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Analysis of group composition in multimember multigroup data

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Abstract

Data from groups often have a multimember multigroup (MMMG) structure. Examples are two-parent families with a female or male child (three members, two groups), two same-gender and opposite-gender peers of different status (two members, four groups), or gay, lesbian, and heterosexual couples (two members, three groups). To analyze such data, a framework called MMMG actor–partner interdependence model (MMMG APIM) is presented considering group composition. Three models are discussed in detail: the three-member two-group APIM, the two-member four-group APIM, and the two-member three-group APIM. Structural equation modeling and cross-sectional and longitudinal data are used to illustrate the approach. To ease the interpretation of APIM findings, a proposal of a general classification scheme is made.

Interpersonal relationships are important for most individuals across the lifespan (Baumeister & Leary, 1995). Some of the most important relationships in one's life include those with family members, friends, peers, teachers, and coworkers (Antony & Swinson, 1998). When we study such relationships, we may very often be interested in the extent to which partners influence each other. For example, we might be interested in whether younger siblings are more influenced by older siblings than younger siblings influencing older siblings or whether same-gender siblings influence each other more than opposite-gender siblings. To assess the degree to which two partners influence each other, the actor–partner interdependence model (APIM; Kenny, 1996) has been developed. This widely used model provides an assessment of intrapersonal and interpersonal effects, called actor and partner effects, respectively. In its most basic form, the APIM consists of a predictor X and an outcome Y, both measured in both dyad members, which might be stress and satisfaction in husbands and wives.

When we study dyads, there is often not just one type of dyad but multiple types. For example, with sibling pairs of different ages, there are four possible group compositions: both male, both female, older sibling male and younger sibling female, and older sibling female and younger sibling male. The same is true with friends of different ages or peers of different status. Also, often, there are more than two partners. Examples of triads are two-parent families with a target child or a tutor with two students. As with dyads, there is often more than one type of triad. Two-parent families with a child typically represent two different groups, one where the child is a male

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and another one where the child is a female. We call data from dyads representing four groups two-member four-group (2M4G) data and data from triads representing two groups three-member two-group (3M2G) data.

Drawing on the basic APIM, this article presents a flexible approach for the analysis of such multimember multigroup (MMMG) data. The approach, called multimember multigroup actor–partner interdependence model (MMMG APIM), facilitates the assessment of the extent to which members influence each other and the testing of specific hypotheses at different levels. It also allows the evaluation of theoretically important patterns that can be a crucial component when interpreting the results and help refine the understanding of interpersonal processes in groups.

For the analysis of data from groups, various models have been proposed. For groups of three and more members, Kenny and Garcia (2012) and Kenny, Mannetti, Pierro, Livi, and Kashy (2002) developed a model to study effects of group composition. With gender as a group variable and an individual outcome, such as members' satisfaction, this approach enables the testing of the influence that the proportion of women to men in the group has on men's and women's outcome. For triads, Bond, Horn, and Kenny (1997) presented a relations model enabling the analysis of a third person's perception of how two people relate to one another. For dyads representing three groups, as, for example, gay, lesbian, and heterosexual couples, West, Popp, and Kenny (2008) proposed an APIM approach enabling researchers to test whether the actor and partner effects differ as a function of dyad members' gender (or any other group variable). We build on the APIM and present a framework for the analysis of group composition effects in dyads and larger groups. To analyze the models, we use structural equation modeling (SEM) that allows the testing of different effects and specific hypotheses. To ease the use of the models, computer files for lavaan (Rosseel, 2012) and Mplus (Muthén & Muthén, 1998–2011) can be downloaded at http://thomasledermann.com/mmmgapim/.

Next, we describe the MMMG APIM approach and address conceptual and technical issues. We then present a general classification scheme for APIM results that facilitates the interpretation of findings. After providing some guidelines for the testing of MMMG models, we illustrate the models using archival cross-sectional and longitudinal data. Finally, we consider other variations and close with a discussion.

The MMMG APIM

The MMMG APIM is a flexible framework for the analysis of associations in groups that go beyond basic APIM designs, such as heterosexual couples or twins. The key of the MMMG APIM approach is that there is a predictor and an outcome, both measured in all group members, as well as one or more group variables that divide the groups into different classes (subpopulations). The simplest version is the two-member two-group (2M2G) APIM that enables the analysis of dyads representing two different populations and that technically resembles the APIM presented by Cook and colleagues (Cook, 1998; Cook & Snyder, 2005) for evaluating treatment effects in dyads. A typical example is mothers with a child whose gender divides the dyads into mothers with a son and mothers with a daughter (e.g., Martini & Busseri, 2012). More examples of data that can be analyzed using the 2M2G APIM are given in Table 1. Figure 1 illustrates this model that can be described by two equations, one for Member 1 and one for Member 2, which might be mother and child. With Y_1 and Y_2 as outcomes, which might be mother's and child's relationship satisfaction; X_1 and X_2 as predictors, which might be mother's and child's attachment style; and G as the group variable, which might be child's gender, the equation for Member 1 is

$$Y_1 = b_{10} + b_{11}X_1 + b_{12}X_2 + b_{13}G + b_{14}X_1G + b_{15}X_2G + e_1, \quad (1)$$

where b_{10} is the intercept; b_{11}, b_{12}, and b_{13} are the coefficients of X_1, X_2, and G on Y_1; b_{14} and b_{15} are the coefficients of the interactions of X_1 and G and the interaction of X_2 and G; and e_1 is the residual term. The equation for Member 2 is

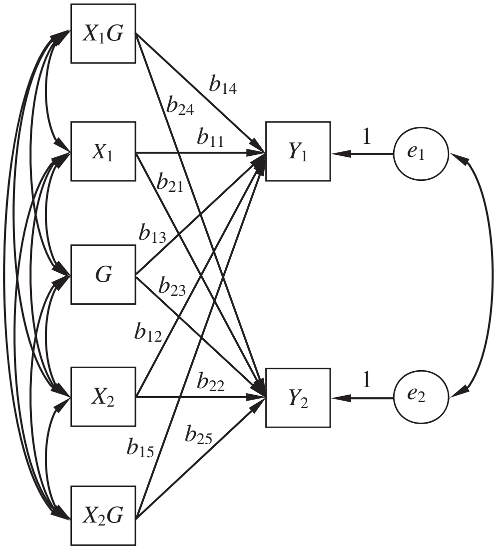

Figure 1. A path diagram of the two-member two-group actor–partner interdependence model.

$$Y_2 = b_{20} + b_{21}X_1 + b_{22}X_2 + b_{23}G + b_{24}X_1G + b_{25}X_2G + e_2. \quad (2)$$

An important issue in dyadic data analysis is whether members are distinguishable or indistinguishable (Kenny, Kashy, & Cook, 2006). Dyad members are distinguishable when there is a meaningful variable that provides a classification of the members into two different groups, such as heterosexual couples who are distinguishable by gender or mother–daughter dyads that are distinguishable by role. Members are indistinguishable, sometimes called exchangeable or interchangeable, if there is no such distinguishing variable. Same-gender twins or homosexual couples are typical examples of indistinguishable members.

Using SEM, the analysis of indistinguishable dyad members requires a series of specific parameter constraints and an adjustment of the chi-square fit statistic and all fit indices based on it (Olsen & Kenny, 2006). Specifically, all parameters that come in pairs (structural coefficients, variances, covariances, means, and intercepts) are constrained to be equal across members. For the 2M2G APIM, details on how to impose these constraints are provided in Appendix S1, Supporting Information. Imposing these constrains, the 2M2G APIM can accommodate data of two groups where the members within each group are indistinguishable, such as male and female monozygotic twins or gay and lesbian couples (see, e.g., Jong & Reis, 2015; Totenhagen, Butler, & Ridley, 2012). Details of how to adjust the fit statistic are given below when we describe the analysis of two-member three-group (2M3G) data.

We present hereinafter three types of MMMG models in detail that may be of special interest to a wide range of researchers. The first is the three-member two-group APIM (3M2G APIM), which is designed for triads representing two different classes (groups). Examples are two parents with a target child whose gender divides the families into those with a female target child and those with a male target child. The second model is the two-member four-group APIM (2M4G APIM), which is proposed for dyads when both members can be classified into one of two groups, and this group membership varies both within and between dyads. Examples that fit into this model are sibling, parent–child, peer, or coach–athlete dyads. In all these instances, gender is a mixed variable that can vary within and between dyads (Kenny et al., 2006). The third model is the two-member three-group APIM (2M3G APIM). This model is designed for dyads representing three groups, such as heterosexual and homosexual couples or same-gender and opposite-gender dizygotic twins. In these examples, the two dyad members can both be male or female, or one can be male and the other one can be female.

