Gendered Interactions and their Interpersonal and Academic Consequences:

A Dynamical Perspective

by

Matthew D. DiDonato

A Dissertation Presented in Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy

Approved June 2012 by the
Graduate Supervisory Committee:

Carol Lynn Martin, Chair
Polemnia G. Amazeen
Laura D. Hanish
Kimberly A. Updegraff

ARIZONA STATE UNIVERSITY

August 2012

ABSTRACT

In response to the recent publication and media coverage of several books that support educating boys and girls separately, more public schools in the United States are beginning to offer same-sex schooling options. Indeed, students may be more comfortable interacting solely with same-sex peers, as boys and girls often have difficulty in their interactions with each other; however, given that boys and girls often interact beyond the classroom, researchers must discover why boys and girls suffer difficult other-sex interactions and determine what can be done to improve them. We present two studies aimed at examining such processes. Both studies were conducted from a dynamical systems perspective that highlights the role of variability in dyadic social interactions to capture temporal changes in interpersonal coordination. The first focused on the utility of applying dynamics to the study of same- and mixed-sex interactions and examined the relation of the quality of those interactions to participants' perceptions of their interaction partners. The second study was an extension of the first, examining how dynamical dyadic coordination affected students' self-perceived abilities and beliefs in science, with the intention of examining social predictors of girls' and women's under-representation in science, technology, engineering, and mathematics.

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Introduction

Within the last decade, support for same-sex schooling has increased among American educators and policymakers, and consequently, more public schools are offering same-sex schooling options than ever before (NASSPE, 2012). To some, this may not come as much of a surprise. A large body of research shows that mixed-sex interactions are fraught with difficulty (see Leaper, 1994), particularly within academic settings, which may result in scholastic underachievement (Harskamp, Ding, & Suhre, 2008; Underwood, Underwood, & Wood, 2000). Proponents of same-sex schooling use this research to support their claim that boys and girls should be educated separately (Gurian & Stevens, 2011; Sax, 2005); however, given that boys and girls must often interact with each other outside of their primary and secondary school classrooms, same-sex schooling does not appear to be the answer to life-long academic or social success. Instead, researchers must determine why boys and girls suffer poor other-sex interactions and establish what can be done to improve them. The following research is presented with the intention of discovering the interactive processes that lead to successful or ineffective same- and mixed-sex interactions. This research was conducted within the framework of dynamical systems theory, where the focus is on variability in behavior and its change over time.

Researchers have long studied change in gendered behavior. Such studies typically utilize longitudinal methods, often make several assessments over extended periods of time, and focus on long-term linear change (e.g., Campbell, Shirley, Heywood, & Crook, 2000; Fredricks & Eccles, 2002; McHale, Shanahan, Updegraff, Crouter, & Booth, 2004; Richards, Crowe, Larson, & Swarr, 1998; Trautner, Ruble, Cyphers, Kirsten, Behrendt, & Hartmann, 2005). However, contemporary research is beginning to show that behavioral change may be more variable than originally anticipated. Characteristics thought to remain stable, such as gendered peer and activity preferences, have been shown to vary dramatically over time, even across relatively short time periods (DiDonato et al., 2012; Martin & Ruble, 2009). This temporal variability raises several questions for social scientists: What does such variability mean? Does it carry information about development or behavior? If so, how might that variability be quantified? Unfortunately, conventional statistical procedures are unable to reach the heart of these questions, as their use requires the assumption that variability around means and trends is treated as random or error. Dynamical systems techniques, however, are not hampered by such an assumption. These techniques highlight variability, not measures of central tendency, as the prime indicator of behavior and change.

The central tenet of dynamical systems theory is that global patterns of behavior emerge from the interactions among numerous interdependent elements (Thelen & Smith, 1994). In applying this principle to the study of child development, one may propose that a child's behavior at any particular moment is a function of the individual characteristics of the child organized with regard to the features of his or her environment. For example, during recess, a preschool boy, Jon, may choose to play tag with a group of boys. Jon's behavior emerged from the interaction of his individual characteristics, such as his desire to play with his peers, his fondness for those peers and the game that they are playing, and his attitudes regarding gender-appropriate play with specific peers. These interactions occurred under particular environmental constraints, such as which peers were at school and who was participating in the game of tag. If the environmental constraints change (e.g., some play partners leave the game), a new form of behavior emerges and Jon's behavior adapts to the new situation (Jon decides to play with a new group of children who are building with blocks). When viewed from dynamical systems theory, children's behavior does not randomly vary from one moment to the next, but does so adaptively in response to the features of the environment and with regard to the individual, interacting characteristics of the child.

Dynamics represents a marked departure from conventional statistical techniques. It sheds new light on the nature of behavioral change and has the potential to inform new theories of gender development. Unfortunately, little gender research has been conducted from within this framework (for exceptions see DiDonato et al., 2012; Martin, Fabes, Hanish, & Hollenstein, 2005). Dynamical research conducted outside of gender studies, however, shows that temporal patterns of interaction are important predictors of social success or failure (Chartrand & Jeffries, 2003; Lakin & Chartrand, 2003; Marsh, Richardson, & Schmidt, 2009; Richardson, Marsh, Isenhower, Goodman, & Schmidt, 2007). Thus, two studies are presented with the goal of examining gendered social interactions from a dynamical perspective and investigating the effect of such dynamical interaction patterns on various outcomes. The first seeks to demonstrate the viability of a dynamical approach to studying gendered dyadic social interactions. To foster positive interactions between boys and girls, it is important to identify the processes that underlie interactive success or failure. Our goal was to use dynamics to examine such processes and determine how dynamical interpersonal coordination affects young adolescents' perceptions of their interaction partner.

The second study builds from the first, using dynamics to understand the effect of social interactions on girls' and women's under-representation in science. Research shows that girls are particularly sensitive to stereotype threat in math and science settings (Ambady, Shih, Kim, & Pittinsky, 2001). Coupling that anxiety with a negative peer interaction, particularly one with a male peer, may lead girls to avoid future math and science courses and careers. Therefore, in the second study we examined the dynamical patterns of same- and mixed-sex dyadic interactions and how they relate to girls' beliefs and attitudes regarding science.

Psychologists from a variety of disciplines have successfully employed dynamics in their research. Some, such as motor coordination researchers, use dynamics extensively; gender researchers, however, have been slow to adopt a similar approach. Employing dynamical methods and analyses will permit the exploration of gendered peer interactions as they evolve over time, providing a new perspective on interactive processes and how they may relate to specific outcomes. By utilizing dynamics to explore social coordination, it is our goal to illustrate the utility and value of dynamics for the study of gender development. Furthermore, in conjunction with previous dynamical research, we hope to demonstrate its potential for the study of social behavior more broadly.

Study 1: Dynamical Gendered Peer Interactions

The subject of same-sex schooling has recently become a hot-button issue among American educators and policymakers. Due to the popularity of several books that support educating boys and girls separately (Gurian & Stevens, 2011; Sax, 2005), more public schools in the United States are beginning to offer same-sex schooling options, such as all male or female classrooms or a complete same-sex school structure (NASSPE, 2012). Some researchers, however, maintain that learning differences between boys and girls are negligible and that same-sex schooling robs children of the opportunity to interact with members of the opposite sex, which may result in strained other-sex relationships outside of the same-sex school setting (Halpern et al., 2011).

Regardless of the presence or absence of sex differences in learning, one area in which boys and girls indeed differ is in their interaction patterns. Boys are typically more assertive, forceful, and competitive whereas girls are more affiliative, relational, and obliging (Fabes et al., 2003; Leaper & Smith, 2004). Perhaps because of these differences, boys and girls often have difficulty in their interactions with each other (Leaper, 1994), which may result in poor performance in collaborative academic activities (Harskamp et al., 2008; Underwood et al., 2000). However, given that boys and girls must often interact with each other beyond the classroom, same-sex schooling does not appear to be the answer to academic or social success. Rather, researchers must discover why boys and girls suffer difficult other-sex interactions and determine what can be done to alleviate them.

The goal of the present study was to examine same- and mixed-sex peer interactions within an academic setting to explore the nature of the difficulties boys and girls experience when working with each other. Methodological and analytical techniques from dynamical systems theory were employed to examine dynamical features of interpersonal coordination.

Gendered Social Interactions

From preschool through young adolescence, boys' and girls' social interactions are heavily sex segregated: boys associate mostly with other boys and girls with other girls (Kovacs, Parker, & Hoffman, 1996; Martin & Fabes, 2001; Vaughn, 2001). This segregation is both a cause and a consequence of differences in the ways in which boys and girls interact, and these differences may lead to undesirable outcomes. Studies show that preschoolers use more negative and controlling verbal and non-verbal behavior when working in mixed-sex dyads compared to same-sex dyads (Holmes-Lonergan, 2003; Leaper & Smith, 2004; Leman, Ahmed, & Ozarow, 2005), and school-age children working in mixed-sex pairs cooperate less than those working with another child of the same sex (Underwood, Jindal, & Underwood, 1994). Girls also forfeit more resources when working with boys (Powlishta & Maccoby, 1990), and students in mixed-sex dyads perform more poorly on academic tasks and exhibit a less balanced interactive style than children and adolescents working in same-sex dyads (Harskamp et al., 2008; Underwood et al., 2000).

To date, gendered peer interaction research has been focused mainly on aggregate levels of behavior. For example, researchers interested in examining affiliative behavior typically tally the number of affiliative speech acts for each partner. This presents a static picture of peer interactions, as information concerning the development of the interaction over time is lost. Interpersonal interactions, however, are not static. A successful interaction requires each partner to continuously adapt his or her behavior to that of the other (Clark, 1996). Changes both subtle (e.g., growing familiarity between interaction partners) and dramatic (e.g., a sudden power imbalance) may occur, requiring subsequent changes from the members to sustain a harmonious interaction. Eliminating these changes through data aggregation may mask important differences in the way boys and girls interact with same- and other-sex peers.

