Synchronized Movement in Social Interaction

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ABSTRACT
Social interaction is a core aspect of human life that affects individuals' physical and mental health. Social interaction usually leads to mutual engagement in diverse areas of cognitive, emotional, physiological and physical activity involving both interacting persons and subsequently impacting the outcome of these interactions. A common approach to the analysis of social interaction is the study of the verbal content transmitted between sender and receiver. However, additional important processes and dynamics are occurring in other domains too, for example in the area of nonverbal behaviour. In a series of studies, we have looked at interactional synchrony – the coordination of two persons' movement patterns – and its association with relationship quality and with the outcome of interactions. Using a computer-based algorithm, which automatically quantifies a person‘s body-movement, we were able to objectively calculate interactional synchrony in a large number of dyads interacting in various settings. In a first step, we showed that the phenomenon of interactional synchrony existed at a level that was significantly higher than expected by chance. In a second step, we ascertained that across different settings – including patient-therapist dyads and healthy subject dyads – more synchronized movement was associated with better relationship quality and better interactional outcomes. The quality of a relationship is thus embodied by the synchronized movement patterns emerging between partners. Our studies suggested that embodied cognition is a valuable approach to research in social interaction, providing important clues for an improved understanding of interaction dynamics.

General Terms
Algorithms, Measurement, Human Factors.

Keywords
Nonverbal synchrony, coordination, social interaction, motion energy analysis MEA.

1. INTRODUCTION
The building blocks of any group or society are the connections between its members. At the present time, we are living in a highly technologically environment, where social connections can take on many different forms ranging from purely digital encounters in a virtual environment to live, face-to-face interaction between partners. Independent of the physical relatedness of interaction partners, human beings regulate and negotiate important apects of their personalities in social interactions. Establishing and maintaining social relationships is a fundamental need for human beings [1]. Close relationships are vitally important from the very first days of our lives [2], and the way interpersonal attachments are formed influences many domains of an adult's life [3]. Difficulties in the area of interpersonal behavior are strongly associated with psychopathology [4] and interpersonal motives clarify the way people behave in social interactions [5]. Being ignored and excluded by others is painful [6], and individuals who feel disconnected from others, who develop a sense of "thwarted belongingness", are at a higher risk for suicide [7].

One very important facet of social interaction is nonverbal behaviour. Apart from the transcribable verbal content that is exchanged in a social interaction, numerous channels of information in other areas than speech are simultaneously active and exert a strong influence on the interaction [8]. A better understanding of the processes that are taking place in the domain of nonverbal behavior will thus help people establishing and maintaining good relationships.

Our research strategy begins by paying attention to the dynamics occurring in social interactions: Here, various patterns of synchrony can be detected. Phenomena of synchrony may occur in quite distinct domains that include physical [9], emotional [10], cognitive [11], and physiological [12] phenomena.

In the present paper, we will focus on one specific domain where patterns of synchronized behavior become apparent during social interaction: the domain of nonverbal behavior. We will review selected empirical work conducted in patient-therapist dyads [13] and in healthy students [14], and we will demonstrate the use and rationale for the methodology of motion energy analysis, MEA.

2. SYNCHRONIZED MOVEMENT
Condon and Ogston [9] were the first to conduct an empirical investigation of synchronized movement in a "sound film analysis of normal and pathological behavior patterns". In their paper, they described a manual frame-by-frame analysis of film material and they coined the term "interactional synchrony". Although their methodology was used in later studies [15, 16], the findings gained through this kind of analysis remained relatively sparse and also controversial [17]. A series of studies by Bernieri and colleagues [18, 19] led to renewed interest in the phenomenon of synchrony, however, it was not until the – now classic – study of Chartrand and Bargh [20], that the field of social psychology rediscovered the potential impact of behavioral imitation.

In the past decade, multiple studies have been published on the so-called chameleon effect (for an overview see: [21]. In terms of studies that dealt explicitly with the phenomenon of synchronized body-movement and its effect on single persons, dyads or groups, the majority of experimental investigations used relatively simple, easily reproducible movement patterns such as arm movements [22], or the synchronized use of rocking chairs [23. By means of these easily reproducible coordinated movement patterns, a

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measurable effect on prosocial and affiliative behavior was induced in participants. Such synchronized behaviors resulted in higher cohesion among group members or in more obedience with a group leader [24].

