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ANALOG COMMUNICATION:
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Konrad Lorenz Institute
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The topic

For a number of reasons, empirical research on human communication at a descriptive ethological level has almost become obsolete. In part this is due to methodological problems related to the observation and description of behavior, but in part also to the nature of human behavior itself.

In 1921 the Viennese psychologist Auguste Flach wrote in the conclusion of her PhD thesis: “Ein Symbol allein, eine Geste ist mehrdeutig. Eindeutig und überzeugend ist dagegen nur die Dynamik der Bewegung." (A symbol or gesture by itself is ambiguous. Only the dynamics of a movement is unambiguous and convincing.) A comparable view may be found in Konrad Lorenz´s idea of the impossibility of an ethological approach to the description of mammalian communication. Lorenz was convinced that in mammals, “atomization“ of behavior had occurred, i.e., each unit has a communicative meaning of its own. However, considering that many communicative channels can be active at the same time, he came to the conclusion that the descriptive ethological approach could not be applied to human communication. At this time Lorenz was not considering the possibility of qualitative changes in behavior that could convey the actual message.

New approaches have changed the situation dramatically in recent years. A fast growing body of literature now deals with the quality of human motion, its underlying brain mechanisms, and the possible theoretical consequences of these findings. Communication is no longer understood as a series of sequentially transferred signals, but rather as a dynamic system of cross-modal attunement.

The recently discovered "mirror neurons" are understood to act as the brain´s core communication device. Constant and real time "mirroring" of conspecifics could provide direct mutual assessment of emotions, feelings, and hence behavioral tendencies, intentions, and goals. This mirror system seems to be crucial to establish an empathic link between individuals.

Communication is now seen as an interaction consisting of attention regulation, engagement, intentional affective signaling, and affectively mediated thinking. As a multi-channel and multi-unit process (a string of many events interrelated in “communicative” space and time), and in relation to the function it serves, it is highly context-dependent (the meaning of a signal is adapted to the situation). Several studies have shown that in human communication, motion carries far more information than the semantic content.

Within this approach, it is also assumed that human communication is primarily analog but not signal-oriented. As contradistinguished from symbolic communication (e.g., intentional use of speech and signs with conventional semantics) it would consist of many indicators of non-conscious, non-verbalizable, and non-memorizable mental processes that are expressed through the quality of motion itself.

It has indeed been shown in several studies that communication can work without involving direct cognitive processing. However, the consequences constitute a threat for semiotics-based communication theories and even for conventional assumptions about the existence of a theory of mind.

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Abstracts

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Moving Beyond Interactionism in the Study of Rhythmicity

In 'The Emergence of a New Paradigm in Ape Language Research' (BBS 2002), Barbara King and I pointed out that in recent years interactionists have increasingly described caregiver-infant communication as a form of dance. We argued that: "The chief appeal of the dance metaphor is that it draws attention to how communicating partners continuously establish and sustain a feeling of shared rhythm and movement." Some time after we'd finished the paper, however, we realized, first, that we hadn't defined rhythmicity but had only alluded to a number of synonymous terms; and second, that the latter were all drawn, understandably, from the interactionist literature that has developed over the past 30 years. The problem with the latter is that, much as interactionists have wished to move beyond Cartesian assumptions, when they set about trying to explain the mechanisms involved in synchrony (mutual attunement, matching, entrainment), there has been a striking tendency to fall back, either on a Cartesian picture of the child as a 'miniature scientist', or else, on nativist assumptions about predetermined mechanisms that enable communicating partners to achieve "bidirectional coordination." In the work we are doing now we are trying to move beyond interactionism in our attempts to operationalize rhythmicity and assess its significance for child development in general, and, in particular, the developmental pathways leading towards developmental disorders such as autism. In this paper I will review the conceptual, methodological, and technical problems involved in the interactionist analysis of rhythmicity, and then outline how we are trying to overcome these problems by shifting to a dynamic systems theory framework.

