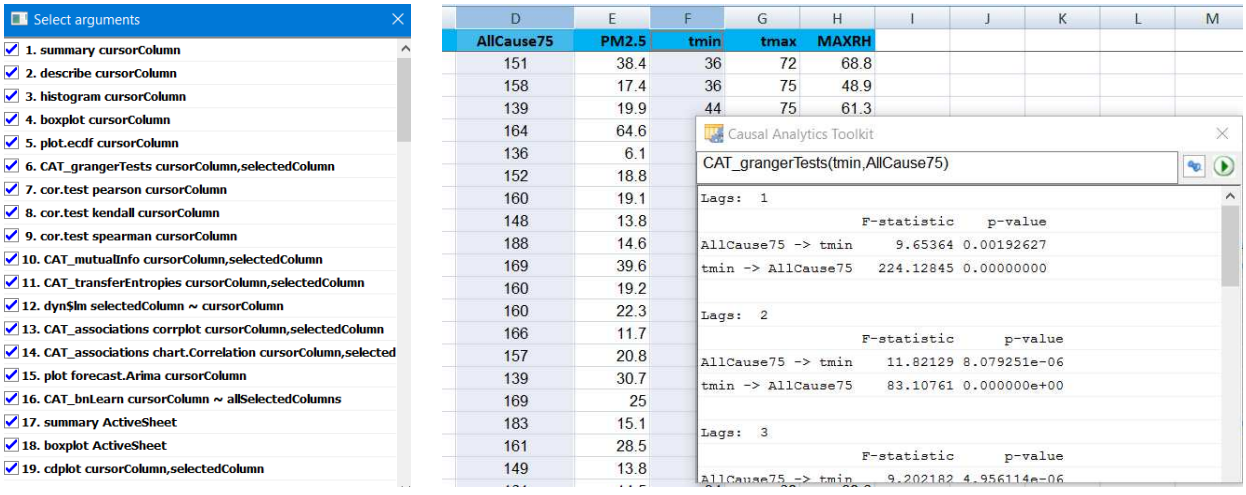
When contents are frozen in the *Data Explorer* window, right-clicking any *empty* cell of an Excel worksheet will transfer contents (text or picture) from the *Data Explorer* window into Excel. This makes results viewed in *Data Explorer* available to paste into other applications such as MS Word or Power Point.

When the *Data Explorer* window is visible, moving the mouse cursor to a column shows statistical results, such as histograms, box plots, and descriptive statistics summary tables, for that column. Moving the mouse cursor up and down within a column shows different results for that column.

The content of the *Data Explorer* window may be a text table or a picture. If it is text, then double-clicking anywhere in the explorer table will pop up a table of options for which displays to include in the *Data Explorer* window. This options table can be also activated using the *Options* menu under the *Data Explorer* drop-down menu when the *Data Explorer* window is not visible. For large data sets, some results can take up to several minutes to calculate. The *Options* menu (under the Data Explorer drop-down menu) allows the user to select which calculations to perform and which to skip.

Some analyses require the user to specify multiple columns. For example, correlations, as well as more advanced analytics options such as Bayesian Networks, require specifying the columns that are to be included in the analysis. Therefore, CAT allows the user to select multiple columns before activating *Data Explorer*. Doing so causes appropriate (multi-variable) displays to be generated as the mouse is moved. For example, clicking on one column and then passing the *Data Explorer* window over other columns will allow a variety of correlations to be viewed between the pre-selected column and the columns that the window (or cursor) passes over.

While the mouse is moving, the current column and all columns selected before the explorer was activated are highlighted. If highlighting is lost, just left single-click on any Excel cell to re-set the focus for Excel.