The 3M2G APIM

The 3M2G APIM is designed for the analysis of 3M2G data. The key of this model is that the group size is three and that there is a group composition variable defining the two classes. We shall see that in triads, members can often be distinguished by their role, as, for instance, in families consisting of a father, a mother, and a child. The group composition variable in this model, which might be the child's gender, can vary between groups but not within groups, and so, the value of the group variable

Table 1. *Examples of two-member two-group, three-member two-group, and two-member four-group data*

Group	Distinguishing variable	Group variable
2M2G data		
Mother with a target child	Role	Child's gender
Male teacher with a student	Role	Student's gender
Female caretaker with care receiver	Role	Care receiver's gender
Doctor with a prostate cancer patient	Role	Doctor's gender
Same-gender coworker dyads	Higher vs. lower status	Female vs. male dyads
3M2G data		
Two-parent families with a target child	Parent's gender and role	Child's gender
Single-parent families with two children	Role	Parent's gender
Relationship therapist with one couple	Role	Therapist gender
Couples and his or her mother	Role	His vs. her mother
Two caregivers and one home resident	More vs. less experienced caregiver and role	Resident's gender
2M4G data		
Sibling dyads	Older vs. younger	Siblings' gender
Couples with one or both partners unemployed	Spouses' gender	Employed vs. unemployed
Veterans and their partners	Spouses' gender	Veteran vs. nonveteran
Parent–child dyads	Parent vs. child	Parent's gender, child's gender
Mother–child dyads	Mother vs. child	Biological vs. stepmother, child's gender
Peer dyads	Higher vs. lower status	Peers' gender
Coworker dyads	Higher vs. lower status	Coworkers' gender
Patient–physician dyads	Patient vs. physician	Patient's gender, physician's gender
Teacher–student dyads	Teacher vs. student	Teacher's gender, student's gender
Coach–athlete dyads	Coach vs. athlete	Coach's gender, athlete's gender

Note. 2M2G = two-member two-group; 3M2G = three-member two-group; 2M4G = two-member four-group.

is a characteristic of the group. This group variable acts as a moderating variable in the 3M2G APIM and can be referred to as a Level 2 variable or a between-groups variable in accordance with what Kenny and colleagues (2006) call a between-dyads variable, which can vary between dyads but not within dyads.

The 3M2G APIM is well suited for a wide range of applications. Table 1 gives examples that fit into this model. In two-parent families with a child, for example, role is the distinguishing variable, and the child's gender is the group composition variable. This group variable allows the testing of group composition effects or, in other words, between group distinguishability.

The 3M2G APIM model can be described by three equations, one for each group member's outcome. The equations for the three members, which might be father, mother, and target child, are

$$Y_1 = b_{10} + b_{11}X_1 + b_{12}X_2 + b_{13}X_3 + b_{14}G + b_{15}X_1G + b_{16}X_2G + b_{17}X_3G + e_1, \quad (3)$$

$$Y_2 = b_{20} + b_{21}X_1 + b_{22}X_2 + b_{23}X_3 + b_{24}G + b_{25}X_1G + b_{26}X_2G + b_{27}X_3G + e_2, \quad (4)$$

and

$$Y_3 = b_{30} + b_{31}X_1 + b_{32}X_2 + b_{33}X_3 + b_{34}G + b_{35}X_1G + b_{36}X_2G + b_{37}X_3G + e_3. \quad (5)$$

In this model, there are six actor effects, three in each type of group. For a child with two parents, there is one actor effect for the father, one for the mother, and one for the child when the child is male and one actor effect for the father, one for the mother, and one for the child when the child is female. Each actor effect equals the effect of the individual's X variable on his or her outcome plus the effect of the interaction of the individual's X variable and the group variable. With the group variable coded 1 (Group A) and −1 (Group B), details of how these six actor effects are calculated are given in Table 2.

There are also 12 partner effects, 2 on each member's outcome. For two-parent families with a target child, the partner effects are as follows: one from the mother and one from the child to the father, one from the father and one from the child to the mother, and one from the father and one from the mother to the child. As the actor effects, these partner effects depend on the group variable. Each partner effect equals the effect of the partner's X variable on the individual's Y variable plus the effect of the interaction of the partner's X variable and the group variable. Table 2 gives details of how these 12 effects are calculated.

Finally, there are also six intercepts, three in each type of group. For each member, the intercept equals the intercept of the equation, b_{10}, b_{20}, and b_{30}, plus the effect of the group variable. Table 2 gives details of how these intercepts are calculated.

This 3M2G APIM can be readily adapted to accommodate indistinguishable members by imposing equality constraints on all parameters that occur across members (further details are provided in Appendix S1). With these constraints, the 3M2G APIM can be used to analyze triads representing two groups, such as male and female working teams, each consisting of three indistinguishable members.

Classification of APIM results

The interpretation of findings from APIM analyses can be eased by evaluating each actor effect and each respective partner effect on the basis of their presence and absence. For an actor effect and a respective partner effect, there are four basic outcomes possible: both effects are present; both effects are absent; the actor effect is present, but the partner effect is not; and the partner effect is present, but the actor effect is not. Figure 2 illustrates these possible outcomes that can be called *mixed pattern*, *unrelatedness*, *actor-only pattern*, and *partner-only pattern*. The actor-only and partner-only patterns were extensively discussed by Kenny and colleagues (Kenny & Cook, 1999; Kenny & Ledermann, 2010). The actor-only pattern reflects an independence process, whereas the partner-only pattern reflects dependence or interpersonal process. Kenny and Cook (1999) and Kenny and Ledermann (2010) describe two additional patterns: the couple pattern and the contrast pattern, which are special cases of the mixed pattern. The couple pattern is indicated if both the actor effect and the partner effect are substantial, of equal size, and in the same direction. The contrast pattern is suggested if the actor effect and the partner effect are substantial, of equal size, but of opposite direction. We note that in the distinguishable case, members can have different patterns (see Fitzpatricka, Gareaua, Lafontainea, & Gaudreaua, 2016, for details), and patterns can be evaluated in terms of either the predictor or the outcome (Kenny & Ledermann, 2010).

A simple method to evaluate the patterns described by Kenny and colleagues is the calculation of the ratio of the partner effect to the respective actor effect (Kenny & Ledermann, 2010). This ratio, known as k, is interesting in two respects. First, k is a measure of the importance of the partner effect relative to the respective actor effect. This relative importance of the partner effect provides useful information

Table 2. *Effects in the 3M2G APIM*

Effect	Coefficient	Example families with a child
Group A ($G = 1$)		*Families with a son*
Intercept		Intercept
Member 1	$b_{10} + b_{14}$	Father
Member 2	$b_{20} + b_{24}$	Mother
Member 3	$b_{30} + b_{34}$	Son
Actor effect		Actor effect
Member 1	$b_{11} + b_{15}$	Father
Member 2	$b_{22} + b_{26}$	Mother
Member 3	$b_{33} + b_{37}$	Son
Partner effect from Member 1 to		Partner effect from father to
Member 2	$b_{21} + b_{25}$	Mother
Member 3	$b_{31} + b_{35}$	Son
Partner effect from Member 2 to		Partner effect from mother to
Member 1	$b_{12} + b_{16}$	Father
Member 3	$b_{32} + b_{36}$	Son
Partner effect from Member 3 to		Partner effect from son to
Member 1	$b_{13} + b_{17}$	Father
Member 2	$b_{23} + b_{27}$	Mother
Group B ($G = -1$)		*Families with a daughter*
Intercept		Intercept
Member 1	$b_{10} - b_{14}$	Father
Member 2	$b_{20} - b_{24}$	Mother
Member 3	$b_{30} - b_{34}$	Daughter
Actor effect		Actor effect
Member 1	$b_{11} - b_{15}$	Father
Member 2	$b_{22} - b_{26}$	Mother
Member 3	$b_{33} - b_{37}$	Daughter
Partner effect from Member 1 to		Partner effect from father to
Member 2	$b_{21} - b_{25}$	Mother
Member 3	$b_{31} - b_{35}$	Daughter
Partner effect from Member 2 to		Partner effect from mother to
Member 1	$b_{12} - b_{16}$	Father
Member 3	$b_{32} - b_{36}$	Daughter
Partner effect from Member 3 to		Partner effect from Daughter to
Member 1	$b_{13} - b_{17}$	Father
Member 2	$b_{23} - b_{27}$	Mother

Note. 3M2G APIM = three-member two-group actor–partner interdependence model. The group variable is coded 1 for Group A and −1 for Group B.

that can aid the interpretation of results. For example, k might be 0.52, which means that the partner effect is about half the size of the actor effect and so indicates a mixed pattern. Second, k enables a direct assessment of the patterns. When k is 0, the actor-only pattern is indicated; when k is 1, the couple pattern is indicated; and when k is −1, the contrast pattern is indicated.

