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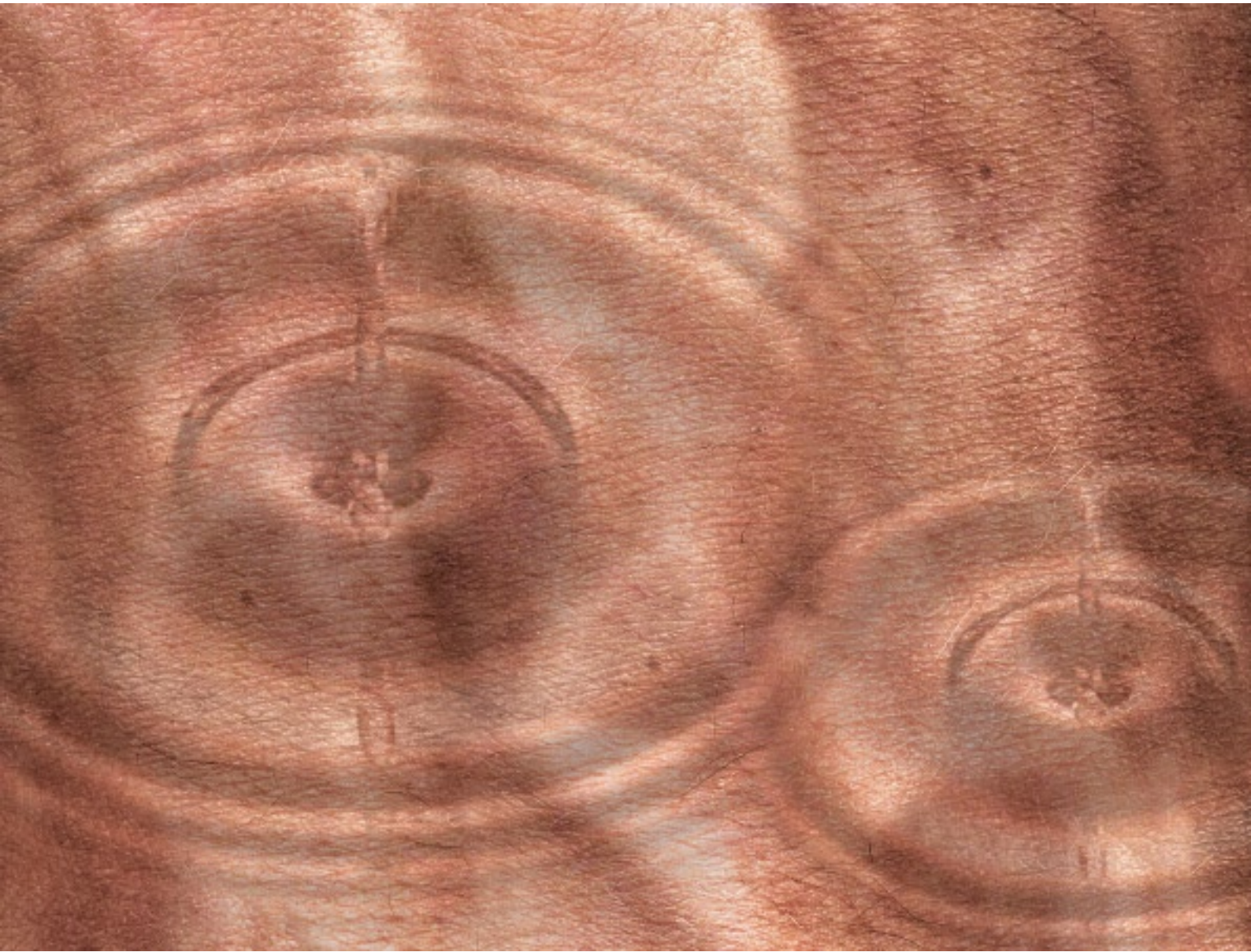
Feel the Vibe

visceral channel of communication



Feel the Vibe

visceral channel of communication

by:
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Thesis in partial fulfillment of the requirements
for the degree of
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I. Abstract

In this thesis a system is developed which forms a visceral channel of communication between collocated people, resulting in social-biofeedback.
This system is positioned as an extension of communication technology to the level of interaction-experience technology, which incorporates people's perceptual motor-, cognitive and affective skills as a whole.
The development of the system is a reaction to existing technology that mediates rational information exchange and research that looks into augmenting interaction technology with affective information. Inspiration is drawn from efforts to mediate interaction in communities and research that augment these with information concerning group dynamics.
Explorations into ambient and tangible media, which afford human capabilities as a whole, form a scaffold for the development of the medium at hand.
Valuable insights are found in evolutionary and social psychology, emotion and perception theory and psychophysiology.

The system consists of a number of wirelessly communicating, wearable devices. The devices are worn against the skin. Each device detects its bearers' heartbeat and from the heartbeat an affect related derivative, i.e., Heart Rate Variability (HRV) is calculated. Heartbeat and HRV values are exchanged between the devices. Each device pulsates with the beats detected as well as with the ones received. Relative to a function of the calculated and received HRV values, each device warms up, doesn't change temperature or cools down.

The system developed on the one hand is intended to challenge notions concerning ethics and privacy as well as show exciting directions for exploration that may result in fundamentally new kinds of products.
On the other hand the system illustrates a possible alternative approach to the process of product development, in reaction to the status quo in product design.

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Less personal, but ever so sincere, I thank
all my friends, colleagues and family
that have given me a willing ear, a strong shoulder, a convenient bed, a healthy meal and all those things I needed to stay healthy and sane.
These people take the concept ‘social fabric’ to new realms.

III. Preface

This thesis project was carried out in pursuit of the degree of Master of Science in Industrial Design Engineering (IDE) at the ID-StudioLab, sub-section of the school for IDE, TU Delft, the Netherlands. The largest part of the project was carried out in the Affective Computing group, part of the MIT Media Laboratory, Massachusetts, USA.

The objective of the Media Laboratory is the development of “enabling technologies for learning and expression by people and machines”. [ML] The Affective Computing group focuses on creating personal computational systems endowed with the ability to sense, recognize and understand human emotions, together with the skills to respond in an intelligent, sensitive, and respectful manner toward the user and his/her emotions. [AC]

The challenge of the ID-StudioLab is to shape the conditions for a satisfactory product experience. Traditionally, products are designed for their aesthetic appeal (aesthetics-driven), their usability (ergonomics-driven), and/or for their smart functions and possibilities (technology-driven). Well-designed as these qualities may be, they do not automatically lead to favored experiences on the part of the user. Taking the experience, of any kind and over time, as a starting point in the design process radically reshapes design research and will ultimately change the face of product design. [Studio Lab]

The Media Lab constitutes a large part of supporting and enabling technologies for products, whereas ID-StudioLab is working on necessary design approaches and implementations. Both are grounded in similar ideologies with regard to involving human capabilities in a holistic way. At the Media Laboratory, however, this results in the invention of technologies that may drive the development of new products. At the ID-StudioLab an essentially different attitude is advocated. Development of products for people should be driven and guided by designers that emphasize the qualities of the product – user interaction. In these terms a product is seen as a context for experience, not merely a piece of functional equipment.
Such a development process may drive the invention and creation of necessary technologies.

This thesis project has benefited from the different cultures at each institute and is the result of the challenges posed by the tension between the respective approaches.

CONTENTS

I. Abstract v

II. Thanks and acknowledgements vi

III. Preface vii

1. Introduction 3
Assignment 4
Implications 4
Overview 5

2. Background 7
Social Interaction 7
Social Interaction Technology 7
Stepping-Stones 9
Ambient and Tangible Media 9
Mediation of Emotion 10
Affective objects 11
Affective Computing 11
Augmenting Group Interaction 11
Complex Adaptive Systems 13
Summary 13

3. Conception 15
Context 15
Dominance of reason – 15
Rudeness of products – 15
Subtleties of human interaction – 15
Embodiment-Tangibility – 15
Consumerism – 17
Individualization – – Awareness of social fabric – 17
Distributed cognition – 17
Self-organizing systems / complexity – 17
Wearable; ubiquitous; distributed computing – 17
Medium is the message – 17
Privacy is overrated: power to the people – 17
Interaction vision 17
Ambiguous / mysterious / uncanny – 19
Awing / making self-conscious / Embarrassing – 19
Symbiotic / synergistic – 19
Sensuous – 19
Product vision 19
Probing / intrusive – 19
Autonomous / unpredictable – 19
Unavoidable – 19
Exposing / Revealing / Confronting – 19
Nodal / liminal / interfacing – 19
Summary 19

4. Building blocks 21
Social and Evolutionary Psychology 21
Perception 21
Perception and Emotion 21
Social Interaction 22
Summary 23

5. Synthesis 25
Merits of Affective Computing 25
Affect Related Physiological Signals 26
Heart: seat of emotions 26
Heart Rate Variability 26
Skin: the boundary of self 27
Mapping 28
Technology 29
Detecting heart rate 29
Cutaneous feedback 30
Digital glue 31
Communication 31
Total System 33
Summary 33