Step 5. Using CAT models

To see results from a CAT model, select some columns from Data worksheet, then click the desired analytics button(s) or icons on the ribbon. The selected columns in the Data sheet are remembered, so you can click on each analytics option in the CAT ribbon (e.g., P for Poisson regression, B for Bayesian Network, etc.) after columns in the Data sheet have been selected. Results from running a CAT analytics model are placed into a sheet with a name corresponding to that analysis (e.g., "Correlations" for the results of correlation analyses, "Bayesian" for Bayesian Network, "Poisson" for a (quasi-)Poisson regression analysis, and so forth). The output sheet is cleared and repopulated each time a CAT analytics model is run. To save the results, just rename the output sheet to a sheet with a different name.

To run a CAT analytics model on some Excel columns, the Excel columns must have been already loaded into R using *Excel to R*. Three exceptions are *Mutual Info, Granger Test, and Transfer Entropies.* For these three analyses, the columns do not have to exist in R, and the *Data* sheet must be the current active sheet. (As usual, explanation and interpretation of these analyses is provided in the R documentation and the references therein; CAT simply makes it easy to apply them to data.)

Advanced Use Cases

For advanced R users, CAT can be used as an R console, with extra added conveniences including:

- Data in Excel worksheets and in R can be exchanged easily
- R commands can be entered into any cell and executed from Excel
- R output results can be placed in any selected cells

Any selected range in an Excel sheet can be exported into R using the *Excel to R* menu. Enter any valid R object name when prompted. If the selected range is 1-dimensional, then the range will be exported into R as a vector or factor depending on whether all values are numeric. If the column contains all numbers but formatted as Text, then it is exported into R as factor. If the range is 2-dimensional, then the range will be exported into R as a data frame. CAT will prompt for whether the top row of a 2-dimensional selection should be used as header.

***Note**: If a data range is modified after it is exported into R, the data in R will not be automatically updated. To update data in R, do "Excel to R" again.*

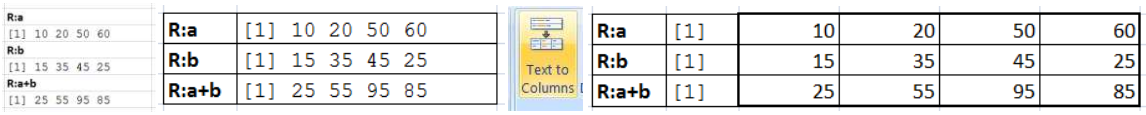
For the following example, there are two rows. First select the top row (yellow), then click *Excel to R* (top left of the CAT ribbon). When prompted, type *a*. This is equivalent to the R command: *a <- c(10, 20, 50, 60).* Similarly, select the second row (green), and export it to vector *b* in R: this is equivalent to the R call *b <- c(15,35,45,25).* Note: the selection may be also a 1-dimensional column.

10	20	50	60
15	35	45	25

To confirm that the Excel selection are exported into R correctly, use the *R to Excel* menu, then select *a* or *b* to import back R values into Excel. R commands can now be executed on these vectors, e.g., *R: mean(a)* returns the value 35, and *R: summary(lm(a ~ b))* summarizes the linear regression of *a* on *b*.

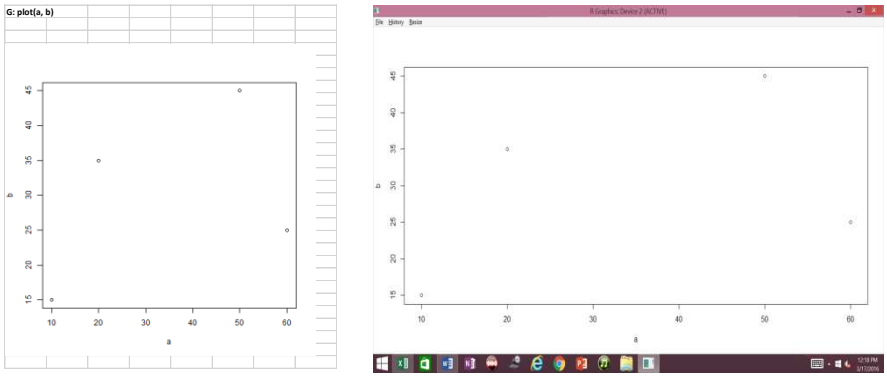
As an alternative, you may also type *R:a* or *R:b* to read values of vector *a* or *b* from R. Type *R:a* then the RETURN key to place the output of the R command in the cell below (as shown in the left picture below). Type *R:a* and then the TAB key to place the output of the R command in the right cell (as shown in the second picture below). You can also type *R:a* then left-click on any other cell to place the output into the selected cell. *Note: if there is any content in the selected cell, the contents will be replaced by the output from R.*

