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67. NEUROGES – A coding system for the empirical analysis of hand movement behaviour as a reflection of cognitive, emotional, and interactive processes

Abstract

The NEUROGES coding system is a research tool for the empirical analysis of the spontaneously displayed hand movement behaviour that accompanies interaction, thinking, and emotional experience. NEUROGES is designed for diagnostic purposes as well as for basic research, i.e., to further explore the anatomy of hand movement behaviour and its relation to cognitive, emotional, and interactive processes. Fields of application are interaction analysis including psychotherapy, psychodiagnostics, and experimental and clinical neuropsychology. In a multi-stage evaluation process resulting in more and more fine-grained units, the behaviour is segmented and classified according to the kinesic criteria. The objectivity, reliability, and validity of the NEUROGES categories and values have been tested in several research studies, thus far including 263 participants, healthy adults as well as patients with brain damage or mental disease. The analysis of the group differences in hand movement behaviour as well as kinetographic and brain imaging studies provide evidence that the NEUROGES categories and values are associated with specific cognitive, emotional, and interactive processes.

1. Aims of the NEUROGES coding system

The NEUROGES coding system is a research tool for the empirical analysis of the spontaneously displayed hand movement behaviour that accompanies interaction,

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thinking, and emotional experience. However, volitional hand movements such as tool use can be analysed as well.

According to kinesic criteria the ongoing flow of spontaneous hand movements is segmented into units and classified with values. For some values the association with cognitive, emotional, and interactive processes is already empirically established and thus, these can be used for diagnostic purposes. Fields of application are interaction analysis including psychotherapy, psychodiagnostics, and experimental and clinical neuropsychology. Furthermore, NEUROGES is designed for basic research, i.e., to further explore the anatomy of hand movement behaviour and its relation to cognitive, emotional, and interactive processes.

2. The theoretical and empirical background of the NEUROGES coding system

The above outlined aims of NEUROGES system imply that hand movement behaviour is linked to cognitive, emotional, and interactive processes. More specifically, hand movements do not only reflect these processes, but likewise, they seem to affect them (Fig. 67.1).

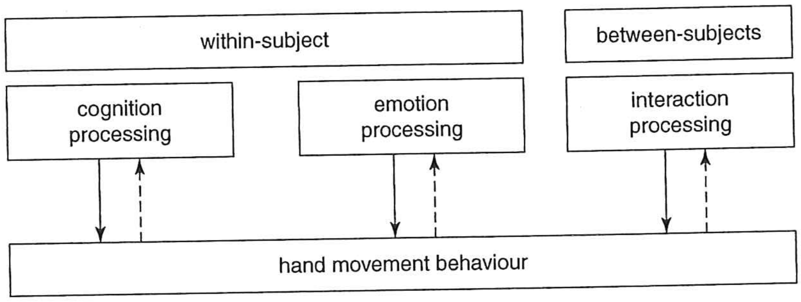

Fig. 67.1: Bi-directional link of hand movement behaviour and cognitive, emotional, and interactive processes.

There is, in fact, ample empirical evidence that spontaneous hand movements are associated with higher cognitive functions, such as language, spatial cognition, or praxis (e.g., Beattie and Shovelton 2006, 2009; Blonder et al. 1995; Butterworth and Hadar 1989; Cohen and Otterbein 1992; de Ruiter 2000; de'Speratie and Stucchi 2000; Duffy and Duffy 1989; Ehrlich, Levine and Goldin-Meadow 2006; Emmorey, Tversky and Taylor 2000; Foundas et al. 1995; Fricke 2007; Garber and Goldin-Meadow 2002; Goldin-Meadow 2006; Haaland and Flaherty 1984; Hermsdörfer et al. 1996; Kita 2000; Kita and Özyürek 2003; Krauss, Chen and Chawla 1996; Lausberg and Kita 2003; Lausberg et al. 2007; Lavergne and Kimura 1987; Le May, David and Thomas 1988; Liepmann 1908; McNeill 1992, 2005; Müller, 1998; Ochipa, Rothi and Heilman 1994; Parsons et al. 1998; Poizner et al. 1990; Sassenberg et al. 2011; Seyfeddinipur, Kita and Indefrey 2008; Sirigu et al. 1996; Wartenburger et al. 2010). Likewise, it has been demonstrated that hand movements are related to emotional processes and that they may reflect psychopathology (e.g., Berger 2000; Berry and Pennebaker 1993; Cruz 1995; Darwin 1890; Davis 1981, 1997; Ekman and Friesen 1969, 1974; Ellgring 1986; Freedman 1972; Freedman and Bucci 1981; Freedman and Hoffmann 1967; Gaebel 1992; Krout