6. Design: visceral channel of communication 35
Cellipus 39
Smartclothing and -Jewelry 41
Buttonhole 43

7. Conclusions 45
The Product 45
The (Near) Future 45
The Process 46
Epilogue 47

References: 49

1. Introduction

Consider a second-class train compartment in the intercity train from Rotterdam to Amsterdam, a journey that usually takes around one hour with three stops along the way.
The train has just left the station. Our compartment is only about half full, but the present people have spread over the seats perfectly evenly. Most people have one free seat next to and one across from them. The man in the middle of the compartment is on his cell-phone, gesticulating wildly while he talks to what is apparently a good friend. His voice is so loud that the whole compartment is witness to the report of his latest victory as a womanizer. It's embarrassing to hear the explicit details of his personal life. The woman sitting diagonally across from him ducks deeper into her book hoping to hide her amused interest that shows in the blush of her cheeks. The elderly couple on the other side of the isle is visibly embarrassed and irritated but they don't dare to say something to the man on the phone. The of the couple woman tries to distract herself and her husband by pointing out he things she sees flitting by outside. She points at a herd of sheep and exclaims surprised: "The sheep! They're standing in the shape of a face! Do you see that?" Her husband looks out the window and shrugs. He sees the sheep-face as well, but says " Don't be childish, it's just a bunch of sheep. I don't play those games anymore. When will we arrive?" His wife says she doesn't care when they get there. She enjoys the ride, the sensation of moving and the world going by.
The next seats over a boy and a girl sit next to each other whispering sweet little nothings, oblivious of the loud voice on the phone. The couple has moved closer and start courting, while the train starts to slow down for the first stop. The man in suit and tie in the seats across the isle from the couple has a hard time concentrating on his laptop. The man on the phone has hung up, but in the corner of his eye now the couple keeps drawing his attention while they blatantly cover their bases. The train has come to a full stop and people are getting on and off the train. A woman and child come into the compartment looking for a seat. The way people have spread over the seats in the compartment leaves her but one choice and she takes the seats directly across from the still entangled couple. This brings them suddenly to reality. They jump up shouting "It's the Hague already! Did you notice we had stopped? We have to get off!" And they run out giggling and laughing. In their haste they nearly knock over the soldier with his big duffle bag on his way to the base.
He's sad, on the verge of crying, but keeps it in because he doesn't want people to see him cry. The rude push of two lovers is the last straw. His emotions bubble out as a tantrum. He shouts and curses at the couple that jumps out the doors just as they start closing. Still growling, the soldier stumbles through the compartment and dumps down across from the woman and child. The train pulls away from he station. The compartment is left in tense silence in the aftermath of the eruption of anger. The child asks her mother: "Mom, do all soldier shout like that?". The mother smiles nervously and glances at the man with the duffle bag. The soldier can't help himself anymore and bursts out in tears looking helplessly at the mother. The mother stares in another direction and the child follows her example. The soldier looks at the people across the isle. They pretend to be submersed in their laptop, Walk man and book. No one pays attention to his sorrow.
Suddenly the train screeches to halt, in the middle of nowhere. The people in the compartment look at each other in wonder. One voice says something about how this always happens with the 'stupid railways'. Another voice agrees and starts telling a story "how once I was in a train that …'. The compartment now starts to buzz with animated conversations about the chaos at the railways and people's experiences in the train.

Let us leave the micro-society of the train compartment at this point and ponder the events.

Why did the people spread so evenly over the seats? Why did the man on the phone not notice his invasion of people's personal space with his private details? Why was he gesticulating, while his friend on the other end could not see this? Why did the woman try to hide her blush? Why didn't the elderly couple express their irritation? What made the woman see a face in a herd of sheep? Why did the man not want to play the seeing game with his wife? What can be said about him wanting to arrive, while his wife enjoyed the journey itself? What is this 'sensation of moving'? How come the courting couple didn't notice they had stopped until they were disturbed? Why couldn't the man with the laptop concentrate while the couple was only in the corner of his eye? Why didn't the soldier want to express his sadness and turned it into anger? What is this tense atmosphere left by his tantrum? When he did start crying, why did people look away and ignored his need for contact? What happened to the atmosphere in the compartment after the emergency stop?

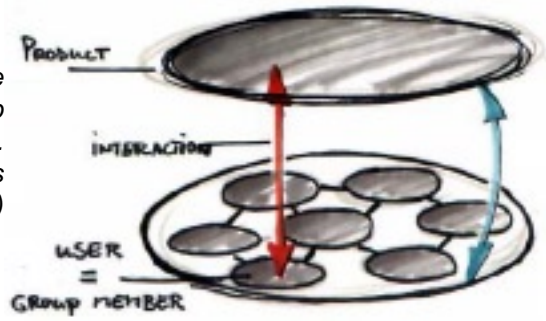
Such pondering concerning, e.g., social interaction, individuality and privacy in a group, human perception and experience, the relation of emotion and reason in human interaction, form the seeds from which this thesis in Industrial Design Engineering has grown.
This thesis explores the questions posed above in the light of product design.

Assignment

Develop and design a product, which augments insight in and experience of interactions in a group, for members of this group.

Implications

This assignment implies a feedback loop. It is an extreme example of the complexity of many human-product systems in a social context.



The white area is the context of use. The bottom plane is the group and group dynamics (black lines between users). The top plane is the product.
The left (red) arrow is the user-product interaction, which implies the arrow on the right (blue)

The product responds to interactions in the group and will influence the group dynamics in its turn. Therefore exciting issues to be aware of are the type of interaction and the values embedded in the product. These values influence the user's perception of the product and context of use. The impact of the user-product system on the context of use defines the experience of the interaction and so whether a dynamic balance in the feedback-loop is established or an explosion into meaninglessness occurs. This system could be compared to a closed-loop- or feedback-control system.

Overview

In the chapter ‘Background’ social interaction is analyzed as well as technology that supports our social interaction. From this analysis a conceptual design space is constructed in the chapter ‘Conception’. In that chapter an abstract vision concerning the product to be designed is cast, rooted in the design space defined.
The chapter ‘Building blocks’ provides insights in human perception, social interaction and psychology from science and theory. These insights are integrated with the vision projected and result in a rephrased and refined assignment. The chapter ‘Synthesis’ brings the still abstract description of the product step by step to a more concrete level. The final stage of the synthesis is the definition of technological system that affords the vision and description of the product. The physical appearance of the product is then discussed in the chapter ‘Design: visceral channel of communication’. This thesis is concluded with a summary concerning the product developed as well as the process followed. Future directions are indicated and a role design may play is advocated.

2. Background

Social Interaction

People are social beings. We live in an environment with many people; some of them in close relationship to us; others are part of more impersonal and wider communities. We hug and talk intimately to our partner or close friends and we avoid the eyes of someone walking in the opposite direction in a hallway.
We have no choice but to interact with others daily.

The interaction may be one-on-one, both intimate and impersonal, or in a group setting. There are many ways in which we interact and communicate with others.
Through the clothes we wear or the car we drive we send signals to others concerning who we (think we) are, what we want to be or consider ourselves part of.
Through verbal language we exchange all kinds of information. We talk to partner or friends about what we feel and think. We exchange facts and instructions, questions and answers with, e.g. the people we work with.
Often we illustrate or emphasize what we express verbally by non-verbal language, i.e. gestures, facial expressions and posture. We touch and hug as a signal of affection or punch and shove to show anger or dissatisfaction.

Apart from these intentional forms of non-verbal expression there are many unintended cues and signals we send out and that escape our immediate attention.
Behavior and body language can unintentionally communicate information about our affective state.
In the field of kinesics much research has looked into how and what is expressed in ‘body talk’, e.g. posture and gesture, and to what extend this contributes to communication and to experience. It has been suggested that 80% of human communication is encoded in this kind of signals. [Birdwhistell, 1952] Often we are not aware of these signals. We do, however, perceive them and are influenced by them in how we think and feel about others.

Apart from these behavioral cues, either intentional or unintentional, Our bodies also send out signals that cannot be perceived explicitly. Pheromones for instance, seem to play an important role in social interactions and our choice for a particular partner.
The roles played and messages carried by this group of airborne molecules are only starting to be investigated.
It is not unthinkable that other similarly unintended and unnoticeable signals that our bodies send and receive, await discovery.

Social Interaction Technology

Not only do we interact with people face-to-face or in the same physical locations, but we also communicate with people who are miles away. There are several media and products that support our social interaction independent from geographical location.

On a one-on-one basis, we talk to people in a distant location by means of (mobile) telephones and video-conferencing systems. We write letters, on paper and through E-mail. We use chat programs on the Internet, short-message- and two-way-pager systems on the mobile telephone network.
Many of the media mentioned can be used for group communication as well. The telephone can be used for telephone-conferencing and video-conferencing can be done with more than two people.
The kinds of media that support group interaction are mainly used

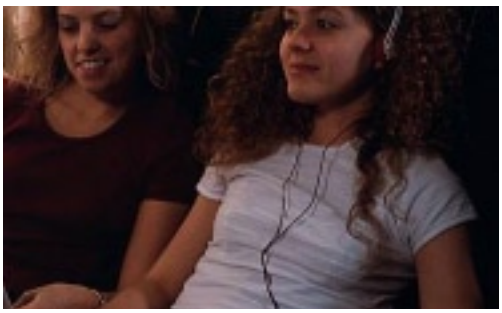
in work environments. In such professional settings the field of Computer Supported Collaborative Work (CSCW) has produced systems that support group tasks and formal interaction, such as making decisions and appointments.

On the Internet possibilities for informal group interaction are abundant, e.g. news groups, multi-user chat sessions and MUD's (Multi User Dungeon). Because of such possibilities we are no longer dependent on physical proximity to be part of a community. Whatever our interests, there are bound to be several virtual communities we can become part of to indulge to some extent in those particular interests with like-minded people.
However, in everyday life media that support one-on-one interactions prevail.

The variety of media available to us has expanded greatly in the last century and the particular kind of information exchanged varies from medium to medium. However, in essence the content of the exchange has hardly changed. Most media we use support the exchange of intentional, verbal information, but have poor bandwidth with regard to the more subtle sides of human interaction. [Picard and Cosier, 1997; Huang ,1999]

This shortcoming indicates a deficiency in many modern electronic products. Most products are developed driven by a technology push and aimed at bare functionality. It has been acknowledged that this approach has been the cause for unusable, frustrating and rude products. [Norman, 1988; Gaver 1991; Hummels and Overbeeke, 2000]
This deficiency reflects the dominance of reason in western society. So-called non-rational elements of the human psyche and resulting behavior are deemed inferior to logic and reason. Quite the contrary is true.
Emotions are more and more proven and considered to play an important role in e.g. cognitive processes, health and in human interaction. [Saul, 1992; Damasio, 1994; Huang, 1999].