To see the results of *a+b* using R, type *R:a+b* in any cell, then the RETURN (or TAB) key: this will execute the R command *a+b* and place the results back into Excel in the next cell (below the command cell for RETURN or to its right for TAB).



To produce R outputs in Excel format, use the *Text to Columns* menu under Excel's *Data* ribbon. The right-hand picture above shows the formatted output results.

For graphics, in addition to the *R:* prefix, CAT uses a *G:* prefix to direct graphics output to the spreadsheet; if *R:* is used instead, then graphics output will appear in a separate window. For example, *G:plot(a, b)* produces the following result on the left; *R:plot(a, b)* produces the standalone window on the right.



R functions can be also defined using the *R:* prefix by putting the function definition in one cell. The following picture shows how to define a new R function called *plus*, and the results of *R:plus(a,b)*.

Note: *to enter multiple lines in a single Excel cell, use the ALT-RETURN key combination.*

```
R: plus <- function(a,b)
{
  return (a+b)
}

R: plus(a,b)
[1] 25 55 95 85
```

Run R scripts

A block of R commands, each with prefix *R:* or *G:*, can be executed sequentially by highlighting it and clicking on *Run R Script* (at the lower right of the Methods section of the CAT ribbon). The output of R scripts is always placed in the next column to the right of the script being executed, overwriting any data already there.

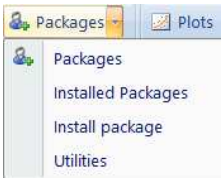
Clear R script outputs

Outputs from R scripts often contain graphics: the normal DEL key only deletes the text. To delete both text and graphs in a selected Excel range, use *Clear Range* (just above *Run R Script*).

Package utilities

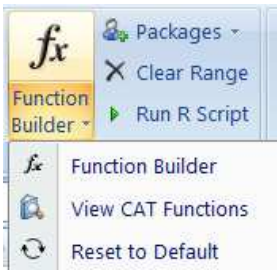
This utility menu contains shortcuts for the following:

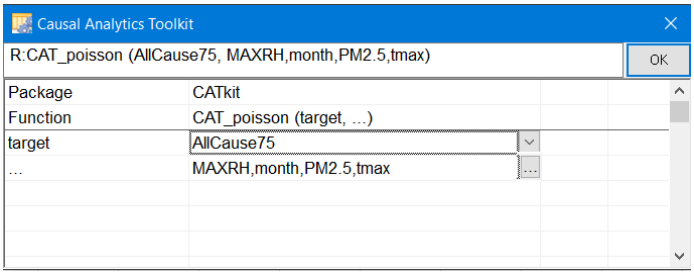
- Load a package from a list of all installed packages
- View all installed packages in a sheet
- Install a new package
- Utilities to install all packages uses by CAT

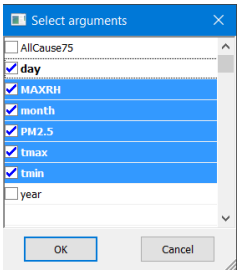


Function Builder

CAT provides a unique utility to build an R or CAT function, called *Function Builder*. It helps the user view available R objects (packages, functions, arguments) and avoid typing errors.







