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# Modeling the complexity of dynamic, momentary interpersonal behavior: Applying the time-varying effect model to test predictions from interpersonal theory

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A B S T R A C T

This paper demonstrates a recently-popularized quantitative method, the time-varying effect model (TVEM), in describing dynamic, momentary interpersonal processes implicated by Interpersonal Theory. We investigated moment-to-moment complementarity in affiliation and control behaviors (i.e., correspondence in affiliation and reciprocity in control between married dyad members) in a five-minute interaction (N = 135), and how complementarity changed over time. Overall, results supported complementarity in affiliation and control. Moreover, effects were time-varying: Complementarity in affiliation increased over time and complementary in control changed over time in a cyclical manner. Dyadic adjustment moderated the strength in complementarity in control during specific timeframes. We discuss implications of these results and future directions. The findings support the utility of TVEM for studying dynamic and time-dependent interpersonal processes.



## 1. Introduction

Researchers interested in understanding transactional processes in interpersonal interactions have developed a number of assessment and coding schemes for sampling the momentary behavior between individuals (e.g., Heyman, 2001; Gottman & Krokoff, 1989; Ekman & Friesen, 1978; Sadler, Ethier, Gunn, Duong, & Woody, 2009). The intensive longitudinal data generated by continuous coding of interpersonal dynamics offer exciting opportunities to examine fine-grained interpersonal processes. Compared to traditional longitudinal data, the total number of observations obtained per participant is substantially larger (e.g., hundreds to thousands of observations per participant per interaction), which provides opportunities to address key questions raised in the field concerning the description and prediction of dynamic processes in interpersonal behavior and hone in on these processes in relatively greater detail.

The dynamic nature of many interpersonal interactions is implicated by Interpersonal Theory (Pincus & Ansell, 2013). According to Interpersonal Theory, interpersonal behavior can be described via the two orthogonal dimensions of the Interpersonal Circumplex (IPC): Affiliation (warmth versus coldness) and Control (dominance versus submissiveness; Leary, 1957; Wiggins, 1979). Commonly, interpersonal phenomena are understood to unfold over time, and often involve individuals behaviorally adapting to the demands of a situation (Pincus & Ansell, 2013; Sadler, Ethier, & Woody, 2011). For instance in the context of dyadic interactions, dominance has been shown to pull for submissiveness (and vice versa) while warmth pulls for warmth (Markey, Lowmaster, & Eichler, 2010; Markey, Funder, & Ozer, 2003; Sadler et al., 2009; Thomas, Hopwood, Woody, Ethier, & Sadler, 2014). This correspondence in affiliation and reciprocity in control is referred to as *complementarity* (Carson, 1969; Sadler et al., 2011). As a result, in order to test the principals comprising interpersonal theory, it is critical to examine these often nuanced shifts in dyadic behaviors as they unfold over time.

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### 1.1. Current methods to examine intensively-assessed interpersonal processes

Prior research has utilized intensive longitudinal data alongside a number of quantitative techniques in order to evaluate behavioral complementarity. By far the most common analytic approach involves computing cross-correlations of moment-to-moment levels of affiliation and control within each dyad, with positive values suggesting correspondence and negative values consistent with reciprocity (Markey et al., 2010; Sadler et al., 2009; Thomas et al., 2014). In cases where several dyads are examined, the cross-correlations can be aggregated to derive a mean and standard deviation for significance testing (Markey et al., 2010; Sadler et al., 2009). Together, these studies have demonstrated that complementarity in affiliation and control occurs in dyadic interactions, on average, with positive correlations in affiliation and negative correlations in dominance among dyads. Relatively more sophisticated approaches that have accounted for the cyclical pattern of many interpersonal interactions, such as computing average weighted coherence indexes using cross-spectral analysis, have arrived at the same conclusions (Sadler et al., 2009; Thomas et al., 2014).

Conceivably, not only would the overall level of complementarity in an interaction be of interest, but also the change in complementarity over time. As previously described, dyads have been shown to be generally complementary in their behaviors; however, as an interaction unfolds, complementarity may shift as the interacting parties negotiate a transactional rhythm and respond to each other's behaviors. To our knowledge, this dynamic aspect of complementarity has yet to be examined. In fact, the quantitative methods used to examine complementarity (e.g., cross-correlations, average weighted coherence scores) aggregate values of complementarity over time—combining momentary instances of complementarity to describe total complementarity of the entire interaction. Thus, these investigations have provided important insight into the occurrence of complementarity, but have not yet determined its temporal pattern within an interaction. Investigating patterns of complementarity over the course of an interaction could provide important insight into how individuals navigate or adapt to different interpersonal situations. Furthermore, evidence of changing complementarity would have important implications for investigating interpersonal phenomena, including highlighting the need to measure the construct repeatedly over the course of the interaction.

Despite the opportunities afforded by intensive interpersonal interaction data, the complex theoretical questions of complementarity pose significant analytic challenges. The specific quantitative articulation of the research question is (a) whether two variables significantly associate (e.g., husband affiliative behavior and wife affiliative behavior), and (b) whether this association changes significantly over time. Several popular methods are available to examine associations among variables over time, such as latent growth curve models (LGCMs) and multilevel models (MLMs) with time-varying covariates. However, these methods are limited in their ability to describe *changing* associations over time. Consider a standard parallel-process, associative, or multivariate LGCM, which is designed to model individual differences in growth in more than one variable over time, and associations among those individual differences in growth trajectories (Bollen & Curran, 2006). A typical example of this popular model type can be found in Wright, Pincus, and Lenzenweger (2013), who showed that as individuals linearly increase in avoidant personality disorder features, they also decrease in dominance, affiliation, and increase in neuroticism. But this type of model does not speak to, for example, changes in the associations among avoidant personality disorder, dominance, affiliation, and neuroticism at different developmental periods, which also might be of interest. In other words, associative LGCMs speak to associated change, but not change in association. In the current context an LGCM would provide the association between the total linear change in affiliation of each dyad member with the total linear change in affiliation for the other. An additional challenge associated with typical associative LGCMs, is that they parameterizes change, limiting their ability to capture highly complex patterns over time, as might be expected with intensive longitudinal data. While more complex functional forms can be specified (e.g., Wright, Hopwood, & Zanarini, 2015), such as piecewise, quadratic, cubic, or cyclical, these functional forms may still over-simplify the conceivably complex relations between interpersonal variables over time (all the while resulting in complex covariance pairings when attempting to interpret the associations between the trajectories).