Another aspect of a reason dominated, modernist western society is the emphasis on the individual as an entity independent from its social environment. It seems the products and media we use reflect this emphasis as well.



Stepping-Stones

Researchers have started over the last decade to explore new directions that may amend to some extent the shortcomings of products mentioned in the previous section 'Social Interaction Technology'.
Some research concerns options for incorporating all human sense modalities in the communication and interaction between individuals. In the section 'Ambient and Tangible Media this is clarified with examples.
Other research looks into mediating the communication of emotions. This is illustrated this are discussed in 'Mediation of Emotion'. As subsections of 'Mediation of emotion', interesting work at the MIT Media Laboratory with regard to automatically detecting affect in people is discussed in 'Affective objects' and 'Affective computing'
A few projects explore the mediation of information derived from group interactions. The section 'Augmenting Group Interaction' discusses these projects.
The examples given in each of the mentioned paragraphs could to a large extent be seen in the light of the other sections as well.

Ambient and Tangible Media

Most information conveyed to us through technology is mapped to explicit, in-your-face signals that require full attention to process. Some research has looked into technology that maps information to signals in a way that incorporates traits of human perception and information processing. The name coined for such media is Ambient or Calm Technology.
In day-to-day life our attention is focused on a task at hand, but an unusual stimulus in the periphery of our attention is noticed immediately. Ambient Media should move easily from the periphery of attention to its center and back. [Weiser and Brown, 1995; Wiszneski, 1999].

A powerful example of an ambient display is Feather. This device supports simple intimacy. Feather is a system where the cuddling of a pillow in one location, sends a feather floating up on a gentle stream of air in another location. [Strong and Gaver, 1996]. Not only has the system an ambient display, it also shows an interesting input action. Cuddling is a natural way of expressing affection. The pillow affords human affective and sensory-motor skills. However, the communication channel is a one way street. There is no feedback to the actions of the cuddler of the pillow. Neither can the person on the feather end of the system reply to the affection communicated.

Research looking into technology that affords sensory-motor skills in inter-personal and human-computer interaction has dubbed this kind of media Tangible. [TMG]

InTouch is a device that affords haptic interaction between people in separate locations. In both locations a contraption of three cylinders forms the interface. Each cylinder in a location can turn independent of the other two. The motion of each cylinder in one location is linked to the motion of the corresponding cylinder in the other. This affords the people in each location to inhibit and activate the motion of all three cylinders on the device, creating a strong impression of physical connection. [TMG]. However, apart from physical connection, the system hardly affords the expression of affect.

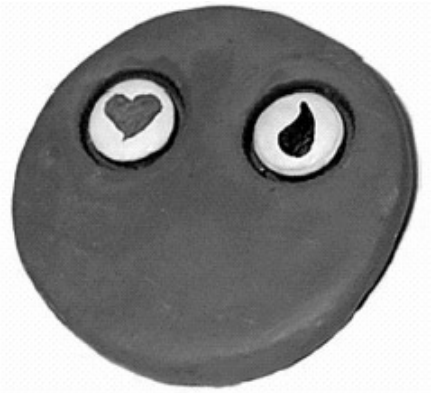
VibroBod allows two users to communicate feeling; hand gestures and vocalizations made by one user convey emotional content to the other user by means of vibration and warmth. VibroBods rest on the laps of individuals having personal conversations via phone, chat or instant messaging, to amplify moods or tones that may otherwise be lost. [Dobson et al, 2001]. The system is meant to be used in conjunction with another form of (explicit) communication media.

An important question in both ambient and tangible media is what information is mapped to what signal.
Some inspiration and insight for this mapping may be drawn from synesthesia.
Synesthesia is a phenomenon manifest in some people, who, for instance, 'see' music as shapes and colors or words or letters have taste. An interesting aspect in synesthetes is that no consistency in combinations of sense modalities across people with this phenomenon has been recorded. Yet the kind of synesthesia in an individual is consistent over time. [Leonardo; Cytowic, 1989].

Some research has looked into to what extent perception of physical shape and color correlate to other sense modalities. [Smets et al, 1994&1995]. A large number of design students were asked to design objects based on, e.g., music, for the design of a Walkman to be used with this music, or the taste of a soft-drink, for the design of its container. This introduces the concept of designed synesthesia.
The research in designed synesthesia does show some consistent correlation between perceived expression and shape in the case of product designers. However, little research has been done to denote cultural dependency or other factors of influence.
An extension of this concept is the expression of shape through gesture. As gestures are a way of expressing affective content as well, correlation between shape and affect is implied. [Hummels, 2000]. Similarly the mapping of certain information to certain signals could be modeled after the concept of synesthesia.

Mediation of Emotion

A device conceived as a research object, is the LoveBomb [Hansson and Skog, 2001], a device that is claimed to encourage the communication of emotions in public spaces. The user has a choice of broadcasting a small number of different signals as an expression of emotional state. LoveBombs in the physical vicinity of the one used to broadcast, will respond with vibrations according to the chosen broadcast.
On the one hand this device could mediate and encourage the expression of emotion. Yet it requires, on the other hand, the active action of choosing an emotion. The user could also choose to broadcast a certain signal when not feeling the corresponding emotion.
LoveBomb shows laudable intentions: communication of emotions. However it fails in widening the communication bandwidth, neither does it open a channel for affective communication. It merely provides a means to express emotion similar to vocabulary or gesture. Also the mapping of expression to vibration is somewhat arbitrary.



Exploration of new interaction and communication technology demands a fundamentally different approach. In the authors opinion it is not enough to amend existing media with human centered aspects. Media should be designed from the ground up with people as a whole of perceptual motor-, cognitive and affective skills in mind. Particularly concerning social interaction and the communication of emotions.

On the one hand people use explicit means to express emotions, e.g. choice of vocabulary and gesture; on the other hand much more subtle cues, often not consciously controlled, convey a much richer and sharper image of what we feel, e.g. posture, intonation, pupil dilation, skin temperature and galvanic skin conductivity (through e.g. hand shake).

Many studies have looked into the physical changes that accompany human emotions. These studies have shown an even larger number of physical changes accompanying emotions, e.g. heart rate, blood pressure and muscle tension. [Cacioppo et al, 1993; Bradley et al., 1996].
People naturally are very good at inferring and perceiving emotional state, but what specific (combination of) cues are involved is not quite clear.

Affective objects

In her research, Jocelyn Scheirer explores the mapping of physiological signals that accompany emotion to more explicit formats: affective communication through the use of Affective Objects.

The Galvactivator™ is an example of such an object. In a type of glove, galvanic skin conductivity of the wearer is mapped to the intensity of light of a LED. Galvanic skin conductivity has proven to be a good indicator of arousal. [Scheirer, 2001]

An interesting question can be raised concerning this type of object: An object that portrays physical changes of the bearer is that part of that person or part of that persons environment?
Exploratory designs of this type of object have proved to cause a strong visceral response in people, both bearer and 'spectator'.
An object with such properties can be considered liminal: it's neither inside nor outside, it's betwixt and between. [Scheirer, 2001; Csikszentmihalyi, 1981]

Affective Computing

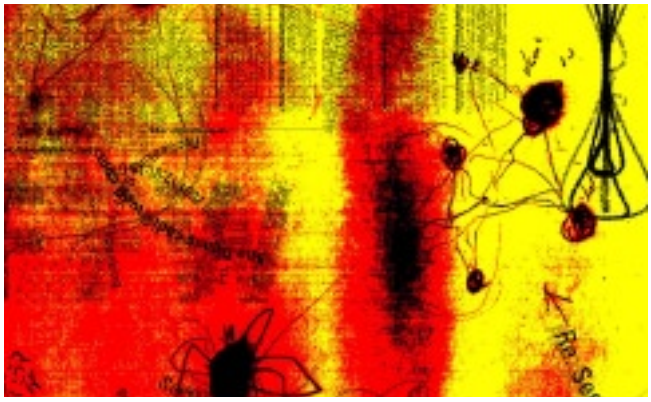
The use of physiological affective signals can be taken one step further and has given rise to the field of Affective Computing. In this field a start is being made to teach computers to infer from the subtle cues people send out, the underlying emotional state and respond accordingly. [Picard and Cosier 1997; Picard, 1997; AC]. Affective Computing will be discussed in more detail in a later section (Synthesis).

Augmenting Group Interaction

Apart from amending the lack of bandwidth of communication with regard to subtle sides of human interaction, a wealth of information is generated by inter-personal interactions. This kind of information may be of interest to participants in this interaction.

As mentioned before, the Internet has been feeding ground for location-independent, virtual communities to grow on. In online communities concepts that are inherent in real-world interactions are not readily available, i.e., online we do not have bodies nor physical spaces. Important issues for participants in virtual communities are the concepts of presence and context awareness, which appear natural in the physical world. Research looking into these aspects, draws on urban planning and architecture for inspiration with regard to the context of interaction. Physical world concepts and ideas have been translated and applied to the virtual in order to recreate meaningful, rich environments for interaction.

As these virtual environments exist in –networked– computers, it is but a small step to log and aggregate behavior of people in these communities.