Several years ago, we sought to pick up the methodological rationale of Condon and Ogston [9] and to transfer it to contemporary computer-vision algorithms [13, 25]. It was our aim to extend previous findings to a more general, widely applicable assessment of synchronized behavior, which could be applied to a variety of already recorded interactions. The application of frame-differencing algorithms used in the domain of computer-vision [26] allowed us to develop a simple and robust measure of global movement activity, which we called motion energy analysis, MEA.

3. MOTION ENERGY ANALYSIS (MEA)

In subsequent paragraphs, we will describe software that allows efficient objective quantification of movement in recorded interactions: Motion energy analysis is a non-invasive way to measure the amount of movement that occurred in selected regions of video recordings or in live video. Using a so-called frame-differencing approach [27, 26], MEA delivers a good approximation of movement activity in freely definable regions of interest. The frame-differencing methodology has been previously used in human ethology research [28, 29], in psychotherapy research [30, 25], and in social psychology [31, 32].

Frame-differencing methods provide theory-free measures of the *dynamics of movement*; they simply (and somehow blindly) quantify the amount of change occurring between consecutive frames. This implies that specific body-parts or the direction of individual movements are neither distinguished nor can they be inferred from raw data provided by this method. This ostensible drawback comes with multiple benefits: MEA is a completely objective, reliable and valid quantification of movement. It is easy to use and cost-effective in terms of time- and financial resources.

The use of frame-differencing imposes certain restrictions on the recordings – otherwise, the results could become strongly biased. The following steps provide some technical details on MEA.

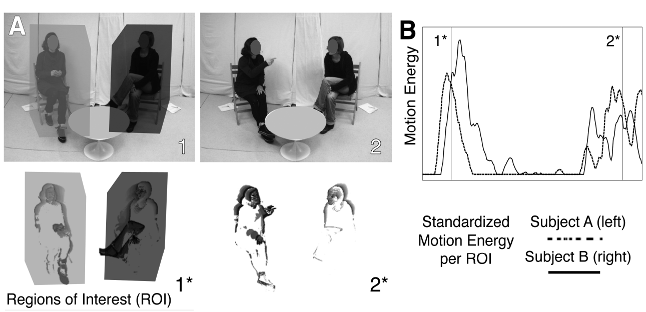

Figure 1. A: Original Video-Frames and Corresponding MEA Quantification. B: Time-series of Motion Energy

3.1 Interactional prerequisites

First of all, the camera needs to be able to record interacting people from a more or less unobstructed angle. If there is more than one person to cover, then subjects in the focus of the investigation should be visible from similar angles. In a dyadic setting, the use of two cameras may be especially appropriate; the two video-streams can be joined into a split-screen image. In order to individually calculate movement activity in every person of interest, subjects are not allowed to move in front of each other (split-screen image: see Fig. 1A)

3.2 Recording equipment

The recording should be done in a minimally invasive way, and within ethically irreproachable limits, filming may also be carried out with concealed equipment. We found firewire video cameras to be very helpful for this task, because they provide digital format recordings and with their small size, they can be easily fit in many different surroundings.

3.2.1 Recording setup

Most importantly, the camera has to remain in a completely fixed position throughout the recording. No zooming, focusing or changes to the aperture should occur, i.e. the settings of the camera should remain fixed for the duration of the recorded sequence. These prerequisites are of utmost importance, because the frame-differencing algorithm calculates the number of pixels that change from one frame to the next, thus any changes in the picture – which are not due to genuine movement of a person – will erroneously be treated as movement. The recording environment should therefore also provide a stable background and constant lighting conditions.

3.3 Software

As described above, different research groups have used various software solutions for frame-differencing. Given that the algorithm is rather simple, it may be invoked in miscellaneous software environments. We have used Max/Msp software [33] with a customized plugin called SoftVNS [34].

3.4 Treatment of data

The analysis of raw data derived with frame-differencing requires some careful steps, because noise originating from the recording situation or invoked by compression/decompression (codec) algorithms may be present. This is of highest importance if the researcher aims to assess synchrony: If the raw data contains systematic noise (e.g. key-frames introduced by certain codecs), the amount of synchrony could be greatly overrated. In our experience, the raw data should be treated with the following steps:

3.4.1 Threshold / deletion of peaks / moving average

The recorded material almost invariably contains a certain amount of noise. The most radical and simple way to get rid of this noise is to use a threshold algorithm [35, 26]. Single peaks may be deleted automatically and in highly noisy data, the calculation of a moving average may be appropriate.

