Acta Biologica Hungarica 53 (4), pp. 515–536 (2002)

INTEROCEPTION, BODY PERCEPTION AND AWARENESS*

The Heritage of György Ádám

A. MÖLTNER[1] and R. HÖLZL[1,2]**

[1]Laboratory of Clinical Psychophysiology,
Otto-Selz-Institute of Psychology and Educational Science,
University of Mannheim, Mannheim, Germany
[2]Faculty of Clinical Medicine Mannheim, University of Heidelberg, Heidelberg, Germany

(Received: June 5, 2002; accepted: July 1, 2002)

Two series of studies are reported dealing with (1) psychophysical characteristics and (2) interactions of visceroceptive and somatosensoric information processing. The first studies characterized detection, graduation and localisation of visceral as compared to somatic stimuli. The second series investigated somatovisceral discrimination, masking, and summation at different levels of awareness.

Methods: Distension of the sigmoid colon served as standard model. The visceral stimulus was applied by a balloon probe in the sigmoid colon, the external abdominal stimulus by a ring-shaped stimulator at two abdominal sites. A forced-choice-paradigm with two observation intervals was applied (multiple staircase) to estimate interactions between somatosensation and visceroception.

Results: The visceral distension stimulus can be detected or discriminated correctly without conscious sensation. Visceral localization of stimuli requires conscious sensation. Combining visceral and somatic stimuli resulted in distinct elevation of visceral thresholds demonstrating somatosensory masking of the visceral stimulus. There are characteristic somato-visceral and viscero-somatic differences in masking and qualitative differences between implicit and explicit processing stages. Specific electrocortical reactions to visceral stimuli could be shown.

Discussion: Visceroception is represented on the highest functional level as a fairly independent submodality of body perception. There are several hints that visceroception and protopathic somatic sensitivity follow the same major paths and comprise the same ontogenetic origin. Perceptual interactions are determined by modality and awareness and depend on the task. The role of implicit and explicit body perception considering the body self and its significance in the context of consiousness are discussed.

Keywords: Visceroception – somatosensation – somatovisceral masking – somatovisceral summation – multiple-staircase method

INTRODUCTION

In the following we give an account of our former endeavours and of several newer considerations on *psychophysiology of interoception*, precisely *visceroception*, connecting this issue along with *body perception* with *research on consciousness* [1–5].

* Dedicated to Professor György Ádám on the occasion of his 80th birthday.

** Corresponding author; e-mail: hoelzl@psychologie.uni-mannheim.de

Parts of this essay are based on a paper read before the research colloquium of the Institute of Psychology, University of Zurich, Switzerland, January 1999 (printed in Marx 1999).

This makes clear how influential the ideas, experimental methods and results of György Ádám and his colleagues were on us and others in the last five decades of the last century [6a, 6].

Damasio's team stands out from neuroscience literature on cortical body representation. Since the publication of his bestselling book on "Déscartes' Error" in 1994 [7] body perception has been connected with neuropsychology of consciousness constructing the so-called *"body self"* [8]. This construct refers to an integrative centre in the parietal cortex around which body perception and "body feelings" are organized concertedly by the brain. According to Damasio's *"model of somatic markers"* (from subcortical regions, particularly amygdale, basal ganglia and pons) these "body feelings" are supposed to be provided with crucial functions relating to planning and controlling complex action in social context. This requires their processing in an intact frontal lobe, in the foremost medium section between the cerebral hemispheres. The CT reconstruction of the famous patient Phineas Gage is widely known due to the press.

This model puts more emphasis on *visceral feedback*, i.e. afferent signals from the intestines and re-afferent signals from visceral cerebral centres, in *body perception* and *self-regulation* as the prevailing theory of neurophysiology would anticipate. Our intestines even affect our conscious voluntary actions by means of the integrated *body self*. This refers strongly to Kihlstrom's (1997) *"body awareness"* and *"embodied Me"* [9], not only in the sense of *having* and perceiving our body but also that we literally *are* – in a phenomenological way – this body with all its definite and vague emotional states.

The following account of the contributions of interoception research on the problem of consciousness has as its twofold motto:

Table 1

THE HEAD IS HOPELESSLY CONNECTED WITH THE BODY

Thomas Bernhard

– *First*, we would like to demonstrate that indeed the head is an integral part of the body, not only anatomically and physiologically but also on highest brain levels.

Others have given detailed accounts of this issue for the skin and – highly rated in our performance-oriented society – the musculoskeletal system of the tangible body. The reader is certainly familiar with the relevant works of Luria and Geschwind due to Oliver Sacks' popular books [10–12]. Therefore in keeping with the issue on hand, we limit ourselves to the invisible(!) soft parts, those inner organs which until lately were controversial issues: Do they have specific sensorial connections to the cortex and all the more do they play a central role in conscious body perception?

Table 2a

CONTRIBUTIONS OF INTEROCEPTION RESEARCH (I)

1. *Functions of interoception*
   a) Visceral regulation and control
   b) Emotion and laterality
   c) Discriminative functions
2. *Interoception and awareness*
   a) Detection and discrimination vs. sensation
   b) Graduation and sensation
3. *Interoception and somatosensation*
   a) Localization and identification
   b) Somatovisceral masking
   c) Somatovisceral summation
   d) Laterality
4. *Somatovisceral integration and body self*
   a) Viscероception, body scheme and body image
   b) "Higher" functions of somatovisceral signals in planning and executing acts

Table 2b

CONTRIBUTIONS OF INTEROCEPTION RESEARCH (II)

5. *Cortical correlates and neuropsychology of interoception*
   a) Visceral evoked potentials
   b) Neuroimaging of processing afferent visceral signals
   c) Functional anatomy of somatovisceral integration
6. *Psychophysiology and functional anatomy of protopathic and epicritic signal processing*
   a) Functional anatomy of sensory and non-sensory processing modules (Luria, Posner)
   b) Viscероception and visceral control (Dworkin)
   c) Afference, reafference, efference copy and exafference in interoception
   d) Extero-interoceptive integration in protopathic "perception" and in fundamental learning (Konorski, Pribram)
   e) Precognition and affective processing of protopathic body signals in subcortical and paleocortical areas (Lang)
   f) Interoception and "emotional perception"
   g) Character, body representation and "signals from the abdomen" (Damasio, Coubertin)

We will discuss *implicit and explicit body perception*, as well as the *discriminability* of signals from the intestines, viscероception, tactile signals from the skin, and proprioceptive signals from muscles and joints. We will discuss somatosensation and proprioception, and above all the *mutual influences* between viscероceptive and somatosensory signals. Finally we will consider the *role of consciousness* in the light of Damasio's concept.