Most often MLMs have been the workhorses used in studies with intensive longitudinal data designs. Typically, a time-varying covariate is entered as a predictor of a time-varying outcome. For instance, using intensive longitudinal data, these methods can investigate complementarity in affiliation by correlating the moment to moment fluctuations in affiliation of one member of a dyad with the other. However, this would typically result in a single, linear coefficient representing the *average* of all moment-to-moment associations in affiliation. Therefore, as typically implemented, the resulting estimates are still averages of temporally concurrent associations that do not allow for examining how the associations vary in strength over time. It is possible though to study whether this association varies over time by including time as a moderator of the association among predictor and outcome (i.e., the interaction term of the predictor and time). Although this might seem to be a viable solution, and may be in some cases, this approach also limits the form of the time varying effect, limiting it to linear, quadratic, or otherwise simple parameterized patterns.

### 1.2. Using the time-varying effect model to examine dynamic interpersonal processes

Thus, to facilitate investigations of how complementarity changes over the course of interpersonal interactions, the current investigation provides a methodological demonstration of a recently popularized quantitative method, the time-varying effect model (TVEM; Tan, Shiyko, Li, Li, & Dierker, 2012). TVEM is an extension of MLM that uses coefficient functions to describe the associations between two variables over time without being confined to a predetermined functional form. This is accomplished by using a non-parametric spline approach (Tan et al., 2012), which divides the coefficient function into intervals (known as knots) where a polynomial term is estimated to represent the change over time within each interval. The result is a single function of time that illustrates the association between a predictor with an outcome at each time point–allowing for time-varying effects. These qualities of TVEM hold the promise for posing and answering exploratory and sophisticated questions about time-varying effects (for substantive examples see Shiyko, Lanza, Tan, Li, & Shiffman, 2012; Wright, Hallquist, Swartz, Frank, & Cyranowski, 2014) that may occur in interpersonal situations, beyond what could be previously accomplished with traditional methods. Specifically, unlike LGCMs and MLMs, TVEM allows the relations between these variables to change freely over time, and by doing so can test the coupling and uncoupling of behavioral associations as time progresses.

TVEM also provides opportunities to examine moderating factors of complementarity over time. This is a particular area of interest because level of complementarity has been previously associated with a number of important outcomes. Greater complementarity has been associated with desirable outcomes such as greater relationship quality and satisfaction (Dryer & Horowitz, 1997; Markey & Markey, 2007; O'Connor & Dyce, 2001), relationship closeness (Ansell, Kurtz, & Markey, 2008; O'Connor & Dyce, 2001) and improved performance on laboratory tasks (Estroff & Nowicki, 1992). Thus, identifying factors that impact the extent of complementarity in an interaction would provide insight into the variation seen between dyads on these outcomes. By examining moderators in a time-varying framework, however, it is possible to examine at what points in time the moderator exerts the greatest effect (e.g., early in an interaction versus later in an interaction).

### 1.3. The current study

In the current study, how complementarity unfolds over time was examined by laboratory observations of affiliation and control behaviors among married, heterosexual dyads while they were observed discussing for five minutes the best things about their relationship. Interactions were coded using continuous, behaviorally-anchored ratings of each spouse on affiliation and control, which were used to investigate complementarity. Complementarity was defined as the association between two dyad members' affiliation and control, respectively. Thus, TVEM examined the strength, and potential variations in the strength, of those associations over the course of the interactions. Consistent with aforementioned research, it was hypothesized that complementarity in affiliation would occur throughout the interaction. Furthermore, given what is known about the relational benefits of reciprocating affiliation and the generally positive nature of the assigned topic, it was hypothesized that complementarity in affiliation of the wife and husband would also increase over time. The pattern of this increase, however, is exploratory with respect to the shape and timing of the increase, which makes TVEM particularly well-suited to examine the nature of these increases over time. In contrast, less is known about how complementarity in control would unfold over time in this context. On average, both control that is complementary (Gray-Little, 1982) and egalitarian (Gray-Little, Baucom, & Hamby, 1996) between husbands and wives have been associated with higher marital satisfaction. Furthermore, within momentary interpersonal interactions, control tends to be cyclical (Sadler et al., 2009; Thomas et al., 2014). Thus, in line with this research, it was hypothesized that, on average, complementarity in control would be supported over the course of the interaction; however, the time-course of such complementarity was relatively exploratory. Lastly, dyadic relational adjustment was examined as a moderator of complementarity over time. It was hypothesized that greater relational adjustment would be generally associated with greater complementarity in both affiliation and control.

## 2. Method

### 2.1. Participants

Data was analyzed from an existing dataset of heterosexual couples (N = 140 dyads) recruited from the Chicago, IL area for an investigation of family relationships, temperament, and psychopathology (Stroud, Durbin, Saigal, & Knobloch-Fedders, 2010; Stroud, Durbin, Wilson, & Mendelsohn, 2011; Wilson & Durbin, 2012a,b). Couples were eligible for the study if they cohabited and had at least one biological child between the ages of three and six. All procedures were approved by local Institutional Review Boards.

Of the original sample, 135 of the dyads completed the interpersonal task of interest and were examined in the present study. The majority (93.2%) of participants were married (mean (M) marriage length = 8.81 years; standard deviation (SD) = 3.96 years) and raising two children (M = 2.32, SD = 0.88). Women's ages ranged from 23 to 49 (M = 36.91; SD = 5.71) and men's ages ranged from 23 to 57 (M = 38.27; SD = 5.89). About 90% of participants provided information on their race/ethnicity. Approximately 76% of men and women were Caucasian/White, 11% Hispanic/Latino, 9% African-American/Black, 8% of women and 5% of men were Asian, 3% of women and 2% of men were Native American, and the remaining endorsed "other" or bi/multi-racial (4% women, 9% men). Most of the partners (80%) endorsed the same race/ethnicity.

### 2.2. Procedure and measures

The present analysis focuses on a discussion task in which each couple was asked to discuss the *best things* about their relationship. The average discussion length was about five minutes (M = 304.79 s, SD = 39.13, range: 157.71–489.37) with 88% ending within five and a half minutes. Given the small number of observations past this time point, only data for the first five and a half minutes were analyzed so that the effects at any time point would not be determined by a small subset of the sample.