1935; Lausberg 2011; Lausberg and Kryger 2011; Mahl 1968; Sainsbury 1954; Scheflen 1974; Ulrich 1977; Ulrich and Harms 1985; Wallbott 1989; Willke 1995). Furthermore, hand movements serve to implicitly and explicitly regulate interactive processes (e.g., Birdwhistell 1952; Davis 1997; Dvoretska 2009; Kryger 2010; Lausberg 2011; Scheflen 1973, 1974) and to communicate information (e.g., Cohen and Otterbein 1992; Cook and Goldin-Meadow 2006; Feyereisen 2006; Holle et al. 2010).

Thus, one rationale for the development of the NEUROGES system has been to integrate the existing empirical knowledge on movement types for which the link to specific cognitive, emotional, and interactive functions had already been established, such as for self-touch and stress. These types are suited for diagnostic purposes.

However, as many aspects of the bi-directional link between hand movements and higher cognitive and emotional functions remain to be explored, the NEUROGES system has also been designed to suit exploratory research. First, the anatomy of hand movement behaviour is examined, such as the duration and the sequencing of certain types of movement behaviour. And second, the correlation between hand movement behaviour units and cognitive, emotional, and interactive parameters are investigated (see below). This procedure implies that hand movements are classified first by kinesic features alone, i.e., independently from other functions such as speech.

3. Development of the NEUROGES system

First, a critical review of the existing coding systems in gesture research, psychology, psychosomatics, psychiatry, psychotherapy, neurology, neuropsychology, and anthropology was conducted (e.g., M. Davis 1991; Dell 1979; Efron 1941; Ekman and Friesen 1969; Freedman 1972; Kendon 2004; Kimura 1973a,b; Laban 1988; McNeill 1992; Müller 1998). Among these, only few systems are suited for segmenting the stream of hand movement behaviour and for classifying all hand movements based on kinesic criteria alone. With these aims in mind, the most influential coding systems for the development of the NEUROGS Module I were the coding system by Norbert Freedman (1972), the Movement Signature Analysis by Davis (1991), and the Laban Movement Analysis (1988). For the development of Module III the Efron coding system for gestures (1941) was seminal.

Second, as indicated above, hand movement types were listed for which the association with cognitive, emotional, and interactive processes had been empirically established. Among these were those types that had been explored in the author's neuropsychological studies (see Lausberg this volume).

Based on the literature review and the author's own research, in a process of repeated testing of the categories and values with the aim to classify all hand movements that occurred in a large sample of subjects, three concerted modules were conceptualized. Module I (Kinesics), serves to segment and classify the stream of hand movement behaviour based on kinesic features such as the trajectory and the location where the hand acts. Recent studies indicate that the Module I categories reflect the complexity of cognitive-motor processes and the focus of attention. Module II (Relation between both hands) codes the relation between the two hands during simultaneous moving. The Module II categories reflect interhemispheric coordination and hemispheric dominance. This module enables to investigate the neurobiology of certain hand movement types (see Lausberg this volume). Finally, module III (Cognition/

Emotion) refers to emotional, cognitive, interactive, physical, or practical functions of hand movements. Thus, the NEUROGES coding system comprises a multi-stage evaluation process in which, at each stage, the hand movement behaviour is segmented and classified, resulting in more and more fine-grained units of behaviour.

To ensure the objectivity of the system, the values were operationalized by kinesic criteria. Over time, the process of the increasing operationalization including a repeated testing of the inter-rater agreement resulted in a comprehensive coding manual (Lausberg forthcoming) with an interactive training CD (Bryjovà, Slöetjes and Lausberg forthcoming). In order to structure the evaluation process from module I through module III, algorithms with several decision steps are provided that lead to the correct value for the unit (see Figs. 67.2–67.4 below).