The use of SEM allows researchers to estimate submodels by imposing specific constraints on the basis of specific patterns. If there is evidence for more than one pattern, a submodel can be specified implying all reasonable

Partner effect	Actor effect	
	Present	Absent
Present	Mixed when PE = AE, then couple when PE = -AE, then contrast	Partner-only (Dependence)
Absent	Actor-only (Independence)	Un-relatedness

Figure 2. Classification scheme for actor–partner interdependence model results. AE = actor effect; PE = partner effect.

patterns. For example, sibling pairs might show a couple pattern for the effect on the younger sister and an actor-only pattern for the effect on the older sister.

General strategy

Drawing on strategies proposed by Kenny and colleagues (Garcia, Kenny, & Ledermann, 2015; Kenny & Ledermann, 2010; Ledermann, Macho, & Kenny, 2011), we recommend the following steps in estimating the MMMG APIM. First, we estimate the unrestricted model (i.e., a model in which there are no constraints on the actor and partner effects). When all variables are manifest, this model is saturated.

Second, we estimate alternative submodels testing whether members are distinguishable and whether specific patterns are reflected. Each submodel consists of a set of constraints and is compared with the unrestricted MMMG APIM. With theoretically distinguishable members, we can test whether members are distinguishable within and between groups. Distinguishability within groups can be assessed by fitting a model with all actor effects and all partner effects set equal within each group. Distinguishability between groups can be tested by estimating a model with the actor effects and the partner effects constrained to be equal across groups. This is a test of whether group composition matters. (Details on these constraints are given in Appendix A.) If in both submodels the decline in the fit is not statistically worse and the overall fit is good, all actor effects and all partner effects can be set equal within and across groups. This submodel is very parsimonious, providing an estimate of one actor effect and one partner effect.

In order to test for specific patterns, we assess the relative importance of the partner effects by calculating k for each partner effect in the unrestricted model and estimate a submodel for each type of pattern indicated by k. If the models support multiple patterns, a submodel can be fitted that implies all these patterns.

The examination of alternative models can be crucial in APIM analysis, especially with distinguishable members, because in our experience, models implying specific patterns very often fit the data better than models implying indistinguishable actor and partner effects (e.g., actor effect wife = actor effect husband and partner effect wife = partner effect husband). The failure to compare alternative models may lead to wrong conclusions.

Third, we address specific questions by comparing specific effects. For example, by fitting a 3M2G model with the two partner effects from the parents to the daughter's outcome set equal, we can test whether daughters are more influenced by mothers or by fathers. By constraining the mother-to-son partner effect to be equal to the mother-to-daughter partner effect, we can test whether daughters are more influenced by mothers than sons. In addition, we can also constrain one set of effects to be equal to another set of effects. For example, by fitting a submodel with the average of the two partner effects on the mother's outcome set equal to the average of the two partner effects on the father's outcome, we can test whether, on average, mothers are more influenced by family members than fathers.

In almost every model with interaction terms, multicollinearity exists between the product term and its constituent components (Aiken & West, 1991). This multicollinearity can often be reduced by centering the lower order terms (i.e., subtracting the mean from the individual scores). Although mean centering affects neither the statistical test of the interaction nor the explained variance overall (Cohen, 1978), it very often enhances the interpretability of the coefficients in interaction models. Thus, in accordance with others (e.g., Aiken & West, 1991; McClelland & Judd, 1993; Shieh, 2011; Whisman & McClelland, 2005), we recommend centering the continuous predictors prior to the creation of the interaction terms. For the dichotomous group variable, we echo Whisman and McClelland (2005) and suggest the use of effect coding.

Illustration of the 3M2G APIM

To illustrate the 3M2G APIM, we use data from The Iowa Youth and Families Project (Conger et al., 2011). This study consists of four waves, conducted in 1989, 1990, 1991, and 1992. The initial sample includes 451 seventh graders from two-parent families in Iowa. We use data from the parents and their target child and depressive symptoms to predict family members' positive affect reported at the first measurement occasion. The age ranged from 31 to 68 years for the fathers ($M = 39.73$, $SD = 4.89$), from 29 to 53 years for the mothers ($M = 37.70$, $SD = 4.12$), and from 12 to 14 years for the target children ($M = 12.61$, $SD = 0.54$). The target child was female in 52.3% of the families. The depressive symptoms were measured by the depression subscale of the Symptom Checklist (SCL–90; Derogatis, 1992). Each of the 13 items was rated on a 5-point scale (1 = *not at all*, 5 = *extremely*). A composite score was computed that could range from 1 to 5, with higher scores indicating greater depressive symptoms (Cronbach's alphas were .866 for fathers and mothers, .847 for sons, and .874 for daughters). Positive affect was assessed by 6 items (e.g., "Were you a happy person?") of the General Positive Affect Scale from the Mental Health Inventory (Veit & Ware, 1983). Each item was rated on a 6-point scale (1 = *all of the time*, 6 = *none of the time*). With all items reversed, a composite score was computed that could range from 1 to 6, with higher scores indicating higher positive affect (Cronbach's alphas were .844 for fathers, .871 for mothers, .834 for sons, and .828 for daughters).

We centered depression separately for each group by subtracting the group mean from the members' depression scores and used effect coding for the group variable (1 = son and −1 = daughter). The patterns were tested for effects on a common outcome. For k, we calculated bias-corrected bootstrap confidence interval (CI) estimates using 5,000 bootstrap samples. We used SEM, which requires data in wide format, where each record has the data of all group members (see Kenny et al., 2006), and the software lavaan. To compute standardized effects, we followed the recommendation of Ackerman, Donnellan, and Kashy (2011) and calculated a pooled standard deviation for X and Y separately for each of the two groups. For the three-member APIM, the pooled standard deviation is

$$SD_p = \sqrt{\frac{(n_1 - 1)\,SD_1^2 + (n_2 - 1)\,SD_2^2 + (n_3 - 1)\,SD_3^2}{(n_1 - 1) + (n_2 - 1) + (n_3 - 1)}}, \tag{6}$$

where n is the number of family members and SD is the standard deviation.

Using these data, we address whether children's positive affect depends on parents' depressive symptoms, whether parents' positive affect depends on the child's depressive symptoms, and whether family members' roles and child's gender matter. Table 3 shows the fit estimates of the 3M2G models. We first estimated the unrestricted 3M2G APIM, which is saturated (Table 3, first model). The estimates and standard errors of the 6 actor and 12 partner effects are presented in Table 4. All actor effects were negative and statistically significant in both families with a male target child and families with a female target child. That is, the more depressive symptoms a family member reported, the lower was his or her positive affect. There were also three statistically significant partner effects, two in families with a male target child and one in families with a female target child. In families with a son, mother's positive affect was negatively associated with both father's and son's report of depressive symptoms, whereas in families with a daughter, daughter's positive affect was negatively associated with mother's report of depressive symptoms.

Next, we fitted alternative models that imply within-group and between-group indistinguishability and specific patterns. To test indistinguishability within groups, we set all three actor effects and all six partner effects equal within each of the two families (see Appendix A for details) and found that these equality constraints resulted in a poor fit (Table 3, second model). This indicates that family members' roles matter. We tested

Table 3. *Tests of model fit of the 3M2G APIM for two-parent families with a target child*

Model	χ^2	*df*	*p*	RMSEA	SABIC
Unrestricted model	—	0	—	—	190.96
Indistinguishability within groups	59.268	14	<.001	.085	209.10
Indistinguishability between groups	12.756	9	.174	.031	177.28
Specific patterns					
Couple pattern for the significant partner effects	44.774	3	<.001	.176	226.92
Actor-only pattern for the nonsignificant partner effects	4.775	9	.853	<.001	169.29

Note. 3M2G APIM = three-member two-group actor–partner interdependence model; *df* = degrees of freedom; RMSEA = root mean squared error of approximation; SABIC = sample-size-adjusted Bayesian information criterion.

indistinguishability between groups by constraining the corresponding actor effects and partner effects to be equal across the families. This simpler model showed a good fit (Table 3, third model), which suggests that child's gender does not matter.

