THE COURTSHIP DANCE: PATTERNS OF NONVERBAL SYNCHRONIZATION IN OPPOSITE-SEX ENCOUNTERS

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ABSTRACT: This study examines the existence of behavioral correlates of synchronization on different levels of analysis and methods. We were unable to demonstrate a relation between synchronization defined in terms of movement echo or position mirroring and subjective experience of pleasure and interest in opposite-sex encounters. Significant results were found for a phenomenon we describe as hierarchically patterned synchronization. These patterns were identified with the help of a newly developed search algorithm. If a female is interested in a male, highly complex patterns of behavior with a constant time structure emerge. The patterns are pair-specific and independent from behavioral content. This rhythmic structure of interactions is discussed in functional terms of human courtship.

Behavioral synchronization is a form of coordinative interaction which is thought to be present in almost all aspects of our social lives, helping us to negotiate our daily face-to-face interactions (Kendon, Harris, & Key, 1975). This "synchronic hypothesis" states that people do not interact randomly or independently, but coordinate and synchronize their behaviors with each other. The phenomenon of "synchronization" may be defined as the precise timing and coordination of movements to coincide the timing or rhythm with the movements of another (Bernieri & Rosenthal, 1991).

Two main categories of studies describe different types of behavioral coordination: movement synchrony and behavior matching or mirroring (Bernieri, 1988). In addition, there is a third and more complex type of potential synchronization; it has not been described yet and might be termed hierarchically patterned synchronization. The aim of this paper is to describe different types of synchronization on a real-time level in interactions between strangers of the opposite sex, because synchronization should theoretically play a major role in the development of relationships and early courtship (Barash, 1977).

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Movement synchrony can be expressed in sequential temporal aspects or timing of movements during an interaction. In the case of movement synchrony, the precise timing and coordination of movements between individuals may be of primary importance, while the nature or similarity of movements is irrelevant. The proximate function of this type of synchronization or interpersonal coordination is its apparent importance for establishing and maintaining rapport (Kendon, 1970). Movement synchronization also may reflect an active and involved type of positive rapport associated with feelings of high positive affect, motivation, interest, and talkativeness. The total experience of rapport is constituted by interpersonal coordination together with emotional positivity and attentional focus (Bernieri & Rosenthal, 1991). Dabbs (1969) showed that people perceive others as more similar to them when their behaviors are congruent, and people who show similar postures are judged to have higher rapport. Bernieri (1988) found that movement synchronization in teacher-student interactions was strongly correlated with rapport.

In contrast to movement synchrony, behavior matching emphasizes the similarity of behavior at a given moment in time. The measurement of posture similarity and mirroring has a fairly well accepted set of objective criteria (LaFrance, 1982). LaFrance systematically studied the relationship between posture mirroring and rapport in classrooms (LaFrance, 1979; LaFrance & Broadbent, 1976) and found a significant relationship between self-reported rapport and posture mirroring. Although movement synchrony and mirroring are correlated, both should be considered separately and may reflect different interaction processes (Bernieri, 1988). It may still be possible to describe both movement synchrony and mirroring as a function of time and/or similarity of behavior.

Synchronization may depend on two processes: the similarity of and the time between the behavior produced by A and B. Thus we should find a set interval between person A producing behavior x_A and person B producing behavior x_B. This set interval determines the perception of synchrony on a time basis. In addition a critical similarity between behavior x_A and behavior x_B seems to be necessary for the perception of synchronization on the basis of behavior categories. If both conditions are fulfilled the behavior stream is recognized as being synchronous. In the case of dissimilar behaviors, the intervening time span should be short, and for similar behavior this time span can be longer while still producing synchronization. Further, on the behavioral level, we can deal with static (postural) or dynamic (movements) simultaneity of events. On the basis of these considerations we have developed working definitions to study the phenomenon of synchronization:

(1) Posture mirroring: A assumes posture x and B assumes posture x' (where x' is a posture similar to x) immediately thereafter, or B assumes an identical posture within a critical time span.

(2) Movement echo: Person A performs movement x and person B performs movement x' (x' is a behavior similar to x) immediately thereafter, or B performs an identical behavior within a critical time span.

These definitions allow one to vary the similarity of behavior and the time span between occurrences in order to set critical time spans and critical similarities for the detection of synchronization. The definition and operationalization of interpersonal coordination is time dependent—at present it is unclear what the proper time criterion for synchrony should be. Additional problems arise. For instance, the longer the time span under consideration and the lower the similarity criterion, the more synchrony we will find. This is the main methodological problem when describing interpersonal coordination on an empirical level.

On the definitional level the problem of synchronizational events is solved, but the realm of empirical observations yields no consistent results. In contrast to posture mirroring, which can easily be operationalized (LaFrance, 1979; LaFrance & Ickes, 1981), the observation of movement echo proved to be difficult. McDowall (1978) filmed a group of six persons and studied synchrony in 18 body parts for each dyad, but only one of the 57 comparisons showed above-chance synchrony. It seems to be difficult to show the existence of synchrony on a real-time level with micro-codings of behavior. These researchers have scrutinized individual body parts until the precise point (frame of film) of a change in movement (that is initiation, termination, change in speed, or change in direction) can be identified. The movement boundaries then are analyzed for their co-occurrence with movement boundaries from other individuals. This procedure leads to the problem that many behaviors can create synchrony on a chance level. Cappella (1981) took issue with the notion that any change in any part of a person's physical motions occurring at the same instant as a change in any part of the interacting person's motions would be evidence of synchrony. With so many discrete events, there is a certain baseline of coordinated movements that would be expected by chance. A method to statistically control this baseline of chance occurrences is needed.

The problems in the development of empirical approaches are contrasted by the fact that humans are capable of perceiving synchronization on a very flexible time basis. Thus Bernieri, Reznick, and Rosenthal (1988) developed a method in which movement synchrony is measured through the Gestalt perception of raters. This approach assumes that people have the ability to directly perceive real stimulus properties in the environment.