4. Description of the NEUROGES coding system

4.1. Module I: Kinesics

4.1.1. The Activation category (Module I step 1)

In the first evaluation step, the stream of hand movement behaviour – right and left upper limbs, i.e., finger(s), hand, arm, and shoulder – is segmented into Activation units based on the criteria motion, anti-gravity position, and muscle contraction. Two Activation values are distinguished:

(i) *movement*,
(ii) *rest position/posture*

(Fig. 67.2, step 1). The Activation category provides a general Impression of the subject's level of arousal.

4.1.2. The Structure category (Module I step 2)

The *movement* units as identified in step 1 are classified according to the Structure category. The Structure of a movement unit is the "kinesic construction" of the movement. It is defined by the trajectory, by the presence/absence of efforts (Laban 1988), by the presence/absence of hand shaping, and as meta-criteria by the presence/absence of phases and by the position of the unit in the segmented behaviour relative to other units. Five Structure values are distinguished:

(i) *irregular*,
(ii) *repetitive*,
(iii) *phasic*,
(iv) *aborted*,
(v) *shift*

(Fig. 67.2, step 2). If the Structure value changes within the given unit, the unit is segmented into subunits (this priniciple of subunit generation applies to all following coding steps). The Structure category reflects the level of complexity of the motor processes. It ranges from continuous non-conceptual (*irregular*) to discrete conceptual (*phasic*).

4.1.3. The Focus category (module I step 3)

The *phasic*, *repetitive*, and *irregular* units that have been identified in step 2 are further classified according to the Focus. The Focus is defined as the entity that the hand acts on. The Focus category is operationalized by the presence/absence of dynamic contact, the counter-part, and the orientation. Six Focus values are distinguished:

(i) *within body*,
(ii) *on body*,
(iii) *on attached object*,
(iv) *on separate object*,
(v) *on person*,
(vi) *in space*

(Fig. 67.2, step 3). The Focus category reflects the subject's focus of attention. It ranges from internal (*within body*) to external (*in space*).

4.2. Module II: Relation between the hands

4.2.1. The Contact category (module II step 1)

The temporal overlaps of the right hand and left hand StructureFocus units constitute the new units for the module II assessment. For these units, in which both hands move simultaneously, first the Contact category is evaluated. It is operationalized by the presence/absence of physical contact between the hands and the quality of that contact. Three Contact values are distinguished:

(i) *act as a unit*,
(ii) *act on each other*,
(iii) *act apart*

(Fig. 67.3, step 1). The Contact category is related to the coördination between the two hemispheres. It ranges from simple (*act as a unit*) to complex (*act apart*).

4.2.2. The Formal Relation category (module II step 2)

The *phasic* and *repetitive* Contact units are further evaluated concerning the Formal Relation. This category is operationalized by the criteria dominance and symmetry. Four Formal Relation values are distinguished:

(i) *symmetrical*,
(ii) *right hand dominance*,
(iii) *left hand dominance*,
(iv) *asymmetrical*,