To assess specific patterns, we determined the relative importance of the partner effects in the unrestricted model by calculating *k* as the ratio of each partner effect to the actor effect on the same outcome. For the three significant partner effects, *k* was between 0.21 and 0.34. In families with a son, the father-to-mother partner effect was 29.7% of the size of mother's actor effect, 95% CI [0.060, 0.619], and the son-to-mother partner effect was 21.3% of mother's actor effect, 95% CI [0.042, 0.445]. In families with a daughter, the mother-to-daughter partner effect was 34.1% of the size of daughter's actor effect, 95% CI [−0.024, 0.861]. The implementation of a couple pattern for each of the three significant partner effects produced a poor fit (Table 3, fourth model). All this indicates a mixed pattern that is something in between the actor-only and the couple pattern. For the nine nonsignificant partner effects, the highest ratios were found for the effects on the son's and the daughter's outcome, with *k*s of 0.166, 95% CI [−0.169, 0.649], and 0.152, 95% CI [−0.176, 0.581], respectively. For the effects involving the parents' actor effects, *k* was between −0.020, 95% CI [−0.183, 0.108], and 0.110, 95% CI [−0.031, 0.322]. These small ratios suggest an actor-only or independence pattern. This is supported by a model implying an actor-only pattern for each of the nine nonsignificant partner effects (Table 3, fifth model), which shows a good fit that is even better than the fit of the model implying indistinguishable actor and partner effects between groups.

Finally, we compared specific effects. First, we tested whether the statistically significant effects differed in magnitude and found that the six actor effects differed across members, $\chi^2(5) = 44.897$, $p < .001$, constraints are $AE_{F_S} = AE_{M_S} = AE_S = AE_{F_D} = AE_{M_D} = AE_D$. In looking at the estimates (Table 4), children's actor effects were about half the size of the parents' actor effects. Indeed, children's actor effects were on average significantly smaller than parents' actor effects, $\chi^2(1) = 39.578$, $p < .001$, constraint is $(AE_{F_S} + AE_{M_S} + AE_{F_D} + AE_{M_D})/4 = (AE_S + AE_D)/2$. No statistically significant difference was found for the three significant partner effects, $\chi^2(2) = 0.298$, $p = .861$, constraints are $PE_{FM_S} = PE_{SM} = PE_{MD}$.

Second, we tested whether female members were more strongly affected by the other family members than male members. In families with a male target child, mothers seemed to be more strongly affected by the other members than fathers, $\chi^2(1) = 6.193$, $p = .013$, constraint is $(PE_{MF_S} + PE_{SF}) = (PE_{FM_S} + PE_{SM})$. No such difference between fathers and mothers was found in families with a female target child, $\chi^2(1) = 0.316$, $p = .574$, constraint is $(PE_{MF_D} + PE_{DF}) = (PE_{FM_D} + PE_{DM})$. This later finding is not surprising as all involved partner effects in families with a daughter were statistically insignificant. Next, we tested whether sons were more affected by their parents than daughters and found that there was no statistically significant difference between

Table 4. *Results of the unrestricted 3M2G APIM for depressive symptoms predicting positive affect in families*

Effect	Estimate	*SE*	95% CI	Stand. est.
Families with a son				
Intercept				
Father (I_{F_S})	4.527	0.037	[4.454, 4.599]	
Mother (I_{M_S})	4.536	0.039	[4.460, 4.612]	
Son (I_S)	4.864	0.046	[4.773, 4.955]	
Actor effect				
Father (AE_{F_S})	−1.075	0.090	[−1.251, −0.899]	−.724
Mother (AE_{M_S})	−0.866	0.077	[−1.017, −0.714]	−.583
Son (AE_S)	−0.555	0.087	[−0.726, −0.384]	−.374
Partner effect from father to				
Mother (PE_{FM_S})	−0.257	0.094	[−0.441, −0.073]	−.173
Son (PE_{FS})	−0.092	0.112	[−0.313, 0.128]	−.062
Partner effect from mother to				
Father (PE_{MF_S})	0.020	0.075	[−0.128, 0.167]	.013
Son (PE_{MS})	0.011	0.093	[−0.171, 0.193]	.007
Partner effect from son to				
Father (PE_{SF})	−0.118	0.070	[−0.256, 0.020]	−.080
Mother (PE_{SM})	−0.185	0.073	[−0.327, −0.042]	−.124
Families with a daughter				
Intercept				
Father (I_{F_D})	4.602	0.035	[4.533, 4.672]	
Mother (I_{M_D})	4.512	0.037	[4.440, 4.584]	
Daughter (I_D)	4.871	0.044	[4.784, 4.958]	
Actor effect				
Father (AE_{F_D})	−0.973	0.082	[−1.134, −0.811]	−.671
Mother (AE_{M_D})	−1.070	0.077	[−1.222, −0.919]	−.739
Daughter (AE_D)	−0.542	0.074	[−0.687, −0.397]	−.374
Partner effect from father to				
Mother (PE_{FM_D})	−0.021	0.086	[−0.189, 0.147]	−.014
Daughter (PE_{FD})	−0.083	0.103	[−0.284, 0.119]	−.057
Partner effect from mother to				
Father (PE_{MF_D})	−0.038	0.075	[−0.185, 0.110]	−.026
Daughter (PE_{MD})	−0.185	0.093	[−0.367, −0.003]	−.128
Partner effect from daughter to				
Father (PE_{DF})	−0.055	0.060	[−0.171, 0.062]	−.038
Mother (PE_{DM})	0.005	0.062	[−0.115, 0.126]	.004

Note. 3M2G APIM = three-member two-group actor–partner interdependence model; *SE* = standard error; CI = confidence interval; Stand. est. = standardized estimate.

the partner effects on the son and the partner effects on the daughter, $\chi^2(1) = 0.903$, $p = .342$, constraint is $(PE_{FS} + PE_{MS}) = (PE_{FD} + PE_{MD})$.

Third, with respect to the three statistically significant partner effects, we tested whether son's depressive symptoms had a stronger effect on mother's positive affect than daughter's depressive symptoms, whether mother's depressive symptoms had a stronger effect on daughter's positive affect than father's depressive symptoms, and whether mother's depressive symptoms were more strongly associated with daughter's positive affect than with son's positive affect. The first contrast was statistically significant, but the other contrasts were not: son-to-mother effect versus daughter-to-mother effect, $\chi^2(1) = 4.152$, $p = .042$, constraint is

$PE_{SM} = PE_{DM}$; mother-to-daughter effect versus father-to-daughter effect, $\chi^2(1) = 0.664$, $p = .415$, constraint is $PE_{MD} = PE_{FD}$; mother-to-daughter effect versus mother-to-son effect, $\chi^2(1) = 2.378$, $p = .123$, constraint is $PE_{MD} = PE_{MS}$. These results indicate that sons' depressive symptoms had a stronger effect on mothers' positive affect than daughters' depressive symptoms.

In conclusion, for the link between depressive symptoms and positive affect, a mixed pattern was found for daughters whose positive affect was not only affected by their own but also by their mothers' depressive symptoms and for mothers with a male child where mothers' positive affect was affected by both fathers' and sons' depressive symptoms beyond their own depressive symptoms. For male family members and mothers with a female child, an independence pattern was indicated.

The 2M4G APIM

The 2M4G APIM serves the analysis of 2M4G data. Typical examples are sibling dyads of different ages (Greer, Campione-Barr, & Lindell, 2015) or parent–child dyads (Juth, Silver, Seyle, Widyatmoko, & Tan, 2015). The key of this model is that dyad members are distinguishable by a meaningful variable (e.g., role in parent–child dyads), and there are two dichotomous group variables, one for each type of dyad member (e.g., gender in parent–child dyads). These two group variables form four possible group compositions. We shall see that the dichotomous group variable is often of the mixed type (i.e., it varies both within and between dyads). For example, in parent–child dyads, parent's and child's gender can be used as a group variable that constitutes four types of dyads: both male, both female, parent male and child female, and parent female and child male.

This 2M4G APIM has probably the widest range of applications of the models discussed in this article. Examples of dyads that fit into this model are given in Table 1. We note that in all these examples, the group variable is mixed, with the exception of mother–child dyads where the mother is either the biological or social mother. Other exemptions are mother–child dyads where the mother is either single or married or grandmother–mother dyads where the grandmother is either the mother-in-law or the biological mother.

The 2M4G APIM can be described by two equations. With G_1 and G_2 denoting the dichotomous group variables of Members 1 and 2, which might be older and younger sibling's gender, the equation for Member 1 is

$$\begin{aligned} Y_1 &= b_{100} + b_{101}X_1 + b_{102}X_2 + b_{103}G_1 \\ &\quad + b_{104}G_2 + b_{105}X_1G_1 + b_{106}X_2G_1 \\ &\quad + b_{107}G_1G_2 + b_{108}X_1G_2 + b_{109}X_2G_2 \\ &\quad + b_{110}X_1G_1G_2 + b_{111}X_2G_1G_2 + e_1 \quad (7) \end{aligned}$$

and the equation for Member 2 is

$$\begin{aligned} Y_2 &= b_{200} + b_{201}X_1 + b_{202}X_2 + b_{203}G_1 \\ &\quad + b_{204}G_2 + b_{205}X_1G_1 + b_{206}X_2G_1 \\ &\quad + b_{207}G_1G_2 + b_{208}X_1G_2 + b_{209}X_2G_2 \\ &\quad + b_{210}X_1G_1G_2 + b_{211}X_2G_1G_2 + e_2. \quad (8) \end{aligned}$$

We note that this model is mathematically equivalent with the moderation APIM (Garcia et al., 2015; Ledermann & Bodenmann, 2006) for the analysis of buffering and enhancing effects when all variables are continuous. However, the two approaches differ in the research designs that can be analyzed and the types of research questions that can be addressed.