They showed that raters rated simultaneous movement, tempo similarity, as well as coordination and smoothness in mother-infant interactions, with high concordance. Correlations with pseudosynchrony (that is, synchronization between randomly paired dyads) failed: this means that raters were not relying on the emotional or motivational state of the interactants, and that they perceived synchronization directly. Comparable results were found in interactions between high school students for ratings of dyadic coordination (Bernieri, 1988). This perception even holds when all individual information is removed by quantizing videos (that is, no facial affect visible and no sound is present) (Bernieri, Davis, Rosenthal, & Knee, 1994). Obviously, we can perceive synchrony on a Gestalt level but are unable to detect it reliably and empirically on a real-time basis. If this is so, synchronization might also be independent from behavior content, and perception actually could rely only on the time structures and rhythmic repetition of movements. Viewed from this perspective, synchronization does not reside in any particular behavior (Baron & Boudreau, 1987; Bernieri & Rosenthal, 1991; Newtson, 1994).

If synchrony truly exists beyond some baseline level attributable to chance movement, and if the level of synchrony is not merely projected onto the stimulus by the receiver, then there must be a physical correspondent in the real world of behavior. One possibility was suggested by Magnusson (1996), who showed that "invisible" patterning may be present in an ongoing behavior stream.

There is a different but related type of synchronization in the real-time structural model of continuous intra- and inter-individual streams of behavior proposed by Magnusson (1983, 1988, 1989, 1993, 1996). This model views behavioral organization as a repetition of intra- and inter-individual behavior patterns. These patterns are characterized by similar time intervals between their components, and patterns of this kind often occur in a cyclical fashion (Magnusson, 1989). In this view, behavior involves repeated performances of hierarchically composed temporal behavior patterns. The larger of these patterns are built up of smaller ones, much like phrases in language are patterns of words. Words, in turn, again are patterns of phonemes that again, are patterns of still simpler sounds and muscular movements and so forth. Certain of these patterns are both inter-individual and causal, such as when one individual causes another to do something he/she might not have done at all or would otherwise have done at a different time.

The pattern definition and the corresponding pattern detection method focuses on the relationships between the occurrence of behavioral event types in real time which constitute the data for the specially developed pattern detection software, called THEME. The search for patterns is done by comparing the times for repeated occurrences of behavior units assuming a chance expectation in which behavior is independent, random, and uniformly distributed over time. If patterns are found on the level of behaviors, these patterns constitute new behavior units which are again subject to pattern search and so on. Thus, complex interwoven patterns can be found with different length, time structure, and hierarchical composition. Some of these patterns may be mutually exclusive and others may overlap in various ways. In addition these patterns can be hidden in a continuous flowing behavior stream and most of them are visually not directly accessible. THEME accesses the rhythmic structure of behavior directly and independent from behavior content.[1]

Seen before the background of the problems of describing and observing interpersonal coordination on a empirical level, it is astonishing that synchronizational phenomena are reported to play a major role in human courtship. Givens (1978) anecdotally reports brief and short movements made in common by a courting pair, followed by rapid desynchronization. Based on observations made in singles bars, Perper (1985) reports a continuing synchronization which initially only involves arm and head movements but then progresses to more complex series of simultaneous shifts of weight and swaying movements that result when the hips, legs, and feet of the two people move in synchrony. According to Perper (1985), the synchronization proceeds until "full body" synchronization is reached.

In examining the ultimate biological constraints posed on human courtship, we find a peculiar situation for the use of signals and communication. Communication through nonverbal signals in courtship-like situations has been described by several authors. Scheflen (1965) described a complete repertoire of female nonverbal signs and Givens (1978) completed this task. Empirical observational data were collected by Moore (1985) and Grammer (1990). Both authors show that only indices of movements can predict female interest or male approaches to females. In contrast to movements there are effects for postures. Laughter can change its meaning from aversion to sexual enticement according to the postures present during the laughter event (Grammer, 1990).

The results quoted above indicate that communication in courtship is a slow process in which the sender slowly reveals his/her intentions and the receiver seems to sum up different combinations of courtship signals over time. Basically women apparently control male approaches and elicit male self-presentation (Grammer & Kruck, 1997; Moore, 1985). In contrast to females, males seem to make their decisions on the basis of interpersonal attraction. Female physical attractiveness is the strongest predictor for male behavior (Grammer, 1990). This fact can be explained again with the help of evolutionary theory, which predicts that females experience higher risk in mate selection than males (Trivers, 1972). Courtship is thus a potentially dangerous situation for females. Indeed, questionnaire studies show that males use deceptive strategies in their self-presentation in such situations much more often than females (Tooke & Camire, 1991). If intentions are revealed too early, then the possibility of deception might rise (Dawkins & Krebs, 1981). Thus the possibility of deception forces communication to a level where intentions are veiled and ambiguous. This will be even more true at the onset of a male-female interaction which subsequently develops into courtship. The level of communication itself could be nonverbal, because nonverbal behavior provides a nonbinding standard (Mehrabian, 1972). Indeed, the present research suggests that females are more skilled in producing nonverbal signals and communication (DePaulo, 1992) and are able to read nonverbal signs better than males.