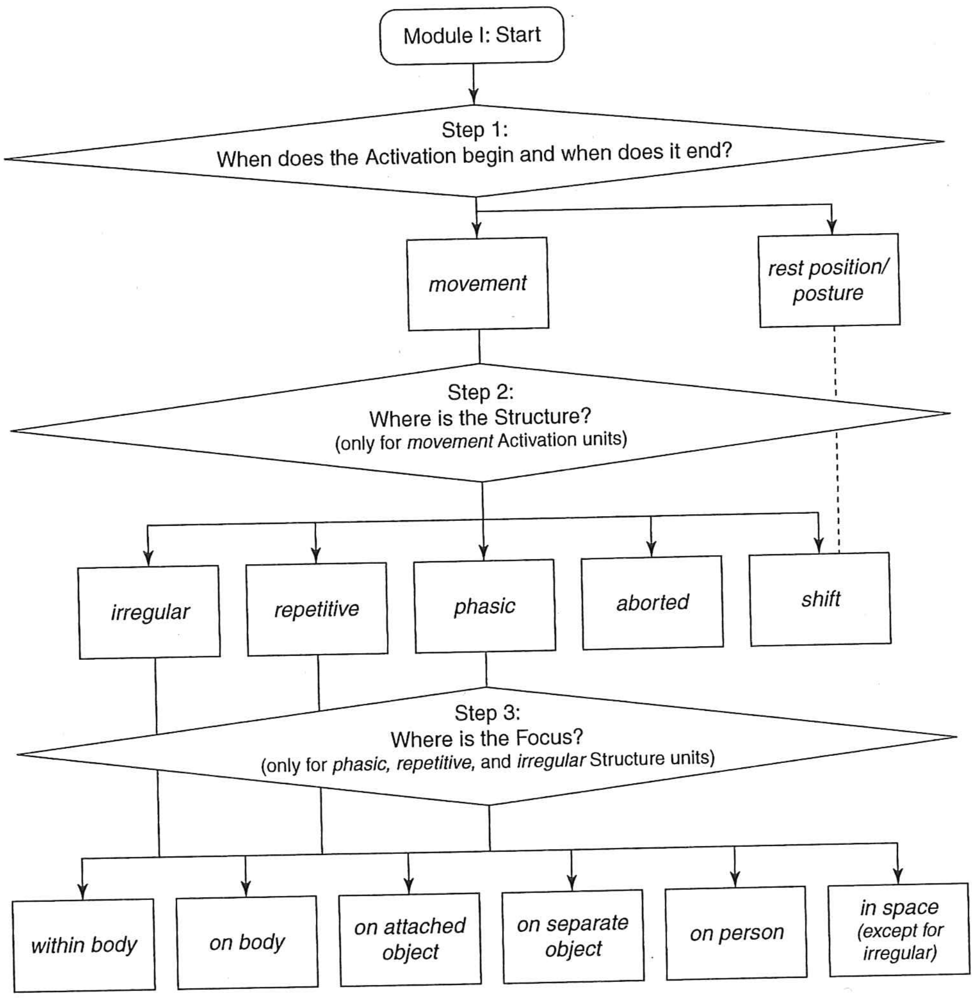

Fig. 67.2: Coding algorithm for module I

(Fig. 67.3, step 2). The Formal Relation category is related to hemispheric dominance. It ranges from no suppression (*symmetrical*) to bilateral suppression (*asymmetrical*).

4.3. Module III: Cognition/Emotion

4.3.1. The Function category

The phasic and repetitive units and the respective bimanual units are submitted to the Function analysis. While in Modules I and II the rater is demanded to focus on specific kinesic features, in Module III the recognition of the Function of a hand movement is demanded. The Function is a complex phenomenon that emerges a cluster of parameters which considers: Structure, Focus, Contact, Formal Relation, body external

