

## R functions for quantifying nonindependence\* in standard dyadic and SRM designs

David Leiva<sup>1</sup>

Antonio Solanas<sup>1-2</sup>

Lluís Salafranca<sup>1</sup>

<sup>1</sup> *Universitat de Barcelona*

<sup>2</sup> *Institute for Brain, Cognition and Behaviour (IRC3)*

*Interdependence is the main feature of dyadic relationships and, in recent years, various statistical procedures have been proposed for quantifying and testing this social attribute in different dyadic designs. The purpose of this paper is to develop several functions for this kind of statistical tests in an R package, known as nonindependence, for use by applied social researchers. A Graphical User Interface (GUI) is also developed to facilitate the use of the functions included in this package. Examples drawn from psychological research and simulated data are used to illustrate how the software works.*

*Keywords: Dyadic nonindependence, Social Relations Model, dyadic designs, R statistical software, R GUI.*

## Funciones de R para cuantificar la interdependencia en diseños dídicos estándar y SRM

*La interdependencia es la principal característica de las relaciones diádicas y, recientemente, se han desarrollado varios procedimientos estadísticos para cuantificar y tomar decisiones estadísticas respecto a esta característica social en diversos diseños diádicos. El objetivo de este artículo es presentar un conjunto de funciones para estos procedimientos agrupadas en un paquete en R, llamado nonindependence, para que pueda ser usado por los investigadores sociales. Para facilitar su uso, se ha desarrollado una Interfaz*

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*Correspondence:* David Leiva, Departament de Metodologia de les Ciències del Comportament, Facultat de Psicologia, Universitat de Barcelona, Passeig de la Vall d'Hebron, 171, 08035. Barcelona. E-mail: dleivaur@ub.edu

*Gráfica de Usuario (GUI) para este paquete de R. Se ilustra además su funcionamiento mediante datos obtenidos en investigación psicológica y simulados.*

*Palabras clave: interdependencia diádica, Modelo de Relaciones Sociales, diseños diádicos, software R, GUI de R.*

## **Introduction**

Social interaction can be defined as any sort of behaviour that manifests itself in a group context involving at least two individuals that have an influence on each other (i.e., a dyad). Two different approaches have been developed for the study of data emanating from such interactions: The dynamic and static analyses of social interaction (Kenny, 1996). The dynamic approach is concerned with sequences of behaviour over time and seeks to identify patterns and relations between different kinds of events. By contrast, the static approach assumes stability of behaviour over time (i.e., established relationships). This paper is primarily concerned with the static approach as the procedures shown assume that patterns of behaviour remain unchanged over time.

In the above definition of social interaction we introduced the concept of dyad. This is the most basic configuration or relationship in a group and it represents the unit of analysis adopted in most interpersonal interaction studies (Card, Selig, & Little, 2008; Gonzalez & Griffin, 1999; Kenny, Kashy, & Cook, 2006; Malloy & Albright 2001; Wasserman & Faust, 1994). And many social researchers have focused on dyadic dependence in explaining social interaction (Albright, Kenny, & Malloy, 1988; Cook 2005; Cook & Kenny, 2004; Delsing, Oud, De Bruyn, & Van Aken, 2003; Iacobucci & Wasserman, 1987; Iacobucci, Neelamegham, & Hopkins, 1999; Kenny & De Paulo, 1993; Malloy & Albright, 1990). Thus, dyad is the unit of analysis for the study of social interaction and similarly the research of mutual influence is founded on pairs of individuals.

Interdependence has, beyond all doubt, constituted the main feature of dyadic data analyses (Card *et al.*, 2008; Griffin & Gonzalez, 2003; Kenny *et al.*, 2006; Malloy & Albright, 2001). Social psychologists have relied mainly on traditional tests, such as ANOVA, which require each unit of analysis to be independent of all other observational units. Thus, researchers obtain individual measures and then apply one or more statistical procedures to analyse social dynamics, that is, individuals rather than dyads constitute units of analysis. Yet, considering units of analyses as independent has adverse effects on Type I and Type II error rates of several standard statistics if data are nonindependent (Kenny & Judd, 1986; Kenny, Kashy, & Bolger, 1998; Kenny *et al.*, 2006). The study of social interaction is, therefore, the study of nonindependence (Marcus, 1998) and any assessment of this interdependence is concerned with the specific type of dyadic design. Here, several designs have been proposed to evaluate nonindependence for distinguishable (i.e.,

when a feature relevant to the recorded response distinguishes the two members in the dyad) and non-distinguishable or exchangeable dyads and for several dyadic data structures, including the standard dyadic and the Social Relations Model (SRM) designs (Alferes & Kenny, 2009; Campbell & Kashy, 2002; Gonzalez & Griffin, 1999; Griffin & Gonzalez, 1995; Kenny & Judd, 1996; Kenny *et al.*, 2006; O'Connor, 2004).

It is frequently pointed out that interdependence is the core of the study of social interaction, as illustrated for instance in the study of aggression among children at play. In such a context, the researcher might be interested in studying the aggressive behaviour of one child towards another. It should be noted that in such a study both children are significant elements. Thus, researchers need to consider the two children rather than just the specific behaviours, that is, the dyad is the unit of analysis as all dyadic behaviours, feelings, and thoughts involve two interdependent individuals. Moreover, when studying dyadic phenomena in groups it is common that individuals are embedded in a social system and have multiple chances of interacting with others. Thus, individuals interact within the group as actors and partners. This dual role of initiating and receiving behaviour in multiple interactions makes the assessment of interdependence more complex (Kenny *et al.*, 2006).