To use *Function Builder*, first select a cell as the starting cell to receive R function output. Then click the Function Builder icon (see left picture above). The top line of the function builder will hold the function being built and the arguments (inputs) for the function that have been specified so far. Clicking on the

dropdown arrow in the Package line will show all loaded packages. (Click or double-click on a cell in the middle column of the Function Builder window to activate its dropdown arrow.) After a package is selected, click on the dropdown arrow in the Function line to display a list of all functions in the selected package (All user-defined R functions using the R: prefix are automatically displayed in the function dropdown list for package CATkit). After a function is selected, its possible argument values (inputs) are displayed in the first column of the table. (For certain functions, such as CAT_regression, the first argument is called "target"; this corresponds to the dependent variable for the analysis.) To select a single R object as an argument for a function, use the dropdown arrow for the argument. To select multiple objects for a list of arguments, click on the ... button for that line, then swipe to select/deselect multiple of objects (see the right-most picture above). Each selection of the argument line will refresh the top result line. When all arguments have been selected, the top line can be edited if desired, e.g., to change the default *R:* prefix to *G:* . Clicking OK executes the function for the specified argument values.

Selecting *View CAT Functions* under the *Function Builder* drop-down menu generates a sheet named *Functions* showing all predefined CAT functions. Any of these can be modified by editing it in this Excel sheet, and then adding an *R:* prefix to read the revised definition into R. Such customized modifications will be remembered for the Excel workbook. To reset all CAT_functions to their base definitions, use the *Reset to Default* option under the *Build Function* drop-down menu. This will reset the definitions in R, but will not change any edits made in the *Functions* sheet.

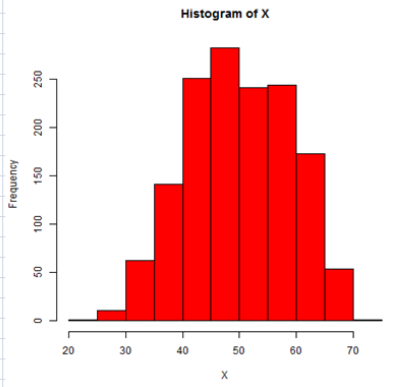
Note: If you've made changes to any existing R:CAT_function in a workbook, and reopen the workbook later after upgrading CAT to a new version, remember "Reset to Default" in order to use the updated CAT_functions in the new version of CAT.

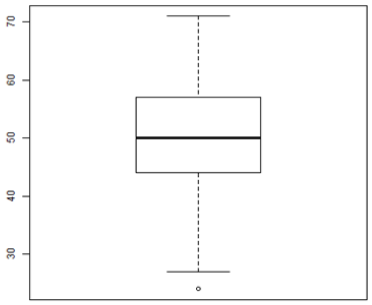
Example: Extending the CAT_describe function

Once the Sample1 data set has been loaded and its columns have put into R using *Excel to R*, typing the CAT command *R: CAT_describe(tmin)* into an Excel cell, or entering via point-and-click it using *Function Builder*, will produce the results on the following page, including a histogram and a box plot for numeric vectors. Now, suppose that we want CAT to color histograms red. This is not an option in the pre-loaded CAT functions. However, Googling on "R histogram color" will show that a histogram can be colored red by inserting *col = "red"* into the *hist()* command. To tie this knowledge about an R command to the CAT_describe function, select *View CAT Functions* under the *Function Builder* drop-down menu. On the resulting *Functions* sheet, line 3 gives the following base definition of the CAT_describe(X) function. (Widen row 3 to see the full definition.)

```
CAT_describe <- function(X)
{
 print(summary(X))

 grf <- CAT_beginGraph()
 hist(X,col="red")
 CAT_endGraph(grf)

 grf <- CAT_beginGraph()
 boxplot(X)
 CAT_endGraph(grf)

 library(Hmisc)
 print(describe(X))
}
```

```
CAT_describe(tmin)
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
  24.00   44.00   50.00   50.35   57.00   71.00
```






```
X
       n missing  unique    Info    Mean     .05     .10     .25     .50     .75     .90     .95
    1461       0      45       1   50.35      35      39      44      50      57      62      65

lowest : 24 27 29 30 31, highest: 67 68 69 70 71
```