Researchers outside of gender studies have employed methods and techniques from dynamical systems theory to illustrate the viability and advantage of examining social exchange as a continuous and dynamic process (Dale & Spivey, 2006; Marsh et al., 2009; Marsh, Richardson, Baron, & Schmidt, 2006; Richardson et al., 2007; Schmidt, Carello, & Turvey, 1990; Shockley, Santana, & Fowler, 2003). When social interactions are coordinated, that is, when patterns of communication are similar across interaction partners, information is exchanged more efficiently and partners report more positive interaction experiences (Chartrand & Jeffries, 2003; Lakin & Chartrand, 2003; Marsh et al., 2009; Marsh et al., 2006; Matarazzo, Wiens, Matarazzo, & Saslow, 1968; Richardson et al., 2007). We propose utilizing a similar approach to measure and quantify continuous coordination in gendered peer interactions and examine it in relation to the success or failure of those interactions.

The Dynamics of Peer Interactions

A dynamic system is a system of elements that changes over time (Thelen & Smith, 2006). A boy and a girl working together to solve a math problem or a group of children on a playground each comprise a system. As their interactions become coordinated, global patterns of behavior emerge, such as successful problem solving or forming a game of tag. These interactions evolve over time in response to changing circumstances, generating new forms of behavior. If several children leave the game of tag, those that remain may form a new game more suitable for fewer players. The dynamics of the system are ever changing and reorganizing to form novel patterns of behavior.

Both conventional (e.g., growth modeling) and dynamical techniques are useful for assessing change over time. They differ with respect to the form of change that is considered. Conventional longitudinal analyses are suitable for examining general patterns of change, for instance, linear growth in the number of positive emotions displayed by a boy and a girl during an interaction. A requirement for estimating such behavioral trends is the assumption that variability around those trends is randomly distributed. Dynamics challenges this assumption. Variability is not considered random, but meaningful, and is thought to represent the primary change in the behavior of a system over time.

Because the focus is on variability, and not measures of central tendency, dynamical analyses are particularly suitable for studying gendered interpersonal coordination, as behavior may vary dramatically over the course of an interaction. If Jon and Chelsea were just acquainted, coordination may at first be awkward.

However, as they become accustomed to each other's interaction style, coordination becomes smoother and more harmonious. Later, Jon's desire to control the interaction may suddenly disrupt coordination. As Chelsea raises an argument, tempers flare and coordination plummets. Chelsea or Jon may then abandon the interaction, resulting in its termination. These complex changes in behavior would be difficult to examine with conventional longitudinal analyses. Dynamics, with its focus on variability, allows one to capture complex temporal change.

Interpersonal Coordination

Dynamical systems theory has been used to show that many processes in human social interaction exhibit interpersonal coordination. These include interaction partner's speaking rate (Street, 1984), vocal intensity and activity (McGarva & Warner, 2003; Natale, 1975), pausing frequency (Cappella & Planalp, 1981), accent (Giles, Giles, & Coupland, 1991), postural sway (Shockley et al., 2003), syntactic usage (Dale & Spivey, 2006), and even when they scratch their noses (Chartrand & Bargh, 1999). Such coordination facilitates a smooth exchange of information (Watanabe, Okubo, & Kuroda, 1996) and is important because it is related to greater rapport (Chartrand & Jeffries, 2003; Lakin & Chartrand, 2003; Matarazzo et al., 1968), more positive perceptions of an interaction (Marsh et al., 2009; Marsh et al., 2006), and feelings of harmony, camaraderie, and comfort (Marsh et al., 2009; Richardson et al., 2007).

Speech, in particular, is essential to many cooperative activities, especially those in which two or more people aim to achieve a common goal, as verbal communication fosters interpersonal coordination (Clark, 1996; Shockley et al., 2003). Similarity or disparity in communication style may serve to facilitate or hinder coordination between interaction partners. For example, when two individuals sit in rocking chairs that are of the same size, they easily coordinate their rocking frequency, even without being expressly instructed to do so (Richardson et al., 2007). If the rocking chairs differ dramatically in size, however, coordination of rocking frequency becomes difficult to achieve and maintain. The same pattern may also describe same- and mixed-sex interactions. In a same-sex interaction, the partners may be "rocking in chairs of the same size." They communicate in similar ways and thus find it easy to establish and sustain coordination. Alternatively, when boys and girls work together they may find that the ways in which they communicate are so different that it is difficult for them to establish much rapport. Coordination is not achieved, or perhaps only minimally, which may adversely affect their perceptions of their interaction partner.

Present Study

The goal of the present study was to employ dynamical methods and analyses to investigate gendered interpersonal coordination in pairs of young adolescents. Potential differences in coordination were assessed across dyad types (i.e., same-sex vs. mixed-sex), and, like previous work (Chartrand & Jeffries, 2003; Lakin & Chartrand, 2003; Marsh et al., 2009; Marsh et al., 2006; Matarazzo et al., 1968; Richardson et al., 2007), the relation of coordination to participants' perceptions of their interaction partner was examined. Fifth-grade boys and girls were paired with an unfamiliar same- or other-sex peer with whom they completed an academic exercise. Pairing adolescents with an unfamiliar peer enabled us to examine the formation of interaction patterns characteristic of each dyad instead of preexisting styles participants may have had with an established peer.

Participants' vocalizations were recorded during the exercise, from which numerous repeated measures were extracted to create a time series of vocal activity for each adolescent. The focus of the present study was adolescents' speech patterns, specifically, the length and patterning of their utterances, a non-content speech variable that has been shown to be a good marker of interpersonal coordination (Matarazzo et al., 1968; McGarva & Warner, 2003; Street, 1983; Street, Street, & van Kleek, 1983). Following the exercise, the adolescents were asked to report how much they liked working with their partner. As in other research (Chartrand & Jeffries, 2003; Lakin & Chartrand, 2003; Marsh et al., 2009; Marsh et al., 2006; Richardson et al., 2007), this measure served to establish interpersonal coordination as a marker of rapport and harmony between interaction partners. Identifying it as such is the first step to distinguishing interpersonal coordination as an indicator of the success or failure of peer interactions and determining how it may be influenced to improve mixed-sex interactions.

Overall, we expected to find a positive relation between coordination and positive perceptions of one's interaction partner. Because of the collaborative difficulties adolescents working with other-sex partners often experience

(Harskamp et al., 2008; Underwood et al., 2000), we also anticipated differences in coordination and partner liking between same-sex and mixed-sex dyads, with same-sex dyads experiencing greater coordination and reporting more partner liking than those in mixed-sex dyads. Furthermore, we hypothesized that coordination would mediate the differences in partner liking across dyad types. That is, we expected the greater coordination of same-sex dyads to account for the dyad differences in partner liking.

Method

Sample

Participants were fifth-grade students (*M* age = 11.11 years, *SD* = .45 years) recruited from public and charter elementary schools in the Phoenix metropolitan area of Arizona, and who participated in a larger study of peer interaction processes. Adolescents included in the present study were those with an available interaction partner (adolescents whose interaction partner was unavailable completed a subset of the pre- and post-interaction measures and were paired with a member of the research team for the exercise; these data were not used in the present study) and with complete audio data (technical difficulties during data collection led to the loss of audio data for some dyads). The final sample consisted of 64 same-sex (33 girl-girl, 31 boy-boy) and 33 mixed-sex dyads, resulting in a total of 194 participants (51% girls). The majority of the sample consisted of Non-Hispanic White adolescents (67%), with the remainder Hispanic (10%), Asian American (6%), Black (3%), Native American (2%), Pacific Islander (1%), or Other (11%). The families of most participants (70%) reported a total income of $60,000 or more.

Procedures

Prior to visiting the laboratory, participating adolescents were paired with an unfamiliar same- or other-sex peer (i.e., a peer from a different school) by the project coordinator. The participants arrived at the laboratory independently, but were tested in pairs. Upon arrival, each member of the dyad completed a short questionnaire assessing his or her general academic attitudes, career interests, and feelings of gender typicality. After completing the questionnaire, participants were introduced to their interaction partner, with whom they collaborated on an academic exercise. The exercise was conducted in a laboratory equipped with a table and two chairs. The adolescents were instructed to sit in the chairs, facing each other across the table. Each dyad member was asked to wear a headset microphone, used to record his or her vocalizations during the interaction. Following the exercise, the two adolescents independently completed measures of their post-interaction perceptions of the exercise, their partner, and several measures of their academic beliefs, attitudes, and abilities. Only data from the post-exercise measures of the adolescents' partner perceptions were utilized in the present study.

Interaction partners were asked to collaborate on a series of chemistry-based physical science tasks in which they constructed molecules using pieces from an organic chemistry molecule model building set. The molecule building pieces that were provided to the adolescents were small colored spheres and connectors representing atoms and bonds, respectively, and a two-dimensional diagram to use as a guide to build the molecule. A total of 10 molecules were assembled.

To facilitate a naturalistic interaction between dyad members, the exercise was designed to progress with as little experimenter intervention as possible. Thus, before beginning, the rules of the exercise were thoroughly explained. The adolescents were each provided with 10 folders, one per molecule, each containing half of the pieces required to build a molecule to encourage collaboration between the dyad members. Adolescents were instructed to acquire the appropriate folder, use the pieces within to complete the molecule, and dispose of their materials and move on to the next molecule after completion.