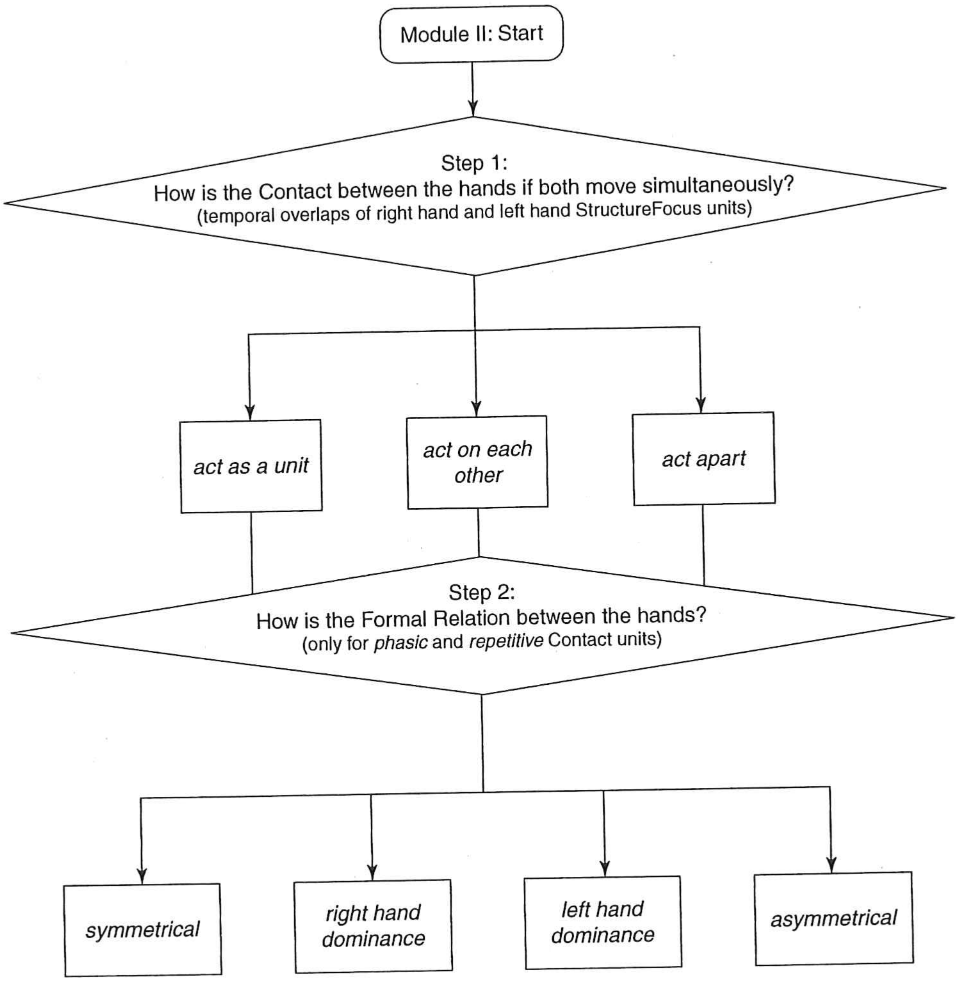

Fig. 67.3: Coding algorithm for module II

space, path during main phase, hand orientation, hand shape, efforts, body involvement, gaze, cognitive perspective (meta criterion), frequency, and duration.

Eleven Function values are distinguished:

(i) *emotion attitude*
(ii) *emphasis*
(iii) *egocentric deictic*
(iv) *egocentric direction*
(v) *phantomime*
(vi) *form presentation*
(vii) *spatial relation presentation*
(viii) *motion quality presentation*
(ix) *emblem*