In interactions between strangers we can assume that courtship occurs in all situations where a suitable mate of the other sex is spotted and interest in the partner is communicated. If interpersonal coordination signals mutual rapport, involvement, and togetherness, then interpersonal coordination should be the hallmark of courtship. In the course of the necessary communication of interest, one or both partners should then try to achieve synchronization in order to test out and/or communicate possible compatibility (Grammer, 1989). Synchronization then would be as a sign of mutual understanding in interactions (that is, the higher the degree of synchronization, independent from the type of synchronization, the higher the degree of mutual understanding). The amount of synchronization achieved in an interaction would thus be the indicator of compatibility between the interactants. In addition, if there is pressure to hide intentions yet still communicate, synchronization should occur on a level where it is not obvious but still perceivable. That it is perceivable but not directly accessible has been demonstrated in various studies of Bernieri (see Bernieri et al., 1994). The non-conscious perception of synchronization can be achieved even when synchronization is independent from behavior content and when it relies solely on rhythmic patterning. Seen against this background, it seems promising to look for rhythmic patterning itself and the communication of intersexual interest.

These considerations on intention showing and possible deception allow two hypotheses on the functions of synchronization in opposite-sex interactions: The first hypothetical function is that synchronization is a communicative signal on the level of signal perception. In an interaction, one or both interactants could use the unconscious Gestalt perception of synchronization in order to deduce the degree of compatibility with the partner. The second hypothesis is that synchronization is a manipulative signal on the level of signal production; for example, one or both of the interactants could try to synchronize with the other in order to demonstrate compatibility without delivering positive feedback cues too early and too obviously. LaFrance and Broadbent (1976) have shown that the more often students mirrored their teacher, the higher was the student's rating of mutual rapport; on the other hand, LaFrance and Ickes (1981) found a reversal of these findings in interactions among strangers and concluded that posture similarity in and of itself does not constitute rapport but instead reflects the attempt to reach a state of rapport. Another positive manipulative function was proposed by Baron and Boudreau (1987). They assume that one person might be the "zeitgeber" (time-giver) for the other person (that is, the external stimulus the person synchronizes with). Then one can speculate that dominance is defined in terms of the discrepancy between the proportion of time Person A serves as the time-giver for an interaction relative to the time Person B serves as the time-giver. If A is the time-giver for B, then A would dominate B. Yet the situation is not this simple, because B could also manipulate A by letting A be the time-giver and thus manipulating A's perception of the situation by using submissive modes. These considerations lead to the question of causality. There are two possibilities, either interest leads to synchronization or synchronization might cause interest itself. The first possibiltity is a manipulative one; in the second case interest could arise if the "zeitgeber" is compatible to the body-rhythms of the second person.

It becomes clear that interpersonal coordination can create ambiguity and show interest at the same time. This makes synchronization the ideal "tool" in interactions where the achievement of compatibility is the main issue (Grammer, 1989). In addition, when a female meets an unfamiliar male:

(1) The higher the interest in each other, the more synchronized both interactants should be.

(2) The more synchronized both interactants are, the higher should be the pleasure they report from the interaction.

(3) Synchronization should be present in rhythmic patterning and not in obvious and directly observable synchrony.

Method

We analyzed 48 ten-minute interactions between strangers of the opposite sex. The material used here is the same as published by Grammer (1990). In this study the subjects were selected randomly from groups of high school students visiting the institute. At each visiting day two groups from different high schools were present. The students of the two schools did not know each other. The randomly selected subjects, one from each school, were asked if they would like to participate in a simple rating experiment. The actual number of interactions might differ from analysis to analysis because of missing data. After introducing the experiment, the experimenter left the couple alone in order to reply to an "urgent phone call." The interaction then was videotaped through a one-way screen (see Grammer, 1990). After the experiment the subjects were debriefed. For comparison reasons, 12 encounters between strangers of the same sex (6 female-female; 6 male-male) were used. The mean age of the participants was 18.5 years.

At the end of the encounter both participants had to fill out a questionnaire, which assessed interest in the partner through ratings of: (1) I would give my telephone number to the person present if I was asked for it, and (2) I would go out to the cinema with the person if I was asked to. The rating scales reached from 1 (very unlikely) to 7 (yes, I will). From these two rating scales, interest scores were calculated as the sum of both ratings. In addition the subjects were asked how pleasurable the situation was for them (1 being disgusting to 7 being highly pleasurable).

A catalogue with 83 body movements and signals was developed to code behavior (see Appendix). The categories were then coded frame by frame with "MacMax," an interactive video coding program, which automatically records the frame number of begin and end of each manually determined behavior unit. This program is available from the authors.[2] The onset and offset of each movement were specified and recorded. A behavior unit or event thus consists of a behavior category with defined beginning and end. The coding was done separately for each behavioral category and subject, that is, first all occurrences of behavior A were recorded, then all of behavior B and so on. This procedure yields a highly reliable scoring. Five interactions were recoded by a second observer. Reliability was calculated according to McGrew (1972) as an index of concordance, i.e., the proportion of occurrences about which both observers agreed. This resulted in a reliability of 84% for the behavior codes. Reliability for begin and end was at a mean of $+-2.8$ videoframes ($SD = .67$). In addition the scores were checked for mutual exclusiveness, as for instance a "Head tilt right" and a "Head tilt left" cannot occur together.

Postures were defined by the endpoints of movements—when a movement occurred, then at its end a new posture was assumed. For instance the movement "Leaning back" would create a posture of "Leaned back" at the end of the movement. Thus the endpoints of movements are postures. For this analysis only the movements creating new postures were used. Movements that ended in the same position from which they started were omitted.