The outcome measures were Continuous Assessment of Interpersonal Dynamics (CAID) by independent observer assessments of both the male and female partners' behaviors. Interpersonal processes during each interaction were coded by four trained undergraduate research assistants (two males and two females) using continuous, behaviorally-anchored ratings of each spouse (Lizdek, Sadler, Woody, Ethier, & Malet, 2012; Sadler et al., 2009). The training on the joystick method was based on a previously established protocol (see Sadler et al., 2009), and included introduction to the IPC, and familiarization and practice with the joystick apparatus that included live observation and feedback of coding process. Raters watched and simultaneously coded the target's continuous expressions of affiliation and control during the discussion task using a computer joystick. Examples of coded expressions of affiliation included physical gestures like moving closer to the other person, making eye contact, or affectionate touching, and verbal gestures like laughing, or providing complements or praises; and for control included directing the conversation, asserting authority, and speaking first during conversational lulls. Affiliation and control assessments recorded twice per second, and were scaled from $-1000$ to 1000 on both dimensions, with 1000 representing extreme control on the y-axis and extreme affiliation on the x-axis. Data were averaged across all reliable coders at each time point (i.e., a coder's ratings for an individual were not included if it had low reliability). Across raters, the internal consistency of our warmth and dominance time-series indicated sufficient inter-rater reliability in our observations. Consistent with past research (e.g., Sadler et al., 2009; Thomas et al., 2014; Ross et al., 2016), inter-rater reliability assessed by absolute value intraclass correlation coefficient (ICC) was higher for dominance (husband ICC = 0.74 (SD = 0.13), wife ICC = 0.73 (SD = 0.15)) than affiliation (husband ICC = 0.44 (SD = 0.20); wife ICC = 0.43 (SD = 0.19)). Consistent with prior CAID investigations, we omitted the first 5 s of data from every dyad (Sadler et al., 2009). For the present analysis, to prevent convergence problems associated with examining outcome variables with relatively large ranges of values, data were rescaled to $-100$ to 100 using a linear transformation (dividing by 10) as others have done as well (Ross et al., 2016).

The Dyadic Adjustment Scale (DAS; Spanier, 1976) is a 32-item self-report inventory designed to assess relationship satisfaction. Meta-Analytic research suggests that DAS scores reliably estimate relationship satisfaction across various demographics (e.g., gender, ethnicity, SES; Graham, Liu, & Jeziorski, 2006). Here we computed total DAS scores by averaging all items to create an indicator of couples' satisfaction.

### 2.3. Data analytic technique

We used TVEM to examine the association between the wife's interpersonal behaviors (i.e., affiliation and control) with the husband's interpersonal behavior on the same dimension. This involved first estimating an intercept-only model to describe each participant's interpersonal behaviors over the course of the interaction. Then, the time-varying association between the wives' and husbands' interpersonal behaviors was tested in two separate models (i.e., wife's affiliation predicting husband's affiliation; wife's control predicting husband's control) using the following equation:

$$AffiliationMale_{ij} = \beta_0(t_{ij}) + \beta_1(t_{ij}) \cdot AffiliationFemale_{ij} + \varepsilon_{ij}$$

In this equation, time $(t_{ij})$ is coded in seconds for each subject $i$ at assessment $j$. $\beta_0(t_{ij})$ is the intercept function that describes the expected affiliation of the male partner over the course of the interaction whose female partner has an affiliation score of 0. The time-varying effect of affiliation of the female partner on the affiliation of her male partner is represented by the slope coefficient of $\beta_1(t_{ij})$. Like traditional linear regression analysis, the selection of the wife as the independent variable was arbitrary and produces the same results as selecting the husband.

The moderating effect of dyadic relational adjustment on complementarity was examined in two complementary ways. First, dyadic relational adjustment was examined as a moderator of the association between husband and wife affiliation using a product term approach. Specifically, dyadic DAS score and its product with the independent variable (in this case either wife control or affiliation) were entered as time-varying coefficients. The benefit of this approach is that continuous moderator variables can be examined while maintaining the total sample in one analysis; however, a limitation is the ease of interpreting the interaction effects. Second, purely as an interpretive aid, the moderating effect was explored by separately estimating TVEMs for individuals reporting relatively high relational adjustment (DAS scores greater than the mean of 213.74) to those reporting relatively low relational adjustment (scores less than or equal to the mean of 213.74). This approach directly compares the strength of the time-varying associations between husband and wife affiliation (or control) between individuals with above or below median DAS scores throughout the interaction.

TVEMs were estimated using the %TVEM SAS macro version 3.0.4, which is available for download at methodology.psu.edu (Li et al., 2015). Notably, this version of the macro includes a new feature to model within-subject correlations using random effects, which takes into account dependence of observations when computing standard errors. Each TVEM was fit using the penalized truncated power spline basis (P-spline) following model fit practices outlined in Tan et al. (2012). The P-spline method identifies the best fitting model by first fitting a model with many knots (K), which are the intervals into which the data are divided. Then, the method automatically penalizes knots that do not capture much variability using a smoothing function (see Tan et al., 2012 for more details). The P-spline method was selected over other methods (see description of B-spline method below) because its automatized process properly balances goodness of model fit with model parsimony in a more efficient manner relative to other methods, thus avoiding model overfitting. K of 10 has been suggested as an adequate number of knots (Ruppert, 2002; Tan et al., 2012), but K around 20 may be necessary for more complicated functions (e.g., with multiple nodes; Ruppert, 2002). We followed the convention of K = 10; however, in cases where this produced a complex coefficient function, K was increased to 20 to determine that increasing K does not meaningfully impact the coefficient function. Robust standard errors are provided using a sandwich estimator. Model fit indexes are not provided in the final output and are not required given that the program will automatically select the best-fitting model.

Alternatively, one may elect to manually fit an optimal TVEM using the basis spline approach (i.e., B-spline) in the SAS TVEM Macro. One may consider this option in cases where one wants to manually compare the shape of coefficients guided by theory as it allows for manually estimating and comparing models that differ in the number of knots and corresponding polynomial terms, or to specify random effects.[1] Furthermore, in cases where truncated power basis functions are highly correlated, B-spline can produce more numerically stable functions (Li et al., 2015). Models can be compared using the provided Akaike information criterion (AIC) and Bayesian information criterion (BIC), which assist in choosing a model with the optimal trade-off of complexity with fit; the model having the lowest AIC and BIC is generally selected. Examples of B-spline and its application are well-described in detail elsewhere (see Wright et al., 2014; Shiyko et al., 2012) and will not be demonstrated here.