Some work has been done to augment virtual communities with this aggregated information – i.e. the social context –, in the form of Social Visualization and Social Navigation. This has resulted in compelling interfaces for and visualizations of on-line communities. [Donath, 1996&1998; SMG; Maeda]

Recently effort is being made to reintegrate virtual communities into the physical world. An interesting example of this is the Chitchat Club [SMG], a café, where some of the visitors are only 'there' as avatars; these visitors are actually physically located in front of a computer equipped with a type of telecommunication technology and controls for the avatar.

The research discussed explores development of interfaces for naturally rich interaction online and augmenting the online world with aggregated information from online behavior.
Advances in wearable, pervasive and interconnected devices provide a platform for augmenting real-world interaction with similarly aggregated information.

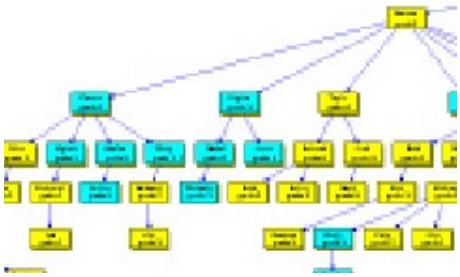
The LoveGety is a commercially available mobile device, which signals the user's romantic availability to other LoveGety users and conveys notifications when matching profiles are found in its physical environment. Next a more conventional get-to-know may follow. The device constitutes a form of active contact add, or an automated dating service.
The LoveGetty deals with human affect in an explicit way. The owner is actively involved in what specific information is exchanged. The LoveGetty uses an explicit interface that is not intuitive to mediate affect. It applies technology and methods developed for explicit verbal communication to affective matter.

Hummingbird [Holmquist et al, 1999] is another mobile device that raises social awareness between users who frequent the same physical location. It requires no user action apart from turning it on. Hummingbird provides information aggregated from physical locations of people that are otherwise hardly available.

Both loveGetty and Hummingbird provide channels of communication similar to fashion. They are to some extent autonomous in conveying certain information about the wearer. Both devices form additions to the concept of physical and social context awareness of people. Particularly Hummingbird shifts the concepts of self and privacy by making information about a user's whereabouts available to others through a personal, wearable device.

In his research, Rick Borovoy applies notions of folklore to electronic communication devices similar to loveGetty and Hummingbird. Folklore is the part of culture that emerges from the evolution of all sorts of information through interaction between people.

I-Ball is a system culminating from Borovoy's research. I-Balls enable kids to create, share and transform a small animation or game (the actual I-Ball) on a handheld computational device. Apart from a platform for emergent culture, I-Balls provided a source for information concerning interactions in a community. The sharing of I-Balls was tracked and combined to create visualizations of the propagation of a certain I-Ball. These so-called Community Mirrors form a powerful means to create insight in the network of interactions in a community of users. Especially when this aggregated information is combined with personal demographic information of the participants, e.g. age, sex and cultural background, such visualizations provide a handle on the structure and workings of the social-fabric they are part of. [Borovoy et al, 2001]



Complex Adaptive Systems

When looked upon from such a systems level, groups of people form complex adaptive systems. These are systems that consist of a (large) number of entities that follow the same basic rules. The behavior at a colony level that emerges from interactions of the basic entities can be unexpectedly complex compared to the basic rules followed by the constituent entities. Traffic jams, ant colonies and beehives are striking examples of such complex systems. Looking at emergent behavior it is difficult to deduct the underlying mechanisms and rules; the other way around, it is very difficult to predict the emerging behavior when the basic rules are known. [Resnick, 1994]

Summary

In our daily lives we interact with others face to face with the whole of our body and mind, cognitive and affective skills. Many of the aspects of that interaction are subtle, unintentional and escape our explicit attention.
There's a variety of media that supports our interaction independent from geographical location, which is limited in bandwidth in comparison to the bandwidth we are capable of processing in collocated interaction. Most of these media support one-on-one interactions independent from their environment

A number of projects were discussed that have looked into several of the shortcomings of the interaction media available today. However, so far no integral approach was encountered.
Looking at the whole of media available, attempts made at amending shortcomings and possibilities that emerge from available technologies, there seems to be a number of exciting new areas to be explored. These areas may enrich our experience of social life and maybe (re-) discover stimulating aspects of our interactions.

Few media are made for physically interacting groups; few afford the subtle and affective sides of interactions. Few projects have looked into mediating emergent behavior and information of groups to group members.

In this thesis an attempt will be made to explore a direction for interaction media that integrates these aspects. The approach taken is aimed at creating new products for a possible future extrapolated from present processes. The following chapter 'Conception' sketches a vision of such a (near) future and an interaction medium that may exist in it.

3. Conception

The objects we use define the way we perceive and interact with the world. In this way products have a strong impact on how we perceive and relate to society. Therefore products and their designers have an important role in navigating and shaping society.
In order to render the objects we use more respectful of human beings as a whole, a product should be conceived as a context for experience, not merely aimed at mechanical, physical functionality. The objects we use should be designed with a human being as a whole in mind, which means taking into account all aspects as a whole: physical aspects, e.g. perceptual-motor skills, as well as cognitive skills, i.e. logical, rational skills and affective, emotional skills. [Gibson, 1972; Papaneck, 1977; Csikszentmihalyi, 1981; Overbeeke and Hekkert, 1999; Hummels, 2000; Hekkert and van Dijk, 2000]

In the previous chapter deficiencies in communications media resulting from a technology-oriented approach have been brought forward. The section Stepping-Stones discusses a number of projects that pose options to amend to some extent these deficiencies. Even though most research mentioned may form stepping-stones towards more respectful products – options for additions to existing products and media are proposed –, hardly any fundamental change in the approach to product development is made explicit.
Yet a number of projects discussed show intriguing new directions for wearable, personal (interaction-) technology and some verge on a holistic approach.

This chapter forms the basis of an essentially different approach. A conceptual framework is constructed which forms a human-centered, context-oriented basis and guide for the development of the design at hand:
“A product that augments insight in and experience of group interaction and dynamics, for members of that group.”

Concepts and ideas derived from the previous chapter are combined with notions mentioned in the introduction of this thesis. Attitudes of the designer are made explicit and also integrated. These factors define a design space or context for the user-product interaction. In order to arrive at fundamentally new products, a qualitative and conceptual vision of the user-product interaction is projected, rooted in the design-space. Qualities of the interaction imply qualities of the product that may elicit the desired interaction within the design space, thus a qualitative and conceptual vision of the product is developed. Interaction- and product-vision are clarified both verbally and graphically. These steps are part of the ViP – Vision in Product development – approach to (product) design, currently in development at IDE. [Hekkert and van Dijk, 2000]

Context

Dominance of reason –

I wish to show other ways of looking at the world than purely logical and rational.

Rudeness of products –

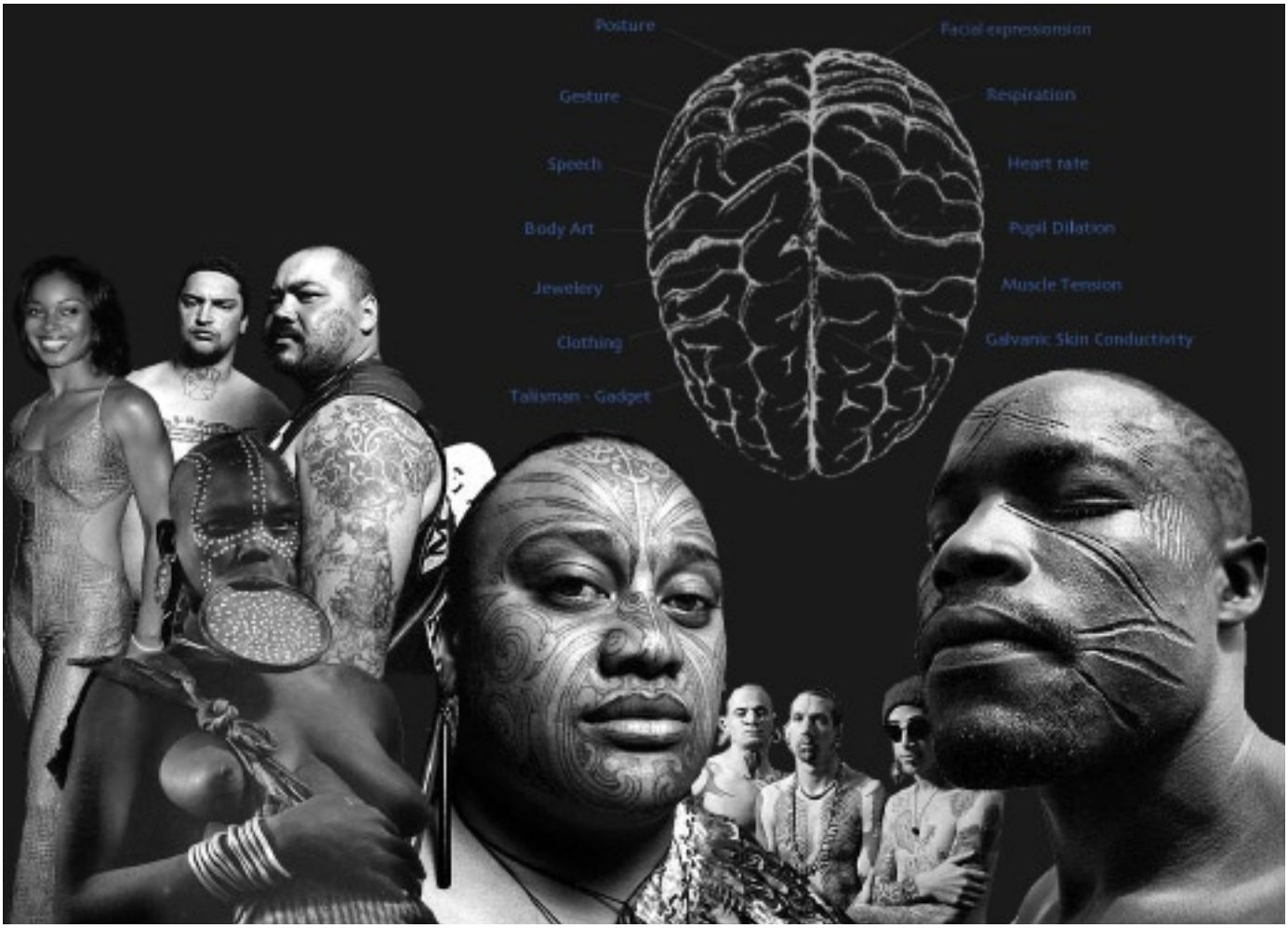
I wish to make a product that is respectful of human capabilities

Subtleties of human interaction –

I wish to work with the subtle sides of interaction, i.e. how do we influence each other apart from with words?

