Nonverbal Synchrony or Random Coincidence? How to Tell the Difference

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Abstract. Nonverbal synchrony in face-to-face interaction has been studied in numerous empirical investigations focusing on various communication channels. Furthermore, the pervasiveness of synchrony in physics, chemistry and biology adds to its face-validity. This paper is focused on establishing criteria for a statistical evaluation of synchrony in human interaction. When assessing synchrony in any communication context, it is necessary to distinguish genuine synchrony from pseudosynchrony, which may arise due to random coincidence. By using a bootstrap approach, we demonstrate a way to quantify the amount of synchrony that goes beyond random coincidence, thus establishing an objective measure for the phenomenon. Applying this technique to psychotherapy data, we develop a hypothesis-driven empirical evaluation of nonverbal synchrony. The method of surrogate testing in order to control for chance is suitable to any corpus of empirical data and lends itself to better empirically informed inference.

Keywords: Nonverbal synchrony, psychotherapy, control for chance, surrogate testing, random sampling, permutation testing, research methodology.

1 Introduction

The phenomenon of synchronized interaction patterns has long been a focus of interest in nonverbal behavior research. Since Condon and Ogston [1] first described interactional synchrony more than 40 years ago, this phenomenon and variants thereof have been investigated in a broad range of contexts. Synchrony has been described in different areas encompassing, among others, mother-infant interaction [2-4], emotion [5], facial imitation [6], teacher-student interaction [7,8], social psychology [9,10], clinical interviews [11] and psychotherapy [12-14]. This diversity has led to numerous definitions and an overwhelming number of terms relating to similar, yet distinguishable phenomena (e.g. synchrony, mirroring, mimicry, imitation, congruence, convergence, coordination, attunement, matching, reciprocity). One important distinction between these terms can be based upon the dynamics of the nonverbal behavior displayed: while some researchers focused on static features (e.g. posture [14]), others tried to capture dynamic features of synchrony (e.g. movement [15,16]). A further distinction concerns the contextual cues (e.g. same posture, facial expression, emotion, movement) and general characteristics of movement (e.g. movement onset,

A. Esposito et al. (Eds.): COST 2102 Int. Training School 2009, LNCS 5967, pp. 182–196, 2010.

speed, duration, complexity). In this paper, we will uniquely focus on dynamic features of synchrony: the coordination of patients' and therapists' body-movements during psychotherapy sessions.

For illustrative purposes, a recent study [17] will serve as an example of how to apply statistical tools that help distinguish genuine nonverbal synchrony from 'pseudosynchrony', i.e. the amount of synchrony one would expect to occur due to coincidental coupling between two interaction partners.

2 Comparing Genuine Synchrony with Pseudosynchrony

Synchrony as a global phenomenon in human interaction has been repeatedly reviewed (e.g. [18-20]) and its significance for interaction research seems obvious. Nevertheless, its empirical foundation has been challenged. The major criticism put forward was the lack of a control for coincidental synchrony [18-21] – synchrony that is caused by random coincidence. The problem is that 'genuine synchrony' may be indistinguishable from synchrony that would occur by chance (e.g. between two persons in the same room yet without visual and acoustical contact and currently not engaged in the same face-to-face conversation).

A first attempt at distinguishing genuine synchrony from synchrony expected by chance was McDowall's [21]. His investigation was initiated in response to studies published by Condon & Ogston [1] and Kendon [22]. He concluded that "... only one dyad out of 57 comparisons showed significantly more synchrony than expected by chance." (p. 963). His critical approach to synchrony, however, did not much influence further research. Ten years after McDowall's work, Bernieri and colleagues [23] took this idea to a higher level of sophistication: they worked with pseudointeractions "... by isolating the video image of each interactant and then pairing them with the video images of other interactants recorded in other interactions." (p. 245 [23]). Pseudointeractions thus generate datasets of 'face-to-face interactions' of persons who did not actually interact with each other. The rationale behind this approach is this: if synchrony is a genuine phenomenon that occurs in real interactions, it should be more pronounced in real interactions as compared to pseudointeractions. This was in fact true, as Bernieri et al. were able to show for interactions between mother and child [23]. In another study, disguised displays of movement [15] were used to attain the same effect while simultaneously controlling for artifacts that might be due to visual cues in pseudointeractions (e.g. both persons speaking at the same time). The paradigm of pseudointeractions has been applied to recent research [24] and appears to be well-suited as an empirical control condition for nonverbal synchrony.