The behavior events were then analyzed with THEME. The program requires time-series of events with a defined beginning and end in order to be able to detect patterns. For a more complete description of the mathematical foundations see Magnusson (1996). Figure 1 illustrates the basic procedure. On the x-axis a real-time sequence of behaviors (c...c) is presented. In the first step, THEME isolates all temporal differences between behavior units which occur more often than expected at chance level. These temporal differences are termed the critical time interval. This critical interval is defined in the following way: Assuming that the time series are independently and uniformly distributed with the observed density, there is a critical time interval relationship that two behavior units will occur in a determined time relationship more often than expected by chance. The critical time interval thus depends on the number of behaviors provided by the two interactants, the number of critical intervals itself, and the length of the time intervals between two behaviors. The exact probability for each critical interval can then be calculated using binomial distributions. Note that this procedure makes pattern detection independent from the number of behavior units under consideration. The problem that synchronization might depend on the number of performed behaviors was addressed by Rosenfeld (1981) and Cappella (1981): one is highly likely to find more synchronous events the more behaviors are performed. The behavior units occurring within a critical time interval are then paired and become terminal nodes for further analysis. In the example of Figure 1, THEME has isolated five occurrences of pattern (d e) and pattern (a b). These new nodes are subsequently treated as single units de and ab. In the second step, THEME reanalyzes the behavior units on Level 2, but this time the subject of the analysis is all behaviors that did not enter as terminal nodes in the first run, together with the already detected terminal nodes. This procedure is repeated until no new patterns are found. As THEME analyzes the time structure, the content of the behavior units is irrelevant. The two patterns found (a b) and (d e) are patterns on the first level of the analysis. These two patterns together then form a pattern at Level 2. At this level we find four times the pattern ((a b) c). At Level 3 three occurrences of (d e) are added to the patterns found on Level 2. This yields three patterns of the form (((a b) c) (d e)) and two remaining patterns from Level 1 (of the form (d e). The pattern (((a b) c) (d e)) consists of five units with 3 hierarchical levels. In the course of real-time interaction, time-constant patterns will be invisibly hidden in the sequence from c...c in Figure 1. Note

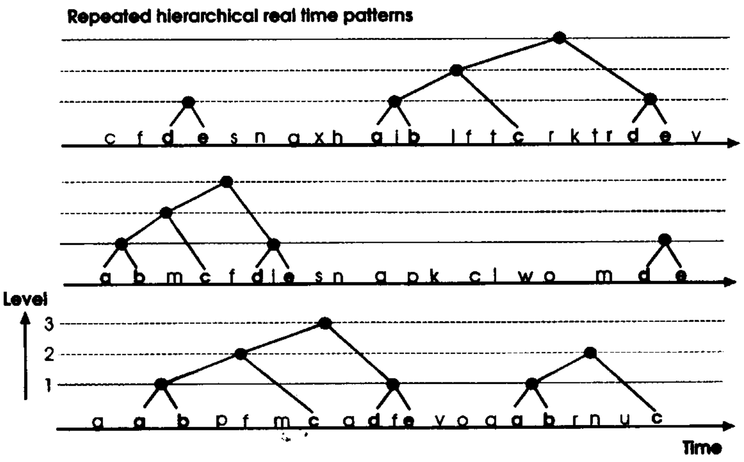

Figure 1. Fictive behavioral sequence starting with behavior c in the upper left and ending with behavior c in the lower right. In a first run, THEME determines all intervals between the behaviors and calculates the critical interval. An interval between two behaviors is critical if it occurs more often than expected by chance. These two behaviors form a pattern (d e) and (a b) on level 1. These new "knots" (marked as black dots) form new primitives for the next run on level 2. A new critical interval detection shows that, on level 2, behavior c joins into the (d e) pattern: ((ab)d). This pattern forms a new knot on level two, and the whole procedure moves to level 3, where in two cases an occurrence of (d e) from level 1 is added to the pattern found on level 2. For details see text.

that THEME detects patterns that are independent from the behavior content, time-constant, and may consist of patterns within patterns. Even a single behavior can become a member of different patterns. Highly complex patterns can emerge which consist of many different behavior units. THEME thus does not describe synchronization per se, but rather describes the constancy of time-structures in an interaction.

Results

Interest Scores

We defined courtship as the communication of interest in an opposite-sex partner. The analysis of the interest scores indicates whether courtship occurred. Both sexes showed interest in their partners with a variation that reaches from no interest to high interest. Interest in the partner showed an interesting gender asymmetry. Male interest in females was significantly higher (n = 48, *Mdn* = 8.5 of 14 maximum) than female interest in males

(*Mdn* = 6.5, Wilcoxon-test, p = .002, two-tailed). This shows that males are globally more interested in females than vice versa and it also suggests that females are more interesting for males than males are for females. The pleasure ratings did not show sex differences but pleasure is not completely independent from interest. The higher the interest of females, the higher perceived pleasure (Spearman rank-order correlation, *rho* = .37, p = .025, two-tailed). The same is the case for males (Spearman rank-order correlation, *rho* = .46, p = .005, two-tailed). Interestingly we find no significant cross-sex correlations for both interest and pleasure.

Movement Frequencies

A total number of 9050 actions were analyzed. Mean movement frequency was 150 movements per episode. Movement frequencies were initially examined because only a person who moves can synchronize with the movements of another person. Females (movements/minute M = 6.52, SD = 4.27) did not move more often than males (M = 6.19, SD = 3.68, Kruskal-Wallis one-way analysis of variance (ANOVA), n = 97, χ^2 = 2.82 p = .93, two-tailed). Both males and females moved more often in the same-sex dyads (Median test, $\chi^2 = p < .001$, male movements/minute M = 16.9, SD = 5.9; female movements/minute M = 8.3, SD = 1.5) compared to males and females in the opposite-sex dyads. The significant difference between same-sex and opposite-sex dyads indicates that the number of movements is be suppressed for females and males when they are together with a stranger of the opposite sex.

The episodes then were divided in two halves in order to analyze a possible time-dependent development of movements and to test for stationarity. None of the groups showed significant differences between the movements in the first half and the second half. The frequencies can thus be pooled over the episodes.

Correlations between interest and frequency showed only that the higher the female interest, the more often she moved in the whole ten-minute episode (Spearman rank-order correlation, *rho* = .36, p = .014, two-tailed; male *rho* = .04, n.s.). This result will be corrected by THEME because THEME controls for the number of occurrences of behavior and calculates the probabilities for the critical time interval accordingly.