Embodiment-Tangibility –

I wish to make people integrate their body and mind


Posture
Facial expressionism
Gesture
Respiration
Speech
Heart rate
Body Art
Pupil Dilation
Jewelery
Muscle Tension
Clothing
Galvanic Skin Conductivity
Talisman - Gadget

Consumerism –

I wish to show people that making a personal effort to get somewhere or make something can be rewarding, satisfying and pleasing.

Individualization – Loss of social capital – Awareness of social fabric –

I wish to show people that they are part of something bigger, that personal gain often is at the expense of others. Together as a group we might stand stronger than as individuals.

Distributed cognition –

I wish to show and make use of the fact that our environment is an integral part of our perception, memory and experience of the world and thus of our cognitive processes.

Self-organizing systems / complexity –

I wish to show and make use of fascinating unpredictably of emergent behavior on community level from behavior of many individuals, without centralized control.

Wearable; ubiquitous; distributed computing –

Wireless networking and miniaturization of electronics opens new possibilities.

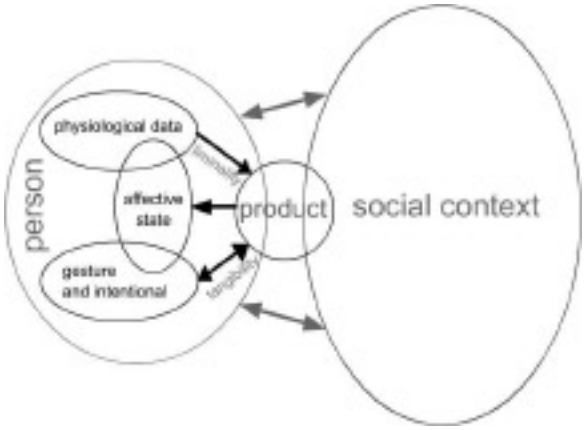
Medium is the message –

A variation on form follows function: when you make something that will show people what their interaction is all about, then what shows this to you should have the same subtlety, sensitivity and inter connectedness as people have.

Privacy is overrated: power to the people –

The currently held notion of privacy is a result of individualization. By making what is considered a danger for ones privacy synchronous, it can be empowering…

Interaction vision



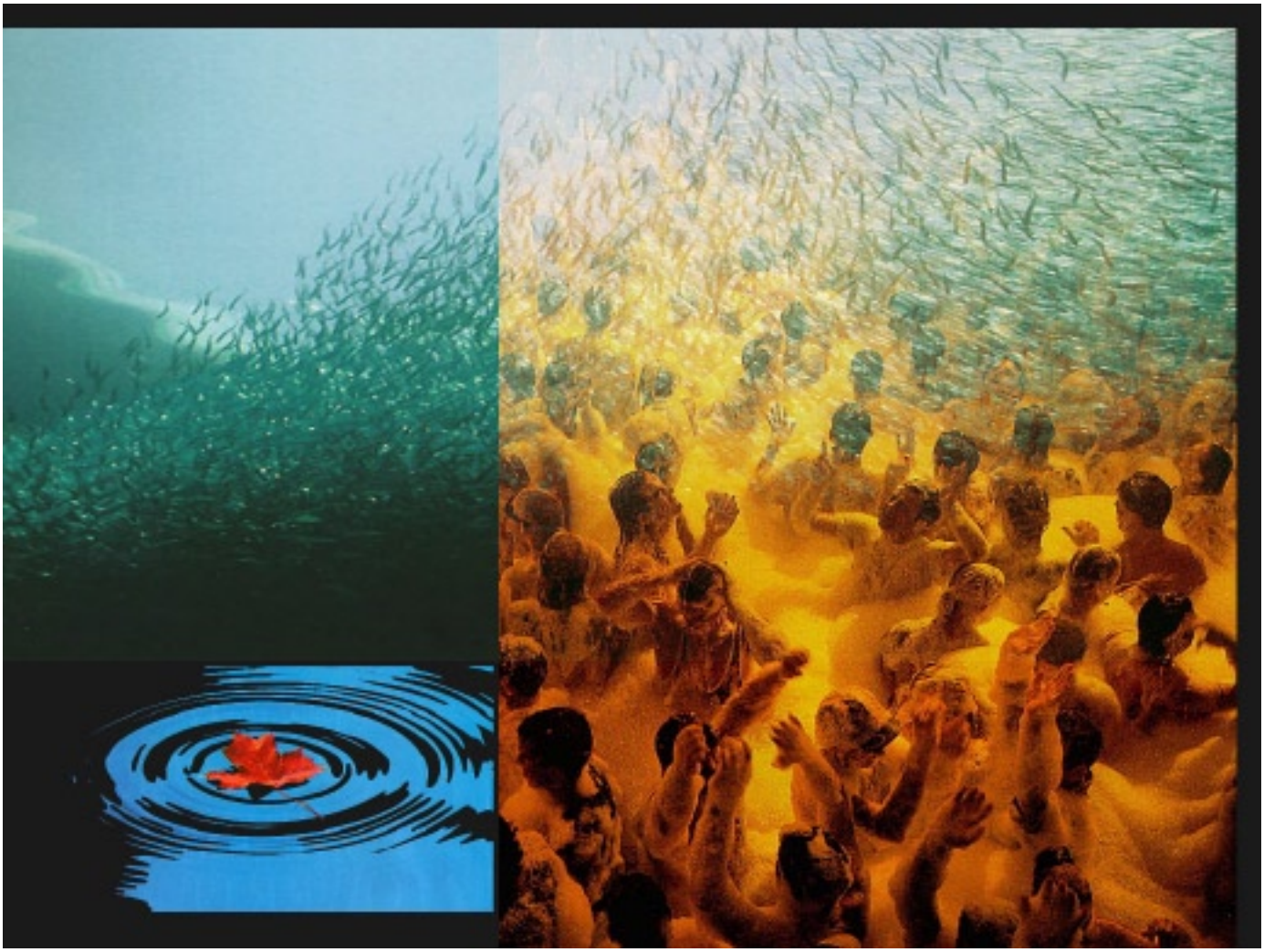
The following words describe qualitatively how I think the interaction between the user and the product should take place in the previously described context.

There is a difficulty with regard to this ‘Interaction vision’ as it is twofold. The product to be designed will ‘augment experience of group interaction’; therefore it is impossible to see the interaction with the product as independent from the interaction with people. Just like one cannot see the interaction between people as separate from the interaction between an individual and her/his body (sic).

The interaction should closely resemble the relation we have with our bodies.

- It is always there, mostly in the background of attention
- It does things that do not need attention; ‘of its own will’
- It sometimes moves into our full attention, mostly for homeostatic reasons (e.g. headache, hungry, need to pee),
- But the more interesting is the relation with our body when it does something out if its own that either surprises or embarrasses us, for instance when we blush or break a sweat out of nervousness or fear, when our stomach makes funny noises, erection of certain parts, a twitching muscle, etc.

I see the relation to the product similar to this last aspect of the relation with our body.
The difference would be that the product redefines what our body is. The product will incorporate part of the social context as if it is part of our body.



The following qualities would apply to describe the interaction:

Ambiguous / mysterious / uncanny –

Capable of being understood in two or more possible senses or ways; being beyond what is normal or expected;

Awing / making self-conscious / Embarrassing –

Making you feel small, a little ashamed, not humiliated, but conscious of oneself in relation to context.

Symbiotic / synergistic –

Living together in more or less intimate association or close union; 1+1 >2

Sensuous –

Physical, of the senses, lush and rich.

Product vision

In order to elicit the interaction between user and product as described above, the product should have the following qualities or character:

Probing / intrusive –

In your personal space and taking intimate information

Autonomous / unpredictable –

Seems to act of its own will

Unavoidable –

Always there, you cannot escape it

Exposing / Revealing / Confronting –

Lays bare, makes public

Nodal / liminal / interfacing –

In part personal in part public, part of a network, interconnected, <A surface forming a common boundary of two bodies, spaces, or phases>

Summary

In the previous paragraphs an outlook for a design has been constructed. The context, interaction-vision and product-vision make the perspective explicit from which a product will be further developed. The elements mentioned in these visions form a source of inspiration as well as guides.

The whole of the conceptual framework implies the need for more thorough analysis of human-centered aspects of an individual in a (social) environment. The following chapter ‘Building Blocks’ discusses the insights that such an analysis has yielded.

4. Building blocks

The characterizations given in the previous chapter form an idealized vision of the product in development. The product will be used by people in a social environment and should be part of or make use of the forces at play in such a setting. Therefore a natural next step in the development is to analyze what is known about the interplay of the mind, the body and the (social) environment.