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Beyond Semantics: Analyzing the Effects of Implicit Communication

Regardless of their theoretical orientation, scholars in nonverbal behavior research have tended to focus on clearly identifiable observation units, i.e. spatio-temporal activity patterns, like facial expressions, gestures, body movements and postures (causes), to which specific meanings (functions) can be assigned. The construction of meaning thus underlies basic time sample principles of the human consciousness and the application of relevant perceptual categories. But what about more implicit and subtle qualities of behavior that are beyond such categories? What about physical properties of body and face movements like speed, acceleration, dimensional complexity, symmetry, etc. that might continuously overlie the sequential production of any kind of distinct motor actions? In fact, recent studies indicate that such movement properties may even have a stronger impact on the observers' impressions than so-called semantic aspects, although they might not be identified as a possible cause (Grammer et al., 1999). Because of the lack of a-priori observation categories the empirical analysis of such implicit behavior characteristics is difficult and requires specific methodological solutions. This holds especially for the study of interpersonal effects of nonverbal behavior. As Lewis et al. (1997) have shown, it is already very difficult to control well defined nonverbal behaviors experimentally by instructing an actor. For the area of implicit behavior qualities as described above the instructional approach is just impossible. Against this background the current paper will present an integrated

approach for the measurement and experimental variation of human movement behavior making use of new technologies for the real-time animation of anthropomorphic computer characters. Results of a series of computer animation experiments will be reported showing the methodological advantages of the approach and pointing to the importance of implicit movement qualities for interpersonal perception. In two studies, head movement activity, laid down in time series protocols of real dyadic interaction, was changed by a speed-up algorithm, increasing the rotation angles at the end position of each head movement (in either one of the three axes). Results reveal a significant effect of the increased head movement activity on observers' impressions but also indicate that effects are context-dependent: Within casual interactions increased activity is rated positive whereas actors showing increased activity within interpersonal conflicts are evaluated more negatively (Krämer, 2001). In a further study it turned out that similar changes in the gesture activity - even when more pronounced - did not change observers' impression to the same degree. Also, we found that computer animated persons showing "meaningful" facial displays (such as smiling, raising of eyebrows) are rated as more likeable than when producing just random facial activity. More interestingly, results of an accompanying fmri-study demonstrated that the perception of those meaningful expressions correlated with increased activity in the ventromedial prefrontal cortex - regardless of whether the observer himself or a fictional third person was addressed (Schilbach et al., 2004). These partially contradictory results suggest that mere changes in the activity level do not cause the same kind of interpersonal effects in all nonverbal subsystems. First thoughts on an integrative model to explain these differences will be introduced.

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EYESWEB - Motion and Emotion

The seminar introduces multimodal interactive systems as user-centered systems able to interpret the high-level information conveyed by users through their non-verbal expressive gesture, and to establish an effective dialog with users taking into account emotional, affective content. The seminar covers two crucial research issues in the design of multimodal interactive systems: (i) the multimodal analysis, i.e., approaches and techniques for extracting high-level non-verbal information from expressive gestures performed by users, and (ii) the interaction strategies that such systems should apply in the dialog with users in order to produce a suitable multimedia output, given the information provided by the analysis and the current context. The two issues are discussed with reference to recent research projects at the DIST - InfoMus Lab and to examples of concrete applications based on the EyesWeb open platform (www.eyesweb.org).

Multimodal analysis of expressive gesture in music and dance performances PDF
Analysis of Expressive Gesture: The EyesWeb Expressive Gesture Processing Library PDF

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The Coordination of Facial Expression, Head Motion, and Gaze

It is known that both the configuration of facial features and the timing of facial actions are important in emotion expression and recognition. The configuration of facial actions in relation to emotion, communicative intent, and action tendencies has been a major research topic. Less is known about the timing of facial actions in part because existing measurement methods, which rely upon human observers, are relatively coarse and time consuming to use. To investigate the timing of facial actions, we developed an automatic facial image analysis (AFA) system that has high consistency with ground truth measures of rigid (head movement) and non-rigid (expression) motion. In a series of studies, we have begun to investigate their timing in adults in solitary and social contexts and in mothers and infants during face-to-face interaction. Facial action, as indicated by lip-corner displacement during spontaneous smiles, was moderately correlated with head and eye motion, as suggested by neuroscience literature. Specific patterns of correlation were specific to interpersonal context. Our findings point to the hypothesis that the communicative meaning of morphologically similar facial actions may be disambiguated by attending to specific patterns of facial action dynamics and their coordination with head rotation and gaze.