Drawing from this approach, we have implemented a novel technique that uses the basic idea of pseudointeractions, which can be applied to a single face-to-face interaction [17]. Our pseudointeractions were generated on short time-scales by using automated surrogate testing algorithms.

Before moving to the technical details of our surrogate data approach, we wish to review a few considerations regarding study-design and methodology that generally apply to research on nonverbal synchrony. After each paragraph, we provide examples of applications to the domain of nonverbal behavior research, putting a main focus on a recent study [17] that will be described in more detail in paragraph 4.

3 Research Methodology

3.1 Hypothesis-Testing vs. Hypothesis-Generating Studies

As a general starting point, the specific type of research question determines which research approach can answer that question. Research questions may target the following domains [25]:

- definition (nature/definition of X)
- description (existence, appearance or history of X)
- quantification (amount/frequency/intensity of X)
- covariation (relationship between X and Y)
- comparison (quantified difference between X and Y)
- measurement (reliability, objectivity, validity of measure X)

In psychology – and related fields as well – an important distinction is made between studies that test specific hypotheses (hypothesis testing) and studies that are used to generate new hypotheses. Depending on the present state of knowledge in a field, one may observe a dominance of hypothesis-testing research with a sound and broad empirical foundation, many replicated, independent findings and good theoretical foundation (e.g. the association between patient-therapist relationship quality and outcome of psychotherapy [26,27]). In research areas still new and less established, and with less solid backing from empirical studies (e.g. the association between therapist age and treatment outcome [28]), the generation of hypotheses may be more dominant. In a simplifying way, one can state that within established fields, hypothesis-testing studies predominate, whereas in less developed fields, hypothesis-generating strategies will be in the foreground.

Examples of applications in nonverbal behavior research in psychotherapy:

Some of the first – and to date now classical – studies on nonverbal synchrony did not use hypothesis-driven strategies: The seminal work of Condon & Ogston [1], for example, was rather an anecdotic, explorative account of what kind of associations these researchers found in dyadic interaction. The same holds true for work done by Scheflen [14,29], who reported instances of synchronous nonverbal behavior from single exemplary cases of psychotherapy sessions. Newer studies by e.g. Geerts et al. [11,30] base their hypotheses on previous studies and established findings.

3.2 Sample versus Convenience Sample

When conducting an experiment, interviewing people, observing interaction, or using any other form of data collection, a researcher is often interested in drawing a representative sample of data from which generalizable conclusions can be drawn. Usually such generalizability is of importance, thus the selection of subjects is crucial to attain this goal. One convenient way to obtain data would be to interview, assess or measure those subjects that are closest at hand and easiest to access: this strategy is called convenience sampling or opportunity sampling (e.g. recruiting all the members of one's laboratory). While such data may yield interesting results per se, their generalizability is questionable because convenience samples tend to be very selective, i.e. the results may not be valid for other groups. The generalizability depends primarily on the heterogeneity or homogeneity of the convenience sample, which would have to be assessed or guessed by comparing the convenience sample with the general population.

A much stronger scientific case can be made by drawing a random sample from a given population. In a truly randomized sampling process, each element/member of a population will have an equal probability to be included in the sample. Within the bounds of the chosen population, a random sampling process yields good generalizability.

Examples of applications in nonverbal behavior research:

The often-cited study by Charny [12] used one single therapy session where nonverbal imitation and progress within the session were investigated. This session pertains to the category of convenience samples; it was recorded from an ongoing therapy. Another prominent study by McDowall [21] used three minutes of one single group-discussion to analyze nonverbal synchrony. Further studies, e.g. LaFrance [8], do not specify how the sample was drawn.

3.3 Experimenter Effect

An important source of bias originates from the investigator conducting the experiment: whether this person is directly involved in the process of data-acquisition or not can be crucial, because his/her hypotheses and preconceptions tend to consciously (or subconsciously) influence subjects, measurements and judgements. The dangers of this so-called experimenter effect have been first extensively described by Rosenthal [31]. The easiest way to circumvent such influences is to separate data acquisition from data analysis. This is especially important when direct social interactions between investigators and subjects constitute a part of the data-acquisition process (such as in interviewing the subjects).