## 3. Results

### 3.1. Descriptive correlations between wife and husband affiliation and control

To illustrate overall patterns of complementarity during the interaction, an average affiliation score and control score for the entire observation period was calculated for each participant. The means and standard deviations were as follows, wife affiliation: 16.39 (12.47), husband affiliation 15.56 (10.91), wife control 0.03 (15.37), and husband control 0.38 (15.78). The correlation between average husband and wife affiliation scores was 0.69 and for control was −0.50, which were both significantly different from zero ($p < 0.001$). To describe how these correlations changed from minute-to-minute, an average affiliation score and control score was also calculated for each participant separately for the first five minutes of the interaction. From the first to fifth minute of the interaction, the correlations between average husband and wife affiliation scores were 0.50, 0.56, 0.67, 0.70, and 0.75; for control, the correlations were −0.60, −0.71, −0.54, −0.55, and −0.30, respectively.

### 3.2. Time-varying intercept functions: dyad affiliation and control over time

The average change over time in husband and wife affiliation is depicted in Fig. 1. On average, husband and wife affiliation was significantly greater than zero (i.e., dyads exhibited warmth) and stable over the course of the interaction. Thus, while the confidence intervals indicate that there was variability in affiliation over time, the majority of behaviors were rated as warm (i.e., 92% and 91% of momentary wife and husband observations, respectively, were rated as warm). On average, affiliation did not significantly differ between the husbands and wives, as demonstrated by the nearly completely overlapping confidence intervals throughout the interaction (see Cummings & Finch, 2005 for discussion of visual inspection of confidence intervals). These patterns suggest that the behaviors of husbands and wives were generally rated similarly and were consistently warm over the course of the interaction. In corresponding B-spline models, the random intercept

[1] For this investigation, the robust standard errors in the P-spline option and specifying a random intercept with the B-spline option yielded consistent findings, with respect to estimates and corresponding confidence intervals.

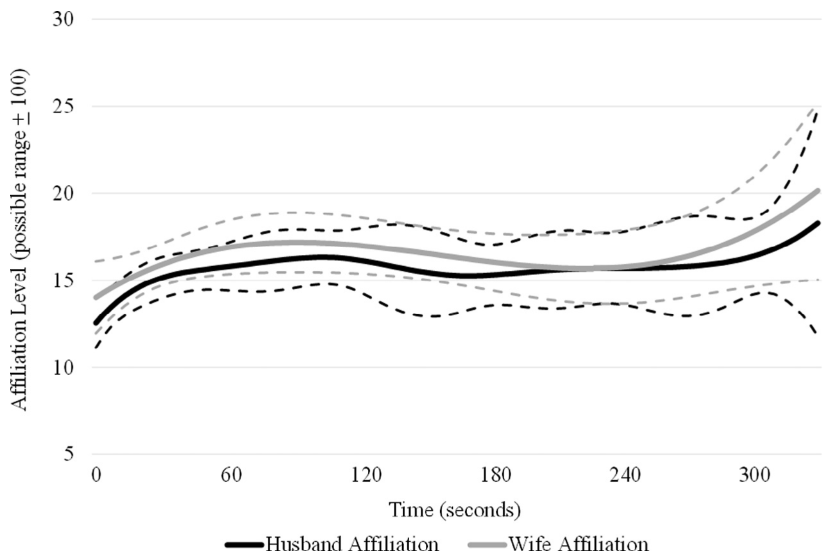


**Fig. 1.** A graphical summary of intercept functions (with 95% confidence intervals), representing the time-varying level of affiliation for husbands and wives when discussing the best things about their relationship for approximately five minutes.

and slope were estimated for husbands (intercept estimate (standard error): 59.85 (7.32); slope: 0.002 (0.0003)) and wives (intercept: 85.48 (10.46); slope: 0.003 (0.0004)).

The average change over time in wife and husband control is depicted in Fig. 2. On average for approximately the first five minutes of the interaction, control ratings of both wives and husbands were neutral (i.e., neither dominant nor submissive), as demonstrated by the confidence intervals inclusive of zero. The variability around the mean control level, as indexed by the confidence interval, suggests that dominance and submissive behaviors were observed for the husbands and wives; however, the net level was zero when averaged across dyads. For instance, throughout the interaction, about 47% and 48% of all moment-to-moment wife and husband observations, respectively, were in the dominant range (i.e., score less than 0). Thereafter, husbands' control increased on average (i.e., husbands became increasingly dominant in the interaction) while wives' control decreased (i.e., increased submissiveness). During this timeframe, husbands' control levels appear to be significant greater than wives' level. This pattern of findings should be interpreted cautiously, however, as only 47% of participants provided data beyond five minutes. A random intercept and slope was identified for both husband control (intercept: 320.80 (39.25); slope: 0.0009 (0.0001)) and wife control (intercept: 249.11 (30.59); slope: 0.009 (0.001)).

### 3.3. Time-varying effect between wife affiliation and husband affiliation

The slope function of the relation between wife affiliation with concurrent husband affiliation is depicted in Fig. 3. Overall, there was a positive association between wife and husband affiliation, as demonstrated by the positive slope function with 95% confidence interval band not inclusive of zero. The magnitude of the association increased over time, with an initial coefficient of 0.53 increasing to a final coefficient of 0.87. This increasing slope function was suggestive of a stronger linkage between wife and husband affiliation over the course of the interaction such that complementarity increased. In other words, moment-to-moment, when a husband was warm, the wife was also warm (and vice versa). Using a corresponding B-spline model, a random intercept and slope were estimated for the association between wife and husband affiliation (intercept: 85.28 (10.46); slope: 0.003 (0.0004)).

When examining dyadic adjustment as a moderator of complementarity in affiliation using product terms, there was no consistent support of a moderating effect. The product term was significantly different from zero at two periods lasting approximately 5 s each (at about 3 min and at the end of the interaction; the coefficient function for the product term is not depicted here). The finding can be illuminated by separately examining complementarity in affiliation for dyads with relatively low versus high dyadic adjustment (Fig. 4), as demonstrated by the largely overlapping confidence intervals for the two subgroups throughout the interaction.