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The Mirror System as a Possible Neural Basis for Evolution of Communication and Understanding of Intention

Mirror neurons have been discovered in a sector of monkey premotor cortex (area F5) which is considered the homologue of the human Broca's area. Interestingly, a set of mirror neurons responds not only to action observation, but also to the action sound. I will present data showing that in the lateral part of area F5 there are neurons activated by the observation of mouth ingestive and communicative actions (mouth mirror neurons). The same observed actions activate the human Broca's area. Considering also the more abstract coding shown by neurons of lateral F5, these observations point to a possible derivation of human communication from a system involved in oro-facial and brachio-manual gesture recognition.
Complex actions are made up of more simple actions. Typically, F5 mirror neurons seem to be activated by the observation of simple actions. I will present recent evidence showing that the visual response of a set of mirror neurons found in the parietal cortex (anatomically connected to premotor area F5) can be modulated when the observed simple action (for example grasping) is followed by different types of simple actions in a sequence (for example bringing to the mouth, in one sequence, or placing, in another sequence). This modulation of the mirror neuron response seems to indicate that these neurons are able to reflect the final goal of a complex action, that is the agent's intention.

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Impression Management and the Communication of Personality

Research in recent years has shown that people are quite accurate in judging another person's personality at zero acquaintance. This is even the case when only thin slices of behavior or short video clips of one person are presented to another person. Information about personality could be used by the recipients to structure their own behavior and to make predictions about the possible outcome of an interaction. In addition we assume that the communication of personality plays a paramount role for the structuring of interactions. However, it is still unclear which behavioral or appearance cues are used to judge personality, and traditional behavior analysis methods fail when they are used to find out which cues could signal personality to a receiver.
Non-verbal behavior seems to have a strong personality dependent component, and thus it has the potential to be the main cue for making such judgments. In contrast to other approaches, however, our approach is based on the assumption that personality factors and their neural correlates directly influence the quality of body movements and thus are unfalsifiable signals.
We hypothesize that information about personality in nonverbal communication is encoded in the "quality" of body movements and in the patterns formed by these movements over time.
I will present the results of several projects where we showed a relation between the quality of body movements analyzed by digital image processing algorithms, and the big five personality components (extroversion, neuroticism, conscientiousness, agreeableness and openness) in interactions between males and females. In other projects we were able to show interrelations between additional personality components like shyness (dancing behavior of males and females) and sensation-seeking behavior (playing action games by males).
These findings have a considerable impact on our understanding of human communication and its principles. We suggest that the commonly used sequential information processing approach (A signals and B decodes it and responds) is replaced by a dynamic theory of human communication where the communicators share a common platform in realtime. The pathway we suggest is the function of mirror neurons.

Key publications

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Natural Variability of Analog Communication in Human Interaction

Recently, innovative techniques for computer animation of natural human movements have systematically been used for analyzing the effects of various nonverbal behavior modifications on perception and judgment of persons (Bechine & Grammer, 2003; Kempter et al., 2003; Krämer et al., 2003). Computer animations of original nonverbal behavior with 3D graphic human models show highly similar effects in ratings and physiological responses as the original video presentation.