Examples of applications in nonverbal behavior research:

If an investigator interested in nonverbal synchrony were to analyze psychotherapies conducted by him- or herself, the investigator's own nonverbal behavior would either consciously or subconsciously be influenced by his or her hypotheses. Therefore, data generated by the investigator would have to be excluded from analysis. This potential bias was inherent in e.g. the study by Navarre [32], who himself formulated hypotheses on nonverbal behavior and later on conducted psychotherapies for this research. A clear distinction between the person conducting therapy and the person doing the analysis was implemented in the fine-grained analysis of one therapy session (30 minutes duration) by Scheflen [29].

3.4 Blinding of Subjects, Experimenters, Raters, Statisticians

The same principles that hold for investigators also apply to subjects and further persons involved in an experiment (e.g. raters, experts): to rule out bias, subjects must be blind with respect to the hypotheses tested.

Examples of applications in nonverbal behavior research:

Many studies on the so-called chameleon effect [9] implemented investigators' secret confederates who either mimicked subjects or not. In these studies, subjects were unobtrusively debriefed afterwards to check whether they had become aware of unusual behavior of the confederate. However, the standard double-blind paradigm of medical studies is not feasible in psychotherapy research or when working with confederates. Most studies that used raters (e.g. the study on the effect of postural congruence on client's perception of empathy [33]) had their raters blinded to the hypothesis under investigation or to the categories of interactions used. Raters who analyze recorded interactions of such studies should thus not be aware of the individual experimental conditions (e.g. mimicry vs. anti-mimicry). Additionally, raters were unaware of whether confederates were present or not.

4 Statistical Considerations

Controlling possible biases on the part of data acquisition is one important step in order to achieve sound empirical data. Further crucial considerations are mandatory when it comes to statistical evaluation. Depending on the nature of the hypotheses formulated beforehand, statistical analysis can either be descriptive (e.g. for hypotheses of definition or description), or inferential (using tests in order to confirm or disconfirm hypotheses). The scaling properties of the data define which statistical tests are applicable. Current statistical software packages offer a wide range of preprogrammed tests and analyses suitable for the most common cases (e.g. interval-scaled data, ordinal-scaled data).

Before these tests are applied to raw data, several caveats have to be taken into account. Especially in the domain of probabilistic testing (e.g. t-test, ANOVA, etc.), the number of possible comparisons has to be factored into the probabilities applied. The most common form of correction for this inflation of probability is the Bonferroni-correction [34,35]. This correction accounts for the increasing chance of accidentally finding a significant result only because of the number of performed tests or comparisons (out of 100 tests, 5 are bound to be significant by chance when the significance criterion is set at $p < .05$).

Surrogate testing is an elegant way to control for chance findings. Variants of this method are known under different terms: bootstrap, jackknife, randomization test, permutation test. All these approaches rely on the original data itself and produce new, surrogate datasets by rearranging the original data [36]. The term bootstrapping has its origin in the tales of Baron Münchhausen, who pulled himself out of a swamp on his own bootstraps. This is the basic idea in all surrogate data methods: producing 'new' data by utilizing an already available original dataset. Such approaches are primarily used for the estimation of confidence intervals and statistical testing. Usually, numerous surrogate samples are produced (hundreds to millions of datasets). These new, rearranged samples can be distinguished on two dimensions: sample size and sampling method. Fig. 2 shows the different methods used for this process.

		Sample Size (for 1 dataset)	
		Subsample	*Full Sample*
Sampling Method	*Without Replacement*	Jackknife	Randomization Permutation Shuffling
	With Replacement		Bootstrap

Fig. 1. A 2 x 2 classification of resampling strategies (adapted from [35]). The multiple generated new datasets can use any of the strategies shown.

The bootstrapped, 'new' datasets can be compiled either by consecutively taking random items, values, etc. from the original data (without replacement) or by using one item of the original data and leaving this item in the available data (with replacement). The different methods can be described in terms of drawing numbers from a hat:

- Jackknife: systematically recomputing the statistical estimates while leaving out one observation at a time from the sample set. From this new set of "observations" new estimates are computed. Mainly used to detect outliers. Drawing from a hat; after each draw calculating statistics for the remaining items inside the hat.
- Randomization, Permutation, Shuffling: Altering the sequence- and/or time structure of data. Drawing from a hat; keeping the drawn item until a new set has been assembled.
- Bootstrap: randomly drawing items from the pool of all observations. Drawing from a hat; noting the item number and putting back the item after each draw (one number may be drawn multiple times).