In the present paper an R package and its graphical user interface (GUI) for quantifying and testing dyadic interdependence are shown. It includes a set of functions that can be used to assess dyadic interdependence in two of the most frequently used dyadic designs: The Social Relations Model and the standard dyadic designs. Additionally, a brief review of these designs and their related methods is made. Finally, some examples (both simulated and real) are used in order to illustrate the functioning of the software developed.

### **Nonindependence: An R package for quantifying and testing dyadic interdependence**

The primary aim in designing the *nonindependence* package is to provide free statistical software for measuring and testing interdependence in several dyadic designs. The best way to achieve this is by writing an R package for the measures and tests reviewed above. R is a free, open-source statistical computing language and a statistical platform that can be run on Linux, MacOS and Windows (Ihaka & Gentleman, 1996; R Development Core Team, 2011). It can be downloaded from the Comprehensive R Archive Network (CRAN) at <http://CRAN.R-project.org/>. The latest available version (as of September 2012) is R 2.15.1. The *nonindependence* package can be obtained from the authors on request. This package can also be run and installed in the main OS as source and binary packages are available for Linux, Windows, and MacOS.

### ***Installing and loading the package***

Installation in Windows of the *nonindependence* package is done via the R GUI, by means of the menu options *Packages ► Install package(s) from local zip files...* Then, users specify the folder containing the binary package. Linux and MacOS users are advised to install the package by means of typing in the usual shell:

```
R CMD INSTALL nonindependence_0.1.tar.gz
```

Once the *nonindependence* package has been installed, users should load it into the current R work session. This can be done directly via the R main menu (*Packages → Load packages*) or by typing at the R prompt:

```
> library(nonindependence)
```

Next, users need to specify the input data, that is, the original sociomatrix or data frame from which the functions included in the package can be called up. A number of the functions included in the *nonindependence* package can be used after loading the original data. Below we describe some of these. Table 1 shows the various functions for quantifying and testing interdependence in the dyadic data designs included in the *nonindependence* package. For a complete review, users should check the package documentation by typing at the R prompt:

```
> help("nonindependence")
```

Or

```
> ?nonindependence
```

### ***Assessing dyadic interdependence in standard dyadic designs***

The standard dyadic is the most frequently used design in social psychology with around 75% of studies adopting this type of data structure (Kenny *et al.*, 2006). In this kind of design individuals are members of only one symmetrical (i.e., both members provide a measure of the variable of interest as actors and partners) or asymmetrical dyad (also called *one-sided* as just one dyad member provides a measure as actor and the other as partner).

Several measures and statistical tests for making decisions related to dyadic nonindependence have been proposed, varying according to the type of standard dyadic design and the scale on which the dyadic variable is measured (Alferes & Kenny, 2009; Kenny, 1996; Kenny *et al.*, 2006). Specifically, the following alternatives are available to social researchers for measuring and testing nonindependence in standard dyadic designs:

TABLE 1. SUMMARY LIST OF FUNCTIONS INCLUDED IN THE *NONINDEPENDENCE* PACKAGE FOR QUANTIFYING AND TESTING DYADIC INTERDEPENDENCE IN STANDARD DYADIC AND SRM DESIGNS.

<i>Standard dyadic design with interval outcomes</i>	<i>Standard dyadic design with categorical outcomes</i>
distinguishable.dyad indistinguishable.dyad pairwise.correlation	categorical.distinguishable.dyad categorical.indistinguishable.dyad
<i>SRM block designs</i>	<i>SRM round robin designs</i>
block.SRM.between.groups.tTest block.SRM.dyadic.reciprocity block.SRM.dyadic.reciprocity.tTest block.SRM.effects block.SRM.generalized.reciprocity block.SRM.relative.variances block.SRM.reliability block.SRM.variances	SRM.beteen.groups. SRM.dyadic.covariance.Ftest SRM.dyadic.reciprocity SRM.effects SRM.generalized.reciprocity SRM.relative.variances SRM.reliability SRM.variances SRM.within.groups.tTest

- Distinguishable dyad members and interval-level scores: Pearson's product-moment correlation ( $r$ ).
- Indistinguishable dyad members and interval-level scores: Intraclass correlation (ICC) and pairwise correlation ( $r_p$ ).
- Distinguishable and indistinguishable dyad members and categorical scores: Cohen's kappa index ( $\kappa$ ).

Kenny *et al.* (2006, p. 33, Table 2.1) use a fictitious example regarding liking in 10 pairs of room-mates. As regards this example, one might be interested in determining whether there is a significant relation between dyadic assessments. As the authors stated, intraclass or pairwise correlation are the proper measures for this type of dyadic design (i.e., indistinguishable dyad members and interval scores). In the following a detailed explanation is presented in order to show how to carry out these analyses by means of the *nonindependence* package.

Suppose that data are saved in a text file called *kenny2006.txt*. Then, it can be easily loaded in the R work session by means of typing the following:

```
> ken2006 <- read.table(file='kenny2006.txt', header=TRUE)
```

Now, the object corresponding to the data frame *ken2006* is ready to be used throughout the working session. For instance, in order to compute the intraclass correlation by means of the function *indistinguishable.dyad* included in the *non-*

*independence* package, users only have to specify the data frame and, optionally, the confidence level for the interval estimation of the intraclass correlation, which is equal to .95 by default:

```
> indistinguishable.dyad(ken2006) # conf.int=.95 by default
```

```
Indistinguishable Members: Intraclass Correlation
```

```
Call:
```

```
indistinguishable.dyad(dataset=ken2006)
```

```
Data (5 first rows shown):
```

```
  dyad X1 X2
1     1  8  6
2     2  5  3
3     3  7  2
4     4  8  5
5     5  8  7
```

```
Descriptive Statistics
```