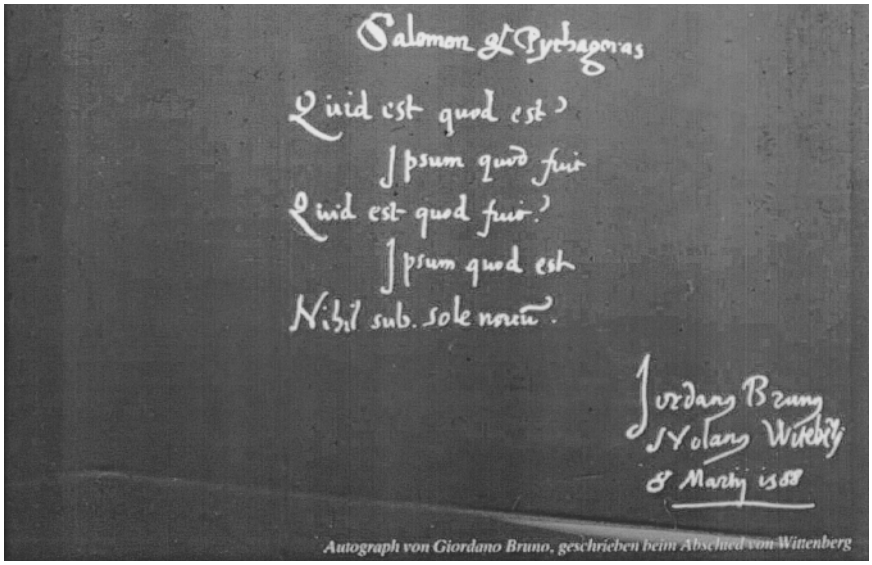

Fig. 1. Giordano Bruno: *Nihil sub sole novum,* or Nothing new from the intestines

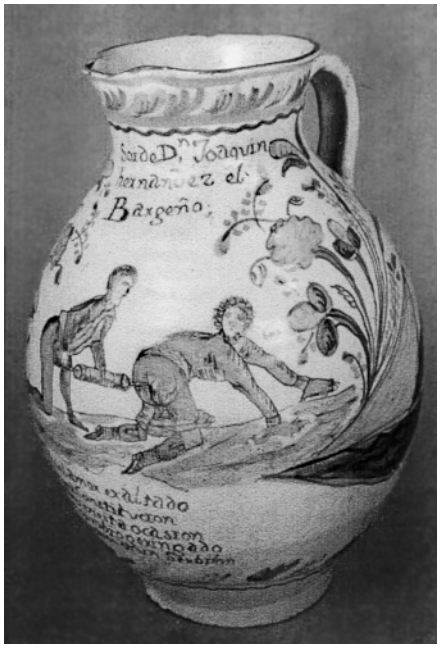

Fig. 2. "The Approach through the visceral back door" (The Enema)

– *Second*, we will show that perhaps there is something new to report from the intestines (?).

Starting from the *head* we now reach the *body*. We approach the body through the *back door* as we did at the Laboratory for Clinical Psychophysiology bearing in mind Freud's old maxim.

Table 3

FLECTERE SI NEQUEO SUPEROS, ACHERONTA MOVEBO*
Vergil, Aeneid, VII
[Motto of "The Interpretation of Dreams", Sigmund Freud (1905)]

Free translation [R.H.]
"If you cannot stimulate the higher regions, you will have to distend the lower ones"

We shall proceed on the back stairs to the intestines and back to the head on the afferent path.

Visceroception and visceral awareness

The psychophysics of visceroception

Those who venture on the *dark side of body perception* must begin with finding an access defining the most elementary relations between stimulus and perception. This implies doing one's homework in psychophysics already accomplished in the field of somatosensory perception.

For this reason we chose the viscera for research, as they are easily reached by appropriate colon stimulation probes through the accustomed body orifices. But there are practical reasons as well along with the clinical role of psychophysiological disorders in the intestines. For technical details one may refer to the original articles. It suffices to remark that we have constructed special intestinal and bladder probes with calibrated distension balloons that enable us to carry out such basic measurements under stable conditions combined with the appropriate adaptive methods, i.e. threshold tracking or staircase procedure [13]. Of course, this took more effort than testing in the auditory, visual or the tactile system, but works on the same principle.

Had we chosen the heart, the favourite organ of psychophysiology, and its perceptions along with its activity we would not have succeeded. The reason is that considering heart perception the stimulus cannot be controlled arbitrarily and supplementary perceptions correlated with spontaneous cardiac activity are measured. You can never be certain which signal sources are involved and, furthermore, psychometric stimulus-perception-curves cannot be measured.

A satisfactory definition of the functional level and the perceptual processing mode resulting in visceroceptive performance can only be obtained by means of the

classical experimental approach. Visceral afferents serve several functions, while most of them are by no means perceptual, e.g. signals from baroreceptors in the carotid sinus to the brain. For our aims no more than perceptual functions are of significance, i.e. effects that suffice the minimal criteria of behaviourally or mentalistically defined perception manifested in behaviour or language [14, 15].

For the moment it remains undecided whether the behavioural discrimination of visceral events is accompanied by explicit, i.e. conscious and verbal, perceptions or whether implicit interoception is feasible without subjective perception. To be more precise the performance of processing has to be considered on various levels of perception and the information extracted by the subject in a given tasks has to be specified. Only then it is possible to wonder what conscious sensation entails.

This extract from Luria's [16] famous case report exemplifies this issue best.

Table 4

"STAGES OF AKTUALGENESE"
OF VISCEROCEPTION SUBSEQUENT TO BODY SCHEMA DISTORTION

"During the night
1 I *suddenly woke up* and had
2 *a sensation of pressure in my abdomen.*
3 *Something* stirred inside but it wasn't that I had to urinate –
4 It was something else. But what? I simply could not
5 *identify* it. Meanwhile the pressure in the abdomen
6 *got stronger* every minute. Suddenly I realized that
7 had to go *to the toilet*
8 I *just did not know how.* I was aware of the organ with which I could urinate, but this pressure
9 was *on another orifice* only that I did not know
10 *what it was used for".*

[Luria (1972), P.45; translation by the authors]

Table 5

PROCESSING STAGES OF PERCEPTUAL SIGNALS

PROCESS Processing Performance	TASK Information Extracted
Detection	Has a (relevant) event happened? – sensory event – change of state
Localization	Where is it? – internal, external, somatic – spatial data, distance – body-part, (visceral) organ
Graduation	How big (strong, intense) is it?
Identification	What (how) is it (like)? – sensory quality – object and visceral event identity
Relevance	What has to be done?

The relatively highly dissolved intensity of visceral distension afferents from evacuation organs does not imply that it would be feasible to identify the somatic sites or even more so the implication of the perception. The description of this patient shows in which qualitatively different stages of processing interoceptive experiences occur above the actual detection threshold and where psychophysical measurements are to be directed to.

Table 5 does not describe all stages our patient had passed through in this memorable night but merely those considered the minimal stages of perception.

Detection, graduation and localisation

Recently we studied under which conditions these various stages of perceiving experimental distension stimuli within the inner organs are attained and how discrimination performance relates to open behaviour implicitly and to perception explicitly.