Relevant experimental perception studies have been proceeding on these results. Subsequently, different static and dynamic modifications were made with animations of original body movements to register various stimulus driven effects within the recipient. In this part we will present the results of our efforts in analyzing the kind of behavioral modifications made in the latter experimental perception studies within the focus of analog communication. By analog communication we mean the recipient's question "How is nonverbal behavior going on?", whereas the question "What is going on?" is covered by definition of symbolic communication. We suppose that every modification directing towards symbolic communication can as such be observed by recipients. On the other side modification of analog communication could be achieved which is as well imperceptible for ordinary recipients. In the latter case differences in human movements would not be observed, for example, because of spatial and temporal minimal level, high complexity of overall stimulus modification or not reaching the focus of attention. Nevertheless under some circumstances, these modifications show effects in cognitive ratings as well as in peripheral physiological responses. Furthermore we found that analog communication can be changed without affecting symbolic communication but not yet vice versa. We will demonstrate all these effects by our computer animation and experimental perception studies of the last years. For stimulus preparation we used a kind of morphing technology for computer animated human movements in movies and other media as well as tachistoscopic and stroboscopic picture presentation. The visibility of movement modification was representatively tested by direct comparison of associated stimuli. Recipients' response to modified stimuli was registered by physiological measurements as well as ratings. The results will be interpreted as related to the question of why analog and symbolic communication should be differentiated in human interaction. Hypothetically, we suppose an individual future perspective in perception of the first category of nonverbal behavior.

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From Mirror Neurons to Social Perception

How do we understand what other people do and feel? I will present data from single cell recordings in monkeys and fMRI experiments in humans that suggest that the brain structures involved in our own actions, emotions and sensations may play a critical role in understanding the actions, emotions and sensations of others. I will show that the monkey's premotor cortex contains cells called mirror neurons that respond not only when the monkey performs certain actions, but also when the monkey sees or hears someone else perform similar actions. Some of these neurons even respond when the actions observed by the monkey are partially occluded from sight, and can therefore only be guessed. In addition, data will be presented that shows that the human insula, normally activated while the participant is disgusted, for instance because he/she is exposed to a disgusting odorant, is also activated when he/she perceives the disgusted facial expression of another individual. Finally, I will show that the secondary somatosensory cortex activated when the participants own leg is being touched is also activated when he/she observes someone or something being touched in a similar way. Altogether this data suggests that the premotor cortex, insula and somatosensory cortex normally involved in the subject's own actions, emotions and sensations, respectively, are also involved in the perception of these actions, emotions and sensations in others. It appears that to perceive what occurs to someone else, our brain runs an internal simulation of that event, as if he/she would do those actions, feel those emotions or have these sensations him/herself.

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In Search of the Uncanny Valley

In 1970 the Japanese roboticist Masahiro Mori coined the term "bukimi no tani" to describe the concept that as a robot became more similar to a human there would be a point at which human reactions to the robot would turn negative. This "uncanny valley" as it was translated has become a popular design concept in the areas of both humanoid robotics and human character animation. Surprisingly, there is little direct psychological evidence to suggest that such a phenomenon exists. In my talk I wish to first extract the essential properties of the uncanny valley that relate to known psychological processes. In doing so I will review recent findings in the perception of human movement that argue for the plausibility of the uncanny valley. I will emphasize recent work from our laboratory that strives to reveal what movement features support the human ability to categorize movement style. This work has investigated the recognition of affect, gender, identity, naturalness and tennis-serve style from synthetic and real human movement and worked on measures to quantify human performance at recognizing action.

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The Correlative Nature of Biological Motion Patterns: Data Driven Motion Analysis

Animate motion contains information about the identity of an agent as well as about his or her actions, intentions, emotions, and personality. The human visual system is highly sensitive to biological motion and has evolved a remarkable capability to extract this socially relevant information from the way a person moves. The effortlessness with which we can adequately interpret other peoples motion grossly