In the 2M4G APIM, there are eight actor and eight partner effects, two in each possible group composition. With the group variables coded 1 (Group A) and −1 (Group B), Table 5 provides details on how these effects and the eight intercepts are calculated.

Illustration of the 2M4G APIM

To illustrate the 2M4G APIM, we used data from sibling pairs who participated in the first and second wave of The Iowa Youth and Families Project (Conger et al., 2011) and siblings' reports of satisfaction with the sibling relationship. The first wave took place in 1989 and the second wave approximately 1 year later. Age was used to classify the siblings of

Table 5. *Effects in the 2M4G APIM*

Effect	Coefficient	Example sibling pairs
Both A ($G_1 = 1$, $G_2 = 1$)		*Both siblings male*
Intercept		Intercept
Member 1	$b_{100} + b_{103} + b_{104} + b_{107}$	Older brother
Member 2	$b_{200} + b_{203} + b_{204} + b_{207}$	Younger brother
Actor effect		Actor effect
Member 1	$b_{101} + b_{105} + b_{108} + b_{110}$	Older brother
Member 2	$b_{202} + b_{206} + b_{209} + b_{211}$	Younger brother
Partner effect from		Partner effect from
Member 1 to Member 2	$b_{201} + b_{205} + b_{208} + b_{210}$	Older to younger brother
Member 2 to Member 1	$b_{102} + b_{106} + b_{109} + b_{111}$	Younger to older brother
Both B ($G_1 = -1$, $G_2 = -1$)		*Both siblings female*
Intercept		Intercept
Member 1	$b_{100} - b_{103} - b_{104} + b_{107}$	Older sister
Member 2	$b_{200} - b_{203} - b_{204} + b_{207}$	Younger sister
Actor effect		Actor effect
Member 1	$b_{101} - b_{105} - b_{108} + b_{110}$	Older sister
Member 2	$b_{202} - b_{206} - b_{209} + b_{211}$	Younger sister
Partner effect from		Partner effect from
Member 1 to Member 2	$b_{201} - b_{205} - b_{208} + b_{210}$	Older to younger sister
Member 2 to Member 1	$b_{102} - b_{106} - b_{109} + b_{111}$	Younger to older sister
Member 1 A ($G_1 = 1$), Member 2 B ($G_2 = -1$)		*Older brother, younger sister*
Intercept		Intercept
Member 1	$b_{100} + b_{103} - b_{104} - b_{107}$	Older brother
Member 2	$b_{200} + b_{203} - b_{204} - b_{207}$	Younger sister
Actor effect		Actor effect
Member 1	$b_{101} + b_{105} - b_{108} - b_{110}$	Older brother
Member 2	$b_{202} + b_{206} - b_{209} - b_{210}$	Younger sister
Partner effect from		Partner effect from
Member 1 to Member 2	$b_{201} + b_{205} - b_{208} - b_{210}$	Older brother to younger sister
Member 2 to Member 1	$b_{102} + b_{106} - b_{109} - b_{111}$	Younger sister to older brother
Member 1 B ($G_1 = -1$), Member 2 A ($G_2 = 1$)		*Older sister, younger brother*
Intercept		Intercept
Member 1	$b_{100} - b_{103} + b_{104} - b_{107}$	Older sister
Member 2	$b_{200} - b_{203} + b_{204} - b_{207}$	Younger brother
Actor effect		Actor effect
Member 1	$b_{101} - b_{105} + b_{108} - b_{110}$	Older sister
Member 2	$b_{202} - b_{206} + b_{209} - b_{211}$	Younger brother
Partner effect from		Partner effect from
Member 1 to Member 2	$b_{201} - b_{205} + b_{208} - b_{210}$	Older sister to younger brother
Member 2 to Member 1	$b_{102} - b_{106} + b_{109} - b_{111}$	Younger brother to older sister

Note. 2M4G APIM = two-member four-group actor–partner interdependence model. The group variables are coded 1 for Group A and −1 for Group B.

each dyad into older and younger sibling. The age ranged from 9 to 17 years for older siblings ($M = 13.92$, $SD = 1.47$) and from 9 to 14 years for younger siblings ($M = 11.56$, $SD = 1.27$). Among older siblings, 220 were females and 231 were males. Among younger siblings, 250 were females and 201 were males. Satisfaction with sibling relationship was measured by three items (e.g., “How satisfied are you with your relationship with your brother or sister in the study?"). Each item was rated on a 4-point scale (1 = *very satisfied*, 4 = *very unsatisfied*). A composite score was computed that could range from 1 to 4 with higher scores indicating higher relationship satisfaction (Cronbach's alphas at the first and second wave were .652 and .698 for older siblings and .681 and .751 for younger siblings, respectively).

We used satisfaction measured in 1989 to predict satisfaction 1 year later in both siblings. In this type of model, with a predictor and an outcome measured at two different time points, the actor effects represent the temporal stability over time, whereas the partner effects represent the extent to which partners influence each other over time (e.g., Cook & Kenny, 2005). We centered satisfaction separately for each group and used effect coding for the group variable (1 = male, −1 = female). The patterns were again evaluated for effects on a common outcome. We used lavaan to estimate the models and bootstrapping with 5,000 bootstrap samples to estimate the CIs of the ratios. Standardized effects were computed by calculating a pooled standard deviation for X and Y separately for each of the four types of dyads.

Using these data, we address whether same-gender siblings influenced each other more than opposite-gender siblings and whether younger siblings were more influenced by older siblings than younger siblings influencing older siblings in their satisfaction with the relationship. The fit of the models are given in Table 6. The first model was the unrestricted 2M4G APIM, which is saturated (Table 6, first model). Table 7 shows the estimates and standard errors of the actor and partner effects of this model. All eight actor effects were positive and statistically significant, which means that the higher siblings rated their satisfaction with the relationship in 1989, the higher they valued this satisfaction 1 year later. There were also three statistically significant partner effects. Two of these partner effects were from the older brother to his younger sibling, brother or sister, and one was from the younger sister to the older sister. That is, the relationship satisfaction reported by the older brother had an effect on the relationship satisfaction reported by the younger sibling 1 year later independent of the younger sibling's gender. No partner effects were found from the younger brother to the older sibling and from the older sister to the younger sibling.

Next, we estimated alternative models implying indistinguishability within and between groups and specific patterns. To test indistinguishability within the groups, we set both actor effects and both partner effects equal within each of the four types of sibling pairs (see Appendix A for details). This simpler model with four actor and four partner effects showed a good fit (Table 3, second model), which indicates that birth order does not matter in sibling pairs. Indistinguishability between groups was tested by constraining the corresponding actor effects and partner effects to be equal across the four types of sibling pairs. This simpler model with two actor and two partner effects was consistent with the data (Table 3, third model), meaning that siblings' gender does not matter. Imposing these within- and

Table 6. *Tests of model fit of the 2M4G APIM for sibling pairs*

Model	χ^2	*df*	*p*	RMSEA	SABIC
Unrestricted model	—	0	—	—	305.54
Indistinguishability within groups	13.100	8	.108	.038	295.13
Indistinguishability between groups	12.235	12	.427	.007	282.52
Indistinguishability within and between groups	14.824	14	.390	.011	279.23
Specific patterns					
Couple pattern for the significant partner effects	5.865	3	.118	.046	302.59
Actor-only pattern for the nonsignificant partner effects	5.512	5	.357	.015	287.55
Couple pattern and actor-only pattern	10.048	8	.262	.024	292.08

Note. 2M4G APIM = two-member four-group actor–partner interdependence model; *df* = degrees of freedom; RMSEA = root mean squared error of approximation; SABIC = sample-size-adjusted Bayesian information criterion.