Movement Echo and Posture Mirroring

These types of synchronization were found in only 30 of 48 dyads, and occurred only 86 times. None of the possible combinations (opposite-sex and same-sex dyads) analyzed yielded significant differences. The me-

TABLE 1

Median and Ranges of Movement Echo and Posture Mirroring in a 10-Minute Episode

Behavior	Similar-within three units		Identical-following immediately	
	Median	Range	Median	Range
Movement echo:				
Female with female	3.5	10	0.0	6
Male with male	4.0	12	0.0	5
Female with male	3.0	11	0.0	7
Male with female	3,0	11	0.5	4
Posture mirroring:				
Female with female	4.0	12	0.0	3
Male with male	3.5	10	0.0	4
Female with male	3.0	11	0.0	6
Male with female	3.0	11	0.0	4

dians of occurrences are shown in Table 1 for the two possible extreme cases of movement echo and posture mirroring. Firstly, there are those cases in which similar but not identical behavior follows within three successive behavior units. These are very weak versions of movement echo and posture mirroring. In this case movement echo is present when a movement in the same body part occurs at least within the next three following coded behaviors. For posture mirroring the assumed endpoint also has to occur at least within the next three postures and similarity is determined by body parts, that is, "identical" means that the identical category occurred, "similar" means that the same body part was moved. Secondly, those cases were identified in which two identical movements followed each other directly or, in the case of posture mirroring, the identical posture is assumed immediately thereafter. The data show that the frequencies were very low, in a range of 12 to 0 instances of synchronization. At a mean movement frequency of 150 movements a fully synchronized pair could create 150 instances of synchrony.

The correlation analysis between movment echo, interest and pleasure was carried out sex-specifically: female imitates male and vice versa in order to test for the initiation of synchronous events. With the exception of one significant correlation between male interest and the male imitating the female (Spearman rank-order correlation, *rho* = .28, $p < .25$, two-tailed), no positive or negative results were found. We find comparable results if we correlate the overall number of synchronous events with interest and pleasure. For this analysis the correlation coefficients ranged between *rho* = −.17 and *rho* = .26 and were all non-significant.

Posture mirroring was found in 30 of 48 dyads, with an *n* of 101. Table 1 provides the respective medians and ranges. As in the case of movement echo, this type occurs very rarely even if the conditions for synchronization are widened. For further analysis the actual number of synchronous events was correlated with interest and pleasure. Here, we were also unable to find significant results. The same holds for the total number of synchronous events produced by the pairs. For this analysis the correlation coefficients ranged between *rho* = −.19 and *rho* = .24 and were all non-significant.

The inability to prove the existence of either movement echo or position mirroring on a real-time basis could be due to the following. First, the number of movements itself could create echo or mirroring by chance. This means that a high number of movements might create synchronous events by chance alone. We therefore corrected the two types of synchronization by the number of occurring movements (number of synchronous events divided by the number of movements); no positive results were found. Second, the type of synchronization does not matter in the perception of synchronization. We therefore added the number of times movement echoes occurred and the number of times position mirroring occurred: again, there were no positive results.

Hierarchically Repeated Patterns

We found *n* = 2220 patterns in the opposite-sex condition and *n* = 1908 in the same-sex condition. The variance in number of patterns per pair was large: it ranged from 0 to 325 patterns per pair in the opposite-sex condition (*Mdn* = 142) and from 0 to 884 in the same-sex condition (*Mdn* = 159). Pattern production seems to be a highly variant process which depends on the absolute number of movements produced. The same-sex pairs, who moved more, produced significantly more patterns than the opposite-sex group (Kruskal-Wallis one-way analysis of variance (ANOVA), *n* = 58, $\chi^2 = 4.32$, $p = .03$).

Pattern Content

Figure 2 describes a typical pattern. This pattern is restricted to this dyad only—another dyad never showed the same pattern. The content of the patterns themselves were highly idiosyncratic. Only two patterns out of