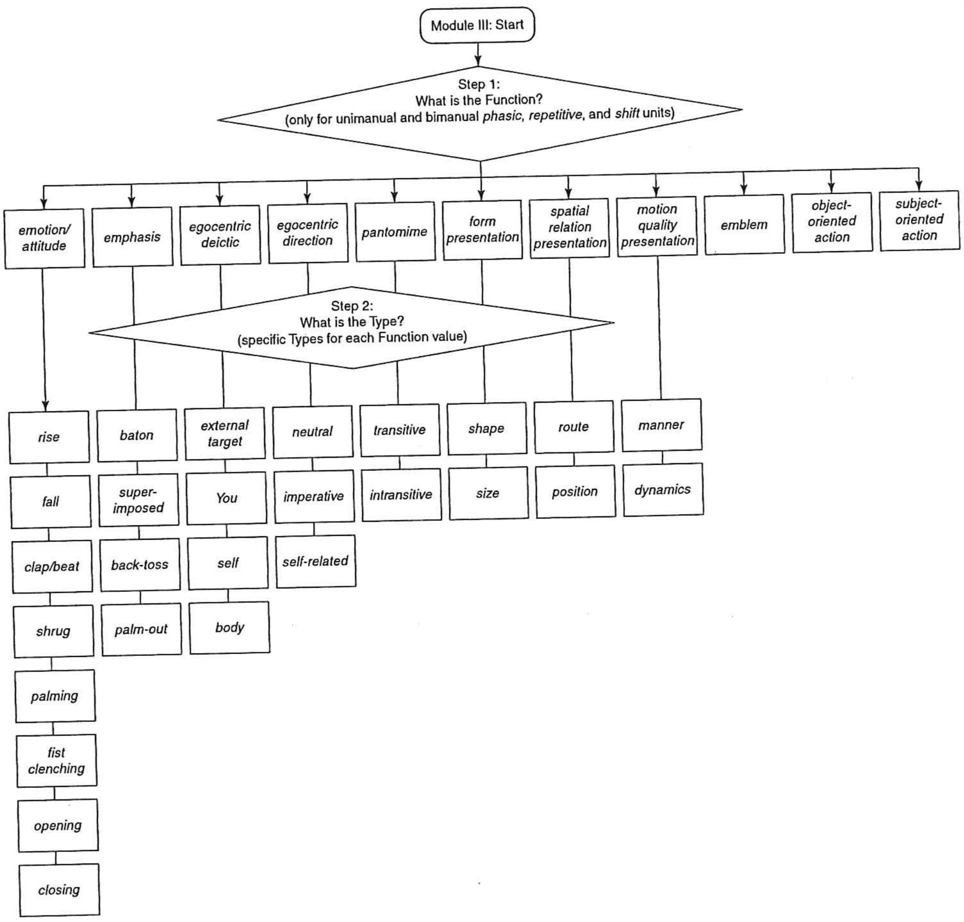

Fig. 67.4: Coding algorithm for module III steps 1 and 2

(x) *object-oriented action*
(xi) *subject-oriented action*

(Fig. 67.4 step 1, top row). The Function category refers to the emotional, cognitive, interactive, physical, and practical functions of hand movements. This definition implies that also those hand movements that are displayed beyond the gesturer's awareness have a function. As an example, a seemingly purposeless *on body* movement may serve psychodynamically for self-regulation.

4.3.2. The Type category

The Type category directly depends on the Function category (Fig. 67.4, step 2). Thus, each Function value. For *emotion/attitude* movements, the Type values refer to the direction of the movement as an embodiment of emotion and attitude. For *emphasis* gestures, the Type values refer to the kinesic form used to create emphasis. For *egocentric deictic* gestures, the Type values specify the target. For *egocentric direction* gestures, the Type values specify the agent who takes the direction. For *pantomime* gestures, they register transitivity. For *form presentation*, *spatial relation presentation*, and *motion presentation*, the Type value classify the physical aspects that are presented in gesture. For *emblems*, instead of specific Type values, a list of commonly used emblematic gestures is provided.

4.4. NEUROGES in combination with the annotation tool ELAN

It is strongly recommended to use the NEUROGES kinesic coding system in combination with the annotation tool ELAN (Lausberg and Slöetjes 2009). For this purpose, the NEUROGES coding system has been transferred into a NEUROGES-ELAN-template.

5. The reliability and the validity of the NEUROGES system

The reliability and the validity of the NEUROGES values were investigated in a meta-analysis on several recent empirical studies using the NEUROGES system including altogether 370 participants (e.g., Dvoretska 2009; Hogrefe et al. under review; Kryger 2010; Lausberg et al. 2007; Sassenberg, Helmich and Lausberg 2010; Sassenberg et al. 2011; Skomroch et al. 2010; Wartenburger et al. 2010). The participants were Germans, U.S. Americans, francophone Canadians, Koreans and Papua New Guineans. In addition to healthy participants, participants with brain damage and mental disorders were examined. Furthermore, neuroimaging and kinematographic studies were conducted to test the NEUROGES values (Helmich et al. 2011; Lausberg et al. 2010; Rein forthcoming; Wartenburger et al. 2010).

5.1. Reliability

Inter-rater reliability was used to assess the quality of the operationalization of the NEUROGES values. As the NEUROGES coding procedure comprises segmentation and classification, the raters' agreement not only concerns the value that is chosen for the unit but also the segmentation, i.e., if the raters agree on when a unit with a specific value starts and ends, when the next unit starts, and ends, etc. Since, thus far, only statistical measures are available which refer to the categorial agreement, Holle and Rein developed a novel algorithm (a modified Cohen's kappa) that takes into account the raters' agreement concerning behaviour segmentation (forthcoming). In the experimental studies that were included in the meta-analysis this novel algorithm was applied. With a few exceptions, for all NEUROGES values the inter-rater agreement was moderate to substantial. Especially with regard to the fact that not only the categorial but also the temporal agreement was considered, this level of inter-rater agreement indicates an overall good objectivity of the NEUROGES values.