The choice between the three methods depends mainly on theoretical and logical considerations. Sampling with replacement would make no sense when e.g. assigning individuals to (surrogate) teams, because by using the replacement sampling method, a bootstrapped team could be theoretically made up of identical individuals, while such a situation is impossible in the method without replacement (where each team member is assigned only once). For applications with few items/samples and where original and bootstrap data should be identical in terms of distribution and data characteristics, sampling without replacement produces better results.

Examples of applications in nonverbal behavior research:

To date, bootstrapping and other resampling methods have been rarely applied in the nonverbal behavioral domain. This lack would not be unassailable because the application of these strategies would be feasible in many studies where observations of behavior have been filmed, transcribed or otherwise recorded on media. This would even apply to some of the examples described above.

5 Calculation of Nonverbal Synchrony in Psychotherapy Sessions

In this section we describe a study on nonverbal sychrony [17] that tried to adhere to the problems discussed above.

Hypotheses

As mentioned in the introduction, nonverbal synchrony has hitherto been studied under various conditions and in different fields of face-to-face interaction. Therefore – in contrast to previous explorative accounts – in our empirical study on nonverbal synchrony in psychotherapy [17], specific hypotheses were formulated that encompassed previous results reported in the literature. One result that had been repeatedly found concerned the association between nonverbal synchrony and the relationship quality of the persons engaged in the interaction.

Hypothesis 1: A positive correlation exists between the amount of nonverbal synchrony and the quality of the therapeutic relationship rated by patient and therapist.

A related association concerns the relation between nonverbal synchrony and the success of the therapeutic intervention. This entails the following hypothesis:

Hypothesis 2: Nonverbal synchrony predicts global success of therapy. There is a positive correlation between nonverbal synchrony and success of therapy at the end of treatment.

Given the specificity of these hypotheses, we were able to refute or confirm these hypotheses using statistical inference. Confirmation of a hypothesis depends on the probability of achieving a similar result by pure chance. This probability is traditionally at $p < .05$, i.e. a probability of 5 percent.

Sample versus Convenience Sample

The population for our investigation on nonverbal synchrony consisted of therapies conducted at the psychotherapeutic outpatient clinic of the University of Bern [37]. Over 300 individual therapies were available, which had been recorded during the time period considered for this study (1996 to 2004). Based on previous findings that reported less synchrony in mixed dyads [38,39], only same-sex dyads were considered. Furthermore, technical necessities (VHS-quality, visibility of both interactants, restriction to verbal exchange without external constraints such as e.g. the use of a pinboard or similar device) limited the total number of therapy sessions available for random sampling. Figure 1 details the randomization process and shows remaining sessions after each step. Taken together, these conditions restrict generalizations to a certain degree: the results obtained apply primarily to (pure) verbal interaction of same-sex patient–therapist dyads in ambulatory therapy settings. In general, however, the random sampling procedure assures that every potentially usable therapy session has the same probability of being drawn for the study. This individual probability can be modified with stratified sampling: characteristics (strata) are defined and further

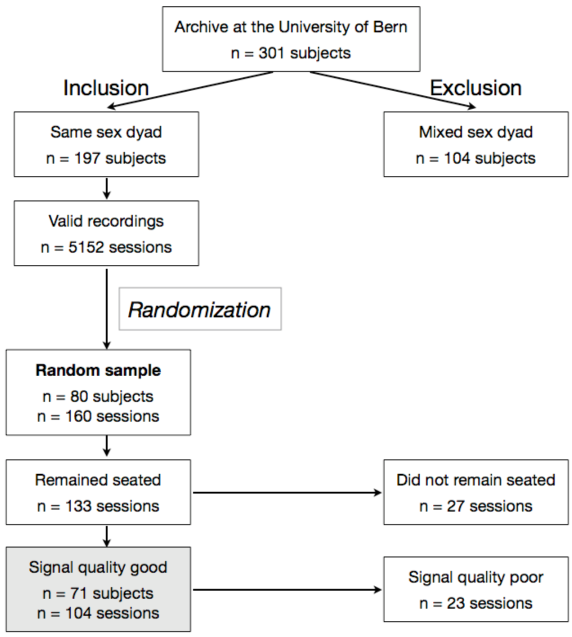

Fig. 2. Flowchart of random sampling procedure and exclusion criteria [17]

control the sampling process. In the nonverbal synchrony study, sex of dyads and phase of therapy (initial vs. final phase) were defined. Sampling 160 sessions out of 5152 sessions results in a probability of p = .03 for any individual session to be included in the study. Stratified sampling assigns different probabilities (depending on strata), but helps achieving a balanced random sample.