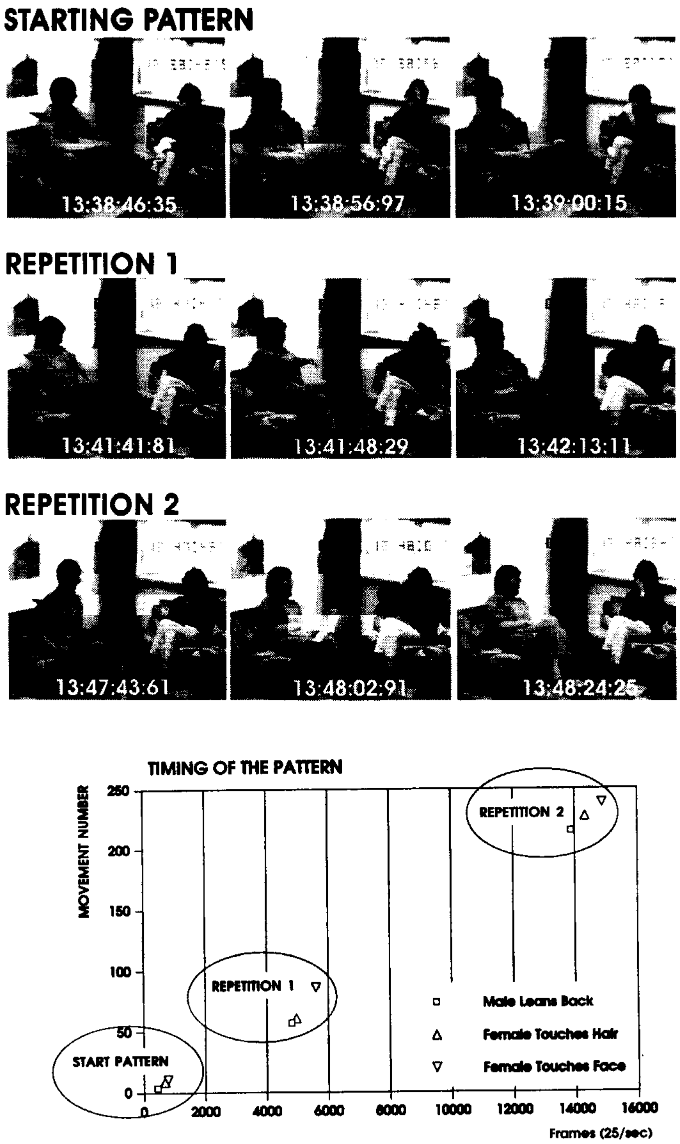

Figure 2. Each series of three pictures in one line shows a pattern which was isolated by THEME. The pattern consist of three elements which are repeated three times. All three patterns are identical: the male leans back, the female touches her hair, and then her face. The temporal sequence organization is identical for all three patterns as shown in the graph below. The x-axis shows the time of occurrence in a

TABLE 2

Behavior Frequencies in Patterns and Total Frequency of Behavior Occurrence

	Mean frequency of body parts							
	Females with males		Males with females		Males with males		Females with females	
Behavior	Pattern	F	Pattern	F	Pattern	F	Pattern	F
Head	.02*	.76*	.02*	.79*	.04*	.82*	.00*	.80*
Shoulders	.11	.03	.05	.01	.01	.00	.02	.01
Arms/hands	.76*	.17*	.75*	.13*	.73*	.13*	.61*	.12*
Trunk	.10	.02	.12	.02	.18	.03	.28*	.04*
Legs	.01	.02	.06	.04	.04	.02	.10	.04

Note: Pattern = mean frequency of behavior units which went into patterns.
F = mean frequency of behavior units occurring in this body part.
* = Wilcoxon Matched-Pairs Signed-Ranks Test significant at $p < .01$ between frequencies of a behavior in patterns (Pattern) detected by THEME and frequency of occurence (F).

4128 patterns detected in one pair also occurred in another pair. One pattern occurred in the opposite-sex interactions and consisted of the female performing a baton and the male pulling his shoulders up. The second pattern occurred in the same-sex dyads, where one male leant back, the second male leant forward, the first male then performing an arms opening movement, shoulders back followed by another event of arms open. This example shows that the patterns can become highly complex and that they

Figure 2 *(Continued)*
10-minute experiment, the y-axis the number of the movement. The starting pattern occurred as movement number 4, 9 and 11. Note that there are 4 movements between the first element (Male Leans Back) and the second element (Female Touches Hair), and one movement between the second and the last element (Female Touches Face) in the starting pattern. In the first repetition there are 3 movements between the first and the second, and 25 movements between the second and the third movement. The members of the second repetition are separated by 11 and 10 other movements. The second pattern starts at a 174.6 sec interval from the first pattern and the third patterns starts in a 362.6 sec interval from the second. Internal time structure is coherent: 9.4 → 4.1 sec difference in the first pattern (second pattern 6.0 →31.6, third pattern 18.2 → 21.8). The original video is posted on the World-Wide-Web: http://evolution.humb.univie.ac.at/multimedia/dance.html.

can be labeled as highly idiosyncratic. This fact also makes an analysis of the patterns on the level of single behavior units unnecessary. We thus examined whether specific body parts went into the patterns.

In all groups the highest frequencies of movements occurred with the head, followed by the arms. As Table 2 shows, there is a significant reversal of this order when we look at the behaviors which went into patterns in both groups. When we test the number of behaviors that went into patterns against the overall number of behaviors that occurred, we find that head movements occurred significantly less often in patterns than arm and hand movements which occurred significantly more often in patterns. In addition, in most cases the rest of the categories were found more often in patterns than expected. The hierarchical pattern synchronization thus affects the whole body with the exception of the head. A correlation analysis of the frequencies with interest and pleasure showed no significant results. What we identified with THEME is thus a time structure of interaction and its rhythmic patterning, independent from behavior content.

Pattern Initiation

Pattern initiation was tested in two ways: firstly, we determined the number of patterns started by each sex and secondly, a first-order Markov analysis was applied to the whole patterns (Drake, 1967).

Each sex started a median of 4 patterns per episode, and thus no sex differences were found. When we calculated the relative number of patterns, that is, the difference of male starts minus the number of instances when the female started, we found a median of zero. This means that males and females equally often started the patterns. In regard to interest and pleasure, only male interest and the number of female starts were correlated ($n = 36$, $r_s = .37$, $p = .025$). Pattern initiation thus seems to play a negligible role on this level.

For the Markov analysis we followed the procedures suggested by Fagen and Young (1978). The four transitions we identified in a 2 × 2 transition table were male act → male act, male act → female act, female act → female act, and female act → male act. For this analysis we selected only dyads in which the number of acts was sufficiently large. Baylis (1975) suggests applying statistical analysis only to dyads which produce more behavior events than 10 * number of all behavior categories (in our case, male and female acts). Accordingly, those dyads which produced more than 40 acts were selected. Another condition for the use of Markov analysis is the stationarity of the data (Slater, 1973). This means that the probabilistic structure of the events remains constant through time This seems to be the case in the present data because we found no significant difference in the occurrences of behaviors in the first and second half of the experiment. After counting the number of transitions in the patterns, we tested for a significant dependence of current acts from past acts by using the procedure developed by Bishop, Fienberg, and Holland (1975). The procedure is as follows: x_{ij} = the observed frequency of transition in a cell and m_{ij} is the expected frequency (calculated like in an ordinary χ^2 test), then Y = $(x_{ij} - m_{ij})/m_{ij}$**0.5. If $|Y| > ((\chi^2_{0.05}, \text{d.f.})2^2)$**0.5, then the transition of act i → act j is occurring at a frequency that differs significantly ($p < .05$) from chance expectation. If this is the case and $Y > 0$ then act i may be said to direct act j, while if $Y < 0$, then act i may be said to inhibit act j.