Table 7. *Results of the unrestricted 2M4G APIM for relationship satisfaction at the first and second waves for sibling pairs*

Effect	Estimate	*SE*	95% CI	Stand. est.
Both siblings male				
Intercept				
Older brother ($I_{O_{mm}}$)	0.042	0.049	[−0.053, 0.138]	
Younger brother ($I_{Y_{mm}}$)	0.005	0.052	[−0.097, 0.107]	
Actor effect				
Older brother ($AE_{O_{mm}}$)	0.420	0.083	[0.256, 0.583]	.456
Younger brother ($AE_{Y_{mm}}$)	0.456	0.093	[0.274, 0.639]	.496
Partner effect from				
Older to younger brother ($PE_{O_m Y_m}$)	0.273	0.089	[0.097, 0.448]	.296
Younger to older brother ($PE_{Y_m O_m}$)	0.056	0.087	[−0.114, 0.226]	.061
Both siblings female				
Intercept				
Older sister ($I_{O_{ff}}$)	0.019	0.046	[−0.070, 0.109]	
Younger sister ($I_{Y_{ff}}$)	0.045	0.049	[−0.051, 0.141]	
Actor effect				
Older sister ($AE_{O_{ff}}$)	0.432	0.085	[0.266, 0.599]	.409
Younger sister ($AE_{Y_{ff}}$)	0.526	0.088	[0.355, 0.698]	.497
Partner effect from				
Older to younger sister ($PE_{O_f Y_f}$)	0.107	0.091	[−0.071, 0.285]	.101
Younger to older sister ($PE_{Y_f O_f}$)	0.239	0.082	[0.079, 0.399]	.226
Older brother, younger sister				
Intercept				
Older brother ($I_{O_{mf}}$)	−0.046	0.049	[−0.141, 0.050]	
Younger sister ($I_{Y_{fm}}$)	−0.078	0.052	[−0.181, 0.024]	
Actor effect				
Older brother ($AE_{O_{mf}}$)	0.531	0.087	[0.360, 0.702]	.480
Younger sister ($AE_{Y_{fm}}$)	0.538	0.093	[0.356, 0.719]	.486
Partner effect from				
Older brother to younger sister ($PE_{O_m Y_f}$)	0.301	0.093	[0.118, 0.484]	.273
Younger sister to older brother ($PE_{Y_f O_m}$)	0.053	0.086	[−0.117, 0.222]	.048
Older sister, younger brother				
Intercept				
Older sister ($I_{O_{fm}}$)	−0.028	0.054	[−0.133, 0.077]	
Younger brother ($I_{Y_{mf}}$)	0.034	0.058	[−0.078, 0.147]	
Actor effect				
Older sister ($AE_{O_{fm}}$)	0.589	0.099	[0.394, 0.783]	.557
Younger brother ($AE_{Y_{mf}}$)	0.371	0.112	[0.151, 0.591]	.352
Partner effect from				
Older sister to younger brother ($PE_{O_f Y_m}$)	0.159	0.106	[−0.049, 0.368]	.151
Younger brother to older sister ($PE_{Y_m O_f}$)	0.095	0.105	[−0.110, 0.300]	.090

Note. 2M4G APIM = two-member four-group actor–partner interdependence model; *SE* = standard error; CI = confidence interval; Stand. est. = standardized estimate.

between-group constraints into a single model, a good fit was obtained (Table 3, fourth model). This submodel has one actor effect and one partner effect and implies that both birth order and siblings' gender do not matter.

To assess specific patterns, we determined the importance of each partner effect relative to the actor effect on the same outcome in the unrestricted model by calculating k. For the three significant partner effects, the partner effect from the older to the younger brother was 59.7% of the size of the younger brother's actor effect, 95% CI [0.133, 1.217]; the effect from the older brother to younger sister was 56.1% of the younger sister's actor effect, 95% CI [0.137, 1.372]; and the effect from the younger to the older sister was 55.3% of the older sister's actor effect, 95% CI [0.116, 1.725]. All three CIs exclude 0 and include 1, which is in support of a couple pattern. Indeed, implementing a couple pattern for each of these three partner effects resulted in a good model fit (Table 6, fifth model). The nonsignificant partner effects were all below 20% of the respective actor effects, with the exception of the effect from the older sister to the younger brother, which was 42.9% of the younger brother's actor effect, 95% CI [−0.104, 1.849]. The model implying an actor-only (independence) pattern for each nonsignificant partner effect was consistent with the data (Table 6, sixth model). Incorporating the constraints of these last two submodels into a single model yielded a good fit (Table 6, seventh model), suggesting a couple pattern for the three significant partner effects and an actor-only pattern for the nonsignificant partner effects. Although all alternative models fit the data about equally well, we favor the models implying specific patterns because we believe that the model implying indistinguishability within and between groups oversimplifies how siblings influence each other in their relationship satisfaction.

Finally, we ran a series of specific comparisons. First, we tested whether the two significant partner effects from the older brother were stronger than the two partner effects from the older sister and the two partner effects from the younger brother. The effects from the older brother did not, on average, significantly differ from the effects from the older sister, $\chi^2(1) = 2.596$, $p = .107$, constraint is $(PE_{O_mY_m} + PE_{O_mY_f}) = (PE_{O_fY_f} + PE_{O_fY_m})$. In contrast, the effects from the younger brother were, on average, significantly smaller than effects from the older brother, $\chi^2(1) = 4.858$, $p = .028$, constraint is $(PE_{Y_mO_m} + PE_{Y_mO_f}) = (PE_{O_mY_m} + PE_{O_mY_f})$.

Second, we tested whether the statistically significant partner effect from the younger sister to the older sister differed from the effect from the older sister to the younger sister and from the effect from the younger brother to the older brother. Both contrasts were not significant: younger-to-older sister versus older-to-younger sister, $\chi^2(1) = 1.014$, $p = .314$, constraint is $PE_{Y_fO_f} = PE_{O_fY_f}$; younger-to-older sister versus younger-to-older brother, $\chi^2(1) = 2.370$, $p = .124$, constraint is $PE_{Y_fO_f} = PE_{Y_mO_m}$. These results suggest that within sister pairs, the partner effects did not differ significantly, and in same-gender sibling dyads, the size of the effects from the younger to the older sibling was independent of siblings' gender.

In conclusion, for relationship satisfaction measured in sibling pairs at two points in time, a couple pattern was found for older brothers whose satisfaction predicted the younger siblings' satisfaction and for younger sisters whose satisfaction predicted the satisfaction of their older sisters 1 year later. An independence pattern was revealed for younger brothers and older sisters whose satisfaction did not predict their siblings' satisfaction and for younger sisters whose satisfaction did not predict older brothers' satisfaction.

The 2M3G APIM

The 2M3G APIM is designed for 2M3G data. Typical examples are gay, lesbian, and heterosexual couples (e.g., Conley, Roesch, Peplau, & Gold, 2009) or male, female, and mixed-gender dizygotic twins. The key of this model is that there is a dichotomous group variable measured in each dyad member, which is gender in gay, lesbian, and heterosexual couples and male, female, and mixed-gender twins. In contrast to the 2M4G APIM, distinguishability within groups is not considered directly, but the inclusion of the group variables measured in each member enables a simultaneous analysis of both distinguishable and indistinguishable members, such as homosexual and heterosexual couples. In addition to couples and dizygotic twins, other examples of dyads that fit into the 2M3G APIM are same-gender and opposite-gender coworker or friend dyads when there is no distinguishing variable but the group variable, which is gender in all these examples.

For this type of dyads representing three different classes, West and colleagues (2008) proposed a multilevel modeling (MLM) approach providing estimates of two-way and three-way interactions. As for the other MMMG models, we use SEM that enables the testing and comparison of all possible actor and partner effects and the evaluation of specific patterns and hypotheses. The questions that can be addressed by the 2M3G APIM are similar to the questions of the other models.

The 2M3G APIM can be described by the same two equations as the 2M4G APIM (Equations 7 and 8), but the 2M3G APIM requires (a) a series of constraints, (b) an adjustment of the fit statistic, and (c) a specific setup of the data. For the specification of the model and the fit adjustment, the method of Olsen and Kenny (2006) for analyzing indistinguishable members can be used. Specifically, all structural coefficients, variances, covariances, means, and intercepts that occur in both members are constrained to be equal across members (details are provided in Appendix S1). In this model, 48 constraints are imposed, which gives 48 *df*.

The chi-square fit statistic can be adjusted by estimating an indistinguishable saturated (iSat) model, which connects all manifest variables of the target model (e.g., the 2M3G APIM) by covariances and includes equality constraints on all parameters (i.e., means, variances, and covariances) that come in pairs (see, e.g., Kashy, Donnellan, Burt, & McGue, 2008). The adjusted fit of the target model is the difference in the chi-square value and the degrees of freedom between the target model and the iSat model. We note that when all variables are manifest, the APIM setup for indistinguishable members is statistically equivalent to the respective iSat model, and so there is no need to estimate a separate iSat model.