Furthermore, to examine intra-rater retest reliability, the same rater coded the same videos with a time interval of 2 years. There was substantial agreement, further indicating a good operationalization of the NEUROGES values.

Kinematography was used to establish parallel-forms reliability. Movement units that had been assessed by raters with the Module I Structure category criteria were analysed with the electromagnetic motion capture system Polhemus Liberty© (Colchester, VT), which records the displacement and orientation (Rein forthcoming). The five structure *values phasic*, *repetitive*, *shift*, *aborted*, and *irregular* (see section 4.1.2.) were reliably distinguished by kinematography and matched the raters' classifications.

5.2. Exploring the validity of the NEUROGES values

5.2.1. The neurobiology of the NEUROGES values

Several studies have been conducted to examine the brain hemispheres and areas involved in the generation of certain NEUROGES values. The studies on split-brain patients as well as the studies on healthy subjects, in which hand preference was used as an indicator of hemispheric specialisation in the generation of certain NEUROGES values, are reported in detail in Lausberg (this volume). Furthermore, neuroimaging studies with functional Magnetic Resonance Imaging (fMRI) and Near Infra-Red Spectroscopy (NIRS) were conducted to investigate the neurobiological correlates of Module III values. The performance of tool use demonstrations, *pantomime–transitive–enclosure* (holding the imaginary object in hand when demonstrating tool use), and *pantomime–transitive–hand-as-object* (the hand itself represents the tool) are accompanied by different cerebral activation patterns (Helmich et al. 2011; Lausberg et al. 2010). While tool use demonstration with tool in hand was accompanied by bihemispheric activation, among the pantomime gestures those with the Technique of Presentation *enclosure* showed a left hemispheric activation and those with the Technique of Presentation *hand-as-object* a right hemisphere activation. In study, in which the structural Magnetic Resonance Imaging was related to hand movement behaviour during a geometric analogy task, a larger cortical thickness in the left Broca's area and transverse temporal cortex was found in participants who produced *presentation* gestures and, in particular, *motion presentation* gestures as compared to those who did not (Wartenburger et al. 2010).

For Module I values, the hemispheric specialisation was investigated in patients with right hemisphere damage (RBD) and patients with left hemisphere damage (LBD) (Hogrefe et al. under review; Skomroch et al. 2010). The left hemisphere damage patients displayed (with their left non-paretic hands) more *phasic* and *repetitive in space* movements than the right hemisphere damage patients (with their right non-paretic hands). In contrast, the right hemisphere damage group displayed a higher amount of *irregular on body* movements than left hemisphere damage patients. The data provide evidence for different neurobiological correlates of *phasic* and *repetitive in space* movements as compared to *irregular on body* movements.

5.2.2. Cognitive and emotional functions

Individuals scoring high in fluid intelligence showed a higher accuracy in a geometric analogy task and produced more gestures (as identified in Module III) when relating to most relevant aspect of the task (Sassenberg et al. 2011). More specificically, their gestural behaviour was characterized by a high amount of *motion presentation* gestures, the use of which implies a non-egocentric cognitive perspective. Currently, the relation between intelligence quotient and hand movement behaviour is further investigated in 85 participants.

Indirect evidence for the association between specific NEUROGES values and specific cognitive and emotional functions is provided by using different experimental settings that challenge the participants differently with regard to these functions. As an example, an intelligence test may require information retrieval or arithmetic abilities, whereas the narration of funny animated cartoons without speech may induce joy and require mental imagery. In the meta-analysis, the pattern of the Structure values differed between the experiments. Experimental settings that induced a pressure to perform (prototyp: intelligence test) were associated with more *irregular* and *shifts* units. In contrast, a high amount of *phasic*, *repetitive*, and *aborted* units and a low frequency of *irregular* and *shift* units were found in experiments that animated the participants (prototype: narration of animated cartoons). The findings indicate a dichotomy between *phasic*, *repetitive*, and *aborted* units on one hand, and *irregular* and shift units on the other with regard to the level of cognitive processing (non-conceptual vs. conceptual). Likewise, for the Focus category a clear picture emerged of *in space* dominant and *on body* dominant experiments. Experiments that elicited visual imagery were accompanied by a high rate of *in space* units. In contrast, stress-inducing experiments were characterized by a high frequency of *on body* units. The finding is in line with the proposition that the Focus *in space* offers the most options for expressive demonstrations whereas the Focus *on body* serves self-regulation.