The distension of the sigmoid colon served as a standard model. Contrary to the somatosensory innervated rectum the sigmoid colon has distinctive visceral afferents to the CNS. In subsequent studies we included the bladder.

A forced-choice-paradigm with two observation intervals (A exclusively or B) was applied in which the subject is forced to decide in which interval the stimulus has occurred. This task is embedded in a continuous tracking method called multiple

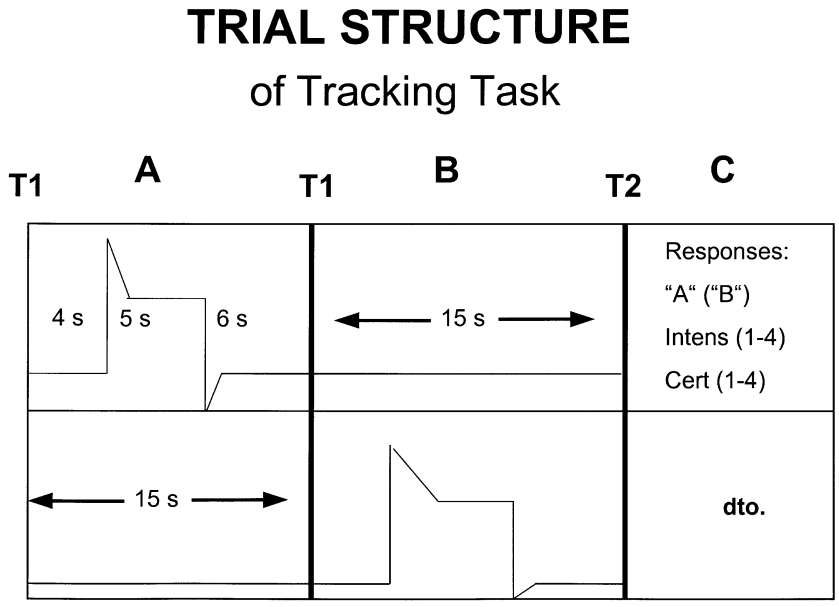

Fig. 3. 2I-FC-procedure measuring sensation intensity and confidence in judgement (trial structure) [1]

staircase adapted from Békésy in which the intensity of the stimulus is tracked up or down depending on the subject's discrimination response. This method is well known in auditory threshold estimation. It controls for instationarities of perceptual thresholds over prolonged periods of testing. Subsequent to the discrimination of the intervals the subject estimates the intensity felt and his certainity in judgement in each trial. This allowed concurrent testing of discrimination with or without sensation.

In this context we only consider the interactions between somatosensation and visceroception and therefore cite two results of the first series of trials without going too far into detail:

1. The visceral distension stimulus can be detected or discriminated correctly without conscious sensation

That is, detection thresholds in forced-choice-paradigms are well below sensation thresholds. This is no surprise and it may imply that discriminating in a forced-choice-paradigm is subject to laxer rating criteria compared to reported perception. The greatest proportion of over 50 subjects is able to discriminate rather precisely (60–90% hits) even without any sensation when instructed to guess if necessary. In subsequent interviews the subjects substantiated that they had felt no conscious sensation. This agrees with the fact that certainity in judgement in trials equals zero in a great proportion of hits.

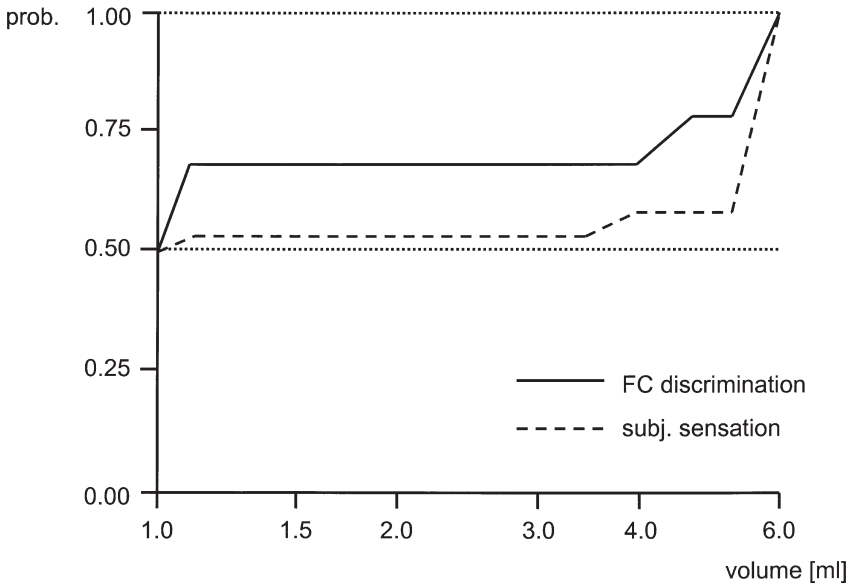

Fig. 4. Detection without graduation, sensation with graduation [4]

Qualitative differences in psychometric characteristics of both response modes are the soundest evidence for implicit processing stages: Prior to sensation discrimination performance rises well above random events with elevation of stimulus intensity and only improves again in the presence of conscious sensation. From then on discrimination and sensation curves run simultaneously.

Detecting low intensity interoceptive stimuli below sensation thresholds may depend on sensorial processes that are either not or only faintly connected. Graduating processes of stimuli requires a second subsequent perceptual process triggered only at higher intensities when conscious sensations occur as well. To our knowledge this is unheard of in classical somatosensation.

2. Visceral location of stimuli requires conscious sensation

This may be a surprise to those only who believe – as most physiologists do – that discriminating pain in the epigastrium or hypogastrium, satiety and nausea may only be possible at rather coarse intensities. The very early findings of György Ádám made plausible that dogs and human beings alike are indeed able to discriminate between stimulations of two balloons in the intestine located only 10 cm apart, provided that the appropriate task is presented [6a].

