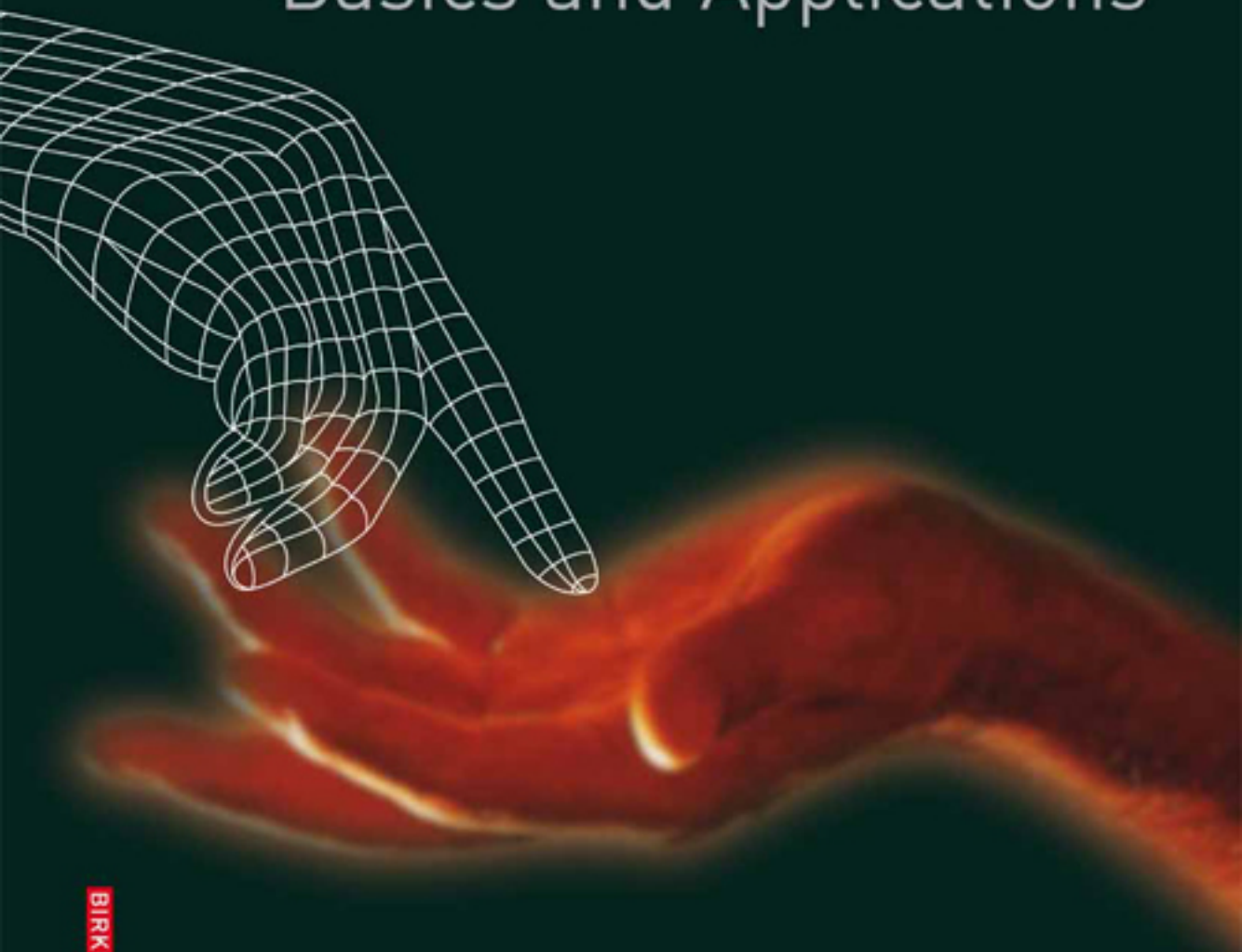


Martin Grunwald
(Ed.)