As for the setup of the data, the assignment of the members to the two groups, 1 and 2, is arbitrary in this model because all dyad members are treated as indistinguishable. We note that dyad members become distinguishable again by the inclusion of the two dichotomous group variables. As a consequence, it is important to note that the theoretically distinguishable members (e.g., husbands and wives) should be assigned randomly to the two groups in such a way that both classes (e.g., husbands and wives) are about evenly distributed in Group 1 and Group 2. Assigning all distinguishable members of one class consistently to Group 1 and all the other members to Group 2 can cause estimation problems (e.g., negative eigenvalues and covariance matrices that are not positive definite). We note that West and colleagues' (2008) MLM approach does not have this problem as it requires a pairwise data set (see, e.g., Ledermann & Kenny, 2015), but it is limited in testing and comparing specific effects and the evaluation of patterns.

In the 2M3G APIM, there are four actor effects and four partner effects. For couples, there is an actor effect for lesbian women, gay men, heterosexual women, and heterosexual men. There is one partner effect in gay couples, one in lesbian couples, and one from men to women and one from women to men in heterosexual couples. There are also four intercepts: one for gay men, one for lesbian women, one for heterosexual men, and one for heterosexual women. All these effects can be estimated using the information provided for the 2M4G APIM in Table 5.

An alternative method, which was initially pointed out to one of us by David Kenny, is the use of multiple group analysis to estimate this model and all its parameters. This method also allows the comparison of variances across members (Rigdon, Schumacker, & Wothke, 1998), but with smaller samples, the use of product terms to distinguish groups may have more power and be more practical.

Illustration of the 2M3G APIM

We illustrate the 2M3G APIM using the same data from the American Couples study (Blumstein & Schwartz, 1983) as West and colleagues (2008) used to demonstrate their MLM approach. The variables were age and a composite score reflecting relationship stability, which was measured by the items "Our relationship is permanent" and "I have someone to grow old with." These two items rated on a 9-point scale (1 = *extremely important*, 9 = *not important at all*) were combined so that higher scores reflect higher stability with a possible range from 1 to 9. There were 943 gay, 762 lesbian, and 4,180 heterosexual couples who provided complete data on these variables. The age ranged from 18 to 90 years for heterosexual men ($M = 39.69$, $SD = 12.14$), from 18 to 82 years for heterosexual women ($M = 37.16$, $SD = 11.59$), from 17 to 74 years for gay men ($M = 36.14$, $SD = 9.46$), and from 18 to 71 years for lesbian women ($M = 33.01$, $SD = 8.01$).

To restructure the original data into a dyad format, we used the program RDDD (Ledermann & Kenny, 2015). We evenly assigned the heterosexual partners to the two groups. We centered age separately for each group and used effect coding for gender (1 = male, −1 = female). The patterns were again tested for effects on a common outcome. We used lavaan to estimate the models and—due to the large sample size—calculated 99% CIs using bootstrapping with 5,000 bootstrap samples. We standardized actor and partner effects by calculating a pooled standard deviation for X and Y separately for each group. Results using West and colleagues' (2008) MLM approach and restricted maximum likelihood estimation are given in Appendix B, Table B1. Table B2 presents the results of multiple group analysis.

Using these data and the 2M3G APIM, we address whether a person's age has an effect on his or her own and the partner's relationship stability rating and whether these effects depend on people's gender. Table 8 shows the fit of the models. The first model was the unrestricted 2M3G APIM (Table 8, first model). The estimates and standard errors of the actor and partner effects of this saturated model are given in Table 9. All four actor effects were positive and statistically significant, indicating, in line with the results of West and colleagues (2008), that older people reported higher relationship stability. There were also two statistically significant partner effects for homosexual partners, which suggest that gay men and lesbian women reported higher relationship stability the older their partners. No significant partner effects were found in heterosexual couples. This is in agreement with the statistically significant three-way interaction between partner's age, actor's gender, and partner's gender using MLM (see Table B1). We note that the results of this unrestricted model were almost identical to those of the multiple group analysis shown in Table B2.

Next, we ran alternative models implying indistinguishability and specific patterns. The model with indistinguishable actor and partner effects showed a good fit using the adjusted RMSEA (Table 8, second model). However, the adjusted chi-square statistic indicates that this simpler model is poor, which is in line with the sample-size-adjusted Bayesian information criterion.

To assess specific patterns in couples, we used k to estimate the relative importance of the partner effects in the unrestricted model. In homosexual couples, the relative importance of the partner effects was 0.568 for gay men, 99% CI [0.137, 1.546], and 0.560 for lesbian women, 99% CI [0.038, 1.784], indicating a mixed pattern. Both CIs exclude 0 and include 1, which supports a couple pattern. In heterosexual couples, the relative importance of the two partner effects was 0.221 for men, 99% CI [−0.208, 1.376], and −0.073 for women, 99% CI [−0.342, 0.536]. Implying a couple pattern in homosexual couples resulted in a good model fit (Table 8, third model), indicating that the partner effects did not differ in size from the actor effects in homosexual couples. For heterosexual couples, the model implying an actor-only pattern showed a good fit (Table 8, fourth model). Incorporating both a couple pattern for the homosexual couples and an actor-only pattern for the heterosexual couples into a single model resulted in a good model fit (Table 8, fifth model).

Table 8. *Tests of model fit of the 2M3G APIM for gay, lesbian, and heterosexual couples*

Model	χ^2_a	df_a	p	$RMSEA_a$	SABIC
Unrestricted model	—	0	—	—	308.14
Indistinguishable actor and partner effects	19.998	6	.003	.020	295.12
Testing patterns					
Couple pattern in homosexual couples	4.675	2	.097	.015	301.81
Actor-only pattern in heterosexual couples	1.345	2	.510	<.001	298.48
Couple in homosexual and actor-only in heterosexual	6.020	4	.198	.009	292.45

Note. 2M3G APIM = two-member three-group actor–partner interdependence model; df_a = adjusted degrees of freedom; $RMSEA_a$ = adjusted root mean square error of approximation; $RMSEA_a = \sqrt{(\chi^2_a/df_a - 1)/(N-1)}$, where N = number of dyads; SABIC = sample-size-adjusted Bayesian information criterion. Fit measures are adjusted for indistinguishable members.

Table 9. *Results of the unrestricted 2M3G APIM for age predicting relationship stability in couples*

Effect	Estimate	*SE*	99% CI	Stand. est.
Intercept				
Gay men (I_G)	7.184	0.043	[7.073, 7.294]	
Lesbian women (I_L)	7.245	0.055	[7.103, 7.387]	
Heterosexual men (I_{H_m})	7.158	0.029	[7.084, 7.233]	
Heterosexual women (I_{H_w})	7.570	0.029	[7.495, 7.644]	
Actor effect				
Gay men (AE_G)	0.033	0.005	[0.021, 0.045]	.170
Lesbian women (AE_L)	0.034	0.007	[0.017, 0.051]	.146
Heterosexual men (AE_{H_m})	0.029	0.005	[0.015, 0.042]	.208
Heterosexual women (AE_{H_w})	0.038	0.006	[0.024, 0.053]	.278
Partner effect				
Gay men (PE_G)	0.019	0.005	[0.006, 0.031]	.096
Lesbian women (PE_L)	0.019	0.007	[0.002, 0.036]	.082
From heterosexual men ($PE_{H_{mw}}$)	−0.003	0.005	[−0.017, 0.011]	−.020
From heterosexual women ($PE_{H_{wm}}$)	0.006	0.006	[−0.008, 0.021]	.046

Note. 2M3G APIM = two-member three-group actor–partner interdependence model; *SE* = standard error; CI = confidence interval; Stand. est. = standardized estimate.

Finally, we evaluated specific contrasts. First, we tested whether the actor effects differed across members and found, in agreement with the MLM approach, that they did not, $\Delta\chi^2(3) = 1.274$, $p = .735$, constraints are $AE_G = AE_L = AE_{H_m} = AE_{H_w}$. Second, we assessed whether the partner effects of the heterosexual couples differed from those of the homosexual couples. We found that the partner effects between homosexual partners were, on average, significantly bigger than the partner effects between heterosexual partners, $\Delta\chi^2(1) = 10.349$, $p = .001$, constraint is $(PE_G + PE_L) = (PE_{H_{wm}} + PE_{H_{wm}})$. Third, we assessed whether the partner effects differed within homosexual couples and found they did not differ, $\Delta\chi^2(1) < 0.001$, $p = .983$, constraint is $PE_G = PE_L$.

In conclusion, a couple pattern was found in homosexual couples for the association between partners' age and their rating of relationship stability. In heterosexual couples, an actor-only pattern was supported.