A very heroic colleague of ours has constructed a three-balloon-probe for visceral discrimination in the sigmoid colon as well as the so-called multiple staircase procedure on the basis of multiple-interval-tasks designed to check Ádám's experiments. The results were quite amazing: estimating site hit rates under forced-choice-para-

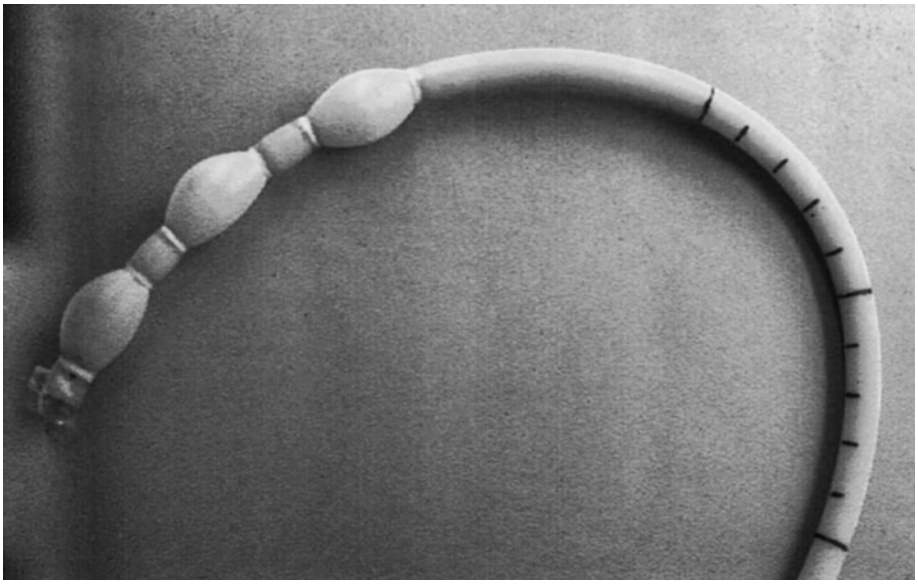

Fig. 5. The three-balloon-probe according to Erasmus (1993 [13])

digm our subjects were indeed capable to discriminate between distensions of two balloons – 12–14 cm apart (both outer balloons in the picture) – in the sigmoid colon close to sensation thresholds. Below this distance hit rates varied randomly (discrimination between an outer and a middle balloon).

Intensity thresholds discriminating between sites are well above simple stimulus detection thresholds, indeed as high as sensation thresholds! Conscious sensation even occurred with the greatest proportion of correct localisation hits.

Localising visceral stimuli requires conscious sensation analogous to intensity graduation. Both processing performances relate to explicit perception of visceral stimuli. Detection and chronological discrimination can be managed on the implicit stage.

Visceroception and somatosensation

Considering Damasio's concept of "body self" and the model of "somatic markers" it is crucial to identify the functional level on which visceral and somatosensory afferents are integrated as well as to determine the quantitative dynamics of their interactions on various levels.

Table 6

INTERACTIONS BETWEEN SOMATIC AND VISCERAL SIGNALS

1.	*Intermodal Discrimination* Two-Interval-Task, Dual Staircase: Direct somatic-visceral comparison
2.	*Somatovisceral Masking* Two-Interval-Task, Fourfold-Staircase: Stimulus Detection & Identification
3.	*Somatovisceral Summation* Two-Interval-Task, Fourfold Staircase: Stimulus Detection alone

First, it has to be established to which extent afferent visceral signals on the perceptual level can be discriminated from somatosensation from the body (there are neurophysiologic as well as clinical reasons to be in serious doubt).

Second, it has to be established which sensorial and perceptual interactions, particularly masking and summation, exist between both afferents.

Third – and this is most central to our discussion – it has to be established whether somatovisceral interactions on the functional level of implicit and explicit processing differ, i.e. whether mutual masking varies when single stimuli are sufficient for discrimination other than for conscious sensation.

Starting our experiments we did not have any knowledge relating to the third issue, while there were neurological or neurophysiologic hints relating to the first

two questions. In this respect we were little better off than the first neurologists and neurophysiologists such as Head, Luria and others [16–18]. The last series of experiments therefore focused on the issue whether somatovisceral interactions depend on awareness [2]. The results of these experiments will be discussed in conclusion.

Somatovisceral (intermodal) discrimination

The simplest relation is in the discrimination between a somatosensory stimulus in a body site and a stimulus from a neuroanatomically assigned visceral section as compared to directly. Considering this assignment the usual somatotopic organisation of the spinal chord and its extension to the CNS is applied.

The previously described experiment on localising visceral stimuli comprises discriminability of somatosensory and visceral stimulation due to the fact that discriminating between an inner stimulus and a tactile stimulus on the abdomen in the corresponding spinal zone is applied as a reference. As a result discriminating between two distension sites in the same stimulus mode – the visceral mode – in fact requires intensities satisfying conscious sensation. This finding does not extend to the discrimination between a (somatosensory) tactile stimulus on the abdomen and an inner (visceral) tactile stimulus.

According to our findings this might imply that explicit perception would not be imperative for this procedure of somatovisceral site discrimination in contrast to discrimination between visceral sites. This is not plausible at all. The simplest explanation would be that site discrimination does not apply within one modality but within viscероceptive and somatosensory submodalities – probably on the implicit processing level as well.

Therefore, body perception does not occur in one single modality. Neurophysiology of the involved sensorium supports this interpretation. Head's experiments at the beginning of last century made clear that visceral afferents do not follow the fast nerve paths carrying tactile information through the spinal chord via thalamus up to the sensorial cortex (S[I]). In contrast, they follow slow, phylogenetically older paths which are followed by some pain fibres. Head categorized the related sensations as "protopathic" (tactile) and "epicritic" perceptions. Both somatosensory submodalities can be differentiated in perception according to our findings. This is of importance relating to somatovisceral interactions discussed in the next section.

Somatovisceral masking

In direct comparison both kinds of stimuli were assigned to one of both intervals. Subjects were asked to decide whether the stimuli in both intervals varied in intensity. Distinct information has to be extracted from afferent signals when stimuli occurred in both intervals and subjects were asked to explicitly identify the intervals of the visceral stimulus and somatic stimulus. Presenting an appropriate combination