Human Haptic Perception

Basics and Applications



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Human Haptic Perception: Basics and Applications

Martin Grunwald
Editor

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Martin Grunwald
University of Leipzig
Paul Flechsig Institute for Brain Research
Haptic and EEG-Research Laboratory
Johannisallee 34
04103 Leipzig
Germany

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Contents

Preface	vii
I. Epistemological and historical aspects	
1. Haptic perception: an historical approach	3
2. German pioneers of research into human haptic perception	15
3. British pioneers of research into human haptic perception.	41
4. Early psychological studies on touch in France	55
5. Haptics in the United States before 1940	67
II. Neurophysiological and physiological aspects	
6. Anatomy of receptors	85
7. Physiological mechanisms of the receptor system	93
8. Neural basis of haptic perception	103
9. The neural bases of haptic working memory.	113
10. Neuronal plasticity of the haptic system	131
III. Psychological aspects	
11. Haptic perception in the human foetus	149
12. Haptic behavior in social interaction	155
13. Learning effects in haptic perception.	165
14. Implicit and explicit memory effects in haptic perception	183
15. Attention in sense of touch	199
16. Haptic object identification	207
17. Haptic perceptual illusions.	223
18. Haptic perception in interaction with other senses	235
19. Haptically evoked activation of visual cortex.	251
20. Haptic perception and synaesthesia.	259
21. Haptic perception in sexuality	268
22. Haptic perception in space travel	273
IV. Clinical and neuropsychological aspects	
23. Phantom sensations	283
24. The neuroscience and phenomenology of sensory loss	295
25. Focal dystonia: diagnostic, therapy, rehabilitation	303
26. Self-injurious behavior.	313
27. Haptic perception in infancy and first acquisition of object words: developmental and clinical approach.	321
28. Haptic perception in anorexia nervosa.	335

V. Haptic interfaces and devices	
29. History of haptic interface	355
30. Principles of haptic perception in virtual environments	363
31. Haptic shape cues, invariants, priors and interface design	381
32. Design guidelines for generating force feedback on fingertips using haptic interfaces.	393
33. Haptic rendering and control.	411
34. Haptic perception in human robotic systems.	427
VI. Applications	
35. Haptic design of vehicle interiors at AUDI.	439
36. Visual-haptic interfaces in car design at BMW.	445
37. Haptics research at Daimler AG.	453
38. Haptic design of handles.	459
39. Vestibular sensory substitution using tongue electrotactile display	467
40. The blind get a taste of vision.	481
41. Tactile ground surface indicators in public places.	491
42. HapticWalker – haptic foot device for gait rehabilitation.	501
43. Haptic sensing of virtual textiles	513
44. Haptic discrimination of paper.	525
45. Haptic banknote design	537
46. Get touched – bodycare as a design of media for self-perception.	549
References	559
List of contributors	641
Glossary	645
Index	659

*If touch is not a single perception, but many instead,
then its purposes are also manifold*

Aristotle (384–322 BC) *De Anima*

Preface

The quotation by Aristotle aptly describes the complexity of content and structure embodied in the sense of touch. No other sense exhibits properties so variable in scope or remains so puzzling even today – understood only in terms of its principle features. Viewed from phylogenetic and ontogenetic perspectives, the sense of touch plays a central role relative to the other senses. Its fundamental significance to humans derives from its epistemological function, making possible an awareness of surroundings and the consciousness of self. In this way, the sense of touch is *sine qua non* for thought, action, and consciousness.

Since the beginnings of scientific research into touch, the most varied of scientific disciplines have investigated one aspect or the other of this sense. The questions posed and the methods used to conduct such research are just as varied as the disciplines devoted to it. The particular results of these efforts, however, have not yet led to a comprehensive theory of the sense of touch. Too many questions remain unanswered. As of today, the wish expressed by Max Dessoire, to integrate the various areas of research pertaining to the sense of touch into one scientific doctrine – described by him as the doctrine of haptic perception – remains illusive. This state of affairs stands in contrast to the fact that there exists a great, almost unmanageable quantity of findings that are oriented toward elucidating basic principles and related to applications that, it must be admitted, clarify many facets of the sense of touch and are of technical benefit. Manifold are the findings in the realm of tactile perception where the investigated subject doing the perceiving behaves passively with

respect to the stimulus. But just as fundamental is scientific clarification of the haptic perception process that derives from a subject who is actively engaged – either aware or unaware. This state of perception-cognition for tactile perception requires the entire scope of properties inherent to the sense of touch and is an everyday, universal process in our lives. Long before our birth, this active process constructs the initial, flexible neuro-sensorial matrix to which all other senses are obliged to relate, a set of circumstances that persists as a life-long requirement for life. And for this reason, ever more scientists worldwide are researching the biological, psychological, neurochemical, and social mechanisms of human haptic perception and its interactions with the other senses. Additionally, new areas of application are continually developing, e.g. in the field of rehabilitation, virtual interfaces, robotics, and in haptic design, where principles of human haptic perception are converted and then implemented in practice.