Measures

Vocal recordings. Adolescents' vocalizations were recorded independently, but in synchrony, through headset microphones onto a laptop computer running Cubase LE4, an audio recording software package, which created a .wav file for each participant. Examples of this type of vocal data are shown in Figure 1. Using Matlab R2010a, time series of vocal activity were generated by sampling each participant's .wav file every quarter second (McGarva & Warner, 2003), where at each sampling a "1" was recorded if the adolescent spoke and a "0" if he or she did not (Warlaumont et al., 2010). This resulted in a time series of 0s and 1s spanning the length of the interaction for each child.

Partner perceptions. After the exercise, the participants completed an 8-item measure of their experience with their partner (α = .82). Rated on a 7-point scale (1 = *not at all*; 7 = *a lot*), sample items included "Would you like to work with the same kid again on similar tasks?" "Overall, how much did you like your partner?" and "How often did your partner listen to you?" Higher scores indicated a more positive interaction experience.

Dynamical Analyses

Because the adolescents' speech (the 1s), not periods of silence (0s), were the focus of subsequent analyses, the 0s in the time series were transformed into 2s for one member of each dyad. Thus, for each dyad, one adolescents' time series was composed of 0s and 1s, whereas the other's series was 1s and 2s. Dyadic coordination was then assessed in these speech patterns with Cross Recurrence Quantification Analysis (CRQ), a dynamical technique used for examining shared or recurrent behavior between two systems (Zbilut, Giuliani, & Webber, 1998). CRQ was chosen because it is more sensitive to subtle patterns of behavioral similarity than other comparable dynamical methods (Shockley, Butwill, Zbilut, & Webber, 2002) and is also amenable to categorical data (e.g., Dale & Spivey, 2006), unlike other dynamical analysis techniques.

In the simplest case, CRQ involves plotting one adolescent's time series against the other to generate a visual representation of the shared structure between the two series, called a recurrence plot (Figure 2). When behavior is shared between the two adolescents a point is drawn on the plot. Various measures can then be calculated from the recurrence plot to characterize the shared structure between dyad members.

In practice, CRQ is not typically conducted with raw time series, but with series that are reconstructed in the appropriate dimensional space. Imagine looking at a group of football players on a field. When viewing them from a standing position, or a one-dimensional perspective, the players appear to be relatively close together (Figure 3A); however, if you instead take an aerial view, observing the field from a two-dimensional perspective, the players appear to be spread out (Figure 3B). The one-dimensional perspective distorted the available information, making the players seem close together when in reality they were not. The same is true for a time series. If projected in a dimension that is too low, information may be distorted and the time series may not be accurately represented. Through phase space reconstruction, a technique used for projecting a time series into higher dimensions, one can eliminate distortions due to lower-dimensional projection and perform a CRQ on the reconstructed series. Recurrent points are those that are similar in reconstructed space.

Before conducting a CRQ, one must select a time delay, embedding dimension, and radius for the analysis. The time delay and embedding dimension values are required to reconstruct the time series in the appropriate dimensional space.[1] For categorical data that is nominal, such as those in the present study, any time delay or embedding dimension can be chosen (Dale & Spivey, 2006; Dale, Warlaumont, & Richardson, 2011); however, because CRQ has not yet been

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[1] For more information regarding the selection of these parameters and how they are applied in the reconstruction of a time series, please see Takens (1981).

widely used for the analysis of binary time series of dyadic speech patterns (for an exception see Warlaumont et al., 2010), we employed more deliberate measures to select our parameters. For the time delay, we chose a value of 1 based on Dale's (R. Dale, personal communication, September 30, 2010) recommendation of this value for CRQ with categorical time series (conducting the analyses with larger time delays generated similar results). The embedding dimension for the phase space reconstruction was chosen with a false nearest neighbors analysis. Consider Figure 3A again. In one-dimension, the two football players on the right appear to be neighbors, that is, they are close together; however, when viewed in two dimensions (Figure 3B) they are not. Thus, they were false neighbors; when viewed in a higher dimension they were no longer close together. A false nearest neighbors analysis calculates the percentage of points in a time series (or two time series) that are false neighbors. The appropriate embedding dimension is one in which the percentage of false neighbors is zero (typically the percentage of false neighbors in subsequent dimensions is also zero; thus, the lowest dimension is chosen). In the present study, the percentage of false nearest neighbors reached zero at an embedding dimension of 2.

Last, the radius parameter defines the size of the neighborhood surrounding each point in reconstructed space.[2] Choosing a small radius limits the size of the neighborhood around each point, resulting in a conservative estimate

[2] For a more thorough description of radius, how it is specified, and how it is used in reconstructed phase space, please see Shockley (2005).

of recurrent points. A larger radius creates a larger neighborhood, increasing the number of recurrent points. In categorical CRQ, the radius is set very close to zero to limit recurrent points to those that completely overlap in reconstructed space (Dale & Spivey, 2006; Dale et al., 2011). Thus, in the present study, we chose a radius of .001. Because the time series were categorical, this small radius limited the CRQ analysis to the examination of coordination in dyadic speech patterns (1s), not periods of silence (0s and 2s).

A variety of measures can be calculated from a recurrence plot to assess various characteristics of systems under consideration. We calculated percent recurrence (%REC), which is the ratio of the number of recurrent points on the plot relative to the total number of possible recurrent points. For example, plotting two 500-point time series generates a recurrence plot with 250,000 potential points of recurrence. If 2500 of those points are recurrent, %REC equals 1%. %REC has been found to reflect behavioral similarity or coordination in dyadic interactions in previous research (Shockley, 2005), and was used in the present study to examine differences in coordination among the adolescent dyads.

Results

We employed CRQ to characterize gendered interpersonal coordination in pairs of young adolescents, examined how same- and mixed-sex dyads differed in their patterns of coordination, and determined the mediating effect of that coordination on dyad-level differences in partner preferences. Example cross recurrence plots are shown in Figure 2. Coordination is calculated from the recurrence plots as %REC, which is interpreted as a percentage between 0 and

100%, where higher values indicate greater coordination. Thus, a %REC value of 10% indicates that for 10% of the interaction the adolescents coordinated their vocal communication patterns.

Four hypotheses were tested in the present study: (a) that adolescents in same-sex dyads would report more positive partner perceptions than those mixed-sex dyads; (b) that adolescents working in same-sex dyads would exhibit greater coordination than those in mixed-sex dyads; (c) that coordination would positively predict partner perceptions; and (d) that coordination would mediate differences across dyad types in levels of partner perceptions.

Means and standard deviations for coordination (%REC) and partner perceptions are presented in Table 1 separately by dyad type. Coordination was a dyad-level variable; thus, the mean and standard deviation were calculated across girl-girl, boy-boy, and girl-boy dyads. Partner perceptions were individual-level variables, and their respective descriptive statistics were calculated within dyad type.

Because adolescents' partner perceptions were measured at the individual level, but these perceptions are nested within dyads (i.e., boy-boy, girl-girl, or boy-girl) and thus acted as a group characteristic, multilevel modeling (MLM) procedures were employed to address the first hypothesis. Using SAS version 9.3, the following model was estimated to examine differences between adolescents in same- and mixed-sex dyads in their partner perceptions (see Equations 1 and 2):

Level 1: $partner\ perception_{ij} = \beta_{0j} + r_{ij}$ (1)

Level 2: $\beta_{0j} = \gamma_{00} + \gamma_{01}(boy\text{-}boy\ dyad) + \gamma_{02}(girl\text{-}girl\ dyad) + u_{0j}$ (2)

Dyad type (boy-boy, girl-girl, girl-boy) was dummy coded, with mixed-sex dyads as the reference group, and significant positive coefficients for γ_{01} and γ_{02} would show that all-boy and all-girl dyads reported greater partner perceptions than mixed-sex dyads. Consistent with our hypothesis, adolescents who worked in boy-boy (γ_{01} = .33, p < .05) and girl-girl dyads (γ_{02} = .79, p < .01) reported liking their partner more than boys and girls in mixed-sex dyads.

To address the second hypothesis, a multiple regression analysis was conducted to examine differences between same- and mixed-sex dyads in levels of coordination. Because both dyad type and coordination are group-level variables, a MLM was not required. Again, dyad type was dummy coded, with mixed-sex dyads as the reference group. Thus, a significant positive regression coefficient would show that boy-boy or girl-girl dyads exhibited greater coordination than adolescents in mixed-sex dyads. The results partially supported our hypothesis. Adolescents in girl-girl dyads were better coordinated than those in mixed-sex dyads (β = .25, p < .05), but there were no differences between boy-boy and girl-boy dyads (β = -.04, *ns*).

Examining the third hypothesis necessitated the prediction of an individual-level variable from a group-level variable. Thus, a second MLM was estimated to examine the prediction of adolescents' partner perceptions from their dyadic coordination (Equations 3 and 4):

Level 1: $partner\ perception_{ij} = \beta_{0j} + r_{ij}$ (3)

Level 2: $\beta_{0j} = \gamma_{00} + \gamma_{01}(coordination) + u_{0j}$ (4)

where γ_{01} estimated the effect of coordination on partner perceptions. The results confirmed our hypothesis (γ_{01} = .03, p < .01), showing that a one percent increase in coordination predicted a .03-unit increase in adolescent-reported liking of their interaction partner[3].