Experimenter Effect

The requirement of independence between investigator and therapist was met in our study by analyzing only those therapies that had been recorded years before the formulation of the research hypotheses, and that had been conducted by therapists other than the investigators involved. Owing to the comprehensive archive at the University of Bern, a retrospective analysis of nonverbal synchrony was feasible avoiding any experimenter effect.

Blinding of Subjects, Experimenters, Raters, Statisticians

Subjects (therapists and patients) in our nonverbal synchrony study had conducted therapies (in the years 1996 to 2004) independently of the research question (formulated in 2006). Thus they were unaware of their nonverbal movement behavior being subjected to an analysis of nonverbal synchrony later (ethical issues and data privacy had been considered here, of course). Because synchrony was calculated objectively using computer-vision algorithms, there was no need for blinding of investigators.

Statistical Considerations

Figure 3 details an example of the randomization test used in the study on nonverbal synchrony. As mentioned above, the original idea of permutation of interaction sequences as a means of chance control in synchrony research was put forward by Bernieri et al. [23], who produced video clips with pseudointeractions. These pseudointeractions were generated by dividing split-screen recordings of interaction partners into two separate video streams. Each single video stream was then assigned an arbitrary different interaction partner, thus generating a surrogate video stream of partners who had never actually interacted. This pseudointeraction provided a base-level of pseudosynchrony, with which the genuine synchrony of interactions could be compared.

Starting from this idea of constructing interactions that never actually took place, we generated pseudointeractions within each patient–therapist dyad on a smaller scale: The entire interaction sequence was divided into one-minute segments that were then permuted segment-wise to generate the same pseudointeractions as in the example of Bernieri et al. [23], just at a smaller time scale. Permutation of original data was done with one-minute segments because this assured that the original structure of data was altered only in relation to the dimension of time, whereas the structure of movement bursts remained intact (see Fig. 3). Theoretically the permutation could be performed with smaller units (e.g. shuffling every single point of data). In keeping the structure of the original movement intact, a much more realistic comparison – i.e. a statistically more conservative test – is achieved.

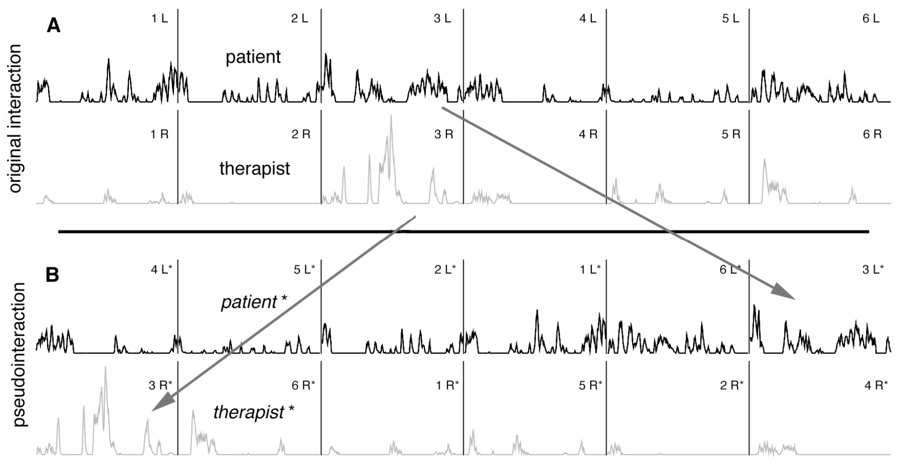

Fig. 3. Bootstrapping of interaction sequences (6 segments with 1min duration each).

Upper panel A: amount of movement of patient (L) and therapist (R), 6 segments (1 to 6) of 1 minute duration; $r = .36$ (correlation whole interaction).