In view of this fascinating, dynamic background, this volume, which subdivides into six sections, compiles contributions from 46 international authors on the most varied topics of human haptic perception. In the first section, philosophical and historical aspects of the sense of touch are introduced. Here, authors from four different countries analyze the beginnings of scientific research into the sense of touch, from the start of the 19th to the middle of the 20th century, a time when psychological, terminological, and methodological foundations were laid for today's research. These contributions are intended to clarify the essential sources of the branches of research that exist today and should be helpful

in placing current research into the required historical context. It will not hereby remain unstated that we are amazed by our own recognition that – during recourse to the progenitors of the science of touch – a number of concepts considered new today are, in fact, more than 100-years old.

The second section of this volume presents fundamental aspects of the anatomical, physiological and neurophysiological conditions in our bodies that provide the basis for the realization of human haptic perceptions. These biological aspects are essential to an understanding of the various psychological and clinicopathological processes of human haptic perception. Beyond that, they represent a link, in terms of function and content, between the human model and areas of virtual-technical application.

As nature would have it, haptic perception fulfills multifaceted psychological functions in all realms and stages of life. Several of these functions, as well as various psychological and psycho-physiological aspects of human haptic perception, are covered in section three of the book. Although such a presentation can never be exhaustive, the contributed topics range from prenatal mechanisms of haptic perception to learning, memory, illusions, synaesthesia – all the way to questions of haptic perception in space travel.

Section four continues with a presentation of various clinico-neuropsychological topics. Even if this subject area is not yet a part of the mainstream of clinicopsychological and neurological diagnostics and intervention, new and exciting perspectives have emerged in recent years that benefit the pathology of haptic and tactile perception both therapeutically and in clinical diagnosis. Of particular significance in this regard is the universal interconnection between haptic perception and body schema representation in relation to different mental disorders.

In parallel with rapid technical developments in recent decades, an innovative and, in part, spectacular field of research and applications has been established, having the goal of implementing the principles of human haptic perception in virtual scenes, different electro-mechanical

interfaces, and in robotic systems. In this way, engineers, psychologists and neuroscientists are making great strides into the field of haptic simulation in the context of various technical systems. As a result, not only are new and beneficial applications being discovered and applied, but, by these means, new perspectives are emerging in the field of research methodology. The fundamental principles of this field of research and the areas of application are described in section five of the book.

Research into our senses has always been associated with the search for practical as well as industrial applications. The search for knowledge has thus never been far removed from the goal of practical utility. In part, such goals are, in fact, the motivation for the research. Even as we see this trend emerge more evidently in other realms of the senses and in our everyday lives, practical/technical applications as far as research pertaining to the sense of touch is concerned often still go unnoticed at large. The spectrum of these developments – so-called haptic design – ranges from new and improved surface properties for devices and products of all types, to changes in complex haptic properties in the operation of machinery or vehicles. Equally broadly diversified are practical applications in the fields of rehabilitation or assistance to help orient the blind and individuals with poor sight. A selection of such types of applications are illustrated in section six by way of examples.

This present volume is tied to the hope that the broadly diversified illustrations of the most varied aspects of human haptic perception will provide a useful tool to those unfamiliar with the field as well as to students and to scientist from various disciplines. Not least, the book should be a stimulus and a support for all those who are currently, or will be in the future, concerned with new perspectives on research and application in human haptic perception. The fact that not all of the planned aspects of human haptic perception could be taken into consideration in this volume is attributable to the natural limitations of such a project. The publisher and the authors sincerely

hope that editions to follow will expand the spectrum of depiction.

The publication of this textbook has only been possible because two powerful and dedicated forces were active in equal measure – for which I would like to express my deepest thanks at this time. First of all, we had the many authors who believed in this project and who, by means of their contributions, created the inherent substance of this book. Equally, I thank Dr. Hans Detlef Klüber, of Birkhäuser Publishers, for his proposal to bring this book into being and for his patient support and optimism in all phases of this project. I would like to give special thanks for the trust placed, and the dedication contributed, by all of those who participated in this book project, as well as for the personal support offered by my colleagues, F. Krause and I. Thomas. I conclude this editorial effort on this volume with the sincere hope that the basic, interdisciplinary research and applications pertaining to the sense of touch will come to assume a central role within the life sciences in the future.