This code may not mean much to many users who do not use R. Even so, it is easy to use the knowledge that adding *col = "red"* to the R *hist()* function colors histograms red to modify the function by replacing the *hist(X)* line with *hist(X, col = "red")*. Doing so and prefixing the entire modified function with "R:" so that it will be processed changes the definition of CAT_describe for the workbook being used. Rerunning the R: CAT_describe(tmin) command with this modified function now produces output with a red histogram. This example illustrates how CAT functions can be modified or extended using readily accessible information about underlying R functions.

.Rsession file

After CAT has been installed, any Excel workbook, say *Book1.xlsx*, will have a corresponding R session file, say *Book1.xlsx.Rsession* file, which holds all information from the R session that CAT initiates on behalf of the user to perform calculations. This *.Rsession* file is automatically created and saved by CAT when Book1.xlsx is deactivated, and it is automatically restored when Book1.xlsx is activated. Only the R vectors/factors and data frames created for the active workbook will be active. These will be offered as possible argument values when *Function Builder* is used.

Note: *R functions from all open workbooks are always available and saved in the .Rsession file, regardless of which workbook is active.*

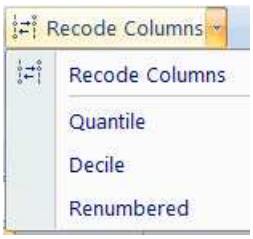
One can remove the .Rsession file at any time if it is no longer needed. (The *.Rsession* file can also be restored from a standard R console if needed using R command *restore.session*.) Any *.Rsession* files saved from a standard R console (using R command *save.session*) can also be also loaded into an Excel workbook if the *.Rsession* file uses the same name as the Excel workbook: this makes it easy to import R data from any session files into Excel worksheets, then use all the features provided by CAT.

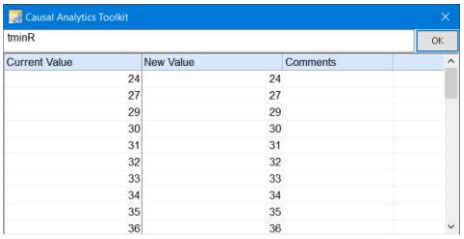
Other Data Utilities

Data utilities described in this section can be used without R to pre-process data before analyzing it.

Recode columns

This utility recodes user-selected columns using a user-defined mapping. Multiple columns can be recoded at the same time. At the top of the recoding window is the default name of the recoded column (an R is appended at the end of the original column header). This default name can be edited. The first column of the table gives the current values for the selected columns in the active sheet, in descending order. To edit the new (recoded) values, double-click the second column, or just start typing in the second column. For the data recoding mapping table, *Missing* is reserved as a keyword to refer to cells without any value.





Quantile and *Decile* recoding work differently. They generate new (recoded) columns with values reflecting percentiles for the frequency distribution of vaues in the original column. Quantile recoding outputs 10, 25, 50, 75, 90, and 100 as the new (recoded) values; a value of 10 means that the original value was in the bottom 10% of all values in that column; a 50 means that it was between the lower quartile and the median value; and a 100 means it was in the top 10% of values. The, Decile recoding is similar, but outputs 10, 20,…, 90, 100 as possible values.

Renumbered recoding will renumber the original values in ascending order consecutively starting from 1.

By default, the new column name for *Quantile* recoding will have *Q* added at the end; *Decile* recoding will have *D*, and *Renumbered* will have *N* added to the end of the original column name. The normal recoding using a user-specified mapping table has *R* appended to the name of the recoded column. This way, by looking at the tails of the column name, it is easy to see which recoding method was used to produce the column.