Lower panel B: one (of $N = 100$) exemplary permutation of original data from panel A. The structure of 1-minute segments remains intact while the time-order of the interaction is shuffled (arrows, randomization without replacement); $r = -.19$ (correlation whole interaction).

Thus, for the movement data, interaction partner A's minute 4 may be paired with interaction partner B's minute 9 and so forth (see Fig. 3). Such a permutation of time-segments was done repeatedly (N = 100) in order to arrive at a large sample of pseudointeractions (i.e., a surrogate sample) with which the genuine interaction was then statistically compared.

A simple, two-sided z-test is used to compare the genuine synchrony value with the distribution of the 100 pseudosynchrony values. If genuine synchrony is two standard deviations above or below pseudosynchronies, then the deviation from randomness or chance level is deemed significant. Such a comparison can either be done directly at the level of single therapy sessions (one genuine synchrony vs. 100 pseudosynchronies, Fig. 4). Alternatively, a similar comparison may be performed at the level of various therapy sessions: for this group comparison, the 100 pseudosynchronies are averaged to one mean pseudosynchrony value. The comparison is then assessed using a two-sided dependent t-test.

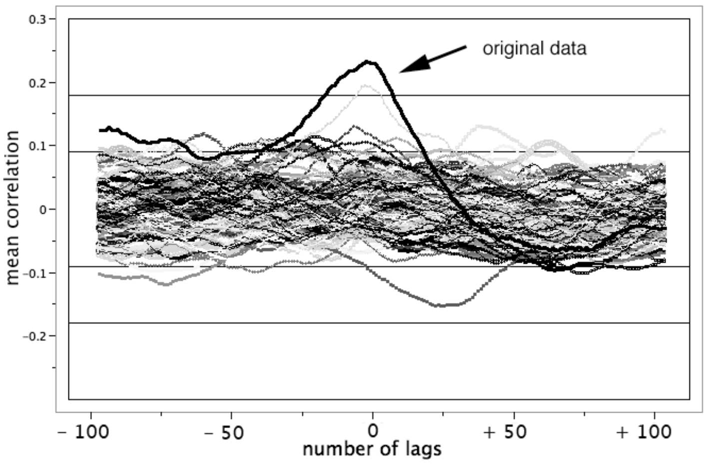

Fig. 4. Genuine cross-correlation coefficients at different lags (*bold black*) among (N = 100) bootstrapped pseudo cross-correlations

Technical Considerations

In order to perform these surrogate tests, a considerable amount of recursive computation is needed. These computations are automated because they would otherwise require too many manual steps. As described by Fan [36], until recently there existed no straight and easy ways to implement bootstrapping and related methods. We have used a customizable software environment [40] to program the steps needed. Here we briefly detail which procedures we utilized for our program:

1. generating random sequences for each interactant's windows
2. arranging the original data according to random sequence
3. performing synchrony calculations (cross-correlations of movement data)
4. repeating steps 1 to 3 (e.g. N = 100 times) to acquire the necessary distribution of pseudosynchronies.

The movement quantifications shown in Fig. 3 were derived from videotapes of psychotherapies by using a computer-vision algorithm called frame-differencing or motion energy analysis (MEA). This method has first been applied to face-to-face interactions by Grammer and his team at the University of Vienna [10,41]. His methodology was then adapted to the psychotherapy setting by Ramseyer & Tschacher [13,16], and independently by Komori et al. [42], and Nagaoka et al. [43].

The calculation of synchrony described here relies on cross-correlations between the two interactants' time-series by MEA. One suitable method for this calculation was described by Boker et al. [44-46], who also demonstrated a way of visualizing cross-correlation plots in color-coded form. Cross-correlations have further been successfully applied to physiological aspects of behavior movement research [47]. For more details, see the description of methods in Ramseyer & Tschacher [16].

Combination of Methodological Elements

We combined the three basic elements, chance-control, motion-energy analysis (MEA), and cross-correlation calculation, to achieve a novel and highly robust measure of nonverbal synchrony. Two exemplary cross-correlation plots of nonverbal synchrony in psychotherapy are shown in Fig. 5: The left plot is from a session (session # 1 of 40) with low synchrony and low quality of the relationship between patient and therapist, the right plot (session # 26 of 40) represents a later session of the same dyad with high synchrony and good relationship quality. Z-values for low vs. high synchrony are 0.51 and 2.39 respectively.