	X1	X2
N:	10.000	10.000
NAs:	0.000	0.000
Min:	2.000	2.000
Max:	8.000	9.000
Mean:	6.000	5.200
Sd:	2.211	2.201
25th Pctl:	5.000	3.250
50th Pctl:	6.500	5.500
75th Pctl:	8.000	6.750

```
F Test:
```

	Mean Sq	Df	F value	Pr(> F )
Between-Dyads	7.42222	9.00000	3.09259	0.09326
Within-Dyads	2.40000	10.00000		

```
Intraclass Correlation and 95% Confidence Interval:
```

ICC	Lower	Upper
0.51131	-0.09989	0.84236

In this case, a positive correlation is found (ICC=.51) which might be interpreted as a dyadic interdependence in the sense that individuals' assessments are positively correlated. Nevertheless, when taking into account the confidence interval one could conclude that there is no significant relation as 0 is included within the interval estimation. Additionally, the ANOVA procedure leads to a

non-significant result,  $F(9,10)=3.09$ ,  $p\text{-value}=.093$ , confirming the previous conclusion.

Another statistical procedure that can be used when assessing dyadic interdependence in standard dyadic designs with indistinguishable members is the so-called *pairwise correlation* (Gonzalez & Griffin, 1999; Griffin & Gonzalez, 1995). The *nonindependence* package includes the function *pairwise.correlation* in order to carry out this statistical procedure. This function only requires the data frame and the confidence level as inputs. For instance, using *ken2006* data frame in the following piece of code would estimate pairwise correlation (*rp*), would provide a confidence interval estimation and carry out a *Z* test:

```
> pairwise.correlation(ken2006) # conf.int=.95 by default
```

Note that, in this case, dyad members are considered to be indistinguishable (i.e., exchangeable) as there are no distinctive roles within dyads. In case the members were distinguishable, Pearson's correlation might have been used. There is also a function for estimating dyadic interdependence in this second case: *distinguishable.dyad*, which is called in a similar way to the previous functions.

The package also includes several functions for estimating dyadic interdependence when using categorical outcomes. Kenny *et al.* (2006, p. 41, Table 2.4) show simulated data in a sample of 200 dyads in which people were asked to respond in a 3-level categorical item. Assuming that data are saved in a text file called *kennycategor.txt*, the following code loads these dyadic data in the R working session:

```
> ken2006cat <- read.table(file='kennycategor.txt', header=TRUE)
```

Again, two alternatives arise when trying to assess dyadic interdependence as dyad members can be considered distinguishable or indistinguishable. Both cases can be analysed by means of the *nonindependence* package. Assuming that dyads correspond to heterosexual couples it is appropriate to select the distinguishable case. Therefore, the *categorical.distinguishable.dyad* function is used for the example data as shown below:

```
> categorical.distinguishable.dyad(ken2006cat) # conf.int=.95
by default
```

```
Distinguishable Members with categorical data: Kappa Index
```

```
Call:
```

```
categorical.distinguishable.dyad(dataset=ken2006cat)
```

Contingency table:

	A	B	C	Sum
A	106	10	4	120
B	22	28	10	60
C	2	12	6	20
Sum	130	50	20	200

Agreement Test:

Kappa Value	Asymp. Std Error	z Value	Approx. Sig.
4.286e-01	5.551e-02	7.720e+00	1.155e-14

95% Confidence Interval:

Lower	Upper
0.3198	0.5374

It can be seen that there is a significant agreement among dyadic assessments as the point estimation for the kappa coefficient equals .4286 and it yields a highly significant result ( $z=7.72$ ,  $p\text{-value}=1.155\times 10^{-14}$ ). Additionally, the confidence interval includes only positive values approximately ranging from .3 to .5. Asymptotical standard error is computed not assuming the null hypothesis ( $H_0: \kappa=0$ ) and statistical significance is estimated using the standard error under this null hypothesis.

### ***Assessing dyadic interdependence in SRM: round robin and block designs***

In multiple dyadic interaction designs in which the dual role of individuals is assumed, the preferred method for assessing interdependence is the SRM. The Social Relations Model has been employed in more than two hundred scientific articles in a broad range of fields that include social psychology, personality and clinical research, human resources, developmental psychology and statistics. However, it is most usually applied in interpersonal perception studies (Kenny, 1994). The popularity of this dyadic approach is due to the richness of information it provides for social interaction analyses. Although it requires more intensive data collection than other dyadic designs, the SRM provides a more realistic description of the nature of social interaction in groups, allowing statistical analysis, at different levels in groups or teams. Alternative SRM designs have also been used, such as *symmetric-block*, *asymmetric-block*, and *block-round robin designs*. For a full description of these, see Kenny and La Voie (1984) and Kenny *et al.* (2006).

The most basic form of the SRM assumes that a dyadic variable results from the sum of a constant parameter and three effects: The actor, partner, and relationship effects. These four elements provide information about social interaction at

group, individual, and dyadic levels. Actor and partner effects have been differently labelled depending on the field of research; for instance, in interpersonal perception research they are known as perceiver and target effects (Kenny, 1994; Kenny *et al.*, 2006). Formulae for estimating the model's effects (as well as those for variance and covariance estimates) vary depending on the type of SRM design used, with round robin designs requiring the most complicated formulae. An explanation of these formulae goes beyond the bounds of the present paper and interested readers are referred to relevant methodological studies (see, for example, Bond & Lashley, 1996; Kenny, 1994; Kenny *et al.*, 2006; Kenny & La Voie, 1984; Lashley & Bond 1997; Warner, Kenny, & Stoto, 1979).