A final MLM was estimated to examine the fourth hypothesis, that coordination would mediate the dyad-level differences in partner perceptions (Equations 5 and 6):

Level 1: $partner\ perception_{ij} = \beta_{0j} + r_{ij}$ (5)

Level 2: $\beta_{0j} = \gamma_{00} + \gamma_{01}(boy\text{-}boy\ dyad) + \gamma_{02}(girl\text{-}girl\ dyad) + \gamma_{03}(coordination) + u_{0j}$ (6)

A significant mediating effect would show that differences in partner preferences between same- and mixed-sex dyads is at least partly due to dyad differences in coordination. Mediation was estimated by calculating the product of the effect of coordination on partner perceptions (γ_{03} in Equation 3) and the effect of dyad type (boy-boy or girl-girl) on coordination (estimated in the regression analyses; Sobel, 1982). Contrary to our hypotheses, the results showed that coordination was not a significant mediator of the differences in partner perceptions between mixed-sex and girl-girl (z = 1.44, p = .15) or boy-boy dyads (z = .37, p = .71).

Discussion

Scientists outside of gender studies frequently apply dynamics to the study of dyadic social interaction and find that coordination predicts important

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[3] Coordination was highly related to the percent of time adolescents spoke during the interaction (γ_{01} = 1.75, p < .001). However, the lack of complete overlap suggests that coordination measured a quality of the interaction beyond how much each dyad member spoke.

outcomes related to interactive success or failure. Many studying gender, however, have not yet embraced dynamics as a perspective or tool with which gendered social interactions can be explored. The present study represents the first endeavor to do so. By employing methodological and analytical techniques from dynamical systems theory, we captured young adolescents' dyadic coordination and examined it in relation to the self-reported quality of their interactions.

Previous research examining the characteristics of same- and mixed-sex interactions has shown that boys and girls often experience more difficulty working with each other than with same-sex peers. Children and young adolescents act more controlling and are less cooperative (Holmes-Lonergan, 2003; Leaper & Smith, 2004; Leman et al., 2005), more frequently disagree over resources (Powlishta & Maccoby, 1990), and struggle more on academic tasks (Harskamp et al., 2008; Underwood et al., 2000) when working with a member of the other sex. Thus, in the present study, we expected boys and girls in same-sex dyads to report more positive partner perceptions than those working in mixed-sex dyads. The results confirmed our hypotheses. Boys and girls in same-sex dyads reported liking their partner more than those working with a member of the other sex.

Although applying dynamics to the study of interpersonal coordination is not new in psychological research (e.g., Dale & Spivey, 2006; Schmidt et al., 1990; Shockley, 2005), the present study is the first to use dynamics to examine gendered social interactions. We measured coordination in young adolescents' interaction patterns with CRQ, with the goal of exploring differences in coordination between same-sex and mixed-sex dyads and examining the relation of that coordination to their post-interaction partner perceptions. Because previous work has shown that same-sex interactions are more harmonious than mixed-sex exchanges, we expected to find that all-boy and all-girl dyads would exhibit greater coordination than mixed-sex dyads. Our hypothesis was partially supported. Girl-girl dyads showed greater coordination than mixed-sex dyads; however, boy-boy dyads were not found to differ from boy-girl dyads. That the difference was significant for all-girl and not all-boy dyads may be because patterns of vocal coordination might better characterize girls' social coordination than boys'. Studies show that girls have a slight advantage in verbal ability compared to boys throughout childhood and adolescence (see studies cited in Hyde & Linn, 1988), that girls speak more than boys during social interactions (see studies cited in Leaper & Smith, 2004), and that girls' play more often involves discourse in small groups than does boys' (Blatchford, Baines, & Pellegrini, 2003). Alternatively, boys' coordination may revolve more around nonverbal communication. Boys are generally more active than girls (Eaton & Enns, 1986; Ridgers, Stratton, & Fairclough, 2005) and their play often revolves more around physical activities, such as a game of baseball or tag, than verbal exchange (Blatchford et al., 2003; Ridgers et al., 2005; Ridgers, Stratton, & Fairclough, 2006). Future studies should examine coordination of physical movement between boys during dyadic interactions. For instance, the distance between interactions partners could be examined as it changes over time to see if they move in synchrony or if their movement patterns are disparate. Such patterns may more accurately characterize boys' dyadic coordination than did the verbal coordination of the present study.

The relation of coordination and positive interaction experiences is well documented. Coordination is related to greater rapport and feelings of harmony and comfort (Chartrand & Jeffries, 2003; Lakin & Chartrand, 2003; Marsh et al., 2006; Marsh et al., 2009; Matarazzo et al., 1968; Richardson et al., 2007). Thus, we expected to find a similar relation. Consistent with our hypothesis, greater coordination was predictive of more positive perceptions of one's interaction partner. The more similar interaction partners were in their patterns of vocal activity, the more likely they were to report enjoying the interaction with their partner. Greater coordination likely facilitated a smoother and more efficient exchange of information (Watanabe et al., 1996), aiding communication and easing what was likely a somewhat stressful situation, making it more enjoyable to work together. The next step for future research is to identify factors that buttress interpersonal coordination. For example, if vocal communication is indeed an important determinant of girls' interpersonal coordination, encouraging boys to speak more when interacting with girls may improve mixed-sex interactions, alleviating some of the negative experiences between boys and girls, particularly within academic settings. Alternatively, if physical coordination is important for boys, encouraging girls to be more active could lead to similarly improved mixed-sex interactions.

Last, to further explore the effect of coordination on adolescents' perceptions of their interaction partner, we examined coordination as a potential mediator of the dyad-level differences in partner perceptions. The results showed that it was not a significant mediator of the differences in partner perceptions between all-boy and mixed-sex dyads. However, this was not unexpected, as these dyads did not significantly differ in how much they liked working with their partner. Coordination did, however, partly explain the difference in partner perceptions between girl-girl and girl-boy dyads but not at a statistically significant level. It may be that coordination is just one of many characteristics of social interaction that contribute to girls' liking of their interaction partners. For instance, research shows that girls often forfeit more resources when working with boys than with girls (Powlishta & Maccoby, 1990). This lack of influence over boys may contribute to the differences in liking across girl-girl and girl-boy dyads. Because they feel they have no control over boys, girls may prefer working with a girl with whom they have a more egalitarian interaction experience. Future work should explore influence, as well as other factors, that are potentially related to social coordination.

Limitations and Conclusions

Some limitations must be considered when interpreting the results of the present study. First, the majority of the participants were white adolescents, which may have had an effect on dyadic coordination, particularly for mixed-sex dyads. Research shows that there is ethnic variation in gendered attitudes. Hispanic and Black men often harbor more traditional gender role attitudes compared to their White counterparts (see studies cited in Kane, 2000). Although such differences have not been found in children, it is possible that children are exposed to traditional gender role attitudes from male authority figures, which may result in more heavily sex segregated peer interactions, as they may desire to conform to these gender roles. This lack of experience interacting with girls may result in poorer coordination than what was found in mixed-sex dyads in the present study. Future research could examine not only the interaction of ethnicity and gender on same- and mixed-sex dyadic coordination, but also how experience with other-sex peers affects coordination in mixed-sex dyads and how that coordination affects young adolescents' partner perceptions.

Second, although we deliberately paired adolescents with an unfamiliar peer to examine the formation of novel interaction patterns, the quality of the relationship they had with an existing peer may have influenced the link between coordination and partner perceptions. Compared to play with an unfamiliar partner, play with a familiar peer is characterized by more task-relevant utterances, more cognitively engaging and complex behaviors, and more positively and negatively valenced expressions (Doyle, Connoly, & Rivest, 1980; Furman, 1987; George & Krantz, 1981). Thus, a poor (or successful) interaction with a peer that an adolescent sees or interacts with frequently may have a greater effect on partner perceptions than one with an unfamiliar peer. However, it is notable that we found a significant relation between coordination and partner perceptions with unfamiliar peers. Future work could explore the effects of familiar peers have on girls' academic beliefs by pairing them with a familiar or unfamiliar peer.

The present study was the first to explore gendered dyadic interactions from a dynamical perspective, and in doing so found that interpersonal coordination was related to interactive success or failure in gendered social interactions. Greater coordination was related to more positive partner perceptions across dyad types, and it partly accounted for the more positive partner perceptions reported by girls in same-sex dyads compared to those in mixed-sex dyads. These results suggest that by finding ways to increase coordination between boys and girls, researchers and educators can facilitate more harmonious mixed-sex interactions, setting the stage for improved inter-gender relations both within and outside of the classroom.

Study 2: The Dynamics of Dyadic Coordination: Social Influences on Girls' Academic Beliefs

In the United States, girls and women are overwhelmingly under-represented in the fields of science, technology, engineering, and mathematics (STEM) compared to boys and men. Women earn the minority of bachelor's (20-34%), master's (21-37%), and doctoral (17-27%) degrees in these fields (Freeman, 2004), and they hold fewer faculty positions in the physical sciences (16-25%) and mathematics (3-15%) (Ceci, Williams, & Barnett, 2009). They are also less likely than men to pursue non-academic careers in engineering, physical science, math, computer science, and chemistry (Ceci et al., 2009; Frome, Alfred, Eccles, & Barber, 2008). Even women who excel in these fields typically choose to pursue non-STEM careers, and those who do enter STEM fields are twice as likely as men to eventually leave them (Ceci et al., 2009; Preston, 2004).

Past research suggests that the most significant determinant of girls' and women's under-representation in STEM is that they choose not to enroll in related coursework or pursue careers in STEM fields (Ceci et al., 2009). Researchers have identified various reasons for this desire to avoid STEM, including brain functioning (Casey, Nuttall, & Pezaris, 1999), contextual factors (Hyde, Fennema, Ryan, Frost, & Hopp, 1990; Jacobs & Eccles, 1985), stereotyping (Lewis, 2005), achievement and performance (Ceci, 1996; Geary, 1996), and motivation (Baron-Cohen, 2007). Although comprehensive in investigating individual differences that predict STEM involvement, very little work has focused on potential social contributors to girls' and women's under-representation in STEM. This is surprising given research suggesting that girls and women may be particularly susceptible to peer influence (Ambady et al., 2001; Johnson & Helgeson, 2002). Negative interactions with peers in math or science settings may deleteriously affect girls' STEM-related interests or competencies and lead them to avoid these fields in the future.