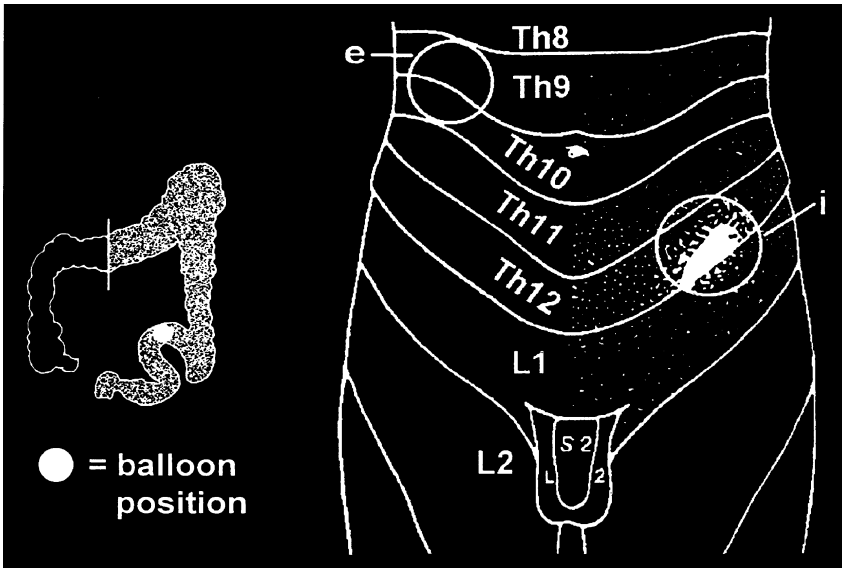

Fig. 6. Stimulation sites in somatovisceral interactions studies

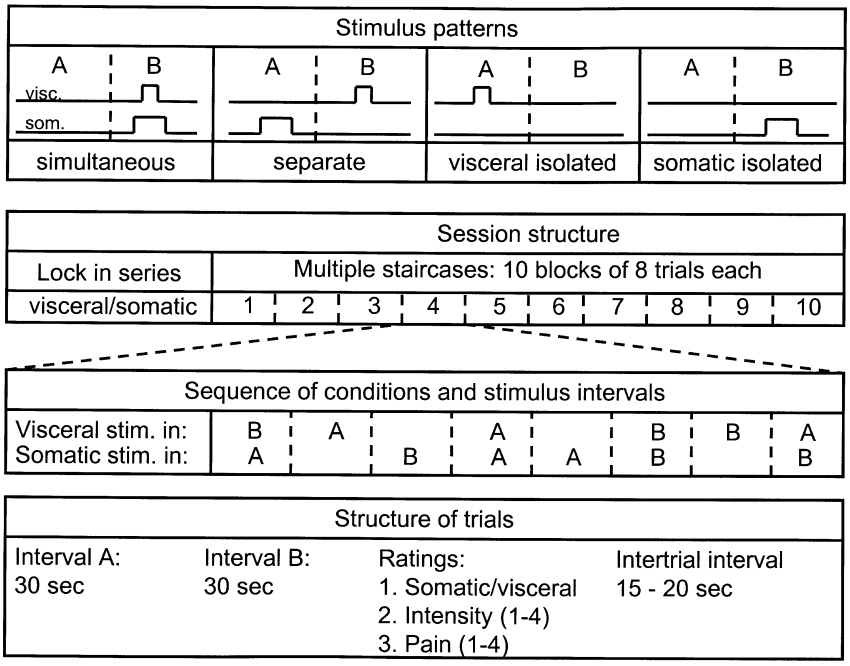

Fig. 7. Trial structure of concurrent somatovisceral masking procedure

of stimuli and tasks this leads to masking or summation. These tests were put into practice by two-interval-tasks and multiple staircase procedure.

Figure 6 illustrates the stimulation sites we used for somatovisceral interactions studies (in the previously described discrimination study we used the same sites): The visceral stimulus was applied by a balloon probe in the sigmoid colon, the external abdominal stimuli by a ring-shaped stimulator at two abdominal sites, one within, the other outside the abdominal reference zone from which visceral and somatic afferents converge at the same spinal level [19].

Masking was assessed as change in visceral and somatic thresholds under various combinations of somatovisceral stimuli. Figure 7 illustrates the design:

1. Visceral distension "isolated" (*"visceral isolated":* third frame in Fig. 7)
2. abdominal pressure "isolated" (*"somatic isolated":* fourth frame in Fig. 7)
3. visceral and abdominal stimulus overlapping (*"simultaneous":* first frame in Fig. 7)
4. visceral and abdominal stimulus combined, but in separate observation intervals as control (*"separate":* second frame in Fig. 7)

The subject is asked in which of the observation intervals the visceral and the abdominal stimulus occurred. Subjects are told us that the stimuli may occur in the same interval, but they are not told us which combination may be presented. The intensity is adjusted in the next trial depending on hit or miss of the subject for the particular stimulus.

As one can see from the group trackings in Fig. 8, combining visceral and somatic stimuli resulted in distinct elevation of visceral thresholds, but not in the separate combination in both observation intervals which gave the same thresholds as when

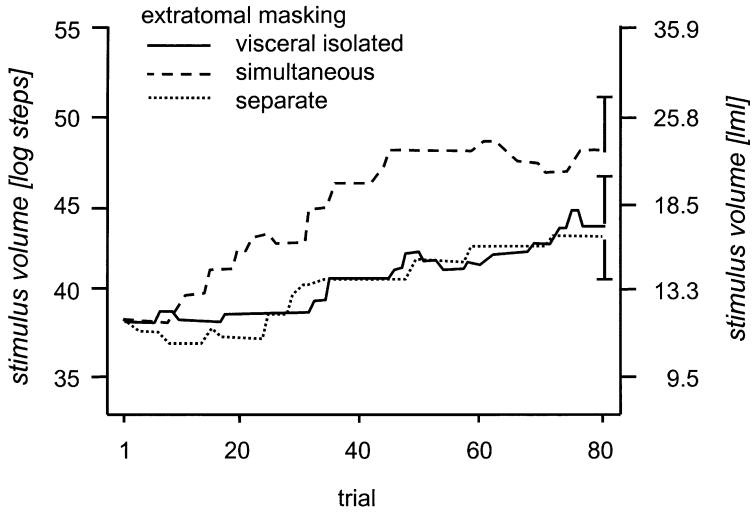

Fig. 8. Mean tracking curves in masking condition

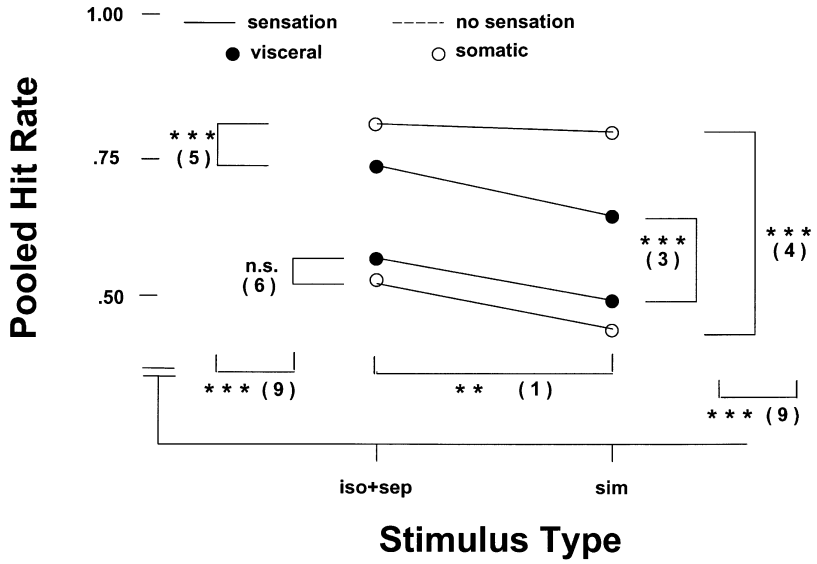

Fig. 9. Discrimination, sensation and somatovisceral masking

the visceral stimulus was presented alone. This demonstrates *somatosensory masking of the visceral stimulus*.

Secondary effects such as distraction and associative combination in the course of long series of hundreds of stimuli may be excluded, due to the fact that control conditions with diachronically presented stimuli ("separate") did not produce masking. Genuine sensorial or perceptual interactions were to be established.