### 3.4 Time-varying effect between wife control and husband control

The slope function of the relation between wife control with concurrent husband control is depicted in Fig. 5.[2] On average, throughout the duration of the interaction, wife control was negatively associated with husband control, supporting complementarity in control such that at any given moment, dominance by one individual would correspond with submissiveness by the other in the dyad. The strength of the association significantly changed over time. Specifically, during approximately the first 90 s, the association between wife and husband control became significantly more negative, starting from a coefficient of −0.53 and reaching the strongest effect of −0.83 (at 79 s). During the subsequent 50 s, the association returned to a level similar to the start of the interaction (−0.51) and then remained relatively stable and did not change significantly for 140 s. Then, there was a subsequent increase in the strength of the association from approximately −0.53 to −0.61. Thus, over the course of the interaction, the pattern of complementarity in control was not monotonic. Results from the corresponding B-spline model estimated a random intercept and slope for the association between wife and husband control (intercept: 177.83 (21.81); slope: 0.007 (0.001)).

Complementarity in control was significantly moderated by dyadic adjustment between the following approximate time frames: 30–65 s, 220–270 s, and 300–310 s (the coefficient func-

[2] The time-varying associations between wife control and husband affiliation, as well as husband control and wife affiliation were also explored. As expected, there were no significant associations throughout the interaction (not presented), which is consistent with control and affiliation being orthogonal on the interpersonal circumplex.

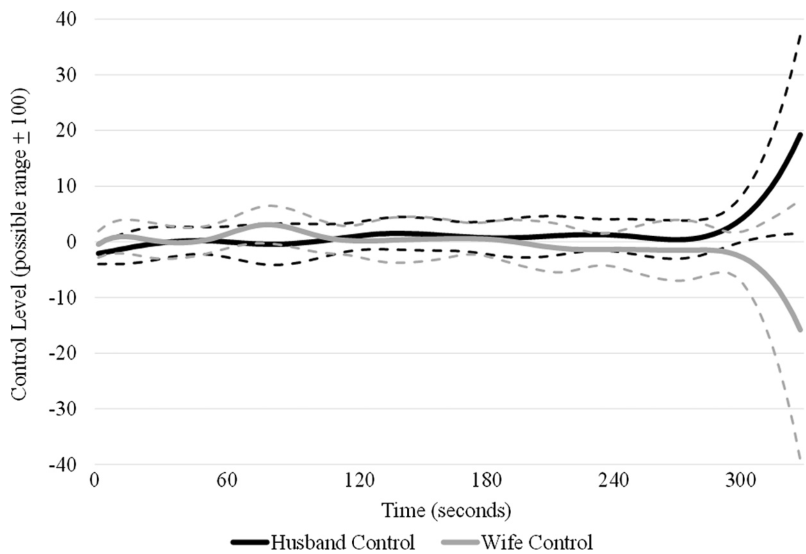


**Fig. 2.** A graphical summary of intercept functions (with 95% confidence intervals), representing the time-varying level of control for husbands and wives when discussing the best things about their relationship for approximately five minutes.

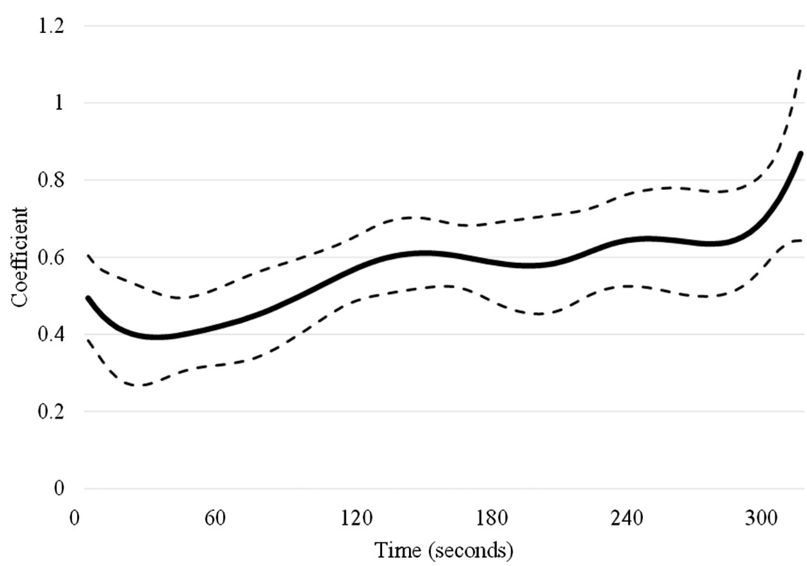


**Fig. 3.** A graphical summary of time-varying effect model function (with 95% confidence intervals) representing the time-varying effect between wife and husband affiliation over the course of discussing the best things about their relationship.

tion for the product term is not depicted). When separately examining complementarity in control for dyads with relatively low versus high dyadic adjustment (Fig. 6), the moderating effect in the first two time frames was attributable to a smaller coefficient in control among couples with lower adjustment relative to higher adjustment (i.e., couples with lower adjustment demonstrated less complementarity); however, for 10 s toward the end of the interaction, lower adjustment was associated with a larger coefficient relative to couples with higher adjustment scores (i.e., couples with lower adjustment demonstrated more complementarity in control).

## 4. General discussion

The primary aim of this investigation was to demonstrate the use of TVEM to examine how complementarity within a dyadic interaction changes over time. Consistent with the existing literature that has supported complementarity using intensive longitudinal data (Markey et al., 2010; Sadler et al., 2009; Thomas et al., 2014), we found evidence for interpersonal complementarity over the course of the interaction. On average, affiliation by the wife in each dyad corresponded with affiliation by the husband. While there was individual variability in this complementarity, supported by the presence of random intercept and slope, wives and husbands were generally rated as warm. This suggests that this complementarity was primarily driven by warmth over time within dyads (as opposed to coldness). Similarly, wife dominance behaviors appeared to elicit or correspond with relatively submissive behaviors from the husband and vice versa. Again, there was individual variability in control; however, average wife and husband ratings were neutral with respect to control behaviors over time. Thus, this complementarity corresponded by moment-to-moment instances of one partner rated as dominant while the other was rated as relatively submissive.