3.4.2 Z-standardization

In most setups, regions of interest will be of varying sizes, thus we advocate a Z-standardization, which neutralizes these differences and makes individual regions more easily comparable.

3.5 Statistical analysis

The quantification of synchrony may be done with different statistical methodologies [36, 37]. Cross-correlations are the most common approach [38, 39], and they provide an easily interpretable metric of the association between two time-series of movement quantification.

3.6 Test against pseudosynchrony

Bernieri, Reznick and Rosenthal [40] were the first to use a clever method that allowed a statistical evaluation of nonverbal synchrony: A measure of pseudosynchrony is generated by isolating the video image of each interactant and then pairing them with video images of interactants from different interactions. Pseudosynchrony represents the amount of synchrony that would occur by chance; it is what may be expected if there is no systematic association between the movements of interactants in a dyad. We have further developed this method [41] by generating surrogate datasets within each dyad: Our pseudointeractions were generated on short timescales by using automated surrogate testing algorithms. Surrogate datasets (n = 100 out of each genuine dataset) were produced by segment-wise (1-min segments) shuffling of the original data, thus aligning subject A's and subject B's movement segments that never actually occurred at the same time. This procedure kept the individual progressive time structure (by minute) of data intact. Pseudosynchrony in shuffled datasets was calculated identically to the synchrony of the original data. For the statistical comparison of nonverbal synchrony versus pseudosynchrony, the mean value of surrogate datasets may be computed (i.e. the base-level of pseudosynchrony) and compared with the value of genuine synchrony.

4. EMPIRICAL RESULTS

Dyads of ambulatory psychotherapy sessions displayed structured and patterned body movements that are interdependent. In other words, patients adapted to therapists and therapists adapted to patients. Furthermore, nonverbal synchrony was positively associated with the self-reported quality of the therapeutic relationship and with the effectiveness of therapy (assessed by self-reports after termination of therapy). A patient's personality characteristics, especially interpersonal variables, were meaningfully associated with nonverbal synchrony. Patients with interpersonal problems were characterized by lower nonverbal synchrony, whereas patients with secure attachment styles showed higher levels of synchrony. We were able to demonstrate this phenomenon on the level of a single-case analysis [42] and in a random selection of 104 therapy sessions that were extracted from a comprehensive archive of recorded psychotherapy sessions [13].

In terms of assessments at the level of a single person, the MEA methodology was successfully extended to recordings of scripted social interactions in schizophrenic patients [35]: more severe psychopathology was associated with less movement and with specific patterns of head movement.

In two projects with healthy individuals, we were able to show that i) nonverbal synchrony was associated with self-reports of relationship quality, ii) nonverbal synchrony was associated with subjects' emotion self-reports [14] and that iii) female and male dyads showed different patterns in the way that relationships were established and maintained across different interaction tasks [43].

5. IMPLICATIONS / EMBODIMENT

A person's body movement is an important social signal that provides information on general characteristics such as gender [44], emotional condition [45], and also allows inference on a person's goals and aims [46]. Viewed from an evolutionary standpoint, these signals are highly important for the successful navigation of an individual's social surroundings. This importance is supported by biological findings in the mirror-neuron system [47].

Nonverbal behavior research has hithereto focused mainly on facial display [48], while whole-body movement has been clearly underrepresented [49]. A long time ago, Merleau-Ponty [50] stated that "It is through my body that I understand other people, just as it is through my body that I perceive 'things'" (p. 216), and from an evolutionary-theoretical stance, the perception of action seems to be a highly important factor [51]. Our findings in psychotherapy dyads, psychiatry patients and in healthy subjects all underscore the impact of nonverbal behavior for social exchange.

6. CONCLUSIONS

Nonverbal behavior plays an important role in many domains of human interaction. There are multiple fields, e.g. political resolution/decision finding and crisis negotiation, where improved knowledge of mechanisms influencing nonverbal behavior would likely provide valuable insights.

We think that a research approach with a focus on embodied cognition [52] – such as motion energy analysis and nonverbal synchrony – opens promising avenues for future applications. Better understanding of embodied processes in social interaction will also be most helpful for possible applications in the development and refinement of human-computer interfaces and in many other domains of translational research.

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