5.2.3. Personality traits and psychopathology

Dvoretska (2009) examined the relation between NEUROGES Module I and the personality inventory NEO-FFI in 40 males and 40 females, who were videotaped during their dyadic interaction. Neuroticism correlated negatively with the frequency of *phasic* and *repetitive in space* gestures. Furthermore, there was a negative correlation between the amount of agreeableness and the frequency of *on body* movements.

Alexithymia as measured with the Toronto Alexithymia Scale is the inability to verbally express emotions. A study on 33 alexithymic subjects (17 female, 16 male) and 33 non-alexithymic ones (17 female, 16 male) evidenced that alexithymia is associated with gender-specific alterations in hand movement behaviour (Sassenberg, Helmich and Lausberg 2010). While the alexithymic women showed a reduction of *phasic* and *repetitive in space* movements as compared to the non-alexithymic women, the reverse was found for the alexithymic versus non-alexithymic men. Furthermore, more shifts were displayed by the alexithymic men than by the non-alexithymic men, while the reverse was found for alexithymic versus non-alexithymic women.

Kryger (2010) examined hand movement behaviour in the course of two successful psychotherapies in patients with eating disorders. The decrease of *irregular on body* movements correlated with clinical improvement. Furthermore, in one patient, the use of *egocentric deictics* in the course of the psychotherapy was explored as an indicator of changes in the relationship to the significant other (Lausberg and Kryger 2011). At the beginning of therapy the patient had localized her mother in the gesture space close to the body center by using *egocentric deictics*, at the end of therapy she projected her mother distant from her body in the left gesture space. Psychodynamically, at the beginning of the therapy, the patient hardly differentiated between herself and her mother, whereas at the end, the patient experienced herself and her mother as separate persons.

5.2.4. NEUROGES and interactive processes

Since long is has been documented that interaction partners show a temporal attunement of their verbal utterances (labelled "turn-taking" by Sacks, Schegloff and Jefferson 1974). Accordingly, the kinesic interaction can be investigated with NEUROGES in terms of turn-taking, i.e., if the interactive partners' units are *overlapping* or *subsequent* (Lausberg 2011).

The interactive patterns in three patient-therapist dyads in psychotherapy sessions were examined with the NEUROGES extended version that includes head, trunk, and leg/foot movements (Lausberg 2011). In all dyadic interactions, *subsequent* turns were more frequent than *overlapping* turns. If one partner starts to move, it is most likely that she/he starts to move when the other partner has finished or is about to finish his/her movement. However, most importantly, the kinesic turn-taking was not a mere reflection of verbal turn-taking, since not only gestures that accompany speech were analyzed but all discrete movements including self-touches, foot movements, positions shifts, etc. The regularity of the kinesic turn-taking suggests that the interactive partners' movement units are implicit reactions to the each other, i.e., on the kinesic level, there is an ongoing interaction that is partially independent of the verbal interaction.

The *subsequent* studies focussed on the kinesic turn-taking patterns for specific NEUROGES values. The mutual understanding in 40 same-sex dyads (20 male, 20 female) was measured with a self-questionnaire by Denissen (2005) and an observer rating. In the group with good mutual understanding as compared to the group with bad mutual understanding, there were more *overlapping* head movements, less *overlapping* right hand movements, and less *overlapping on body* movements (Dvoretska, Denissen and Lausberg submitted). In the above mentionned study by Kryger (2010) also the kinesic interaction between patients and psychotherapist was examined. Psychotherapy sessions with a high proportion of *overlapping* hand movements that were of the same Structure (Focus) value, e.g. patient and therapist simultaneously performed shifts, were associated with a good therapeutical relationship as assessed by a post-session questionnaire step. In contrast, sessions for with the therapeutical relationsship was considered to be less effective showed a higher proportion of simultaneous hand movements of different Structure (Focus) values, e.g. the patient performs an *irregular on body* movement while the therapist performs a *phasic in space* movement.

Acknowledgments

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68. Transcription systems for gestures, speech, prosody, postures, and gaze

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