Leipzig, April 2008

Martin Grunwald



I.
**Epistemological and
historical aspects**

Haptic perception: an historical approach

Robert Jütte

Traditional perceptions of the sense of touch

The idea that perception or sensation may be localised in certain physical organs (e.g., skin) has a long tradition. It pervades many cultures. The system of sensory physiology (of which touch is one important element) is shaped by the influence of both medical thought and the philosophy of nature. Let us turn first to ancient Indian medicine or natural philosophy, as it appears in the Vedas. The Vedas are the most ancient Indian religious texts and consist for the most part of hymns, liturgical chants, sacrificial formulas and magic spells. The Rgveda, the oldest of the vedic texts, has not yet a verb for 'touch' or 'feel' and no expression for the corresponding sensation which – in a later text entitled Atharvaveda – is called *sam-sparsa* (feeling) [1]. In the Ayurveda, which forms an appendix to the Atharvaveda, the primeval matter (*sattva*) acts upon the five senses of knowledge or *buddhīndriya* (hearing, touch, sight, taste, smell – Fig. 1). The sense of touch is associated with the wind, one of the five elements in ancient Indian philosophy. The skin, as one of the sense organs, is envisaged simply as the meeting point of the qualities or object assigned to this sense: skin – finger – grasping – feeling.

In ancient China, too, the human organism was perceived as a miniature copy of the universe. The doctrine of the five elements or the five phases of transformation is the basis of the idea that there are many numerical correspondences between nature and the human body (Fig. 2).

The sense of touch thus plays an important role in Chinese pulse diagnostics, e.g., in a clas-

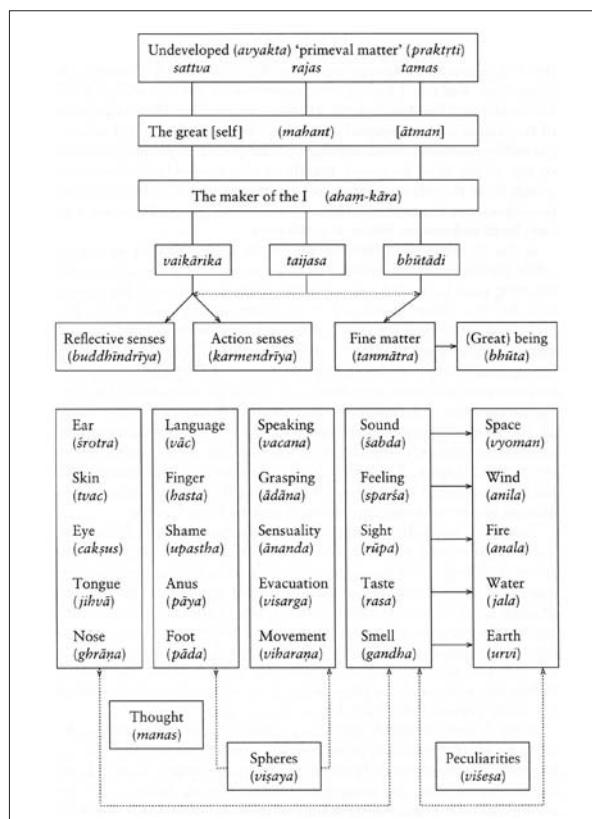


FIGURE 1. THE SYSTEM OF THE FIVES SENSES IN ANCIENT MEDICINE

Source: RFG Müller (1951) Grundsätze altindischer Medizin. Munksgaard, Copenhagen, 83

sical text entitled 'Seven sorts of Pulses which indicate danger of Death' (dating back to the 3rd century AD). The metaphors used in describing these pulses concern tactile perception, for example: "If the Motion of the Pulse resembles the hasty pecking of the Beak of a Bird, there is a failure