There are two interesting aspects in the results of this study which differ from other masking experiments in exteroception:

First, the masking relation is asymmetric, that is, the abdominal stimulus is not masked by the visceral stimulus whose threshold is not increased under simultaneous condition. There is no indication that distraction effects occurred.

Second, the masking effect on the visceral stimulus is not greater when the abdominal stimulus is presented within the spinal reference zone as compared to outside. Somatosensory input from the somatovisceral reference zone in the left hypogastrium does not mask more intensively than somatosensory input from the right epigastrium.

This shows that the effect is not produced in the spinal chord where according to the doctrines of physiology afferents from the intestines converge as somatosensory afferents from the abdominal reference zone do (You may recall the previously mentioned Figure). According to this doctrine plain viscerоceptive neurons that are not simultaneously fed from receptors in the skin or the abdominal musculature do not exist. The effect in our findings is unmistakeably produced supraspinally – we even

suppose in the somatosensory cortex, S(II), and insula, although this is not substantiated by our findings alone.

Third, and most important, there are *specific differences* in visceral and somatosensory discrimination performance when the subject had also had a conscious sensation as compared to when he had not.

A more precise analysis of hit and sensation rates in both channels under various stimulus conditions can be obtained by means of log-linear-models. Interactions between conditions can be estimated and controlled for effects from pure intensity variations of stimuli. I may add that this analysis was only feasible by means of multiple staircase procedure permitting the necessary trial amount under more or less stationary conditions and controlling for instationarities of thresholds.

The results are shown in Fig. 9. There are quantitative and qualitative differences between viscerception and somatosensation under different awareness conditions:

– In Fig. 9 a global difference between hit rates with or without sensation in both modalities can be observed. As one would expect, stimuli with conscious sensation were better discriminated.

– This difference under awareness condition is smaller for the visceral stimulus than for the abdominal stimulus – as previously shown, discriminating colon stimuli does not depend on sensation.

– These differences become more clearly considering masking with a concurrent stimulus from the other channel: As long as the abdominal stimulus is sensed consciously a simultaneously presented visceral stimulus will lead to no effect. The vis-

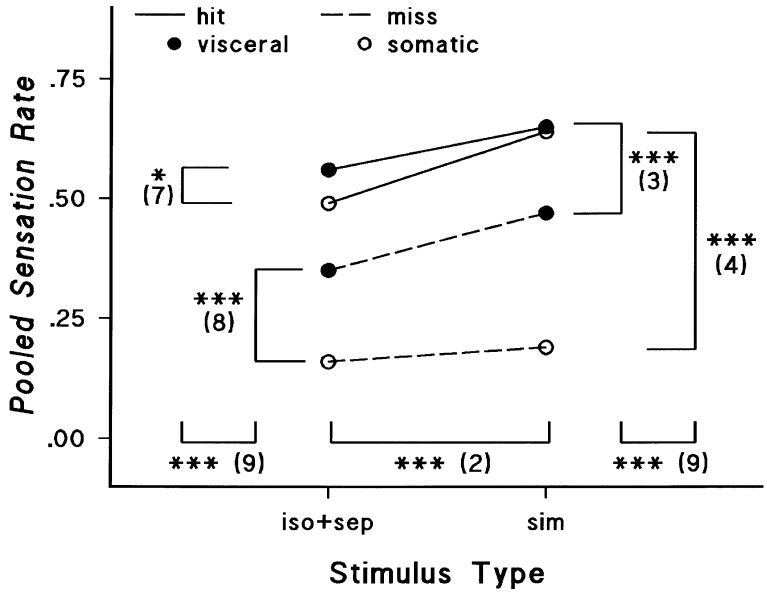

Fig. 10. Sensation and discrimination

ceral stimulus is discriminated poorer when simultaneously a somatic stimulus is presented. The subsequent sensation presumably is due to confounding with the somatosensory channel.

– Without sensation hit rates for both channels with concurrent visceral and somatic stimulation are based on chance.

Complementary specifica appear when sensation rate is considered a function of hits or misses of the forced choice discrimination which is illustrated in Fig. 10 without going too much into detail.

Sensation of the visceral stimulus rises higher than sensation of the abdominal stimulus under concurrent conditions, particularly when subjects produce misses (dashed lines between full circles, Fig. 10). Presumably, sensation originating from somatic afferents is attributed more easily to visceral stimuli. Somatosensory sensation cannot be deceived in this way (dashed lines between open circles, Fig. 10).

The details would lead too far here. It will be sufficient for the present purpose to note that, *first*, there are characteristic somato-visceral and viscero-somatic differences in masking, and, *second*, there are qualitative differences between implicit and explicit processing stages.

Somatovisceral summation

The second possible interaction between both submodalities of body perception, i.e. somatovisceral summation, was studied with an analogous procedure.

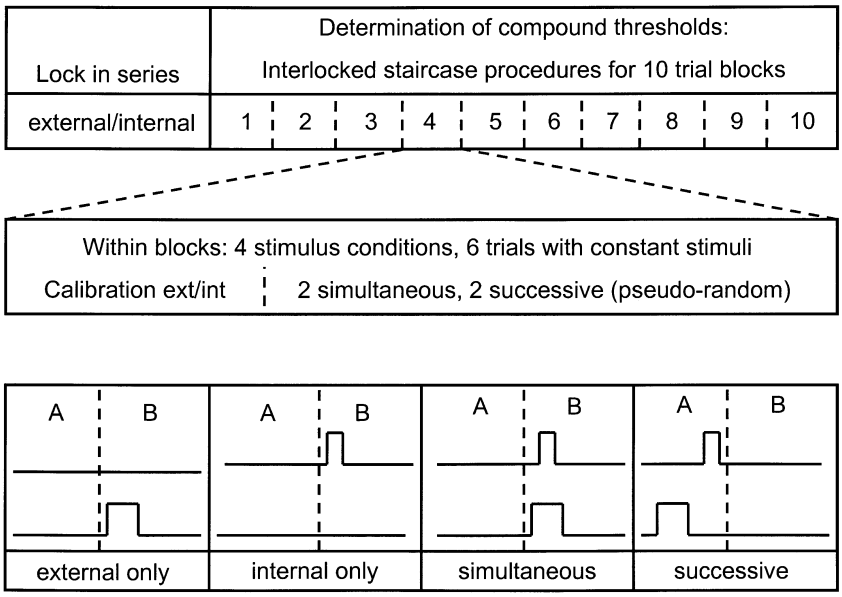

Fig. 11. Multiple staircase of somatovisceral summation (trial structure)

In the summation task the subject is not to identify the sensory mode or channel (visceral or somatic) as in the masking condition but he has only to detect any stimulus at all and to discriminate the observation interval in which the stimulus occurred. In this case internal (viscероceptive) and external (somatosensory) signals may be combined to increase detection rates when presented in combination.

This is in fact the case and thresholds drop while hit rate increase. These findings do not occur under control conditions (successive presentation) when both stimuli are presented diachronically within the same interval controlling for summation of afferent signals during input. This excludes interpretations plainly attributing raised hit rates to summation of independent contribution of information of the visceral and abdominal stimuli.