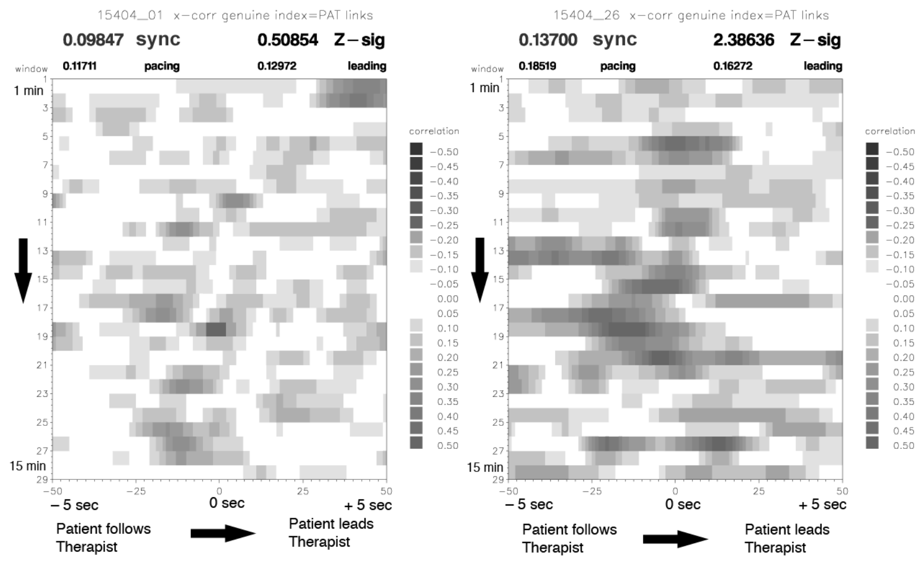

Fig. 5. Color-coded cross-correlation plots of low (left panel) vs. high (right panel) synchrony from one psychotherapy dyad. Gray areas indicate phases of high synchrony.

5.1 Results: Nonverbal Synchrony vs. Pseudosynchrony

Using the statistical methodology described above, we quantified nonverbal synchrony in psychotherapy sessions recorded routinely in an ambulatory psychotherapy setting. The comparison with pseudosynchrony was done at the group-level of all (N = 104) therapy sessions considered. This yielded a significant superiority of genuine synchrony versus pseudosynchrony ($T = 5.92$; $p < .0001$) with a moderate effect size [48] (Cohen's $d = 0.49$). This effect size is similar to results obtained with the original pseudointeraction approach by Bernieri [18,23], recently used in a study by Kimura & Daibo [24] ($d = 0.63$).

6 Conclusions

Our methodology comparing genuine interactional synchrony with pseudosynchrony yielded a highly significant result. The effect size of this finding was medium, which suggests that the phenomenon is not very easily detected. It was therefore necessary to establish a rigorous reference condition to which the measured phenomenon (nonverbal synchrony) can be compared (pseudosynchrony). We have demonstrated a surrogate testing approach for assessing nonverbal synchrony in psychotherapy. Further applications in established corpora of data are feasible and will help to clarify the highly divergent views in this field, where some researchers claim nonverbal synchrony has been over-evaluated [20] while others view synchrony as the basis of any interaction [18].

The methodology described here is suitable to many different domains. It is conceivable that synchrony found in nonverbal movement might be present in verbal channels as well. Verbal and paraverbal synchrony could thus be similarly assessed and compared to randomness.

The application of the concept of randomness described above has some pitfalls: randomness as conceptualized here depends on the fact that there is not an overarching periodicity that lies beyond the window-size used (if we were to compare two pendulums, i.e. a highly periodic system, with the described method, random synchrony would be as high as genuine synchrony. This implies that before its application, a test on stationarity and especially a check of periodicity should be applied.

Taken together, our findings in psychotherapy sessions support the view that synchrony indeed is a valid marker of relationship quality. One may say that nonverbal synchrony embodies relationship quality. Whether this applies to face-to-face interaction cannot be generalized from psychotherapy sessions alone, but with the methodology available, further research in other domains of interaction, interpersonal or man-machine interaction, will shed more light on the significance of nonverbal synchrony. This methodology can be extended to many other domains and promises to provide more rigorous empirical backing to findings in these fields.

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