We also found that complementarity unfolds dynamically over the course of an interaction. Specifically, over the course of dis-

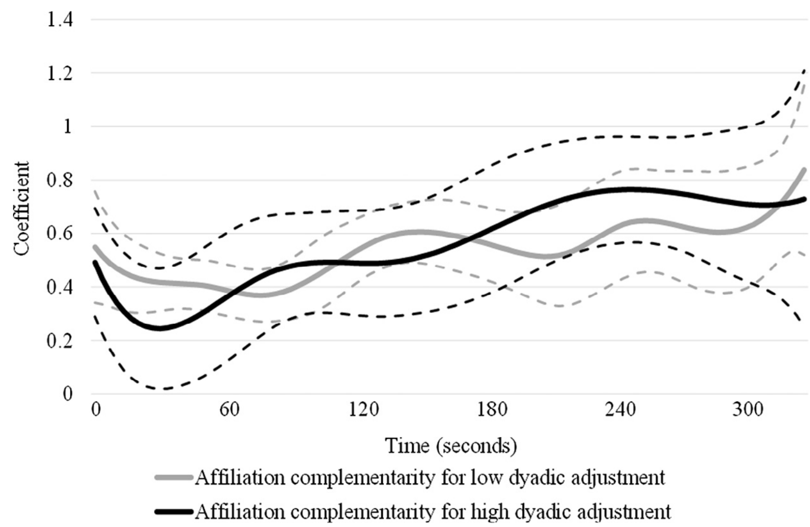


**Fig. 4.** A multiple group analysis illustrating the moderating effect of dyadic adjustment on the time-varying effect between wife and husband affiliation over the course of discussing the best things about their relationship.

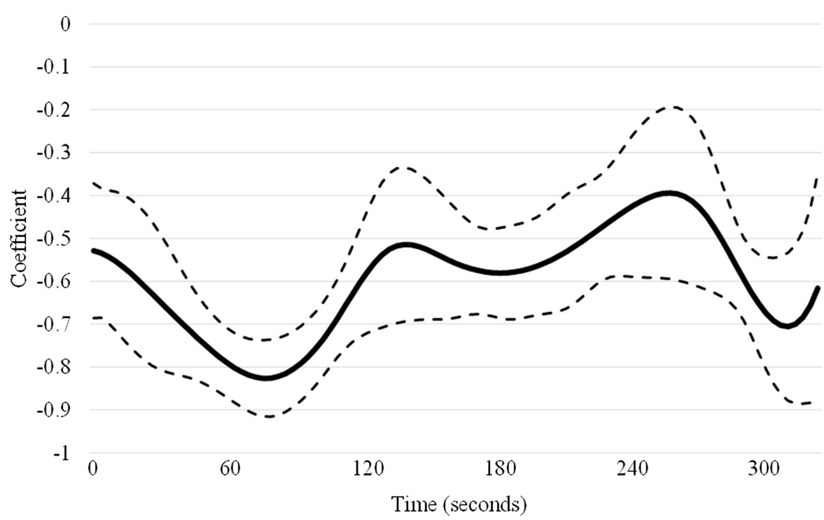


**Fig. 5.** A graphical summary of time-varying effect model function (with 95% confidence intervals) representing the time-varying effect between wife and husband control over the course of discussing the best things about their relationship.

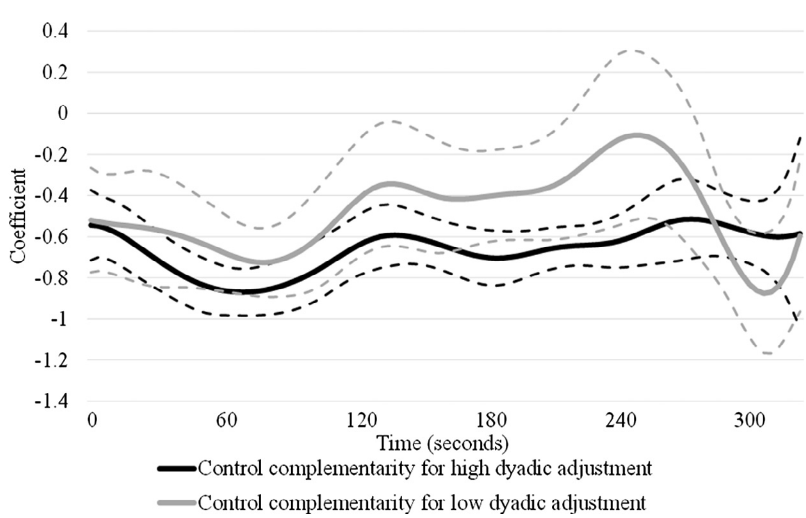


**Fig. 6.** A multiple group analysis illustrating the moderating effect of dyadic adjustment on the time-varying effect between wife and husband control over the course of discussing the best things about their relationship.

cussing the best things in their relationship, the strength of the association between husband and wife affiliation increased, which supports an increase in their complementarity of affiliation over time. This was initially identified when comparing correlations in affiliation between each minute of the interaction, which steadily increased from 0.50 to 0.75. By applying TVEM, however, it was possible to examine the dynamic relation between husband and wife affiliation more continuously without coarsely and arbitrarily binning the data. The TVEM results demonstrated that there were no changes in average affiliation for wives and husbands over time; however, on average, the complementarity of these behaviors increased over time. This finding adds to the existing literature by demonstrating that interpersonal exchanges may not only be characterized by each dyad member's level of affiliation and their overall complementarity (Markey et al., 2010; Sadler et al., 2009; Thomas et al., 2014), but also by the extent to which this complementarity changes over time.

Although this is the first study to demonstrate that couples become more "in sync" during this positive interaction, this dynamic feature of complementarity is suggestive of a number of interesting interpersonal processes. For instance, the upward trend may be due to the couples' tendencies to become accustomed and comfortable to a new discussion topic. Furthermore, prior research has linked overall complementarity in affiliation to positive relationship outcomes (Dryer & Horowitz, 1997; Markey & Markey, 2007; Tracey, Ryan, & Jaschik-Herman, 2001). The increased complementarity in affiliation in the present study may be a manifestation of greater relationship satisfaction over the course of discussing positive aspects of their relationship. Notably, in the present study, a global index of dyadic adjustment correlated with marital satisfaction, did not moderate the strength of complementarity in affiliation over time. Future research is warranted to investigate the causes and potential benefits of increased complementarity in affiliation over the course of interpersonal interactions.