Social and Evolutionary Psychology

Prevailing emphasis in the study of social dynamics lies with adaptive and pattern-producing characteristics of groups rather than interpersonal processes. As with complex adaptive systems emergent behavior on a colony or community level is the result of interactions between individuals, which in its turn is the result of processes within the individuals that constitute the colony. Therefore the individual in a group context, rather than the group itself may be the proper unit of study. The field of social psychology does precisely that. [Ross&Nisbett, 1991]
Evolutionary psychology approaches the processes in our brains as mechanisms whose design evolved as a result of ancestral adaptations to and natural selection by the environmental circumstances, physical as well as social. [Cosmides&Tooby, 1992]

The processes within us cannot be seen as independent from our social and physical environment

We are equipped with a set of information processing mechanisms that help us perceive and respond to what we perceive. Much of this processing has an autonomous character: we are unaware of the complexity of the processes that underlie our perception, emotions, actions and thoughts.
Biological machines, such as ourselves, from birth are calibrated to the environments in which they evolved. In this sense we possess mechanisms that in some sense already “know” a lot about our environment.
For example, a newborn’s brain has response systems that “expect” faces to be present in the environment: babies less then 10 minutes old turn their eyes and head in response to face like patterns, but not to scrambled versions of the same pattern with identical spatial frequencies. [Johnson & Morton, 1991]. What is true for our visual perception is very likely to be true for other sense modalities as well.

Perception

Mechanisms that already “know” about our environment form the core of what may be described as our skills to detect signal in noise. Our environment bombards us with an enormous amount of information. Our senses and perception mechanisms help us make sense of what happens in our environment; in other words to give meaning to the stimuli we receive.

Recognize signal in noise, give meaning to stimuli

These mechanisms enable the human to quickly and efficiently respond to events in our environment.
In the case of life threatening situations a fast prioritization of and quick response to signals we perceive is of utmost importance.
Apart from innate processing, we have an innate capability to learn. We can learn on an autonomous level to attach meaning to stimuli.
This brings us to an interesting question in human psychology, specifically emotion theory: Do we run from a bear because we are afraid, or are we afraid because we run? [James, 1890]

Perception and Emotion

In contemporary emotion theory it is accepted that an initial stimulus is automatically appraised, given value and reacted upon before there is time to cognitively process the information [Arnold, 1960; LeDoux, 1996]. This gives us a fast prioritization mechanism and action initiation necessary to survive. Emotions may automatically and pre-consciously determine meaning and activate states of arousal.

Emotions give meaning to stimuli

Not only external stimuli, but also internal – physical and mental – stimuli seem to be processed in this way. This indicates that boundaries between thought and emotion obscure the experiential and neurobiological reality of their inseparable nature. [Damasio, 1994; Siegel, 1999]. Emotions thus play an important role in all our thought processes.

No thought without emotion

Furthermore it is implied that on the one hand emotional responses have a physiological counterpart; on the other hand it implies that assessment and categorization of emotional state in active thought is based on mental states as well as on proprioceptive stimuli from the body.

Emotions are mental and physical: gut-feeling and intuition

Some research indicates that the experience of affect may be directly influenced by proprioceptive cues. In a striking example of this research test subjects were asked to hold a pen in their mouths such that a smile was either facilitated or inhibited while they rated the funniness of cartoons. Although subjects were not aware of the meaning of the particular muscle contractions, their reported amusement corresponded to the induced expressions. [Stepper&Strack, 1993]

Social Interaction

Facial expressions are more commonly seen as communicating emotions to others. For the largest part of our evolutionary history we have lived in social circumstances, in hunter-gatherer groups. This is reflected in autonomous mechanisms that are of use in social situations. Charles Darwin first observed that certain kinds of bodily expressions or displays are common in both humans and mammals. E.g., goose bumps are a mild form of piloerection (hair standing on end) [Darwin, 1872]
More recently evidence has been found that certain emotion expression, especially through facial expressions, is essentially innate, involuntary and is the conduit for communicating approval, danger, sympathy, anger and other signals from one individual to another. [Izard, 1971; Ekman, 1992]. The conclusion drawn is that expressions and interpretations of certain emotions are genetically determined. Neuronal clusters have been found that interpret facial expressions. [Schore, 1994].

Communication of affect is innate and autonomous

Apparently involuntary emotional expression is a form of communication which can occur autonomously and which may be more revealing about a person's emotional state than a person's words.

Emotional mechanisms have been found to require significant time and experience to mature. An infant learns to regulate its inner world primarily through attachment relationships with primary caregivers. The infant accomplishes this by aligning its state of mind with that of its caregiver, establishing a conduit of empathetic attunement which functions as an emotional umbilical cord. "Early in life, affects are both the primary medium and the primary subject of communication." [Stern, 1985].
In other words, the first social interaction we have in our lives is by means of affective cues, which actually help shape and mature emotional mechanisms in the brain. The matured mechanisms of social referencing are used later in life for the assessment of affective states in a social environment, which functions as a form of subtle, automatic feedback to an individual with regard to her behavior. In this way affect can be seen as the basis of group dynamics.

The core of social dynamics is affective

SUMMARY

In the light of the conceptual vision of the product, theoretical elements from the previous paragraph form important building blocks for a product that closely resembles the vision.

The core of group interactions seems to be affective. Affective cues from our social environment are for a large part autonomously communicated. Stimuli from our environment are automatically appraised and evaluated. These mechanisms are to some extent present at birth, but also we can learn to attach new meanings to new stimuli through experience. Emotions play an important role in this processing and have an integrated effect on mental as well as physiological processes. Assessment of feelings in ourselves may to some extent be a form of internal biofeedback.

With these insights, the visions of the product may be realized in:
“A channel of communication between our body and our social environment, which conveys physiological signals that correspond to affect.”
Our skills in information processing and attaching meanings to stimuli may give us the possibility to learn the meaning of physiological signals in our social environment that we normally cannot perceive. In this sense we may develop a form of gut feeling with regard to social dynamics: ‘insight in’ through ‘experience of’.

5. Synthesis

Moving from the abstract to a more and more concrete level, the previous chapters have first discussed a vision projected on a product that enriches social interaction. Successively insights from sociology and psychology were integrated with the visions to arrive at a somewhat less abstract description of the product.

As mentioned in the previous chapter, the product will form a medium through which affect related physiological signals are exchanged between people in a collocated group. Before a choice in the abundance of technologies available and possible can be made, first a few implications of the description have to be made explicit.

The system in development will open a visceral channel of communication of physiological signals between people in a given physical location. Implicit in this description, as well as in the vision, is that the product will be wearable, part of a person, not part of a persons physical environment, e.g., architecture. In some way the product is also part of the social environment of a person, as it conveys signals to and from other people.

Such a system has two main levels:
Individual device
The device worn by a person senses some affect related signal from that person's body and combines this with information from similar surrounding devices. The signals are then mapped to the stimulation of one –or more– of our sense-modalities.
Network of devices
All devices worn by people in a given location will have to communicate with each other in order to share the physiological information of their bearers.

In the following paragraphs the still general description is further refined to a physical level, with regard to human physique and with regard to the technology that realizes the desired functionality.

The choices made are preliminary; in the sense that first a (set of) prototype(s) will be built to test the assumptions made so far.
The choices made below in part reflect the constraints that are imposed because this is a one-man masters' thesis in Industrial Design Engineering with limited time, money and scope.
The goal of this thesis therefore is to create a first step in a possibly new direction. An attempt is made to limit complexity in order to increase feasibility within the constraints.

Merits of Affective Computing

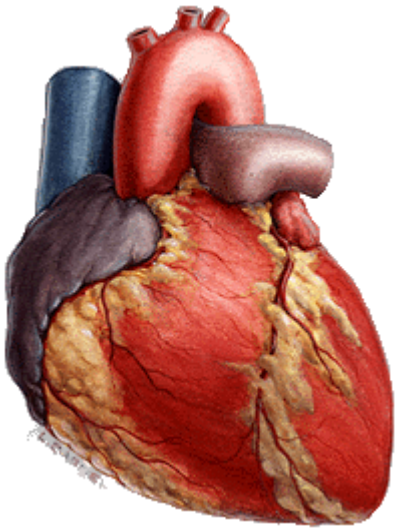
Previously the field of affective computing was introduced briefly. Affective Computing is a young discipline that tries to tackle the complex integration of a number of rapidly evolving fields. The approach taken is controversial and innovative and will most likely yield valuable insight in what emotions are and what roles affect plays in our lives.
The aim of affective computing is to create computer reasoning that may infer an individual's affective state from a combination of affect related physiological cues, and have the computer respond appropriately.
To this end sensors are developed to detect the affect related physiological signals. Concurrently evaluations of the affective states by people are collected. The next step in the approach is to create and train processing algorithms by overlaying the two kinds of data. The resulting computer reasoning has been proven to infer with striking accuracy the affective state of an individual from physiological affective signals. [Healey and Picard, 1998]. However promising, the mentioned accuracy concerns data sets from one individual, thus no discriminating

generalizations can be made –yet–. One of the problems is of semantic nature: different people evaluate feelings differently. Another –related– hurdle is that there is hardly any integral theory of emotion.

In this project a subtly, but essentially, different approach is taken. Instead of having a computer attach meaning to affective cues and respond appropriately, the same cues may be made more directly available to people. Human skills in signal processing may then attach meaning to these signals.
This project makes use of the knowledge and skills from affective computing, with regard to physiological signals that correlate with affect and ways to detect and process them.

Affect Related Physiological Signals

Many studies have looked into the physiological changes that accompany human emotions. These studies have shown a number of physiological changes that accompany emotions, e.g. heart rate, blood pressure, muscle tension and electro-dermal response or galvanic skin conductivity. Each of these relates to some extent to affective state. [Cacioppo et al, 2000]. Galvanic skin conductivity for example is a consistent indication of arousal. When a person is startled, skin conductivity shoots up. The previously discussed Galvactivator™ is based on this phenomenon. In the context of this thesis it carries too far to discuss all available signals and what they correlate with. A summary of affect related physiological signals may be found in [Healey, 2000] and [Cacioppo et al, 2000]. I will suffice by discussing the signal used in this project.