Elements <i>hsing</i>	Direction <i>fang</i>	Sense organ <i>kuan</i>	Tastes <i>wei</i>	Smells <i>chou</i>	<i>Yin-yang</i>	Internal organ <i>tsang</i>	Part of body <i>thi</i>
Wood	East	Eye	Sour	Goatish	Yin in yang or lesser yang	Spleen	Muscles
Fire	South	Tongue	Bitter	Burning	Yang or greater yang	Lung	Pulse(blood)
Earth	Centre	Mouth	Sweet	Fragrant	Equal balance	Heart	Flesh
Metal	West	Nose	Acrid	Rank	Yang in yin or lesser yin	Kidneys	Skin and hair
Water	North	Ear	Salt	Rotten	Yin or greater yang	Liver	Bones (marrow)

FIGURE 2. SYMBOLIC CORRELATIONS OF THE SENSE ORGANS IN THE CHINESE TRADITION

Source: J Needham (1978) *The shorter science and civilisation in China*. CUP, Cambridge, Table 9 (selection)

of *Spirits in the Stomach*: one may also conclude that the Heart performs its Functions but ill, and that the Blood is in no good condition” [2]. Other descriptions of dangerous pulses do not refer to a primarily tactile perception, although some figurative comparisons may be explained by a tactile experience of sensing distinctive ‘pulses’. According to Elisabeth Hsu these descriptions do not solely express the physicians’ tactile experiences but are part and parcel of a more general familiarity with tactile perception.

The Greek philosopher Empedocles uses the word *pagamai* (flat of the hand or gripper) to denote the senses in general [3]. This means that his descriptions of sensory perception in general refer to the sense of touch. In his *Timaeus*, Plato deals systematically with the senses. Unlike the other senses, he does not attach the sense of touch to a specific physical organ. In his opinion sensations of pleasure and pain and other qualities perceptible to the senses, such as warm and cold, feature as “disturbances that affect the whole body in a common way” (*Timaeus*, 65c). Aristotle (384–322 BC) not only expanded the hitherto merely inchoate physiology of the senses, but also advanced them to a state of completion that retained its authority well after the Christian Middle Ages [4]. In the Aristotelian view, each function is determined by its object. Applied to the senses, this means that each sense organ is assigned to a specific object of perception. Aristotle’s *De anima* deals with the senses one by one in the order of sight, hear, smell, taste and

touch, placing special emphasis on each case on the object of the perception. The organ of the sense of touch is not the skin, but the heart. The corresponding medium (the flesh) is thus in the body itself, and not outside it. Aristotle describes the object of the sense of touch as palpable. The distinction between the palpable and the visible or the resonant lies in the fact that, while the latter are perceived through the agency of the medium, here “it is as if a man were struck through his shield, where the shock is not first given through the shield and passed onto the man, but the concussion of both is simultaneous.” (*De anima*, 423b, 15ff). For this reason, Aristotle considers the sense of touch to be more closely related than the other senses to the four elements, since the properties of the elements (e.g., dry and wet) are palpable (Fig. 3).

The Aristotelian doctrine of the fully unified and independent nature of the sense of touch was scarcely ever questioned in the subsequent centuries. The *De anima* of Albertus Magnus (c. 1197–1280) follows him in similarly classifying qualities such as hard and soft and rough and smooth as derivatives of the qualities primarily registered by the sense of touch (e.g., warm or cold) [5]. As we know today, these tactile qualities are, in fact, detected by sensors in the skin that pass on the corresponding stimuli to the brain *via* the peripheral nerves and the spinal cord. But until the 19th century, by which time experimental physiology had made substantial progress, it was impossible to form any definite,