Proponents of same-sex schooling have used this research to support their claims that boys and girls should be educated separately (Gurian & Stevens, 2011; Sax, 2005). However, given that boys and girls often must interact with each other outside of primary and secondary school, academic segregation does not appear to be the answer for life-long intellectual achievement. Instead, by mitigating the interactive difficulties between boys and girls within the classroom we may alleviate many of the individual differences that explain the gender gap in STEM, such as motivation and stereotype threat. The goal of the present study was to examine such interaction processes and determine their relation to girls' attitudes and beliefs toward science. The study of peer interactions was guided by dynamical systems theory, with the goal of assessing and analyzing variability in young adolescents' gendered peer interactions as a marker of interactive success or failure.

The Influence of Peers on Girls' Academic Achievement and Beliefs

Boys' and girls' academic outcomes are influenced by their peers. Although friends often share similar characteristics, they also converge over time in their academic motivation, self-competence, performance, achievement beliefs, and their enjoyment of school (Altermatt & Pomerantz, 2003; Berndt, Laychak, &

Park, 1990; Crosnoe, Cavanagh, & Elder, 2003; Kindermann, 1993; Kurdek & Sinclair, 2000; Ryan, 2001; Urdan, 1997). An association with academically oriented peers even acts as a buffer against adverse academic outcomes, such as poor grades and dropout (Crosnoe et al., 2003). These effects are not limited to friendships, as academic evaluations made by classmates are also related to changes in academic achievement and engagement over time (Hughes, Dyer, Luo, & Kwok, 2009).

Although peers influence the academic outcomes of all children, such effects may be stronger for girls and women than for boys and men. Women are more likely than men to incorporate feedback into evaluations of themselves, particularly negative feedback (Roberts, 1991; Roberts & Nolen-Hoeksema, 1989; Rudawsky, Lundgren, & Grasha, 1999), and they are also more likely to report lower self-esteem and to modify their future behavior in response to negative evaluations (Johnson & Helgeson, 2002; Roberts & Nolen-Hoeksema, 1994; Rudawsky et al., 1999). These effects may be further exacerbated within masculine academic settings and when working with male peers. Experimental studies show that the stereotype of feminine inferiority in mathematics adversely affects girls' math test scores (Ambady et al., 2001), and women are also more sensitive to feedback on mathematics examinations than those testing verbal skills (Kiefer & Shih, 2006). When working with boys, girls typically forfeit more resources (Powlishta & Maccoby, 1990) and perform more poorly on academic tasks than those working in same-sex dyads (Harskamp et al., 2008; Underwood et al., 2000). Poor interpersonal experiences with boys, particularly within masculine academic settings that highlight stereotypes of female inadequacy, may cause girls and women anxiety and serve to reinforce feelings of incompetence and inferiority in STEM, leading them to avoid such activities in the future.

Coordination and Dyadic Peer Interactions

When two individuals interact, aspects of their behavior often become more similar over time. For example, two adults who are interacting while sitting in separate rocking chairs will eventually match rocking frequency, moving back and forth at the same time, even without being expressly told to do so (Richardson et al., 2007). Other behaviors that converge over time include aspects of verbal communication such as speaking rate, intensity, and activity (McGarva & Warner, 2003; Natale, 1975; Street, 1984), pausing frequency (Cappella & Planalp, 1981), accent (Giles, Giles, & Coupland, 1991), and syntactic usage (Dale & Spivey, 2006), nonverbal communication such as postural sway (Shockley et al., 2003) and leg swinging (Schmidt et al., 1990), and even biological processes such as heart rate variability (Watanabe et al., 1996). This convergence reflects behavioral coordination. Such coordination facilitates a smooth exchange of information (Watanabe et al., 1996), and greater coordination is related to greater rapport and comfort between interaction partners (Chartrand & Jeffries, 2003; Lakin & Chartrand, 2003; Marsh et al., 2009; Matarazzo, Weins, Matarazzo, & Saslow, 1968; Richardson et al., 2007).

Previous work examining coordination in adolescent dyadic interactions showed a similar relation between coordination and liking of one's partner (Study 1). Coordination was also weaker between boys and girls in mixed-sex dyads than between girls in same-sex dyads. If girls exhibit such poor coordination when working with a boy in a math or science classroom, short-term problems may arise with girls' avoiding working with boys on math and science problems, or placing less value on doing well in those subjects. Longer-term consequences may also occur, such as choosing not to enroll in math or science courses in the future or pursue careers in related fields.

In Study 1 we employed methods and analyses from dynamical systems theory to quantify adolescent dyadic coordination. Rather than focusing on aggregate levels of behavior, this approach allowed us to examine variability in behavior and its change over time. In the present study, we employed the same techniques to examine temporal variability in young adolescent girls' same- and mixed-sex dyadic interactions and examine how dyad-level differences in coordination affected their academic self-perceptions.

Present Study

The present study seeks to examine dyadic social coordination within a masculine academic setting in a sample of young adolescents and determine its effect on girls' science-related self-perceptions. Perceived abilities (i.e., competency) and values (e.g., feelings of importance, interest, or cost) are positively related to performance and course enrollment in math and science (Multon, Brown, & Lent, 1991; Simpkins, Davis-Kean, & Eccles, 2006; Simpkins, Fredricks, Davis-Kean, & Eccles, 2006; Updegraff, Eccles, Barber, & O`Brien, 1996). If a student believes that she is inadequate in science, that it is not important for her to be knowledgeable in science, and that there are many costs associated with pursuing science, the student will likely choose to avoid future science classes. Increasing girls' and women's desire to pursue science coursework and careers necessitates a similar increase in their feelings of competency, importance, and interest in science, as well as a reduction in the perceived costs associated with such endeavors. Because girls' self-perceptions are typically affected more by peer influence and feedback than are boys' (Johnson & Helgeson, 2002; Roberts, 1991; Roberts & Nolen-Hoeksema, 1994; Rudawsky et al., 1999), particularly with masculine academic settings (Ambady et al., 2001; Kiefer & Shih, 2006), we expected girls who experienced poor social coordination with partners on science tasks to also report poor science-related academic beliefs.

Fifth-grade girls, who at this age are beginning to diverge from boys in their involvement in math and science (National Science Foundation, 2008), were paired with an unfamiliar boy or girl with whom they completed a series of physical science (i.e., male-typical) tasks. Pairing them with an unfamiliar peer enabled us to examine the formation of interaction patterns characteristic of each dyad instead of preexisting styles they may have had with an established peer.

We focused on coordination in the adolescents' speech patterns, as speech is essential to many cooperative activities and fosters interpersonal coordination (Clark, 1996; Shockley et al., 2003). Thus, the adolescents' verbalizations were recorded throughout the interaction, from which numerous repeated measures were extracted to create a time series of vocal activity for each adolescent, characterizing the adolescents' speech patterns. Specifically, the length and patterning of their utterances was examined, as this non-content speech variable has been used to explore patterns of interpersonal coordination in previous research (Matarazzo et al., 1968; McGarva & Warner, 2003; Street, 1983; Street et al., 1983). After the science tasks, the adolescents were asked to complete several measures of their self-perceived abilities in, their motivation for, and their enjoyment of physical science.

Given girls' susceptibility to peer and social influence, particularly within masculine academic settings, we expected to find that girls in same-sex dyads would report more positive academic beliefs than those in mixed-sex dyads. In addition, because greater coordination is indicative of a positive interaction experience (Chartrand & Jeffries, 2003; Lakin & Chartrand, 2003; Marsh et al., 2009; Matarazzo et al., 1968; Richardson et al., 2007; Study 1), we expected coordination to also predict improved academic outcomes. Specifically, we anticipated a positive relation between coordination and science self-competence, interest, and values, and a negative relation with the costs associated with pursuing science coursework. Furthermore, we also hypothesized that coordination would mediate the differences in academic beliefs across dyad types. That is, we expected the greater coordination of same-sex dyads to account for the differences in academic beliefs of girls in same-sex dyads versus those in mixed-sex dyads.

Method

Sample

Participants were fifth-grade students (*M* age = 11.09 years, *SD* = .44 years) recruited from public and charter elementary schools in the Phoenix metropolitan area of Arizona, and who participated in a larger study of peer interaction processes. Adolescents included in the present study were those with an available interaction partner (an adolescent whose interaction partner failed to appear for the laboratory visit was paired with a member of the research team for the exercise; these data were not used in the present study) and with complete audio data. The final sample consisted of 33 girl-girl and 33 girl-boy dyads participated, resulting in a total of 132 participants (75% girls). The majority of the sample consisted of Non-Hispanic White adolescents (65%), with the remainder Hispanic (11%), Asian American (7%), Black (3%), Pacific Islander (1%), or Other (13%). The families of most participants (68%) reported a total income of $60,000 or more.

Procedures

Girls were randomly paired with an unfamiliar male or female peer by the project coordinator and were invited to the laboratory for participation in the study. Participants arrived independently, and upon arrival completed a short questionnaire assessing general academic attitudes, career interests, and feelings of gender typicality. After the initial assessment, participants were introduced to their interaction partner and received instruction on the collaborative academic exercise. Each participant wore a headset microphone, used to record his or her vocalizations during the interaction. After the exercise, the members of each dyad independently completed measures of their academic self-perceptions.