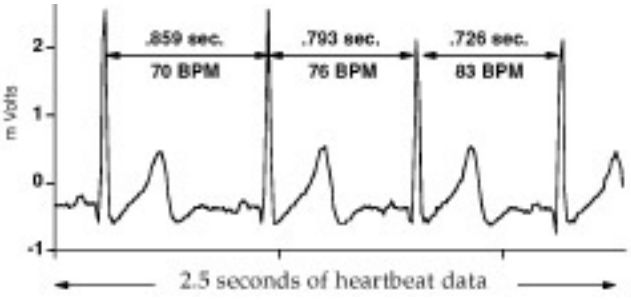


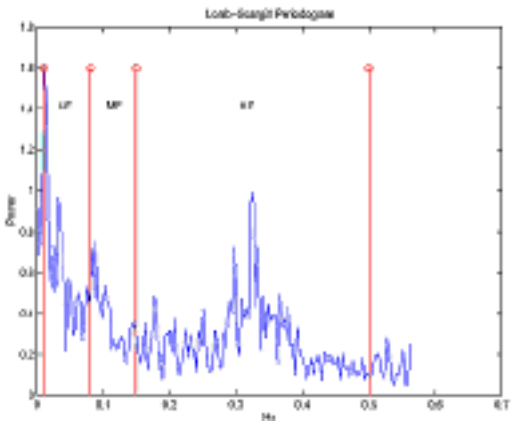
Heart: seat of emotions

The heart is popularly referred to as the seat of emotions. Apart from a poetical perception, there is indication that heart rate and some related measures are affiliated with affective states. An interesting phenomenon in a social context is that the hearts of two people in close proximity influence each other and will synchronize over time. [Russek&Schwartz, 1994; McCraty et al., 1998]
An object that has a (artificial) heartbeat is easily considered to be alive and causes a strong visceral response in people.

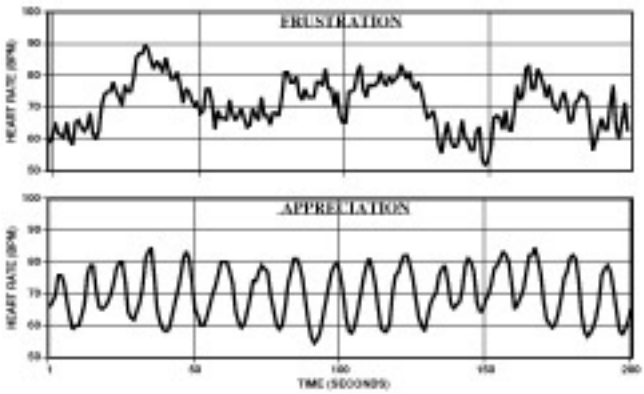
Heart Rate Variability

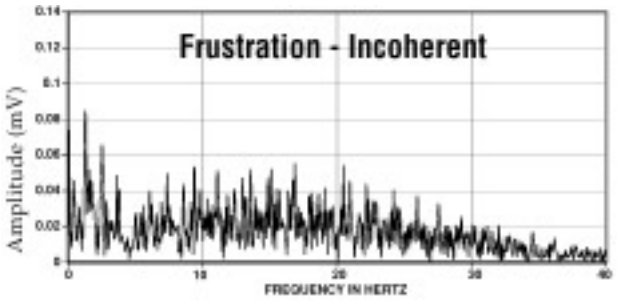
Heart Rate Variability is a measure derived from the heartbeat.
The autonomic nervous system (ANS) is the portion of the nervous system that controls the body's visceral functions, including action of the heart, movement of the gastrointestinal tract and secretion by different glands, among many other vital activities. It is well known that mental and emotional states directly affect the ANS. There have been studies looking at to what extent data taken from the heart can be used to indicate the influence of certain mental and affective states on the ANS. These studies have mainly used Heart Rate Variability (HRV) as a measure.

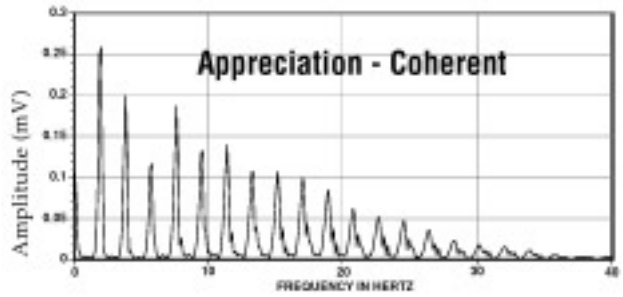




The heart does not, as you might think, beat monotonously regular when a person is at rest. A healthy heart at rest beats surprisingly irregular.
HRV is a measure for the short-term variations in heart rate derived from the electrocardiogram. HRV has been measured both in the time and in the frequency domains. The term HRV often refers to the variations of the inter-beat-intervals (IBI) of the heart; this is considered to be a good measure of short-term variation in the electrocardiograph. Other time series measures have been used to assess long-term variation of the heart spec-







trum, e.g. -among others- the difference between the maximum and minimum IBI in a given interval. [Healey, 2000; McCraty et al, 2001]

Lately, short-term power spectral density analysis as a method for assessing HRV has come within reach with the availability of digital recording and signal processing.
The power spectrum of the heart shows three distinct peaks, one in the lowest frequencies under 0.1Hz; one near 0.1Hz and another in the higher frequencies between 0.3 and 0.5Hz.
In the spectral domain, the relative strengths of the sympathetic and parasympathetic influence on HRV can be discriminated. The parasympathetic nervous system activity modulates all frequencies between 0-0.5Hz and decreases heart rate, while sympathetic nervous system modulates heart rate with a significant influence only below 0.1Hz and increases heart rate. The integrated response depends on the balance between the two. [Healey, 2000]
It has been proposed that a ratio of low frequency to high frequency portions of the spectrum can be used as measure of sympathovagal balance. What frequencies to use exactly has been subject of debate.

Some studies suggest that a level of stress or 'anger' can be identified using the LF/HF ratio and relaxation or 'appreciation' can be identified using mid-range frequencies. [McCraty et al, 1995]

In the Affective Computing group, Yuan Qi, Thomas Minka and prof. Rosalind Picard have developed a fast and robust algorithm for power spectral density analysis, making real-time, ambulant analysis of heart signals a possibility. [Qi et al., 2002]

Conclusion:
Heartbeat and derived measure of Heart Rate Variability seem interesting physiological aspects to make available through the proposed channel of communication between our body and our social environment.

SKIN: THE BOUNDARY OF SELF

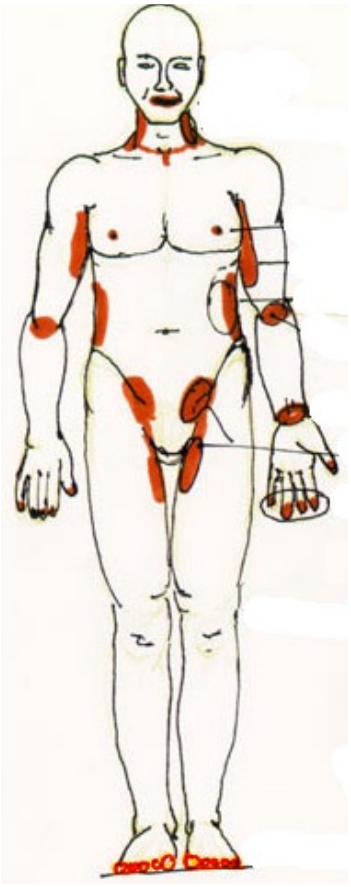
The skin is the interface layer between body and environment. The skin forms a physical boundary between what we consider a person and the rest of the world; it keeps our internals in and the world out. However, the skin is our largest sense organ and through it signals in the environment are perceived.
Our cutaneous sense helps us perceive a variety of signal modalities. The skin may tell us about environmental (ambient) aspects such as temperature and humidity. Through our sense of touch we may perceive hardness, surface texture, vibration and temperature of an object. With our eyes we may perceive an object, but through touch the object gains substance. Tangibility is an important factor in gaining experience and insight about the physical world around us. Hence, tangibility and tactility may be an important factor in understanding (other) abstract forms of information.

It is argued that during human infancy we crave tactility and touch. Tactility is gradually transformed as the child learns to accept its mothers voice as a surrogate. Caressing becomes the chief form of intimacy and expression of affection with appropriate words and tones of voice and other affective cues. Thus all physical contacts become more meaningful and colored by emotion. Hence touch is not merely experienced as

a simple physical modality, as sensation, but affectively, as emotion. [Montagu, 1971; Gunther, 2001]. One study provides direct evidence for a connection between vibrotactile stimulation and emotional experience. [Bassel&Schiff, 2000].

The skin seems to be a natural choice for presenting affective cues of our social environment to.

The skin contains a number of different receptors. Some receptors are stimulated by vibration. Some of these are sensitive to different frequency ranges. Some receptors detect skin deformation, e.g., pressure, shear, and puncture. Other receptors respond to temperature and others again to hair displacement.
The spread of different kinds of receptors over the body and density at different sites varies greatly. Thus, at different sites on the body the skin is sensitive to varying kinds of stimuli and to varying extent. [Kaczmarek et al, 1991; Montagu, 1971; Gunther, 2001]
Below a concise overview of the various receptors, the stimuli they are sensitive to and portions of the skin where they can be found is presented. This information is summarized in a general cutaneous sensitivity map of the skin.