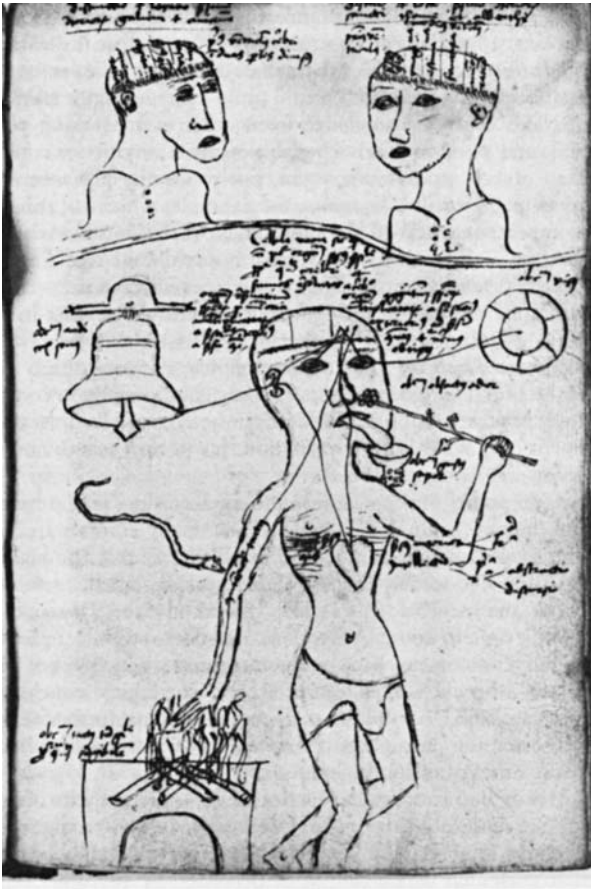


FIGURE 3. MEDIEVAL REPRESENTATION OF ARISTOTLE'S DOCTRINE OF THE SENSES (1496)

Source: R Jütte (2005) *A history of the senses. From Antiquity to Cyberspace*, translated by James Lynn. Polity Press, Cambridge, 37

let alone correct, idea of the way these stimuli were relayed, even though Albertus Magnus had already drawn attention to the central role of the nerves in the sense of touch.

The sense of touch held on to the special position in the hierarchy of the senses granted to it by Aristotle well into the Middle Ages, and even to the modern era. Much of this was due to the pivotal medieval philosopher and theologian St Thomas Aquinas (1224/25–1274). In his own *De anima*, Aquinas endorsed Aristotle's view that

without the sense of touch there could be no other senses [6]. In his pithy formulation, touch is “*the first sense, the root and ground, as it were, of the other senses*” [7]. Aquinas's ranking of the senses is based on the doctrine of *immutatio spiritualis* or mental modification, an incorporeal yet material transcription of sensory stimuli. Thus, a beam of light striking the eye does not produce a physical change. In the case of hearing, smell and taste, on the other hand, a hybrid form of mental and physical change is already present, while in the case of touch a material transcription takes place.

The status of touch

The sense of touch is the extremist among the senses, for it has frequently been ranked both at the bottom and at the top of the scale of esteem. This apparent contradiction goes back to its variable status in Aristotle, for, while ranking it fifth in order of merit (after sight, hearing, smell and taste) the treatise on the soul also describes it as a sense that reaches its highest form of development in man (*De anima*, 412a, 22). The Arab scholar Avicenna (980–1037) provides one explanation of Aristotle's conflicting statements. As he understood it, what the Greek philosopher meant was that with respect to honour the primacy of the sense of sight applied, but that from a point of view of natural aptitude the sense of touch merited priority. This resolution of the contradiction met with the approval of many medieval scholars. Aquinas developed a complex theory based on Aristotle's doctrine of the soul, in which touch and sight are granted more or less equal rights. In common with Avicenna the thought that, in addition to the traditional hierarchy dominated by vision, there was a second hierarchical order in which the sense of touch played the major perceptual role. With his exhaustive and conclusive arguments for the alternative primacy of sensation, Aquinas shows himself to be a decidedly original thinker.

Aquinas opens his case for the superior status, and systematic primacy, of the sense of

touch by noting that sensitive life forms define themselves by means of their sense of touch: “touch [is] the first sense, the root and ground, as it were, of the other senses, the one which entitles a living thing to be called sensitive” [8]. The haptic comprehension of the world is also of central importance for the survival of the individual and the species, since it is the means by which we distinguish between the edible and the inedible – an argument already advanced by Avicenna [9]. Another important argument for the priority of touch, according to Aquinas, is that it is the root (*radix fontalis*) of all sentient activity. It follows from this that the other senses are all derived from it: “In the first place touch is the basis of sensitivity as a whole; for obviously the organ of touch pervades the whole body, so that the organ of each of the other senses is also an organ of touch, and the sense of touch by itself constitutes a being as sensitive” [10]. Thus, the operations of the other senses are seen as subordinate to *tactus*. Aquinas’s third argument for the precedence of touch rest upon its optimal performance in the process of gathering knowledge: “Therefore the finer one’s sense of touch, the better, strictly speaking, is one’s sensitive nature as a whole, and consequently the higher one’s intellectual capacity. For a fine sensitivity is a disposition to a fine intelligence” [11]. Following Aristotle’s idea of the flesh as the medium of touch, Aquinas argues that sensorial being with ‘hard flesh’ would not perceive things as well as those with soft flesh (e.g., man) and would therefore be less receptive to perception of any kind.