Dyad members collaborated on a series of chemistry-based science tasks in which they constructed molecules using pieces from an organic chemistry molecule model building set. The molecule building pieces were small colored spheres and connectors representing atoms and bonds, respectively, and a two-dimensional diagram to use as a guide in building the molecule. To promote a pattern of coordination that was characteristic of each dyad, a total of 10 molecules were assembled. A measure of coordination was extracted from this characteristic interaction pattern.

To encourage naturalistic interaction between dyad members, the exercise was designed to progress with as little experimenter intervention as possible. Before beginning, the rules of the exercise were thoroughly explained. Dyad members were provided with 10 folders, one per molecule, each containing half of the pieces required to build a molecule to encourage collaboration. After acquiring the appropriate folder, the adolescents were instructed to use the pieces within to complete the molecule, dispose of the materials after completion, and then move on to the next molecule.

Measures

Vocal recordings. The adolescents' vocalizations were recorded independently, but in synchrony, through headset microphones onto a laptop computer. The software package Cubase LE4 was used to record participants' vocalizations and create a .wav file for each dyad member. Time series were generated with MATLAB R2010a by sampling each participant's .wav file every quarter second (McGarva & Warner, 2003), where at each sampling a “1” was recorded if the adolescent spoke and a “0” if he or she did not, resulting in a time series of 0s and 1s for each adolescent.

Academic self-perceptions. The measure of self-reported academic self-perceptions was comprised of four scales assessing the adolescents’ perceived academic competency, importance, interests, and costs in each of four academic subjects: mathematics, chemical science, life science, and reading and writing. A distinction was made between chemical and life sciences because girls achieve higher grades in life sciences than boys, whereas boys receive higher grades than girls in chemical sciences (Britner, 2008; Ceci et al., 2009). These measures were derived from those created by Eccles and colleagues, which have been shown to be reliable and valid (Eccles, Wigfield, Harold, & Blumenfeld, 1993; Jacobs, Lanza, Osgood, Eccles, & Wigfield, 2002). In the present study, we only employed the measures for perceptions of chemical science.

The measures of competency, values, interests, and costs were each rated on a 7-point scale. The competency scale was comprised of five items that measured adolescents’ perceptions of chemical science achievement (α = .88; “How good are you at science about liquids and solids, molecules and atoms?”; 1 = *not very good*; 7 = *very good*). The measure of values was a 3-item scale that assessed the importance adolescents place on chemical science (α = .90; “In general, how useful is what you learn in science about liquids and solids, molecules and atoms?”; 1 = *not at all useful*; 7 = *very useful*). Interest was assessed with a 3-item measure in which the adolescents reported on their enjoyment of chemical science ($\alpha = .88$; "How much do you like doing science about liquids and solids, molecules, and atoms?"; 1 = *not at all*; 7 = *very much*). Finally, costs were assessed with thirteen items measuring adolescents' beliefs about the costs associated with pursuing science. These items comprised two scales, the first measuring the cost of the time and effort it takes to achieve highly in science ("The amount of effort it takes to do well in science classes is not worth it to me"; 1 = *not at all true*; 7 = *very true*), and the second assessing the trouble or futility of trying hard in science ("Even if I do well in math, I think others would not see me as being good in math"; 1 = *not at all true*; 7 = *very true*). These subscales were highly correlated ($r = .63$, $p < .01$), and thus were combined into a single costs scale ($\alpha = .86$).

Results

As in Study 1, we quantified dyadic coordination using Cross Recurrence Quantification Analysis (CRQ), a dynamical technique developed to examine shared or recurrent behavior between two systems (Zbilut et al., 1998). In CRQ, the time series of one adolescent's vocalizations is plotted against the time series of the other to generate a visual representation of the shared structure between the two dyad members, called a recurrence plot, which is illustrated in Figure 2.[4]

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[4] This example represents a somewhat simplified description of CRQ. In practice, a recurrence plot is not generated from raw time series, but from series that have been reconstructed in the appropriate dimension. For more information, see

When behavior is shared between the two adolescents, that is, when their vocal patterns are similar, a point is drawn on the plot.

A variety of measures can then be calculated from a recurrence plot to assess various characteristics of dyadic interaction. In studies of dyadic interactions (e.g., Shockley, 2005; Study1), percent recurrence (%REC) has been found to reflect behavioral similarity or coordination. Thus, in the present study we employed %REC as our measure of coordination. %REC is calculated as the ratio of the number of recurrent points on a recurrence plot relative to the total number of possible recurrent points. Greater values indicate greater coordination. For example a %REC value of 10% indicates that 10% of the adolescents' interaction was coordinated across individuals.

Means and standard deviations for the study variables are presented in Table 2 separately for girls in same-sex and mixed-sex dyads. Coordination was a dyad-level variable; thus, the mean and standard deviation were calculated within girl-girl and girl-boy dyads. Self-competence, values, interest, and costs were individual-level variables, and their respective descriptive statistics were calculated across all girls in girl-girl dyads and across only girls in girl-boy dyads. Significant differences between girls in same- versus mixed-sex dyads in the study variables are described below. Correlations among the academic belief variables (Table 3) show consistently high correlations. Self-competence, values,

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Shockley (2005). In addition, please see Study 1 for more information on the parameters that were chosen to conduct CRQ in the present study.

and interest were all positively related with each other and negatively related to costs.

In the present study we examined three hypotheses: (a) that girls working with other girls would report higher physical science self-competence, values, and interest and fewer costs than those working with boys; (b) that coordination would significantly predict academic beliefs (positively for self-competence, interests, and values, and negatively for costs) for girls; and (c) that coordination would mediate differences between girls in same-sex dyads versus those in mixed-sex dyads in their academic beliefs.

Because the adolescents were not independently assessed, but were nested within dyads, multilevel modeling (MLM) procedures were employed to examine the first hypothesis. Four MLMs were estimated (see Equations 7 and 8), one each for chemical science self-competence, interest, values, and costs,

Level 1: $academic\ belief_{ij} = \beta_{0j} + \beta_{1j}\,(contrast) + r_{ij}$ (7)

Level 2: $\beta_{0j} = \gamma_{00} + u_{0j}$ (8)

$\beta_{1j} = \gamma_{10}$

where γ_{10} estimated differences between girls in same-sex versus mixed-sex dyads. By using a contrast code as the predictor variable (-0.5, 0, and 0.5 for girls in same-sex, boys in mixed-sex, and girls in mixed-sex dyads, respectively), differences in academic beliefs for girls in same-sex and mixed-sex dyads could be examined. Contrary to our hypothesis, however, the results showed no significant differences for any of the academic beliefs variables (γ_{10}s = -.06 to .11, all *ns*).

Four more MLMs were estimated to examine the second hypothesis (Equations 9 and 10), that coordination, a dyad-level variable, would positively predict the individual-level measures of girls' self-competence, interest, and values, and negatively predict their costs,

Level 1: $academic\ belief_{ij} = \beta_{0j} + \beta_{1j}\,(boy) + r_{ij}$ (9)

Level 2: $\beta_{0j} = \gamma_{00} + \gamma_{01}(coordination) + u_{0j}$ (10)

$\beta_{1j} = \gamma_{10} + \gamma_{11}(coordination)$

where γ_{01} assessed the prediction of academic beliefs by coordination for girls. Unexpectedly, the results showed that dyadic coordination was not a significant predictor of girls' academic beliefs (γ_{01}s = -.02 to .004, all *ns*).

The final hypothesis was examined with a mediated multilevel modeling analysis. Because the predictor (the contrast code) and outcomes (academic beliefs) were measured at level 1 and the mediator (coordination) at level 2, this model was estimated with structural equation modeling procedures (Preacher, Zyphur, & Zhang, 2010). Figure 4 illustrates the model. The mediating effect was determined by calculating the product of the two paths comprising the indirect effect (*ab*) (Preacher et al., 2010). Contrary to our hypotheses (but not unexpectedly, given that there were no significant dyad-level differences for girls' academic beliefs) coordination was not a significant mediator of those differences (*ab*s = -.02 to .11, all *ns*).

Discussion

To identify social predictors of girls' and women's under-representation in STEM, we examined interpersonal coordination as it relates to young adolescent girls' science-related academic beliefs. Given research showing that girls' academic beliefs may be especially susceptible to peer influence (Johnson & Helgeson, 2002; Roberts, 1991; Roberts & Nolen-Hoeksema, 1989; 1994; Rudawsky et al., 1999), particularly from boys and within masculine academic settings (Ambady et al., 2001; Kiefer & Shih, 2006), we expected to find that girls in same-sex dyads would report more positive academic beliefs than those working with boys. In addition, given research showing a positive relation between interpersonal coordination and positive interaction experiences (Chartrand & Jeffries, 2003; Lakin & Chartrand, 2003; Marsh et al., 2009; Matarazzo et al., 1968; Richardson et al., 2007; Study 1), we expected that greater coordination would predict more positive academic beliefs for all girls, and that coordination would mediate dyad-level differences in academic beliefs. The results, however, did not support our hypotheses. Girls in same- and mixed-sex dyads did not differ in academic beliefs. Also, coordination did not significantly predict academic beliefs, and thus could not act as a mediator of differences in academic beliefs between girls in same-sex and mixed-sex dyads.