The new recoded columns created by recoding are always placed to the right of the table of previously populated columns.

Lags/Delta

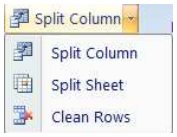
This option is used to create a new column from the original by lagging its values by a user-specified number of lags (i.e., shifting all values up by that number of rows). The output may be selected to be either the lagged data, or the delta (difference between lagged and original values) for the given lag. This is useful for time-series and longitudinal analyses. Lagging a column creates rows with missing values at the bottom of the table. Selecting the *Clean Rows* option under the *Split Columns* drop-down menu (in the Data section of the CAT ribbon) will remove these incompletely populated rows and should be used so that CAT and R functions that expect columns of equal length will continue to work.

Split Columns

This option will simply split (recode) the selected column as a set of columns of binary (0-1) values, with a 1 in a specific row and in the column for a specific value indicating that the original column has that value in the same row, and a 0 indicating that it does not. This is useful for converting discrete variables to equivalent 0-1 dummy variables for use in regression or other analyses.

Split sheet dropdown menu will split a data table into several worksheets, using the unique value combinations for the selected columns. This is useful when the data table is large. For example, national data may be split into smaller ones using State and/or county.

Clean Rows dropdown menu simply deletes all rows that contain at least one missing value.



Predefined Menu for User Defined R Functions

There are ten menu slots under the User Defined drop-down menu (currently at the bottom of the Time Series Causality section of the CAT ribbon) that are not pre-populated by CAT. These are for easy execution of user-defined functions. For example, boxplot can be created using Data Explorer for a single column or whole Data sheet. But there is no menu defined to view boxplot for a subset of selected columns. To create a boxplot for selected columns, say PM2.5, AllCause75, tmin, the user could create a one-time R script such as the following:

G:boxplot(PM2.5, AllCause75,tmin)

If this is a frequent task, however, then it is more efficient to create a new user-defined function by entering (or pasting) the following definition into any blank cell:

```
R:USER_defined <- function(...)
{
 grf = CAT_beginGraph()
 boxplot(...)
```

```
 CAT_endGraph(grf)
}
```

Once the function is defined, it will be remembered in the .Rsession file. Now selecting any columns in the Data sheet and clicking on *User_defined* will generate a box plot for the selected columns.

In addition to the name *USER_defined*, there are 9 other names reserved for user defined functions, i.e., *USER_definedX* where X=1 to 9.

Creating new user-defined functions requires knowledge of R, but once they have been created, any user can apply them via the CAT interface by simply selecting columns on the *Data* sheet and selecting functions to apply to the selected columns by clicking on the user-defined function list.

Conclusion

This concludes our summary of CAT's core capabilities. For most users, the main purpose of CAT is to give simplified access to the analytics power of the vast array of R packages and commands that are useful for detecting, analyzing, quantifying, and visualizing associations and other relations (such as information relations among multiple variables) in data sets using standardized, well-documented, and well-supported algorithms. For advanced users, CAT provides a convenient way to integrate R programming directly into Excel, while also providing pre-built commands with simplified syntax, push-button analytics capabilities that can save time on routine tasks, and reports that often integrate the analyses from multiple R packages to provide different perspectives on relations in the data.

We encourage users at all levels to use CAT in conjunction with Google. Google can be used to find useful R packages and capabilities and CAT can then be used to install additional packages as needed and to access them via CAT's simplified interfaces. More capabilities are likely to be added over time, and CAT will be updated as R releases and packages are updated and new packages for advanced analytics and causal analysis are added to the CRAN repository. We therefore encourage users to check for CAT updates often here. We also welcome and encourage users to send comments, questions, notifications of bugs or difficulties in using CAT, and suggestions for improvements and additions to info@cox-associates.com or tcoxdenver@aol.com .

We hope to make CAT as useful and easy-to-use as possible. Your feedback will help to achieve this goal.