The SRM is essentially a two-way random-effects ANOVA model, in which variances due to actor, partner, and relationship effects can be estimated. representing row main effect ( $\hat{\sigma}_\alpha^2$ ), column main effect ( $\hat{\sigma}_\beta^2$ ), and cells effect ( $\hat{\sigma}_\gamma^2$ ), respectively. Our interest focuses on determining whether there are significant differences among the levels of the same factor, in other words, identifying the presence of differences among individuals in terms of their roles as actors and partners or among dyads in terms of their response levels. These estimates can be interpreted in terms of the proportion of total variance accounted for by each component, that is, by the actor, partners, and relationship components.

As interdependence also exists in round robin data, two different covariances can be estimated for the previous estimators: the individual and dyadic covariances. The first of these covariances, symbolised by  $\hat{\sigma}_{\alpha\beta}$ , represents the relationship between the behaviours, feelings or thoughts of individuals as actors and partners. The second covariance shows the relationship between unique adjustments of individuals within the dyad and is denoted by  $\hat{\sigma}_{\gamma\gamma'}$ . In order to enhance the interpretability of these covariances, two correlation measures can be obtained: *actor-partner* and *dyadic* correlations,  $\hat{\rho}_{\alpha\beta}$  and  $\hat{\rho}_{\gamma\gamma'}$ , respectively. These two correlations represent generalized and dyadic measures of social reciprocity (Kenny & Nasby, 1980; Marcus 1998).

Once the descriptive indices have been obtained, researchers may then be interested in testing null hypotheses. For instance, they may be required to test the null hypothesis that establishes a specific value for a variance parameter in the population. If so, a number of statistical techniques are available, including the Jackknife test, between-group or within-group *t* tests (Warner *et al.*, 1979; Lashley & Bond, 1997). Furthermore, several exact expressions have been derived for the sampling distributions of SRM statistics (Bond & Lashley, 1996). It should also be taken into account that the most appropriate technique for a given dyadic design or dataset will depend on such factors as the group size and the number of groups analysed (Lashley & Bond, 1997; Kenny *et al.*, 2006).

In this section an illustrative example is provided in order to demonstrate how some of the functions for SRM designs included in the *nonindependence* package work. In so doing, data drawn from psychological research are analysed using the *nonindependence* package. Specifically, a sociomatrix containing the interpersonal perceptions of six undergraduate students regarding their partners' contributions to the group performance (Sierra, Andrés, Solanas, & Leiva, 2009) is used to quantify and test SRM variances and covariances. Table 2 contains the interpersonal perception data of the six students as well as the actor and partner effects.

TABLE 2. INTERPERSONAL PERCEPTIONS IN A GROUP OF SIX STUDENTS. MAIN DIAGONAL IS FILLED WITH DASHES AS SELF-ASSESSMENTS WERE NOT ALLOWED.

		<i>Partner</i>					
		<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>F</i>
<i>Actor</i>	<i>A</i>	-	6	3	2	6	4
	<i>B</i>	5	-	2	4	6	5
	<i>C</i>	6	6	-	6	5	1
	<i>D</i>	4	6	2	-	4	3
	<i>E</i>	6	6	2	3	-	4
	<i>F</i>	6	5	4	2	5	-

The user would then load these data in the working session from an existing file or just type at the R prompt the following line:

```
X <- c(0,6,3,2,6,4,5,0,2,4,6,5,6,6,0,6,5,1,4,6,2,0,4,3,6,6,2,3,0,4,6,5,4,2,5,0)
```

As the functions included in the *nonindependence* package need special objects as data input, an initial formatting of the data should be done before calling SRM special functions. Specifically, all SRM functions of the package expect attributes for the number of individuals, occasions (or indicators) and groups. In order to provide data with a proper format, users could call *prepare.SRM.matrix* function. The general expression of this function (i.e., non-optional arguments are shown) is:

```
prepare.SRM.matrix (data, number of individuals, number of occasions, number of groups)
```

This calling results in an object of type *srmRRmatrix* which is appropriate to be used as input in all SRM functions for round robin data included in the package. In the case of the previous example:

```
> Y <- prepare.SRM.matrix(X,6,1,1)
```

Now, several SRM effects can be estimated using a round robin data design. If we were interested, for example, in obtaining them from the sociomatrix shown above using the *nonindependence* package, the following command prompt would be useful for estimating actor, partner and relationship effects:

```
> SRM.effects(Y)
```

```
SRM Effects: Round Robin Design
```

```
Actor and Partner Effects:
```

group	time	individual	type	effect
1	Group 1 Time 1	Ind. 1	actor	0.12500000
2	Group 1 Time 1	Ind. 2	actor	0.41666667
3	Group 1 Time 1	Ind. 3	actor	0.16666667
4	Group 1 Time 1	Ind. 4	actor	-0.70833333
5	Group 1 Time 1	Ind. 5	actor	0.08333333
6	Group 1 Time 1	Ind. 6	actor	-0.08333333
7	Group 1 Time 1	Ind. 1	partner	1.12500000
8	Group 1 Time 1	Ind. 2	partner	1.58333333
9	Group 1 Time 1	Ind. 3	partner	-1.66666667
10	Group 1 Time 1	Ind. 4	partner	-1.04166667
11	Group 1 Time 1	Ind. 5	partner	0.91666667
12	Group 1 Time 1	Ind. 6	partner	-0.91666667

```
Relationship Effects:
```