Prior work examining the effect of peers on academic outcomes has focused on evaluative feedback, finding that women are more influenced by peer evaluations than men (Roberts, 1991; Roberts & Nolen-Hoeksema, 1989; 1994). We did not achieve similar results in the present study. This may have occurred because we did not subject participants to direct evaluations of their performance on the task. Rather, with regard to previous research (Chartrand & Jeffries, 2003; Lakin & Chartrand, 2003; Marsh et al., 2009; Matarazzo et al., 1968; Richardson et al., 2007; Study 1), we assumed a poor interaction between a boy and a girl, particularly within a masculine academic environment, would serve as an indirect form of task evaluation. For instance, if a girl experienced a poor interaction with a boy, she would feel that she did not do well on the task and then report low science self-competence. However, this was not a strong enough form of evaluation to affect girls' science-related academic beliefs. A potential avenue for future work could be to provide participants with explicit evaluative feedback, either from peers or an experimenter, throughout the interaction and examine how that feedback affects dyadic coordination and their resultant academic beliefs.

Another factor that may have contributed to the lack of significant findings may have been the inability of a single interaction to meaningfully affect girls' science-related self-competence, values, interest, or costs. Self-perceived academic beliefs likely develop over an extended period of time across a variety of situations. Research shows that young children's academic beliefs are initially optimistic. They typically rate themselves high in ability and values, but these ratings decrease as they age (Eccles et al., 1993; Nicholls, 1979). These declines, however, occur over many years as children experience more and become increasingly sensitive to academic feedback and social comparison (Eccles, Wigfield, & Schiefele, 1998). Thus, a single experience with an unfamiliar peer and in an unfamiliar environment may be unlikely to significantly change such beliefs. Instead, repeated exposure to the same peer (or peer group) and task may be required. Future research should examine whether change in these beliefs varies depending on exposure to and experiences with same- or other-sex peers. For example, participants could be paired with the same peer on multiple occasions and across a variety of science-related tasks. This repeated exposure may have a stronger effect on girls' academic beliefs than a single experience alone.

Alternatively, the effect of repeated peer exposure may also be examined by comparing the interactions of familiar and unfamiliar peers. Although in the present study we chose to examine the development of characteristic interaction patterns in unfamiliar peers, those who are already acquainted would bring to the experiment their history of shared interactions. This familiarity may allow them to bypass the period of "discovery" that characterizes the interactions of unacquainted peers and experience a more significant interaction. Research indeed shows that, compared to play with an unfamiliar partner, play with a familiar peer more frequently results in task-relevant utterances, is more cognitively engaging and complex, and is more emotionally valenced (Doyle et al., 1980; Furman, 1987; George & Krantz, 1981). This cognitive and emotional investment in the interaction may have a more consequential effect on girls' science-related academic beliefs, particularly if it is an interaction with a male peer, which is often characterized by greater negativity (Harskamp et al., 2008; Powlishta & Maccoby, 1990; Underwood et al., 2000). Capitalizing on the history of interactions between familiar peers may allow researchers to tap into the effect of repeated exposure to same- and other-sex peers and examine its effect on science-related academic beliefs.

Limitations and Conclusions

Some limitations must be considered when interpreting the results of the present study. First, the majority of the participants were white, non-Hispanic youth. This may have had an effect on dyadic coordination, particularly for mixed-sex dyads. Hispanic and Black men often harbor more traditional gender role attitudes compared to their White counterparts (see studies cited in Kane, 2000). Although such differences have not been found in children, it is possible that exposure to such attitudes from male authority figures may strengthen the belief that girls are inferior to boys in science, and may have resulted in poorer coordination than what was found in mixed-sex dyads in the present study. Future research could examine the effect of ethnicity and gender on same- and mixed-sex dyadic coordination and its effects on adolescents' academic beliefs.

Second, because we only employed a post-interaction measure of academic beliefs, we could only infer an effect of coordination if there were resulting dyad-level differences girls' academic beliefs. However, measuring academic beliefs before and after the interaction would have allowed us to examine intra-individual change in academic beliefs that directly resulted from the interaction experience. Future work could assess both pre- and post-interaction academic beliefs and examine the effect of coordination on change in beliefs over time.

Although the hypotheses of the present study were not supported, this study represents one of the first investigations of social factors associated with girls' and women's under-representation in STEM, and the first to use dynamical methods to explore the nature of potentially influential social relationships. Our hope is that this study can serve as a platform for future work aimed at uncovering similar processes. For example, other dynamical research has examined social influence in dyadic interactions (Dale & Spivey, 2006). Given work showing that girls forfeit more resources to boys than to other girls (Powlishta & Maccoby, 1990), influence may serve as a stronger predictor of girls' academic beliefs than the coordination that was examined in the present study. Girls may feel that they have no control over boys, particularly in academic settings that highlight female inferiority, which may result in a loss of competence or interest in science and lead them to avoid future science courses. Social influences on academic beliefs remain an understudied area that may serve to highlight processes related to girls' and women's under-representation in STEM.

General Discussion

The goal of the present studies was to examine gendered social interactions from a dynamical perspective and determine the effect of dynamical interaction patterns on young adolescents' partner perceptions and science-related academic beliefs. Dynamical coordination proved important for interactants' partner perceptions, as greater coordination was related to more positive impressions of interaction partners and enjoyment of working with them. Coordination was not, however, related to academic beliefs, but limitations of the present work suggest that dynamical interactions patterns may still play an important role in adolescents' academic outcomes and that future research should be conducted to examine dynamical processes that have such an effect.

Together with prior work (DiDonato et al., 2012; Martin et al., 2005), the present research shows that dynamics can be applied to the study of gender and that doing so offers a different perspective on gender-related development and change. The focus of dynamics is on change over time, across both long and short time intervals. This focus alters the conceptualization and measurement of gendered phenomena. For example, when gender typicality is measured at the beginning and end of a school year, it appears relatively stable (Yunger, Carver, & Perry, 2004). But when measured multiple times a day throughout the school year, it becomes clear that gender typicality fluctuates greatly over time (DiDonato et al., 2012). Dynamically quantifying that variability may provide a fuller, more nuanced understanding of gendered phenomena. For example, consistent with previous research, DiDonato et al. (2012) found that an aggregate measure of gender typicality was positively related to psychological adjustment; however, when the same data were examined dynamically, overall gender typicality was no longer important. Instead, it was a child's ability to adaptively change their gendered behavior over time that predicted positive adjustment. Similarly, in the present research, we focused on the dynamics of young adolescents' speech patterns rather than an aggregate measure. Creating an aggregate score by collapsing across the interaction would have eliminated dynamical variability and the ability to examine how vocal patterns are coordinated both contemporaneously (coordination at the same point in time for both dyad members) and at different points in time (how speech patterns for one adolescent affect later speech patterns for the other) during the interaction. By rapidly measuring their vocalizations, we were able to examine fluctuations in their vocal patterns throughout an interaction and examine how the coordination of those vocal patterns was related to dyadic interactions.

That we found evidence of coordination in the length and patterning of their utterances, without regard to the content of their speech, suggests that information is carried not only in what words are communicated but how and when they are spoken. This has implications for future work aimed at studying dyadic coordination. For instance, it may not be necessary to rely on time-intensive methods of extracting interaction data (e.g., transcription). Rather, measurements of non-content speech variables can be collected rapidly and immediately with the methods described in the present research. Such methods also present the opportunity for real-time analyses, which may be valuable for instantly examining the effect of intervention efforts.

Including the present research, the application of dynamics to the study of gender has mainly focused on gender-typed play behaviors and peer interactions (DiDonato et al., 2012; Martin et al., 2005). However, its application is not limited to these areas. Research shows that cognitive processes such as decision-making and attitude change follow dynamical patterns (van der Maas, Kolstein, & van der Pligt, 2003; van Rooij, Bongers, & Haselager, 2002). Similar processes in gender research are only measured once, which precludes the ability to examine them dynamically. By taking a dynamical approach, similar models could be used to explore the dynamics of gendered cognitions and stereotyping, such as what types of toys are most desirable or what behaviors are appropriate for boys and girls. Observations of gender-typed behavior also show dynamical variability (DiDonato et al., 2012), and self-perceptions of gender typicality may exhibit a similar pattern.

It is our hope that the present research, in conjunction with other studies of the dynamics of gender, inspires other scientists to examine gendered phenomena from a dynamical perspective. By examining both aggregate levels of behavior and the dynamics of variability, we can gain a fuller understanding of gender and its development over time.

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Table 1

Descriptive Statistics for Study 1 Variables

Measure (absolute range; actual range)	Boy-Boy Dyads (n = 62)		Girl-Girl Dyads (n = 66)		Girl-Boy Dyads (n = 66)	
	M	*SD*	*M*	*SD*	*M*	*SD*
Coordination (%REC) (0 – 100%; .07 – 28.33%)	6.86	5.99	10.38	5.95	7.38	4.94
Partner Perceptions (1 – 7; 3.63 – 7)	6.09	.74	6.56	.54	5.77	.93

Note. %REC is a measure of coordination. A value of 10% indicates that the adolescents' vocal patterns were coordinated for 10% of the interaction.

Table 2

Descriptive Statistics for Study 2 Variables

Measure (absolute range; actual range)	Girls in Girl-Girl Dyads (*n* = 66)		Girls in Girl-Boy Dyads (*n* = 33)	
	M	*SD*	*M*	*SD*
Coordination (%REC) (0 – 100%; .24 – 28.33%)	10.38	5.90	7.38	4.94
Chemical Science Self-Competence (1 – 7; 2 – 7)	5.56	1.10	5.48	1.07
Chemical Science Values (1 – 7; 1.33 – 7)	5.48	1.41	5.53	1.47
Chemical Science Interest (1 – 7; 1.67 – 7)	5.40	1.46	5.35	1.51
Chemical Science Costs (1 – 7; 1 – 5.23)	2.26	1.07	2.18	1.00

Note. The means and standard deviations for physical science self-competence, values, interest, and costs were calculated across all girls in the girl-girl dyads and across only girls in the girl-boy dyads. %REC is a measure of coordination. A value of 10% indicates that the adolescents' vocal patterns were coordinated for 10% of the interaction.