In contrast, while the extent of complementarity changed over time for control, it did not follow a consistently increasing or decreasing pattern as the interaction unfolded. When the correlations between husband and wife control were examined for each one-minute bin, there appeared to be an increase in complementarity from the first to second minute (i.e., stronger negative associations), and then a subsequent decrease during the last 3 min. A cyclical pattern of change in complementarity was revealed when examining time more continuously using TVEM, consistent with the cyclical pattern in dyadic interactions that has been described in prior research using other quantitative methods (Sadler et al., 2009; Thomas et al., 2014).

While the cause of these cycles could not be determined in the present study, it is notable that the cycles were uniform enough between dyads such that these patterns could emerge. Indeed, unless these patterns were reasonably generalizable in the sample, no significant effects would have been identified. Thus, this cyclical pattern likely reflects natural transition points in the exchange that generalized across many dyads. Increases in complementarity in control, as was seen early in the interaction, are suggestive of greater reciprocity that could occur if there is a brief period of deciding who will be in charge followed by a period with the chosen person leading the interaction. The cause of the subsequent reductions and increases in control in complementarity are less clear. Interestingly, we found that these fluctuations were most pronounced among couples with relatively lower dyadic adjustment; whereas, control complementarity remained relatively high and stable among couples with higher dyadic adjustment. Thus, it is possible that the fluctuations are due to greater difficulties maintaining complementarity in control as the task progressed—for instance if the couples either began to talk over each other or simultaneously disengage from the topic. Additional research is warranted to determine if these transition points are generalizable to other interpersonal interactions.

The findings of the present study should be considered in the context of some limitations. The results of the present investigation should be considered exploratory, as the estimated patterns of interpersonal behaviors and their interrelationship are inherently data-driven, and may be specific to married couples (who were largely employed and effectively raising their children) discussing an assigned, positive topic. Specifically, non-parametric methods, such as TVEM, can yield results specific to particular data. Additional work is warranted to determine to what extent these findings generalize to other interactions, for instance using freely interacting dyads with varying relationships (e.g., unacquainted, family members, friends). Another limitation of the investigation is that it was not possible to identify the within-couple dynamics that resulted in complementarity in control. Specifically, complementarity in control could have been driven by a combination of dyads in which an individual was consistently dominant with a consistently submissive partner, or by partners that alternate being dominant or submissive throughout the interaction. In our sample, a combination of these within-dyad patterns was observed. Specifically, within-dyads, the mean proportion of observations in which the husband was more dominant than the wife was 52% (standard deviation = 28), however, there were cases in which one partner was almost exclusively more dominant that the other (i.e., range of proportions was 0–100%). Analyzing these patterns would be important for future research, and argues for the use of TVEM in tandem with existing methods that may better capture within-dyad dynamics, such as time-series analysis.

Future investigations of interpersonal interactions using TVEM would also benefit from examining how factors related to the characteristics of the data (e.g., frequency and length of observations, reliability of coders, sample size) impact study findings. For instance, while efforts were made to increase reliability of coders, any coder biases or unreliability present in the data could have reduced our ability to find significant effects. Also, in the present study, the length of interactions was not standardized. As a result, relations estimated towards the end of the interactions may be biased for a number of reasons, such as due to having a smaller, non-representative group of individuals who had longer interactions. Furthermore, as TVEM is a relatively recent addition to psychological and behavioral research tools, additional work is needed to determine minimum sample sizes and frequencies of observations to produce sufficient power to detect any effects that exist. We anticipate that our sample size and observation frequency were adequate as they surpass Tan et al. (2012) suggestion of 10 or more observations with 100 or more persons; however, having fewer participants can be made up for by having more observations and vice versa.

### 4.1. Conclusion

TVEM has previously been used to investigate how relations between outcomes change over time in the context of substance use and mental health treatment research (Shiyko et al., 2012; Wright et al., 2014); it also appears that TVEM can provide novel and valuable insight into the nature of interpersonal interactions over time. By utilizing TVEM, the present investigation provided initial support that complementarity in dyadic interactions is dynamic. Furthermore, it is anticipated that future investigations using TVEM could provide additional insight into interpersonal processes by examining the consequences of changing complementarity on key interpersonal outcomes, additional time-varying moderators over the course of an interaction (e.g., personality), time-varying effects of complementarity on individual's response (e.g., emotional, physiological) to the interaction, and time-varying relations between other key variables in personality and interpersonal theories (e.g., affect).

The application of TVEM in the field also opens the door for investigating additional questions concerning personality researchers more broadly. Essentially, any process thought to change over time and be differentially influenced by other outcomes or moderators over time may be of interest, such as effects of interventions, relationship formation, response to major life events, or predictors of normative and abnormal personality development. As TVEM is well-suited for many types of data, these investigations could make use of a variety of intensive longitudinal data sources that have gained popularity in the field (e.g., daily diary, GPS data, physical movement, facial action coding), including those where the schedule of measurement can vary across individuals (e.g., ecological momentary assessment, longitudinal studies). Taken together, we anticipate that TVEM could offer researchers a new, flexible tool to investigate the dynamic nature of interpersonal interactions and other personality processes over time.

## Conflict of interest disclosure

All authors of this manuscript have no conflicts of interest.

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## References

Ansell, E. B., Kurtz, J. E., & Markey, P. M. (2008). Gender differences in interpersonal complementarity within roommate dyads. *Personality and Social Psychology Bulletin, 34*(4), 502–512.

Bollen, K., & Curran, P. (2006). *Latent growth curve models: A structural equation approach*. Hoboken, NJ: Wiley.

Carson, R. C. (1969). *Interaction concepts of personality*. Chicago: Aldine Publishing Co.

Dryer, D. C., & Horowitz, L. M. (1997). When do opposites attract? Interpersonal complementarity versus similarity. *Journal of Personality and Social Psychology, 72*(3), 592–603.

Ekman, P., & Friesen, W. (1978). *Facial action coding system: A technique for the measurement of facial movements*. Palo Alto, CA: Consulting Psychologists Press.

Estroff, S. D., & Nowicki, S. (1992). Interpersonal complementarity, gender of interactants, and performance on puzzle and word tasks. *Personality and Social Psychology Bulletin, 18*(3), 351–356.

Gottman, J. M., & Krokoff, L. J. (1989). Marital interaction and satisfaction: a longitudinal view. *Journal of Consulting and Clinical Psychology, 57*(1), 47–52.