For $n = 11$ dyads a significant determination of transitions could be found. This consisted of female→female transitions with a median of 12 (Median of Y = −1.08), female→male transitions with a median of 36 (Median of Y = 0.83), male → female transitions with a median of 26 (Median of Y = 1.20), and male→male transitions with a median of 10 (Median of Y = −1.06, Friedman two-way ANOVA, $n = 11$, $\chi^2 = 11.40$, $p = .007$). Thus the most frequent number of transitions is female → male, in which at the median, female acts promote male acts. In addition we also find a positive mean of Y in male → female transitions. Thus female behavior seems to promote male behavior, while male behavior promotes female behavior less often but to a higher degree.

In regard to interest, we find only correlations between the number of male→female transitions and female interest ($n = 11$, $r_s = .55$, $p = .07$), whereas the same type of transitions correlate negatively with male interest ($n = 11$, $r_s = -.49$, $p = .12$).

Pattern Length

The length of the patterns (that is, the number of behavioral units forming a pattern) in the opposite-sex and the same-sex dyads did not differ significantly (opposite-sex dyads $M = 4.05$, $SD = 1.30$, same-sex dyads $M = 4.13$, $SD = 1.04$). In the opposite-sex dyads, pattern length correlated with female interest ($r_s = .42$): the more the female is interested in the male, the longer the patterns are (see Table 3). Although this correlation exists, pattern length alone does not appear to be a critical parameter for the distinction between the opposite-sex and same-sex dyads. We must therefore examine the internal hierarchical organization of the patterns.

Repetition and Variability of Patterns

The stereotype nature of patterns can be described in two ways: (1) the number of different patterns a dyad produces, and (2) how often the same pattern is repeated compared with all other patterns. The production of different patterns was different for opposite-sex and same-sex dyads. The opposite-sex dyads produced a median of 44 different patterns, whereas the same-sex dyads produced a median of 50 different patterns. Again these differences were highly variant. The same-sex dyads produced significantly more different patterns than the opposite-sex dyads (Kruskal-Wallis one-way ANOVA, $\chi^2 = 4.30$, $n = 58$, $p = .037$). In addition, pattern repetition or overall variation (sum of all different patterns divided by the sum of all patterns) was analyzed. The opposite-sex dyads showed a quotient of .25 ($SD = .12$), the same-sex dyads .28 ($SD = .09$) for variation. This difference was not significant. Comparing both variables with interest and pleasure showed that for females, the higher the female interest and/or pleasure, the more often the same patterns were repeated: the patterns became more stereotyped (see Table 3).

Pattern Organization

In computing the patterns we restricted the possible search levels to a maximum of five, and we did not find a significant difference in the levels reached by opposite-sex ($M = 1.92$, $SD = 1.2$) and same-sex ($M = 2.4$, $SD = 1.0$) dyads. We did, however, find a positive correlation between mean pattern level and female interest. The higher the female's interest, the higher the mean hierarchical level of the patterns. In an opposite-sex pair the pattern organization thus became more complex when the female was interested in the male.

TABLE 3

Correlation of Cyclic-Redundant Pattern Characteristics with Interest and Pleasure in Mixed-Sex Dyads

Pattern characteristics	Female interest	Female pleasure	Male interest	Male pleasure
Number of patterns	0.27	0.25	−0.10	0.10
Pattern length	0.42**	0.39**	−0.03	0.20
Variability	0.28	0.25	−0.11	0.10
Pattern repetition	0.28	0.33*	−0.20	−0.04
Mean level of organization	0.32*	0.28	−0.11	0.08

*Spearman-Rank, $p < .05$; ** $p < .01$ two-tailed

Validation of THEME Findings

Although these findings (the differences in pattern form and correlation between interest and patterns) suggest that THEME detected "meaningful" patterns, it is still possible that the patterns were an artifact generated by the fact that the number of movements simply increased with interest and thus the possibility of finding patterns in dyads is related to the amount of movement. The results therefore have to be validated, that is, we have to show that THEME is robust against such effects.

Testing here could theoretically be done with random data in which the number of behavior units is increased steadily. Unfortunately, behavioral data are difficult to randomize. The better approach is to create random pairs out of the original data, a method termed pseudosynchronization by Bernieri and Rosenthal (1991). Accordingly, we randomly selected 10 pairs (same- and opposite-sex) and recombined them at random. The number of behaviors produced by the interactants varied between 24 and 358, with a mean of 153.7 (SD = 90.1). THEME should identify no (or very few corresponding to pure chance expectancy) patterns between "interactants" who never interacted in reality. With the exception of the random pair 8, this is actually the case. Nine random pairs did not show a single pattern. Overall, the interactants in the real data produced 24 different patterns which occurred 92 times, whereas the random interactions produced only 4 different patterns which occurred 12 times. Patterns were only produced by random pair number eight. As would be expected based on the zero hypothesis, THEME is sufficiently robust.

Discussion

Our results did not show that imitation and behavior echo are related to interpersonal processes such as interest in another person; furthermore, both phenomena cannot be found in everyday behavior on a real-time basis. This could be due to different factors: (1) human time processing in perception is more flexible than a rigid mathematical limitation of time-intervals, and (2) echo and imitation occur rarely and thus cannot be processed by the use of normal statistical methods. Neither of these possibilities can be ruled out.

Instead, we found that synchronization exists on a completely different level, with highly complex time structure, where inter-individual timing rapport between movements can be extended over considerable time spans. This method is complementary to other methods used to describe synchrony. Its drawbacks are basically the enormous coding effort.

hypothesis that hierarchical pattern synchronization has a communicative, or even more so, a manipulative value—the female synchronizes with the male and thereby communicates interest.