This remarkable reappraisal of touch may be encountered in the works of other Christian, Muslim and Jewish scholars of the Middle Ages, although their approach was sometimes slightly different and their distinctions less subtle. After the 13th century, the Jewish tradition, for example, underwent a change that also may be seen later in the allegorical representations of the five senses in the Renaissance or in the Age of baroque: the sense of touch falls increasingly into disrepute. The culprit, once more, is Aristotle, or, more precisely, his *Nicomachean Ethics* (III, 8b), where the sense of taste is asso-

ciated with “*the pleasures of love*” and accused of “*disorderliness*”. No less a figure than the Jewish medieval philosopher and learned physician Maimonides (1135–1204), who refers to this passage in his *Guide for the Perplexed* (II, 36), decided to approve it. It was, however, his later translators and commentators who forged a connection between this approving quotation of Aristotle and various places in the Bible (e.g., Deut. 4: 28), thereby helping to ensure that the mental association of touch with sinful behaviour (voluptuousness and unrestrained sex drive) became widespread. Thus, both Abraham ben Schemtov Bibago, who was a doctor at the Court of King Juan II of Aragon towards the end of the 15th century, and the celebrated Talmudist Moses Isserles (c. 1525–1572) refer explicitly to the sense of touch as shame (hebr. *cherpah*) [12]. The association of touch with the sexual urge in the language and visual imagery of the Middle Ages and above all, the modern era has other roots besides these. The Christian tradition should be mentioned here. It was Eve who first touched the apple when she seduced Adam. In this way, the haptical perception became a symbol of eroticism as such, to which poets and painters of not only the early modern age returned time and time again.

Tactile imagery

Aristotle had assigned no specific organ to the sense of touch and insisted that haptic perception was distributed all over the body. Nevertheless, if it was to be represented at all it had to be positioned somewhere in the body. The obvious organ was the hand, with which the human being feels, holds and ‘grasps’ in the metaphorical sense [13]. In the biblical scenes which were used to adorn 16th century allegories of touch the fifth and last sense is represented by various forms of hand-touching. The biblical passages used in these allegories symbolised the ambivalence of the tactile sense: on the one hand it is the only source of salvation and on the other the cause of doom (Fig. 4).

FIGURE 4. ALLEGORY OF TACTUS BY MARTEN DE VOS (1532–1603)

Source: S Ferino-Pagden (ed) (1996) *Immagini del sentire. I cinque sensi nell'arte*. Leonardo Arte, Cremona, 115



Following Aristotle's praise of the relative reliability of touch in situations where the other senses may be deceived, it is not surprising that, in the Bible, for example, touching and feeling are the most effective ways of convincing ourselves of the real existence of a thing or phenomenon (cf. Luke 24: 38–39, John 20: 27). Touching consequently becomes the simplest and most basic form of communion with the sacred. This plastic idea was not least a factor in the formation of the medieval cult of relics, in which a large role is played by the touching of the bodily remains of saints and items of their clothing.

According to the American medical and cultural historian Sander L. Gilman, many medieval pictorial representations of sensory perception refer to pleasure, and particularly to sexual lust [14]. Indeed, there can be little doubt that tactile experience had sexual connotations well into the modern era. When the characters of the decidedly earthy Shrovetide plays spoke of liking to 'feel a woman' they had more in mind than the fondling of breast and the various other forms of

sexual harassment. Most of the pictorial representations that show a man reaching into a woman's décolletage are unambiguous iconographic symbols of sexual intercourse (Fig. 5).

On the other hand, the emblematic art of the 16th and 17th centuries is also concerned with the relation between bodily sensation and pain [15]. The Dutch art of this period is full of allegorical representations of the sense of touch centred on the theme of pain during sickness and treatment. The interpretation of the tactile sense as a medium of pain and other unpleasant physical experiences was largely influenced by Cesare Ripa's *Iconologia* (1593), a standard work on iconography for artists in which the sense of touch is almost exclusively associated with pain.

Numbness

Before the advent of modern diagnostic techniques (e.g., computer tomography) the loss of physical sensation (*tactus imminutus*) was