Table 3

*Correlations among Study 2 Variables (*n *= 99)*

		1	2	3	4
1	Chemical Science Self-Competence	--			
2	Chemical Science Values	.52***	--		
3	Chemical Science Interest	.59***	.72***	--	
4	Chemical Science Costs	-.49***	-.34***	-.30***	--

$^{***}p < .01$.

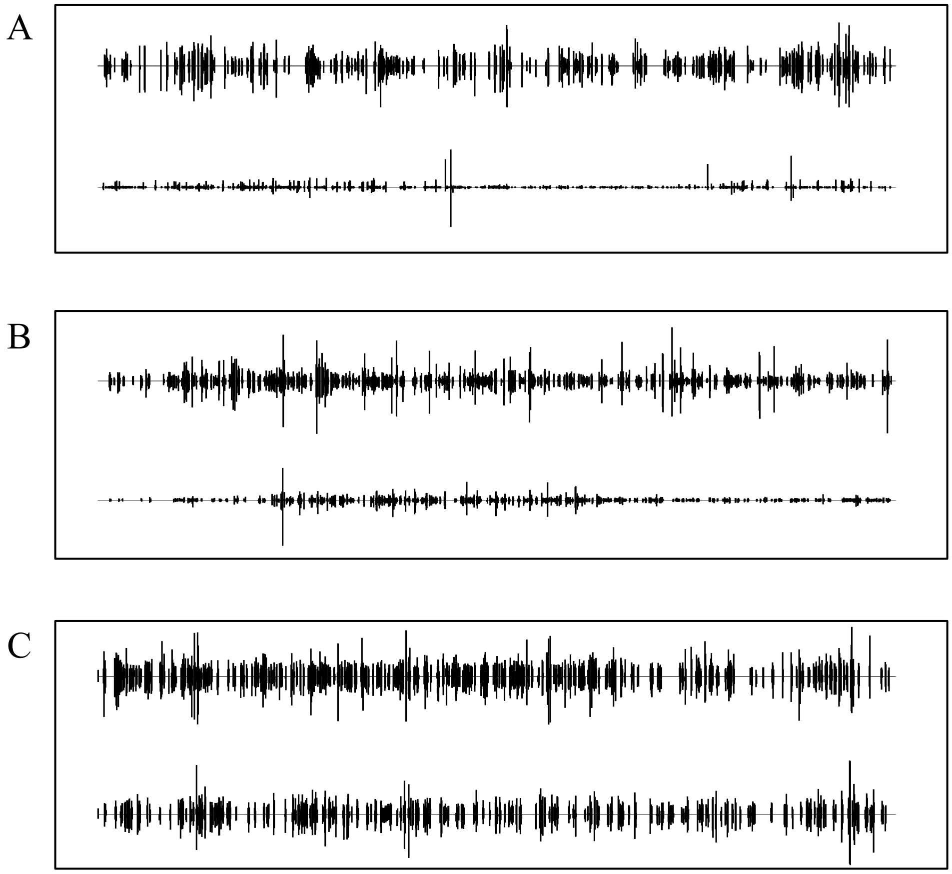

Figure 1. Examples of vocal data from interacting adolescents. Vocal data illustrate a boy-boy dyad (Panel A), a girl-girl dyad (Panel B), and a mixed-sex dyad (Panel C).

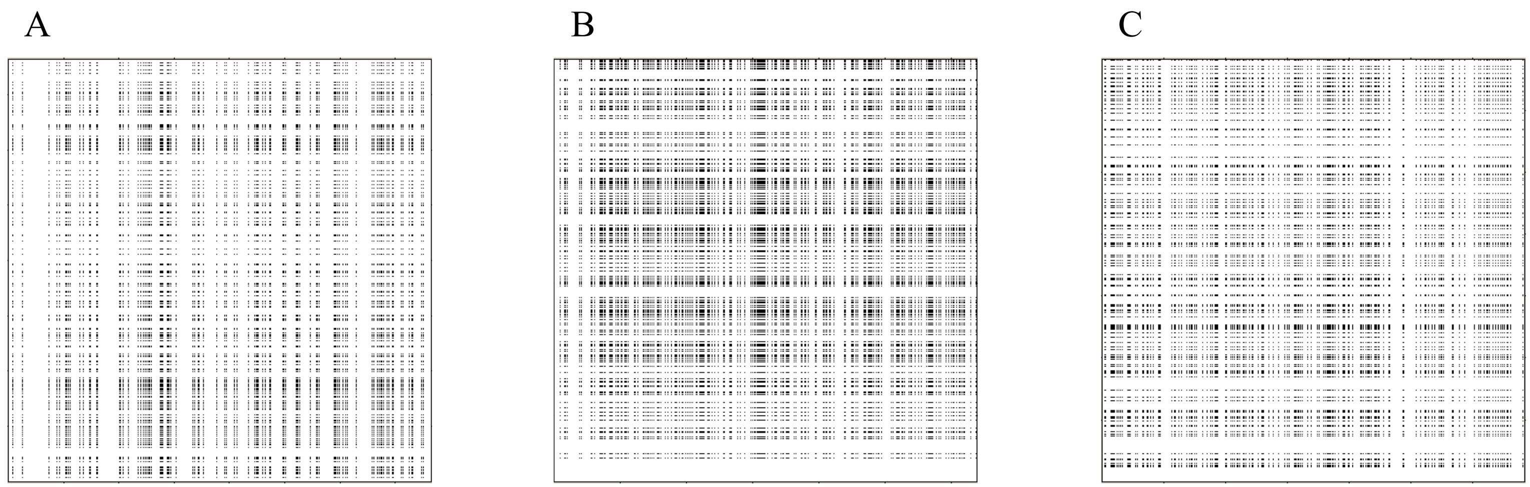

Figure 2. Example cross-recurrence plots. Cross-recurrence plots illustrate a boy-boy dyad (Panel A), a girl-girl dyad (Panel B), and a mixed-sex dyad (Panel C).

A

B

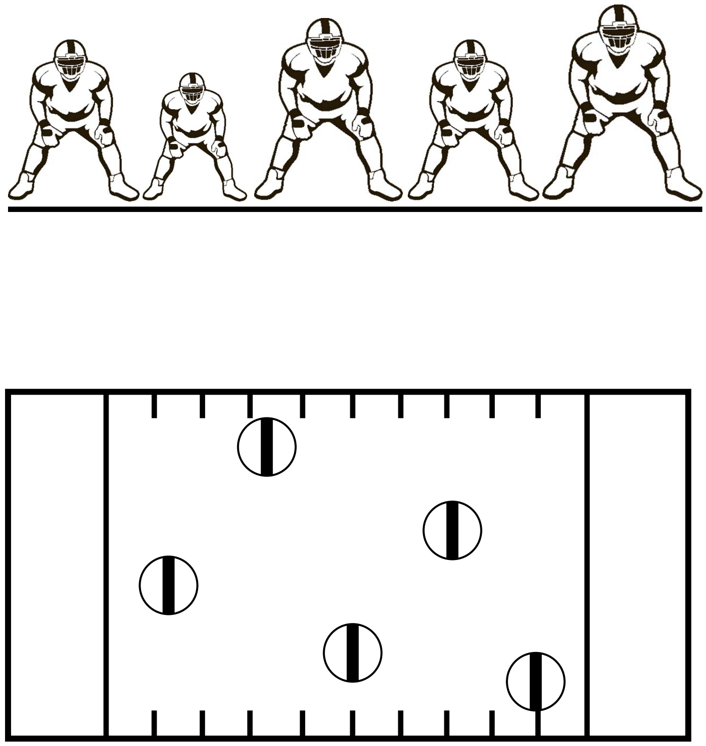

Figure 3. An illustration of one- (Panel A) and two- (Panel B) dimensional projection.

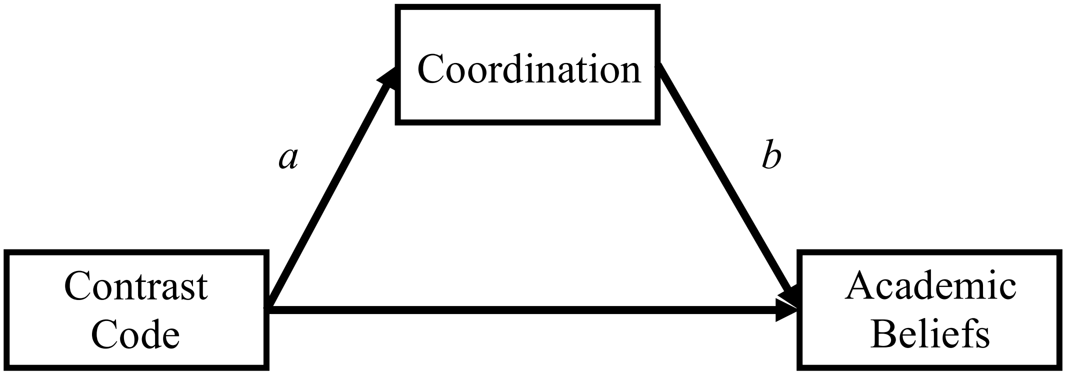

Figure 4. An illustration of the mediated multilevel model that was estimated to examine the mediating effect of coordination on differences between girls in same-sex dyads versus those in mixed-sex dyads in their academic beliefs. The mediating effect is calculated by multiplying the values for the *a* and *b* paths.