contrasts the fact that we still know very little about the mechanisms underlying information encoding in, and retrieval from, biological motion patterns.
In this contribution, I want to outline a framework that enables us to successfully search for the effects of a number of different traits on human gait patterns. The proposed model is based on the statistics of a database of motion capture data. Based on linearization of the motion data, a motion space is defined which is spanned by the first few principal components obtained from the database of input walkers. Using biological and psychological traits attributed to the input walkers, linear discriminant functions are computed which define vectors in the motion space that generalize the respective trait. The framework will be used to explore variances in human walking patterns with respect to sex, age, attractiveness, a number of different emotions and identity.
In doing so, I will stress the fact that successful retrieval of the respective information from the input data is only possible if we treat the moving person in a holistic way which retains the complex correlations between different moving parts of the articulated body as well as between the kinematics and static, structural properties of the body.
The framework used to analyze animate motion is a generative model, which can also be used for motion synthesis. In order to create psychologically convincing motion it is crucial to preserve the correlative nature of animate motion. The human visual system is extremely sensitive to violations of the complex correlation patterns and I will present examples on how it uses implicit knowledge about the biomechanics (and general physics) of articulated motion causing these correlations.

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Movement Simulation for Embodied Conversational Agents

Embodied conversational agents are computer-generated characters that have properties resembling those of humans in verbal and nonverbal face-to-face conversation. With the artificial humanoid agent MAX under development at the University of Bielefeld we explore to what extent realistic "embodied communication" can be realized by an artificial agent embodied in virtual reality. Clearly such an agent does not have a body in the physical sense, but can be equipped with verbal conversational abilities and employ its virtual body to express non-linguistic communication qualities such as gesture movements. Equipped with a synthetic voice and an articulated body and face, Max is able to speak and gesture, and to mimic emotions. By means of microphones and tracker systems, Max can "hear" and "see", and process spoken instructions and gestures.
One of our current research challenges is the question of how far Max can imitate iconic gestures demonstrated by a human communication partner. Iconic gestural movements are assumed to derive from imagistic representations in working memory, which are transformed into patterns of control signals executed by motor systems. Could an artificial agent construct a "mental image" of shape from an observed iconic gesture and reexpress it by way of iconic gestures? Another research challenge is emotion. Could an artificial agent express emotions related to internal parameters that are themselves influenced by external and internal events? Our research is led by the expectation that the construction and test of an "artificial communicator" will help to reach a more profound understanding of human nonverbal communication.

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Shared Neural Systems for Imitation and Language

Recent imaging studies of imitation and observation of hand and mouth movements unveiled a neural architecture for imitation that comprises three critical regions, the inferior frontal cortex, the rostral part of the posterior parietal cortex, and the posterior part of the superior temporal cortex. These three areas seem to be the human homologues of macaque brain areas F5,
PF and STS, where neurons coding actions of others are found. Data from brain-damaged patients with language disorders and brain imaging studies of language also suggest that human inferior frontal cortex, rostral posterior parietal cortex, and posterior superior temporal cortex are critical areas for language. Taken together, this evidence suggests an evolutionary sequence that goes from some level of understanding of the actions of others to imitation and finally to language. The picture shows in red the areas for imitation, in yellow the classically defined Broca's and Wernicke's language areas, and in orange the overlapping areas.

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The Evolution of Analog Communication

Signals in analog communication develop by ritualization from non-signals. A signal is a character whose merit to the signaler is in providing information to the recipient. I do not consider as signals characters that may provide information to recipients but have not evolved in order to provide such information.
Analog signals evolve to be reliable by a special selection process that differs from the process that selects all other characters other than signals: The evolution of a signal imposes a handicap (an investment) on the signaler.
The recipient has an interest in recognizing differences in quality or motivation between other individuals. That interest selects for standards of investment best suited to display variations in particular qualities or motivations of the signalers. The nature of the handicap is therefore related to the message encoded by the signal; for example, wealth is displayed by wasting resources, strength by carrying loads, and defiance by taking a risk.
Although most biological signals are analog, some digital information has evolved from the standards used for displaying quantitative analog information. The pattern of a particular standard may be used as a digital signal, providing a message devoid of quantitative information. Unlike analog communication, which has evolved to be reliable, digital information is not inherently reliable. However, reliability may be introduced into digital systems by imposing handicaps on the use of these signals.