The interesting thing is that in this condition no decoupling of sensation and discrimination takes place and visceral and somatic discrimination do not differ in this respect: Hits without sensation in the visceral and somatic channels alike are based on chance.

Cortical correlates

Considering perception of visceral and somatic stimuli combined with specific signals from different afferent channels the task of the brain is to extract task-specific partial information from the *overall pattern.* There is every indication that task-specific processing is not entirely based on sensorial effects.

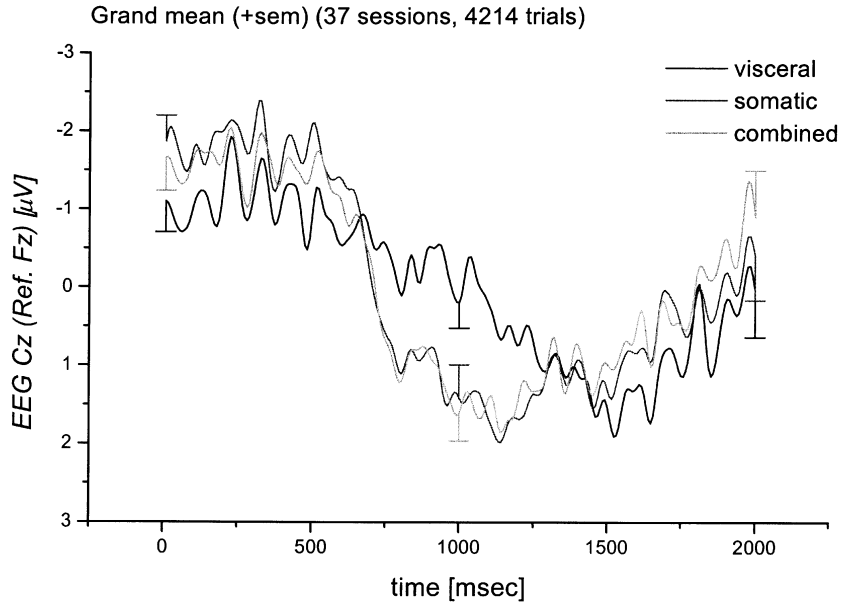

Fig. 12. Visceral evoked potentials with or without somatically evoked potentials

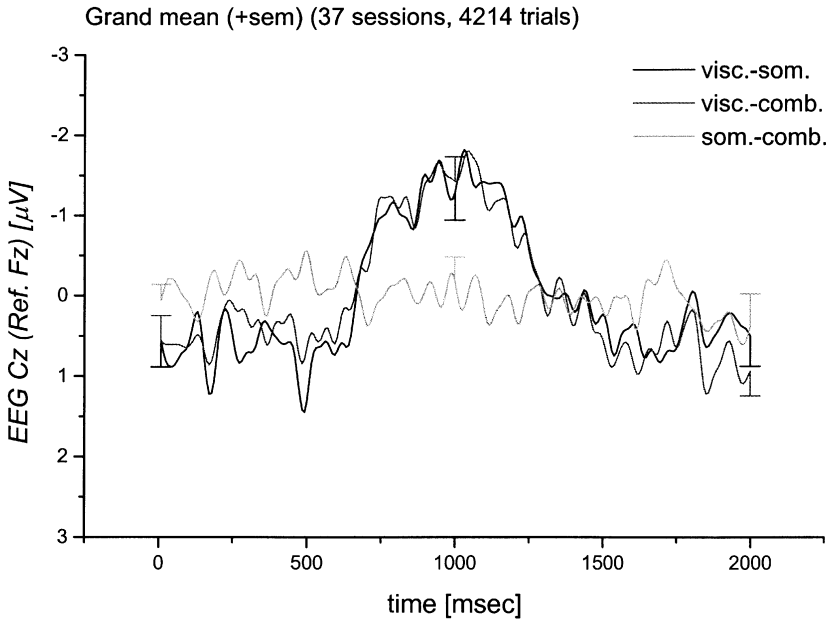

Fig. 13. Cortical viscero-somatic differential potentials

At this point functional black-box analysis undoubtedly reaches its limits. Some time ago by means of electrophysiological recording (event-related potentials) we started to determine what the brain actually views when viscera are stimulated, respectively whether visceral evoked potentials can be discriminated from somatosensory evoked potentials. Provided that visceroception is an independent submodality this should be accomplished. Unfortunately, this turned out to be awfully strenuous, even more strenuous than psychophysics of the intestines.

Contending several methodical difficulties we indeed found specific electro-cortical reactions on stimulating the intestines and the bladder which could be discriminated from somatosensory potentials [20]. Figure 12 illustrates results from a study in which we presented visceral and somatic stimuli separately and combined with the aim of differentiating the components.

Figure 13 shows that there are early and very late reactions that do not occur in somatosensation. This complies with our concept of a visceral channel as an archaic and slow submodality relating to the slow pain channel of protopathic body perception according to Head, Konorski and Pribram.

CONCLUSION

These fundamental studies provide us with important consequences of general significance:

Table 7

CONCLUSION

1. Two steps of stimulus processing
   – not intensity based and
   – intensity based mode
2. Implicit stimulus detection without sensation
3. Localization and graduation of intensity with sensation alone
4. Individual differences of transition
5. Somatovisceral discrimination without sensation
   – from detection to graduation
   – of the output-characteristics
6. Differences in somatovisceral masking with and without sensation
7. No differences in summation with and without sensation
8. Effect of the perceptual task

It has been established that viscerоception is represented on the highest functional level as a relatively independent submodality of body perception. It also presents mode-specific differences between implicit and explicit perception (with or without awareness) which do not exist in epicritic somatosensation.

An evaluation of protopathic somatosensation would require neuropsychological assessment of corresponding neural lesions analogous to Head's classical neurological studies. We have not been able to accomplish this task so far, although this issue would be of particular importance to our clinical purposes. We do presume that there is a strong relation due to the recently isolated electro-cortical correlates.

Furthermore, there are several hints from neurophysiology and genetic biology that viscerоception and protopathic somatic sensitivity do not only follow the same major paths but also comprise the same ontogenetic origin.

Taking into account the previously described interaction studies we can conclude in particular that perceptual somatovisceral interactions are determined by modality and by awareness as well.

We can also conclude that these interactions are not only sensorial but also depend on the task (the "set"), i.e. they depend on the information the brain extracts from both afferents via somatosensory epicritic and interoceptive protopathic paths under predetermined instructions. In our case processing the dual inflow from the body depends on instructing (!) the subject to discriminate between both parts (this leads to an interference with the concurrent epicritic signal having a stronger path to the cortex) or on instructing the subject to combine both signal components to improve

discrimination. The latter might only succeed on the explicit level, the former proceeds on the implicit level as well (without awareness).