group	time	actor	partner	relationship
1	Group 1 Time 1	Ind. 1	Ind. 2	-0.0083333333
2	Group 1 Time 1	Ind. 1	Ind. 3	0.241666667
3	Group 1 Time 1	Ind. 1	Ind. 4	-1.3833333333
4	Group 1 Time 1	Ind. 1	Ind. 5	0.6583333333
5	Group 1 Time 1	Ind. 1	Ind. 6	0.491666667
6	Group 1 Time 1	Ind. 2	Ind. 1	-0.841666667
7	Group 1 Time 1	Ind. 2	Ind. 3	-1.050000000
8	Group 1 Time 1	Ind. 2	Ind. 4	0.325000000
9	Group 1 Time 1	Ind. 2	Ind. 5	0.366666667
10	Group 1 Time 1	Ind. 2	Ind. 6	1.200000000
11	Group 1 Time 1	Ind. 3	Ind. 1	0.4083333333
12	Group 1 Time 1	Ind. 3	Ind. 2	-0.050000000
13	Group 1 Time 1	Ind. 3	Ind. 4	2.575000000
14	Group 1 Time 1	Ind. 3	Ind. 5	-0.3833333333
15	Group 1 Time 1	Ind. 3	Ind. 6	-2.550000000
16	Group 1 Time 1	Ind. 4	Ind. 1	-0.716666667
17	Group 1 Time 1	Ind. 4	Ind. 2	0.825000000
18	Group 1 Time 1	Ind. 4	Ind. 3	0.075000000

```

19 Group 1 Time 1 Ind. 4 Ind. 5 -0.508333333
20 Group 1 Time 1 Ind. 4 Ind. 6 0.325000000
21 Group 1 Time 1 Ind. 5 Ind. 1 0.491666667
22 Group 1 Time 1 Ind. 5 Ind. 2 0.033333333
23 Group 1 Time 1 Ind. 5 Ind. 3 -0.716666667
24 Group 1 Time 1 Ind. 5 Ind. 4 -0.341666667
25 Group 1 Time 1 Ind. 5 Ind. 6 0.533333333
26 Group 1 Time 1 Ind. 6 Ind. 1 0.658333333
27 Group 1 Time 1 Ind. 6 Ind. 2 -0.800000000
28 Group 1 Time 1 Ind. 6 Ind. 3 1.450000000
29 Group 1 Time 1 Ind. 6 Ind. 4 -1.175000000
30 Group 1 Time 1 Ind. 6 Ind. 5 -0.133333333

```

The actor effects show the tendencies of the students to elicit interpersonal perceptions regarding the importance of their partners' contribution to group performance, whereas partner effects refer to their tendencies to receive this assessment regarding their own contribution to the group performance. The relationship effects show the dyadic adjustment for the interpersonal perceptions of contributions to group performance. By using all these effects, the *nonindependence* package also allows the researcher to compute actor, partner and relationship variances, as well as the actor-partner and relationship covariances. Thus, if data shown in Table 2 are used, the results obtained are:

```

> SRM.variances(Y)

SRM Variances: Round Robin Design

group  time  actor  partner  relationship  actor.partner  dyadic
Group 1 Time 1 NA    1.577778  1.405556      0.26111111  -0.177778

```

Note that in the previous results actor variance equals NA which, in this case, means that a negative variance has been obtained. Negative variances, which are impossible theoretically, can be obtained by means of the original formulas; in these cases they should be considered to be equal to 0 (Kenny, 1994).

In order to compute the relative weights of the variance components function *SRM.relative.variances* can be used. Complementarily, standardized actor-partner and relationship covariances can be estimated by means of *SRM.generalized.reciprocity* and *SRM.dyadic.reciprocity*, respectively.

The *nonindependence* package includes several functions to make decisions about the variances and covariances obtained by means of the *SRM.variances* function shown above. For instance, if social researchers test dyadic covariance by means of an *F* test for the hypothetical sociomatrix shown in Table 2, the following results are obtained:

```

> SRM.dyadic.covariance.Ftest(Y)

```

## SRM Dyadic Covariance F Test: Round Robin Design

Group	Time	MSb	MSw	df1	df2	F value	Pr(> F)
Group 1	Time 1	4	2.666667	2	3	1.5	0.3535534

The package also includes a function to estimate statistical significance for all the variance and covariances by means of the so-called within-group *t* test (Lashley & Bond, 1997). The following piece of code allows users to carry out this statistical procedure for the interpersonal perception data in the group of six students:

```
> SRM.within.groups.tTest(Y)
```

```
Within group t-Test: Round Robin Design
```

	Estimates	std.value	std.error	t	df	p.value
actor var	NA	NA	NA	NA	NA	NA
partner var	1.5777778	0.5288641	0.9995196	1.5785362	5	0.087637126
relationship var	1.4055556	0.4711359	0.4159038	3.3795211	5	0.009842224
actor-partner cov	0.2611111	NA	NA	NA	NA	NA
dyadic cov	-0.1777778	-0.12648220	0.4159038	-0.4274493	5	0.343417710

Note that the differences in the interpersonal perceptions of the partners' contributions to the group performance can only be explained by the relationship variance, that is, by the differences in the individuals' adjustments within dyads regarding the evaluation of their partners' contributions. Nevertheless, it should be taken into account that, in this example, relationship variance cannot be separated from error variance due to the fact that just one sociomatrix is analysed. That is to say, it is needed to use at least two observations or indicators in order to separate these two variance components. Additionally, no significant correlations are found either at generalized or at dyadic level.

As shown in Table 1, there are also a set of functions suitable for block designs in order to estimate SRM variances and covariances. Their functioning is quite similar to that explained for round robin designs. There is a function called *prepare.block.matrix* that transforms original data into an *srRRblockmatrix* object which is required in the functions for SRM block designs.