Variations and Extensions

We envision that researchers will adapt the models presented herein to analyze more complex multiple group designs or to explore theoretically important questions more specific to their discipline. For example, researchers investigating families with two children could extend the 3M2G APIM to a 4M4G APIM (equations are provided in Appendix S1). In studies of sibling pairs of different ages, age is often chosen as a distinguishing variable (e.g., Brody, Kim, Murry, & Brown, 2003; Greer et al., 2015; Whiteman & Christiansen, 2008; Yu & Gamble, 2008). An alternative for analyzing sibling pairs is an extension of the 2M3G APIM that has both siblings' age as additional continuous moderators (the equations for this 2M3G moderation APIM are provided in Appendix S1). As for the 2M3G APIM, this model requires equality constraints on all parameters that come in pairs (structural coefficients, variances, covariances, means, and intercepts).

Data from dyads allow researchers to test effects unique to group data. Kenny and Cook (1999) discuss three types of actor–partner interactions that can be tested within the APIM. With dyads representing one or multiple groups, the APIM equation can be extended by a product term of the members' predictors to study buffering and enhancing effects (see also Wickham & Knee, 2012), the difference between members' predictors to probe similarity (congruence) effects, and the higher or lower score of the two members' predictors to investigate cost and compensational effects. With three and more members, the product method has the problem that the model becomes exponentially complex, but the lower/higher score method seems to be especially alluring as there is only one additional variable per type of group.

When we study distinguishable members, very often we may want to know whether the means differ across members (West et al., 2008). For example, we may want to know whether family members' depressive symptoms vary depending on their gender and role. The models presented in this article can be readily simplified by dropping the *X* variable to conduct both omnibus tests and specific contrasts.

Discussion

In many domains where small groups are investigated, questions arise as to the nature of the degree to which members influence each other and the effect of group composition. In this article, we have described a flexible framework for the analysis of MMMG data allowing researchers to assess the degree to which group members influence each other and to test specific patterns depending on the group composition. Moreover, submodels can be estimated, which can be more meaningful and enhance the interpretation of the results. We also proposed a general classification scheme that accommodates all possible APIM results and that has been found to be useful to summarize results from multiple APIM studies (Weidmann, Ledermann, & Grob, in press).

To estimate effects specific to group membership, we used interaction terms. An alternative approach is multiple group analysis. This method has some advantages. One is that multiple group analysis does not require a reassignment of the distinguishable members when using the 2M3G APIM. Another one is that it is more general and gives the researchers more flexibility in testing noninvariance of parameters. For example, multiple group analysis allows the estimation of separate means and variances for each group. However, multiple group analysis requires larger sample sizes, perhaps as many as 50 per group for the models presented in this article, although for the large couple data analyzed in this article, the results of the two methods were almost identical. Future research may clarify this issue.

The approach presented herein has some limitations. First, we used lavaan and Mplus to take full advantage of the MMMG APIM approach, which both have capabilities to assess specific effects and contrasts and to test submodels. Alternatively, MLM could be adopted to estimate the models, but most MLM software programs are limited in the assessment of specific effects and the testing of submodels (Ledermann & Kenny, in press).

Moreover, the structuring of the data becomes complicated for groups with three and more members. Second, the use of maximum likelihood estimation assumes multivariate normal data, but both lavaan and Mplus allow the analysis of ordinal variables and nonnormal data (see also Loeys, Cook, De Smet, Wietzker, & Buysse, 2014). Third, accurate ratio estimates might require larger samples (i.e., in the high hundreds). We note that in mediation analysis, an accurate estimate of the ratio of effects requires a sample size of at least 500 (MacKinnon, Warsi, & Dwyer, 1995). Finally, the use of self-reports is likely to cause a positive bias in actor effects and a negative bias in partner effects because two sources of information are involved in partner effects, but only one source of information is involved in actor effects. Using SEM, Orth (2013) and Matthews, Conger, and Wickrama (1996) showed how these biases can be avoided by introducing a latent variable for each member with self- and partner reports as indicators.

In conclusion, we believe that the approach presented in this article will serve as a useful means to address a wide array of interesting and yet unexplored questions in group research. Specifically, the information about which members influence each other depending on the group composition along with the evaluation of specific patterns can contribute to a nuanced understanding of interpersonal processes and create new opportunities for theory refinement and building.

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Supporting Information

Additional Supporting Information for this article may be found in the online version of this article and on the first author's website at http://thomasledermann.com/mmmgapim/

Appendix S1. Computer Code to Estimate the Models Using lavaan and Mplus

Appendix A

Testing Distinguishability in the 3M2G APIM

Constraints for distinguishability within groups (AE = actor effect, PE = partner effect)

Families with a son: $AE_{F_S} + AE_{M_S} + AE_S$, $PE_{FM_S} = PE_{FS} = PE_{MF_S} = PE_{MS} = PE_{SF} = PE_{SM}$.

Families with a daughter: $AE_{F_D} = AE_{M_D} = AE_D$, $PE_{FM_D} = PE_{FD} = PE_{MF_D} = PE_{MD} = PE_{DF} = PE_{DM}$.

Constraints for distinguishability between groups (AE = actor effect, PE = partner effect)

Actor effects: $AE_{F_S} = AE_{F_D}$, $AE_{M_S} = AE_{M_D}$, $AE_S = AE_D$.

Partner effects: $PE_{FM_S} = PE_{FM_D}$, $PE_{FS} = PE_{FD}$, $PE_{FM_S} = PE_{FM_D}$, $PE_{MS} = PE_{MD}$, $PE_{SF} = PE_{DF}$, $PE_{SM} = PE_{DM}$.

Testing Distinguishability in the 2M4G APIM

Constraints for distinguishability within groups (AE = actor effect, PE = partner effect)

Both male: $AE_{O_{mm}} = AE_{Y_{mm}}$, $PE_{O_m Y_m} = PE_{Y_m O_m}$.

Both female: $AE_{O_{ff}} = AE_{Y_{ff}}$, $PE_{O_f Y_f} = PE_{Y_f O_f}$.

Older brother, younger sister: $AE_{O_{mf}} = AE_{Y_{fm}}$, $PE_{O_m Y_f} = PE_{Y_f O_m}$.

Older sister, younger brother: $AE_{O_{fm}} = AE_{Y_{mf}}$, $PE_{O_f Y_m} = PE_{Y_m O_f}$.

Constraints for distinguishability between groups (AE = actor effect, PE = partner effect)

Actor effects: $AE_{O_{mm}} = AE_{O_{ff}} = AE_{O_{mf}} = AE_{O_{fm}}$, $AE_{Y_{mm}} = AE_{Y_{ff}} = AE_{Y_{mf}} = AE_{Y_{fm}}$.

Partner effects: $PE_{O_m Y_m} = PE_{O_f Y_f} = PE_{O_m Y_f} = PE_{O_f Y_m}$, $PE_{Y_m O_m} = PE_{Y_f O_f} = PE_{Y_m O_f} = PE_{Y_f O_m}$.

Appendix B

Table B1. *Results of age predicting relationship stability in couples using MLM and restricted maximum likelihood estimation*

Effect	Estimate	*SE*	*p*
Intercept	7.285	0.020	<.001
Age actor (XA)	0.033	0.003	<.001
Age partner (XP)	0.011	0.003	<.001
Gender actor (GA)	−0.104	0.019	<.001
Gender partner (GP)	0.074	0.019	<.001
GA × GP	−0.071	0.020	<.001
XA × GA	−0.004	0.003	.185
XA × GP	0.001	0.003	.615
XA × GA × GP	0.000	0.003	.868
XP × GA	0.003	0.003	.230
XP × GP	−0.002	0.003	.590
XP × GA × GP	0.009	0.003	.001

Note. Gender was coded 1 for male and −1 for female. MLM = multilevel modeling; *SE* = standard error.

Table B2. *Results of the unrestricted 2M3G APIM for age predicting relationship stability in couples using multiple group analysis*

Effect	Estimate	*SE*	99% CI
Intercept			
Gay men	7.184	0.046	[7.064, 7.303]
Lesbian women	7.245	0.061	[7.089, 7.401]
Heterosexual men	7.178	0.026	[7.111, 7.246]
Heterosexual women	7.534	0.024	[7.472, 7.595]
Actor effect			
Gay men	0.030	0.005	[0.017, 0.043]
Lesbian women	0.035	0.007	[0.017, 0.053]
Heterosexual men	0.028	0.005	[0.014, 0.042]
Heterosexual women	0.039	0.005	[0.026, 0.052]
Partner effect			
Gay men	0.021	0.005	[0.008, 0.034]
Lesbian women	0.018	0.007	[0.001, 0.035]
Men to women	−0.003	0.005	[−0.016, 0.009]
Women to men	0.007	0.006	[−0.008, 0.021]

Note. 2M3G APIM = two-member three-group actor–partner interdependence model; *SE* = standard error; CI = confidence interval.