Graham, J. M., Liu, Y. J., & Jeziorski, J. L. (2006). The dyadic adjustment scale: A reliability generalization meta-analysis. *Journal of Marriage and Family, 68*(3), 701–717.

Gray-Little, B. (1982). Marital quality and power processes among black couples. *Journal of Marriage and the Family*, 633–646.

Gray-Little, B., Baucom, D. H., & Hamby, S. L. (1996). Marital power, marital adjustment, and therapy outcome. *Journal of Family Psychology, 10*(3), 292–303.

Heyman, R. E. (2001). Observation of couple conflicts: clinical assessment applications, stubborn truths, and shaky foundations. *Psychological Assessment, 13*(1), 5–35.

Leary, T. (1957). *Interpersonal diagnosis of personality*. New York, NY: Ronald Press.

Li, R., Dziak, J., Tan, X., Huang, L., Wagner, A., & Yang, J. (2015). *TVEM (time-varying effect model) SAS macro suite users' guide version 3.0.4.*. Penn State: University Park: The Methodology Center.

Lizdek, I., Sadler, P., Woody, E., Ethier, N., & Malet, G. (2012). Capturing the stream of behavior a computer-joystick method for coding interpersonal behavior continuously over time. *Social Science Computer Review, 30*(4), 513–521.

Markey, P., Lowmaster, S., & Eichler, W. (2010). A real-time assessment of interpersonal complementarity. *Personal Relationships, 17*(1), 13–25.

Markey, P. M., Funder, D. C., & Ozer, D. J. (2003). Complementarity of interpersonal behaviors in dyadic interactions. *Personality and Social Psychology Bulletin, 29*(9), 1082–1090.

Markey, P. M., & Markey, C. N. (2007). Romantic ideals, romantic obtainment, and relationship experiences the complementarity of interpersonal traits among romantic partners. *Journal of social and Personal Relationships, 24*(4), 517–533.

O'Connor, B. P., & Dyce, J. A. (2001). Rigid and extreme: A geometric representation of personality disorders in five-factor model space. *Journal of Personality and Social Psychology, 81*(6), 1119–1130.

Pincus, A., & Ansell, E. (2013). Interpersonal theory of personality. *Handbook of Psychology: Personality and Social Psychology, 5*, 141–159.

Ross, J. M., Girard, J. M., Wright, A. G. C., Beeney, J. E., Scott, L. N., Hallquist, M. N., & Pilkonis, P. A. (2016). Momentary patterns of covariation between specific affects and interpersonal behavior: Linking relationship science and personality assessment. *Psychological Assessment*. http://dx.doi.org/10.1037/pas0000338.

Ruppert, D. (2002). Selecting the number of knots for penalized splines. *Journal of Computational and Graphical Statistics, 11*(4), 735–757.

Sadler, P., Ethier, N., Gunn, G. R., Duong, D., & Woody, E. (2009). Are we on the same wavelength? Interpersonal complementarity as shared cyclical patterns during interactions. *Journal of Personality and Social Psychology, 97*(6), 1005–1020.

Sadler, P., Ethier, N., & Woody, W. (2011). Interpersonal complementarity. In L. M. Horowitz & S. Strack (Eds.), *Handbook of interpersonal psychology* (pp. 123–142). New York, NY: Wiley.

Shiyko, M. P., Lanza, S. T., Tan, X., Li, R., & Shiffman, S. (2012). Using the time-varying effect model (TVEM) to examine dynamic associations between negative affect and self confidence on smoking urges: Differences between successful quitters and relapsers. *Prevention Science, 13*(3), 288–299.

Spanier, G. B. (1976). Measuring dyadic adjustment: New scales for assessing the quality of marriage and similar dyads. *Journal of Marriage and the Family*, 15–28.

Stroud, C. B., Durbin, C. E., Saigal, S. D., & Knobloch-Fedders, L. M. (2010). Normal and abnormal personality traits are associated with marital satisfaction for both men and women: An actor–partner interdependence model analysis. *Journal of Research in Personality, 44*(4), 466–477.

Stroud, C. B., Durbin, C. E., Wilson, S., & Mendelsohn, K. A. (2011). Spillover to triadic and dyadic systems in families with young children. *Journal of Family Psychology, 25*(6), 919–930.

Tan, X., Shiyko, M. P., Li, R., Li, Y., & Dierker, L. (2012). A time-varying effect model for intensive longitudinal data. *Psychological Methods, 17*(1), 61–77.

Thomas, K. M., Hopwood, C. J., Woody, E., Ethier, N., & Sadler, P. (2014). Momentary assessment of interpersonal process in psychotherapy. *Journal of Counseling Psychology, 61*(1), 1–14.

Tracey, T. J., Ryan, J. M., & Jaschik-Herman, B. (2001). Complementarity of interpersonal circumplex traits. *Personality and Social Psychology Bulletin, 27*(7), 786–797.

Wiggins, J. S. (1979). A psychological taxonomy of trait-descriptive terms: The interpersonal domain. *Journal of Personality and Social Psychology, 37*(3), 395.

Wilson, S., & Durbin, C. E. (2012a). Dyadic parent-child interaction during early childhood: contributions of parental and child personality traits. *Journal of Personality, 80*(5), 1313–1338.

Wilson, S., & Durbin, C. E. (2012b). Parental personality disorder symptoms are associated with dysfunctional parent-child interactions during early childhood: A multilevel modeling analysis. *Personality Disorders: Theory, Research, and Treatment, 3*(1), 55–65.

Wright, A. G., Hallquist, M. N., Swartz, H. A., Frank, E., & Cyranowski, J. M. (2014). Treating co-occurring depression and anxiety: Modeling the dynamics of psychopathology and psychotherapy using the time-varying effect model. *Journal of Consulting and Clinical Psychology, 82*(5), 839–853.

Wright, A. G. C., Hopwood, C. J., & Zanarini, M. C. (2015). Associations between changes in normal personality traits and borderline personality disorder symptoms over 16 years. *Personality Disorders: Theory, Research, and Treatment, 6*(1), 1–11.

Wright, A. G. C., Pincus, A. L., & Lenzenweger, M. F. (2013). A parallel process growth model of avoidant personality disorder symptoms and personality traits. *Personality Disorders: Theory, Research, and Treatment, 4*(3), 230–238.