Although all these procedures involving the use of the R command prompt is fast and highly flexible, it can prove difficult to handle for novice users. For this reason, we have also developed a friendly interface for using the *nonindependence* package, which is explained below.

## A graphical user interface for the nonindependence package

R is an open-source implementation of the S programming language with a *Command Line Interface* (CLI), which requires users to be familiar with its com-

mands. Learning R programming language can, however, prove an arduous task for occasional users wishing to apply one specific function to their empirical data. Although R does not include a *Graphical User Interface* (GUI), that is, an interface with menus and dialog boxes, it does include tools for building GUIs for each of its statistical functions. R GUIs are mainly based on a *Tcl/Tk* GUI toolkit implemented in *Tcl/Tk* package (Dalgaard 2001, 2002). Several examples of R GUIs can be found in recent publications (Baier & Neuwirth, 2007; Fox, 2005; La Grange, Le Roux, & Gardner-Lubbe, 2009; Thioulouse & Dray, 2007).

In this section, we present a development for accessing some of the functions included in the *nonindependence* package via an R GUI: An R Commander *plug-in* known as *RcmdrPlugin.nonindependence*.

R Commander (*Rcmdr* package; Fox, 2005, 2012) is an R GUI originally designed for a basic statistics course. This program allows users to see the relationship between the selected options in the GUI and the R command prompts and helps to ensure that inappropriate functions are not selected for the data being analysed (e.g., calculating standard deviation for a non-numeric variable). In addition to its obvious pedagogical uses, R Commander can also provide a GUI for any R package, as it incorporates a *plug-in* mechanism specifically for this purpose (Fox, 2007). This is of great convenience as it allows developers to extend the functionality of the R Commander by adding optional R *plug-in* packages without creating a huge menu in which users might easily get lost. Thus, we chose to develop an R Commander *plug-in* for the *nonindependence* package: The *RcmdrPlugin.nonindependence* package. This package is also available on request from the authors, but its functioning requires the *nonindependence* package to be already installed in the computer. Also mention that we followed the recommendations given by Fox (2007) in developing this *plug-in* package, in line with similar applications (Andronic, 2009; Fernández-Palacín & Muñoz-Márquez, 2010; Groemping, 2012; Husson, Josse, & Lê, 2012).

Once the *RcmdrPlugin.nonindependence* package has been installed, users should load it into the R Commander session by choosing *Tools* → *Load R Cmdr plug-in(s)...* in the R Commander main menu. Then, the *Nonindependence* tab will appear in the main menu (see Figure 1). This R Commander *plug-in* allows researchers to call through a GUI the main functions included in the *nonindependence* package, including *SRM.effects*, *SRM.variances* or *dyadic.covariance.FTest*. After specifying the analytical procedure from the main menu, a graphical device (i.e., a new window) prompts users to determine the main features and options depending on the selected function (e.g., SRM for round robin designs in Figure 2). It requires data to be loaded from an existing text file. Finally, all the results of the callings via this GUI appear in the R Commander output window.

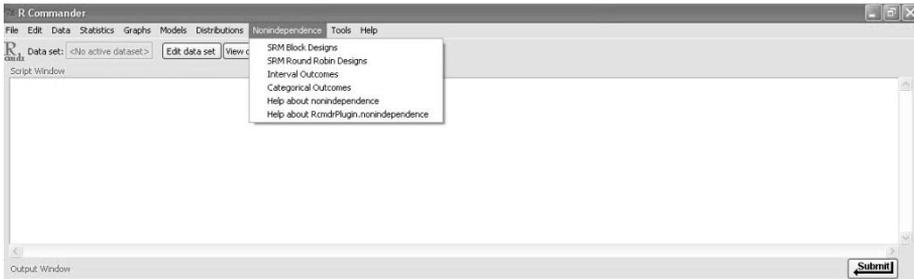


Figure 1. Screenshot of the R Commander once the RcmdrPlugin.nonindependence package has been installed. The Nonindependence menu has several submenus: SRM Block Designs, SRM Round Robin Designs, Interval Outcomes and Categorical Outcomes (both for standard dyadic designs). Direct access to the documentation of nonindependence and RcmdrPlugin.nonindependence packages is via the last two submenus, respectively.

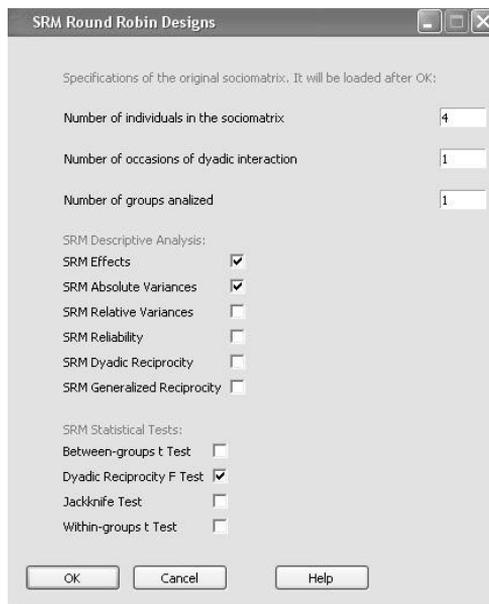


Figure 2. Dialog box for SRM round robin designs. Once the user clicks OK, a new dialog box will open in which he or she can specify the text file that contains the original sociomatrix.