We were unable to prove or disprove the assumption of Baron and Boudreau (1987) that one person might act as a "zeitgeber" for the second person and thus dominate him or her. Males and females start patterns equally often. Nonetheless male interest is higher the more often the female acts as a time-giver for him. In Baron and Beaudreau's terms this would mean that males develop interest when females dominate them; in our terms, when males are interested in females they let them dominate in order to manipulate them. This result has to be clarified with further experiments. The internal sequencing of patterns shows that female → male transitions are the most prominent ones. But only male→female transitions are correlated with female interest. Several potential hypotheses could explain this result. Females could use the male's rhythmic movements to create the patterns and/or let themselves be dominated by males. This could be in conflict with the same tendency in the males, thus producing such contradictory results.

These findings converge to suggest either that men typically don't realize that they are even involved in a courtship dance, or that they are typically very poor dancers.

Although speculative, it seems more interesting to examine those time structures in behavior which are independent from the content of behavior itself. Although we did not find significant results for imitation and echo, there still could be a relationship between interest and these types of synchronization.

Thus, we cannot reject the hypothesis that synchronization plays a prominent role in courtship, but it is doubtful that imitation and echo are the main processes. We hypothesized that attempts to synchronize are initiated by the females so that she can test the compatibility with the male. This hypothesis cannot be rejected because we demonstrated that such patterns are highly idiosyncratic within particular dyads and that these patterns are not artifactual (that is, they are rare in randomly paired dyads). Furthermore the patterns are more prominent in opposite-sex than same-sex dyads, except when the female of a an opposite-sex dyad reports higher interest in the male. In addition we demonstrated that the number and complexity of patterns is related to female interest in the male and the pleasure the female experienced in this situation, but not vice versa. This supports the interpretation of a testing phase which takes place very early in an encounter. We also found a relation to the pleasure felt in such a situation—although the causalities remain unclear. It could well be that this context is laughing together, where the female joins the male in laughing, which also can be seen as a synchronization effect.

This result sheds a different light on behavior in potential courtship situations. Besides a typical courtship repertoire (Moore, 1985) there seems to be an overall suppression of showing any nonverbal signs. This might be caused by social anxiety or because showing signs might be interpreted as interest in the partner. As soon as signaling reappears, it is a sign of interest; on this basis, patterned synchronization can then occur. It could well be a female tool for testing out compatibility because she does so only when she is interested in the male.

Nevertheless, there are two serious drawbacks to the present study. The first is the direction of causality between interest and behavior. We do not know whether our subjects behave in a specific way because of their interest in the other person, or interest develops because of the occurrence of behavior and success. Second, interpersonal nonverbal coordination can greatly depend on speech production because the former can occur in order to facilitate the latter (Wylie, 1985), and body movements are intimately linked to the rhythm of speech. Normally we invoke our entire body when communicating with others (Condon, 1970) and our body tends to coordinate also with the verbal utterances of anyone we happen to listen to. Even when the verbal coordination deteriorates, the degree of interpersonal coordination continues unabated (Rutter & Stephenson, 1977). Seen in this light we simply might have measured the amount of conversation and conversation alone could be related to interest. This possibility is a problem for any type of research in interpersonal coordination, because we do not know whether it is the smooth flow of conversation or its nonverbal part which possesses signal function. With newly developed methods for direct analysis of behavior and speech (Grammer, Fieder, & Filova, 1996), we will be able to address this question.

Notes

1. A description of the possibilites implemented in the current version of THEME can be found on the World-Wide-Web: http://www.rhi.hi.is/~msm/behavior.html.
2. For more information see: http://evolution.humb.univie.ac.at/research.html.

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Appendix: Behavior Catalogue

Body part	Behavior	Description
Head	head forward	Moore (1985)
	head back	
	tilt head	
	straighten head up	Moore (1985),
	shake head	Grammer (1990)
	nod	
	head toss	
	cast down	Givens (1978)
	look at partner	
	look away from partner	
	look around	
Shoulders	shoulders normal	Givens (1978)
	l/r shoulder up	
	shoulders forward	Givens (1978)
	shoulders back	Grammer (1990)
Arms/Hands	l/r arm parallel	Grammer (1990)
	l/r arm open	
	l/r arm open and hands fold	Givens (1978)
	cross l/r arms	
	stretch out l/r arm	
	l/r arm stretched out vertical to body	Goffman (1976)
	l/r upper arm stretched out, forearm points at body	
	head akimbo with l/r arm	
	hide l/r hand	Ekman and Friesen (1969)
	illustrator l/r	
	baton with l/r hand	Ekman and Friesen (1969)
	pictograph with l/r hand	Ekman and Friesen (1969)
	deictograph with l/r hand	Ekman and Friesen (1969)
	object adapting with l/r hand	Ekman and Friesen (1969)
	primp with l/r hand	Scheflen (1965)
	l/r palm upward	Scheflen (1965)

Appendix (*Continued*)

Body part	Behavior	Description
	automanipulation of face with l/r hand	Moore (1985)
	automanipulation of trunk with l/r hand	
	manipulation of shoes/ stockings with l/r hand	
	roll up sleeves	
Trunk	trunk normal	Goffman (1976)
	turn trunk	
	trunk forward	
	trunk back	
	trunk tilt	
Legs	stretch out l/r leg	
	l/r knee up	
	pose l/r shin vertical	
	legs parallel	
	legs open	
	open l/r leg	
	cross legs, shin on shin	
	cross legs, thigh on thigh	
	cross legs, shin on thigh	
	cross legs, ankle on shin	
	scrape feet	
	rock knees	
Mixed	prop up head	Moore (1985)
	prop up head on l/r hand	
	hair flip with l/r hand	

Note: l/r: left, right, or both if not indicated