This is the kind of experimentally specifying somatovisceral dynamics on different functional levels we think is necessary, if talking about functions of awareness in the context of body perception is to become more than a *façon de parler*. We then can turn to cerebral fundamentals of these performances with a better "feeling"-within the meaning of the somatic-marker-theory of cognition.

Subcortical structures are no longer considered the site of these extensive perceptual differentiations. Such specifications in performance cannot be conceived of without the neocortex and the somatosensory cortex, at least. We even presume that executive and integrative functions in body perception do play an important role. How far we actually reach the level of integration of Damasio's body self remains doubtful. It also remains uncertain whether we have finally reached the entrance via the back stairs. At least we seem to have ended up inside the head and we did not promise more than that.

Perspectives

We are now certain that in case of successfully creating an extensive model of body perception and its highest level of integration in the body self we cannot do without integrating the results of interoception research of the last three decades combining those findings with established neuropsychological knowledge on central body representations. Since the 1990s the expedient significance to understand common disorders in perception and in the regulation of somatic processes has been recognized progressively.

This applies to clearly defined disorders of visceral control subsequent to peripheral and central neural lesions, to paraplegia, to stroke patients, and to elder people as well as to rather "soft" somatic symptoms presented to us by psychosomatic patients for which physicians cannot find an apparent organic cause.

It may become apparent especially for psychosomatic symptoms – today rather dismissed as *somatization disorder* or *somatoform symptoms* to the realms of hypochondriasis – that their indistinctness and variability are not indicative of a lacking somatic cause but are a *form of expressing perceived* pathological states in the represented body with all its concrete and indistinct positive and negative emotional states which we only start to understand.

The major characteristic of protopathic perception is its very susceptibility by non-sensory aspects, above all by affective evaluation – pain is the best example. If we can show similar aspects for the pathology of sensations from the intestines, we will link our fundamental studies with psychophysiological mechanisms of *symptom perception* – one of the urgent issues in psychosomatics. We hence plead for their de-psychiatrization and their assignment to clinical neuroscience.

Table 8a

PERSPECTIVES ON APPLICATION

1. *Somato-Psychic Comorbidity*
   a) Anxiety Disorders and visceral perception
   b) Depression and somatic symptoms
   c) Symptom perception, "somatization disorders" and hypochondriasis
2. *Disorders of body regulation*

Interoception and Biofeedback

Specific disorders of visceral regulation and visceroception
   a) Disorders of visceral perception and regulation in neurological diseases and trauma
3. *Chronic pain*
   a) Visceral Pain Syndrome
   b) Chronic Pain and ANS?

Table 8b

PERSPECTIVE ON SYMPTOM PERCEPTION

Sometimes the patient experiences
A mysterious discomfort.

Is it the head? The heart? The abdomen?
Does the beer disagree with him?

These difficult diagnostic questions
Cannot be answered by the doctor either.

[Volker Kriegel, Neues vom Bären, 1998; NB5, 12.12.1998; translation by the authors]

ACKNOWLEDGMENTS

Supported by grants Deutsche Forschungsgesellschaft (German Research Council), Germany (reference Ho 904/8), and the Ministry of Science and Research, Baden-Württemberg, Germany (Research Priority Programme 2001). English translation was kindly delivered by Alexandra Bernhardt, with kind support of Dagmar Baus.

REFERENCES

1. Hölzl, R., Erasmus, L.-P., Möltner, A. (1996) Detection, discrimination and sensation of visceral stimuli. *Biol. Psychol. 42,* 199–214.
2. Hölzl, R., Neidig, C. W., Erasmus, L.-P., Möltner, A. (1998) Somatovisceral interactions in visceral perception: Abdominal masking of colonic stimuli. *Integr. Physiol. Behav. Sci. 33,* 264–279.
3. Erasmus, L.-P., Neidig, C., Möltner, A., Hölzl, R. (1996) *Beeinflussung der viszeralen Sensibilität durch somatosensorische Signale. Teil II: Summation.* Forschungsberichte aus dem Otto-Selz-Institut für Psychologie und Erziehungswissenschaft der Universität Mannheim: Nr. 28.
4. Hölzl, R., Möltner, A., Neidig, C., Kleinböhl, D. (1996) Merkmale und Kriterien interozeptiver Wahrnehmung. In: Mandel, K. (ed.) *Bericht über den 40. Kongress der Deutschen Gesellschaft für Psychologie.* Hogrefe, Göttingen.

5. Hölzl, R., Möltner, A., Neidig, C. W. (1998) Body perception and consciousness: contributions of interoception research. *Acta Biol. Hung. 49,* 77–86.
6a. Ádám, G. (1967) *Interoception and behaviour. An experimental study.* Akadémiai Kiadó, Budapest.
6. Ádám, G. (1998) *Visceral perception: Understanding internal cognition.* Plenum, New York, London, Washington, Moscow.
7. Damasio, A. R. (1994) *Descartes' Error. Emotion, reason and the human brain.* Grosset/Putnam, New York.
8. Damasio, A. R. (2000) *The feeling of what happens. Body and emotion in the feeling of consciousness.* Heinemann, London.
9. Kihlstrom, J. F. (1997) Consciousness and me-ness. In: Cohen J. D., Schooler, J. W. (eds) *Scientific approaches to consciousness.* Lawrence Erlbaum Associates, Hillsdale, pp. 451–468.
10. Sacks, O. (1984) *A leg to stand on.* Duckworth, London.
11. Sacks, O. (1985) *The man who mistook his wife for a hat.* Duckworth, London.
12. Sacks, O. (1995) *An anthropologist on Mars. Seven paradoxical tales.* Knopf, New York.
13. Erasmus, L. P., Püll, O., Kratzmair, M., Hölzl, R. (1994) Method and apparatus for pressure-controlled distension of the lower gastrointestinal tract. *Med. Engin. Phys. London 16(4),* 338–347.
14. James, W. (1890) *Principles of Psychology.* Macmillan and Co. Ltd., London.
15. Skinner, B. F. (1938) *Science and human behavior.* Free Press, New York.
16. Luria, A. R. (1972) *The man with a shattered world.* Basic Books, New York. [Orig Moskau 1968].
17. Head, H. (1893) On disturbances of sensation with especial reference to the pain of visceral disease. *Brain 16,* 1–133.
18. Mackenzie, J. (1893) Some points bearing on the association of sensory disorders and visceral disease. *Brain 16,* 321–353.
19. Cervero, F. (1994) Sensory innervation of the viscera: peripheral basis of visceral pain. *Physiol. Rev. 74,* 5–138.
20. Möltner, A., Kleinböhl, D., Schellberg, D., Hölzl, R. (1997) *Kolonisch und abdominal evozierte kortikale Reaktionen in Abhängigkeit von physikalsichen Reizparametern und der subjektiven Empfindungsstärke.* Forschungsbericht aus dem Otto-Selz-Institut. Mannheim, Universität Mannheim: Nr. 45.