## Conclusions

This paper summarises the main features of the *nonindependence* package. To this aim, some of its functions have been presented and illustrated by means of

several examples. A *Graphical User Interface* for the *nonindependence* package has been developed to facilitate its applicability. In addition, a review of several methods for quantifying and testing interdependence in dyadic data designs has been undertaken. The ultimate goal of this paper is to make this package more generally available to a wide audience of social scientists.

Mainly, *nonindependence* package can be useful to assess dyadic interdependence, this software is a complement of other existing programs (e.g., *SOREMO*: Kenny, 1988; *TripleR*: Schönbrodt, Back, & Schmukle, 2012) and also incorporates some new features. First, it includes functions, which makes it applicable to a wider set of dyadic designs. Second, its graphical interface allows novel users to avoid R syntax. And third, by contrast to other programs (e.g., *TripleR* includes functions for univariate and bivariate social relations analyses), *nonindependence* package allows users to carry out multivariate analysis for round robin designs without restrictions regarding the number of individuals, observations (or indicators) or groups. The program has been developed as a package in R because the latter is a powerful free statistical software. In this regard, dyadic data analysis implies a wide variety of statistical methods that can be currently implemented under the R platform. According to free software policies, the source code (i.e., algorithms) can be consulted, reused and modified by the users. And that is an important point for researchers who need to adapt statistical methods to their own data. Nevertheless, there are some features of the package that still need improvements. The program implements the method of moments estimates (i.e., estimation founded on ANOVA). As a consequence, it cannot handle missing values, negative estimates of variance and correlations out of range are computationally possible. Moreover, significance tests requires unlikely assumptions (e.g., variances must be normally distributed). In order to avoid all these problems a Bayesian approach has been recently proposed (Lüdtke, Robitzsch, Kenny, & Trautwein, 2012). This new procedure allows researchers to estimate SRM variances and covariances for round robin designs. For that purpose, the authors present some code that combines R with *WinBUGS* software (Spiegelhalter, Thomas, Best, Gilks, & Lunn, 2003). Specifically, they use the R package *R2WinBUGS* (Sturtz, Ligges, & Gelman, 2005). A promising future development is to implement this method in the *nonindependence* package. Additionally, *nonindependence* package needs to be extended to other dyadic designs (e.g., one-with-many designs) and to other dyadic models of interest for social researchers (e.g., APIM: Actor-Partner interdependence model, Kashy & Kenny, 1999).

## REFERENCES

- Andronic, L. (2009). RcmdrPlugin.Export: Graphically export objects to LaTeX or HTML (R package version 0.3-0) [Software]. Available from <http://cran.r-project.org/web/packages/RcmdrPlugin.Export>.

- Albright, L., Kenny, D.A., & Malloy, T.E. (1988). Consensus in personality judgements at zero acquaintance. *Journal of Personality and Social Psychology*, *55*, 387-395.
- Alferes, V.R., & Kenny, D.A. (2009). SPSS programs for the measurement of nonindependence in standard dyadic designs. *Behavior Research Methods*, *41*, 47-54.
- Baier, T., & Neuwirth, E. (2007). Excel :: COM :: R. *Computational Statistics*, *22*, 91-108.
- Bond, C.F., Jr., & Lashley, B.R. (1996). Round-robin analysis of social interaction: Exact and estimated standard errors. *Psychometrika*, *61*, 303-311.
- Campbell, L., & Kashy, D.A. (2002). Estimating actor, partner, and interaction effects for dyadic data using PROC MIXED and HLM: A user-friendly guide. *Personal Relationships*, *9*, 327-342.
- Card, N.A., Selig, J.P., & Little, T.D. (Eds.). (2008). *Modeling dyadic and interdependent data in the developmental and behavioral sciences*. New York: Routledge.
- Cook, W.L. (2005). The SRM approach to family assessment. An introduction and case example. *European Journal of Psychological Assessment*, *21*, 216-225.
- Cook, W.L., & Kenny, D.A. (2004). Application of the Social Relations Model to family assessment. *Journal of Family Psychology*, *18*, 361-371.
- Dalgaard, P. (2001). A Primer on the R-Tcl/Tk package. *R News*, *1*, 27-31.
- Dalgaard, P. (2002). Changes to the R-Tcl/Tk package. *R News*, *2*, 25-71.
- Delsing, M. J. M. H., Oud, J.H.L., De Bruyn, E.E.J., & Van Aken, M.A.G. (2003). Current and recollected perceptions of family relationships: The Social Relations Model approach to members of three generations. *Journal of Family Psychology*, *17*, 445-459.
- Fernández-Palacín, F., & Muñoz-Márquez, M. (2010). RcmdrPlugin.orloca: orloca Rcmdr Plug-in (R package version 2.1) [Software]. Available from <http://cran.rproject.org/web/packages/RcmdrPlugin.orloca>.
- Fox, J. (2005). The R Commander: A basic-statistics Graphical User Interface to R. *Journal of Statistical Software*, *14*, 1-42.
- Fox, J. (2007). Extending the R Commander by "Plug-In" packages. *R News*, *7*, 46-52.
- Fox, J. (2012). Rcmdr: R Commander (R package version 1.9-0) [Software]. Available from <http://cran.r-project.org/web/packages/Rcmdr>.
- Gonzalez, R., & Griffin, D. (1999). The correlational analysis of dyad-level data in the distinguishable case. *Personal Relationships*, *6*, 449-469.
- Griffin, D., & Gonzalez, R. (1995). The correlational analysis of dyad-level data: Models for the exchangeable case. *Psychological Bulletin*, *118*, 430-439.
- Griffin, D., & Gonzalez, R. (2003). Models of dyadic social interaction. *Philosophical Transactions of the Royal Society of London Series B, Biological Sciences*, *358*, 573-581.
- Groemping, U. (2012). RcmdrPlugin.DoE: R Commander Plugin for (industrial) Design of Experiments (R package version 0.11-6) [Software]. Available from <http://cran.r-project.org/web/packages/RcmdrPlugin.DoE>.
- Husson, F., Josse, J., & Lê, S. (2012). RcmdrPlugin.FactoMineR: Graphical User Interface for FactoMineR (R package version 1.02) [Software]. Available from <http://cran.r-project.org/web/packages/RcmdrPlugin.FactoMineR>.
- Iacobucci, D., Neelamegham, R., & Hopkins, N. (1999). Measurement quality issues in dyadic models of relationships. *Social Networks*, *21*, 211-237.
- Iacobucci, D., & Wasserman, S. (1987). Dyadic social interactions. *Psychological Bulletin*, *102*, 293-306.
- Ihaka, R., & Gentleman, R. (1996). R: A Language for Data Analysis and Graphics. *Journal of Computational and Graphical Statistics*, *5*, 299-314.
- Kashy, D.A., & Kenny, D.A. (1999). The analysis of data from dyads and groups. In H. T. Reis & C. M. Judd (Eds.), *Handbook of research methods in social psychology* (pp. 451-477). New York: Cambridge University Press.
- Kenny, D.A. (1988). *SOREMO* [Software and manual]. University of Connecticut, CT.
- Kenny, D.A. (1994). *Interpersonal perception: A social relations analysis*. New York: Guilford Press.

- Kenny, D.A. (1996). The design and analysis of social interaction research. *Annual Review of Psychology*, *47*, 59-86.
- Kenny, D.A., & De Paulo, B.M. (1993). Do people know how others view them? An empirical and theoretical account. *Psychological Bulletin*, *114*, 145-161.
- Kenny, D.A., & Judd, C.M. (1986). Consequences of violating the independence assumption in analysis of variance. *Psychological Bulletin*, *99*, 422-431.
- Kenny, D.A., & Judd, C.M. (1996). A general procedure for the estimation of interdependence. *Psychological Bulletin*, *119*, 138-148.
- Kenny, D.A., Kashy, D.A., & Bolger, N. (1998). Data analysis in social psychology. In D.T. Gilbert, S.T. Fiske, & G. Lindzey (Eds.), *Handbook of social psychology* (4th ed., Vol. 1, pp. 233-265). Boston: McGraw-Hill.
- Kenny, D.A., Kashy, D.A., & Cook, W.L. (2006). *Dyadic data analysis*. New York: Guilford Press.
- Kenny, D.A., & La Voie, L.J. (1984). The social relations model. In L. Berkovitz (Ed.), *Advances in experimental psychology* (Vol. 18, pp. 142-182). San Diego, CA : Academic Press.
- Kenny, D. A., & Nasby, W. (1980). Splitting the reciprocity correlation. *Journal of Personality and Social Psychology*, *38*, 249-256.
- La Grange, A., Le Roux, N.J., & Gardner-Lubbe, S. (2009). BiplotGUI : Interactive biplots in R. *Journal of Statistical Software*, *30*, 1-37.
- Lashley, R.B., & Bond, C.F. Jr. (1997). Significance testing for round robin data. *Psychological Methods*, *2*, 278-291.
- Lüdtke, O., Robitzsch, A., Kenny, D.A., & Trautwein, U. (2012, July 16). A general and flexible approach for estimating the Social Relations Model using bayesian methods. *Psychological Methods*. Advance online publication. doi: 10.1037/a0029252.
- Malloy, T.E., & Albright, L. (1990). Interpersonal perception in a social context. *Journal of Personality and Social Psychology*, *58*, 419-428.
- Malloy, T.E., & Albright, L. (2001). Multiple and single interaction dyadic research designs: Conceptual and analytic issues. *Basic and Applied Social Psychology*, *23*, 1-19.
- Marcus, D.K. (1998). Studying group dynamics with the Social Relations Model. *Group Dynamics: Theory, Research, and Practice*, *2*, 230-240.
- O'Connor, B.P. (2004). SPSS and SAS programs for addressing interdependence and basic levels-of-analysis issues in psychological data. *Behavior Research Methods, Instruments & Computers*, *36*, 17-28.
- R Development Core Team (2011). *R: Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna: Austria.
- Sierra, V., Andrés, A., Solanas, A., & Leiva, D. (2010). Agreement in interpersonal perception as a predictor of group performance. *Psicothema*, *22*, 848-857.
- Schönbrodt, F.D., Back, M.D., & Schmukle, S.C. (2012). TripleR: An R package for social relations analyses based on round-robin designs. *Behavior Research Methods*, *44*, 455-470.
- Spiegelhalter, D.J., Thomas, A., Best, N.G., Gilks, N.R., & Lunn, D. (2003). *BUGS: Bayesian inference using Gibbs sampling*. Cambridge, England: MRC Biostatistics Unit.
- Sturtz, S., Ligges, U., & Gelman, A. (2005). R2WinBUGS: A package for running WINBUGS. *Journal of Statistical Software*, *12*, 1-16.
- Thioulouse, J., & Dray, S. (2007). Interactive Multivariate Data Analysis in R with the ade4 and ade4TkGUI packages. *Journal of Statistical Software*, *22*, 1-14.
- Warner, R. M, Kenny, D.A., & Stoto, M. (1979). A new round-robin analysis of variance for social interaction data. *Journal of Personality and Social Psychology*, *37*, 1742-1757.
- Wasserman, S., & Faust, K. (1994). *Social network analysis: Methods and applications*. Cambridge: Cambridge University Press.