Mapping

In the previous paragraphs of this chapter the heart was brought forward as the source of physiological signals to be conveyed in a system that mediates the exchange of affect relate physiological signals in a social environment. Successively the skin –cutaneous sense– has been proposed as the perception channel to which the physiological signals (and possible derivatives) of the environment are offered. A decision will be made next as to what precise form the signals offered to the skin will take, guided once again by the vision laid down in the chapter ‘Conception’.

Every time our heart beats, a pressure wave surges through our veins and bodies. We usually are not aware of these pulses, unless something out of the ordinary happens, e.g. in case of physical strain (hear your blood rush) or headache (feel the pressure surges). An object that pulses or vibrates in a frequency similar to the heart is easily considered to be alive and causes a visceral - affective response.
It seems suitable to map the heartbeat to a pulsing device that sends a pressure pulse to the skin. This pulse may aptly move to the periphery of our attention and has the uncanny, autonomous and sensuous character desired. Also pressure pulses may be perceived as coming from within the body and thus may connect to our proprioceptive skills.

The beats from all other people in range will be mapped to the same pulsing device. In this way synchronization of beats may become apparent. In a possible branch following this thesis multiple pulsating devices may be explored.

Combined affective states of people in a group can be considered to amount to the phenomenon of group-mood. Affective state and moods are often described in terms of temperature. Heart Rate Variability is an indication of, roughly speaking, positive (open, interested, warm) and negative (closed, angry, cold) affective state.
Slow temperature changes (over several minutes) in our environment are often hardly noticed. We are more readily aware of quicker changes in temperature. Extremely quick and severe changes cause retreat-like reflexes.
In some sense group mood could be considered similar to weather.
It seems appropriate to map heart rate variability to temperature

(-changes) presented to the skin. Slow changes may reside in the periphery of our attention; faster changes may become intrusive and even startling, supporting an autonomous, confronting character.

The combination of HRV signals from various individuals will initially be an average. More complex or weighed combinations may result in more meaningful sensations. For instance the distance between people could be used to modulate the various signals (the further away, the smaller the influence). This will not be explored in this thesis.

Technology

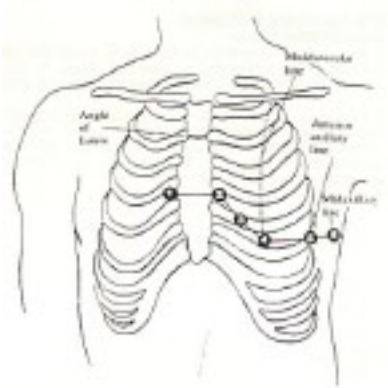
So far requirements of the product have been defined, from conceptual qualities down to what input (heart) and output (skin; pulse and temperature) will be used. Now it is time to start turning the requirements into physical reality. Necessary technology may introduce constraints with regard to the requirements defined so far, as well as with regard to the physical shape the product will assume.
Technology will be discussed that enables detection of heartbeat and derives heart rate variability. A device for generating pulses and temperature change is presented. Digital glue, as a metaphor for the power of micro controllers for connecting all sorts of devices, is introduced. As products worn by different people will have to share the information concerning their bearers, technology that enables communication between them is discussed.

Detecting heart rate

Blood Volume Pulse

Generally speaking there are two ways of detecting heart rate.
Blood Volume Pulse (BVP) sensors use the reflectance of infrared light of the skin. The reflectance of the skin varies with the amount of blood circulating in the skin. With each heartbeat, a pressure surge in the bloodstream causes more blood to circulate through the skin. Thus the infrared reflectance of the skin varies.
BVP sensors detect the effect each heartbeat has on blood pressure and circulation; hence it is an indirect measurement. The amount of blood in the skin is influenced by other factors as well, e.g. temperature regulation of the body. Movement artifacts are difficult to avoid in BVP sensors, as slight movement or increase and decrease of the pressure with which the sensor is placed on the skin occur easily.
The best positions for a BVP sensor are on sites that have many superficial veins, such as the fingers and the earlobe.

Electrocardiogram

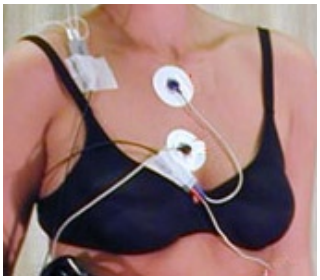


In an Electrocardiogram electric effects of the electrical activity of the heart muscles are detected on the skin. Electrodes with good electrical conductance are placed in various locations on the skin, such that the electrical effect generated by the heart can be optimally detected. The number of electrodes varies depending on the purpose for which the data is collected. Most common for medical application is a 12 or 8 point ECG where electrodes are placed forming sort of a mirrored J configuration from the lower side of the left chest, across the middle of the chest bone to the right shoulder.

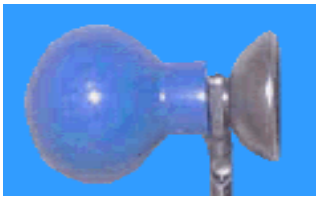
In sports heart rate monitors, a chest strap is used with only two electrodes, each on a side of the chest. These systems perform severe filtering of the signal, as the body functions as an antenna for all sorts of electro-magnetic ‘noise’ from the environment.

Another option with regard to noise is to use three electrodes: one ground and two for the signal. These latter two electrodes can be positioned pretty much anywhere on the body, as long as they are on opposites sides with regard to the heart; but the further away from the heart, the weaker the signal and the more activity of other muscles can

interfere with that of the heart. The ground electrode should be placed away from the other two.
These three electrodes form the input to an instrumental amplifier with high common mode rejection ratio, which means that signals that occur on all electrodes are rejected.
Amplification is necessary, as the signals detected are in the range of tens of millivolts (mV). For further (digital) processing higher levels are desirable.



Electrodes need to have a good electrical connection to the skin. Most common are stick-on silver Chloride electrodes (medical standard). In the sports strap conductive silicone (conductive filler e.g. silver) is used. Other forms for this material may be suction-cups, -pads or -coated fabric.
Important aspects of electrodes that are worn daily, all day long, are low allergenic material, breathability and other comfort aspects. Interesting options for solving the problem of comfortable electrodes may come from smart textiles and materials, e.g. conductive yarn or fabric (usually silver Chloride coated).



The development of comfortable and easy to apply electrodes forms a challenge for a whole separate thesis. For the prototypes conductive silicone will be tested as an electrode, similar to the sports-chest-strap. If this doesn't work properly, standard medical electrodes may be used.

Above an algorithm has been mentioned developed in the Affective Computing group, at the MIT Media Lab, which is a good option to process sampled ECG data to derive heart rate and –variability.

Cutaneous feedback

Pulse

For generating a tactile pulse, an electromechanical device is needed with enough 'punch' to stimulate the skin. A number of small solenoids were tested, but found bulky, power greedy and too low intensity. A piezo-electric bender was tried, but found unfit for a wearable device in contact with the skin, as high voltages –hundreds of volts– are needed. Inspired by the piezo-bender, briefly electrical muscle stimulators were considered, but found too intrusive.

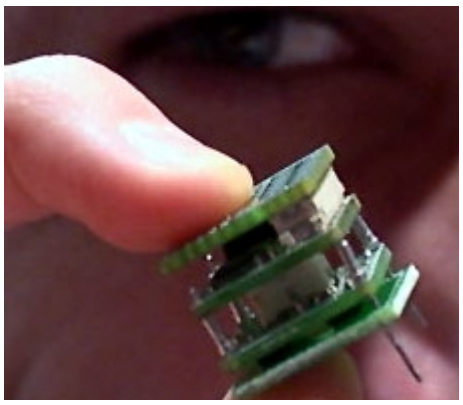
Ultimately elements were chosen that are used in a type of vibrotactile aid for the hearing impaired [Tactilator]. The element functions similar to a speaker. Combination of a current through a coil and a static magnet displaces a membrane. Adding mass to the membrane intensifies the punch of this system.

Temperature

Positive as well as negative temperature changes need to be presented to the skin, ranging from fast and large changes to slow, subtle changes. The only option found is an element that is an array of Peltier junctions. This is a type of semiconductor that functions as a heat pump. The semiconductor material is sandwiched between two ceramic plates. Heat is transported from one of these plates to the other, depending on the direction current flows through the material. The strength of the effect is proportional to the supplied voltage (current drawn]. The maximum temperature difference between the two plates is 65°C, under ideal circumstances, i.e., high heat dissipation for the plate that warms up. Peltier elements draw are enormously power hungry compared to their size: 1-3 Amp., depending on the size of the element and on the required speed and degree of the change in temperature.

Digital glue

The ECG signal is an analog signal. In order to work with this signal, the first stage is sampling this signal. A robust Kalman filtering algorithm (Bayesian spectrum estimation algorithm) is applied, developed in the Affective Computing group to derive heart rate and –variability. This operation is rather processing intensive and needs floating point capabilities, as a fast Fourier transform needs to be performed.
The best option for sampling and processing the ECG signal would be a Digital Signal Processor.
The values derived from the ECG by the DSP need to be mapped to pulse and temperature change. These values also need to be exchanged and combined with values from similar products in the vicinity. This part of the functionality is performed by a micro-controller. There may be micro-controllers or DSP's that are powerful enough to perform all necessary tasks on their own, especially if a dedicated chip were to be developed.



For initial testing of the system the functionality will be simplified to the extent that HRV is calculated as change in Inter Beat Interval (IBI). In this way the complex task of programming a DSP and interfacing it with a micro controller is avoided.

In the prototypes for initial testing a micro controller system developed by Joshua Lifton at the Media Lab and is called 'Pushpin computer'. The Pushpin features a Cygnal 22Mhz micro controller with 2 on board 10-bit A/D conversion around an 8051 core, amongst other very practical and useful peripherals. [Lifton, 2001]

Communication

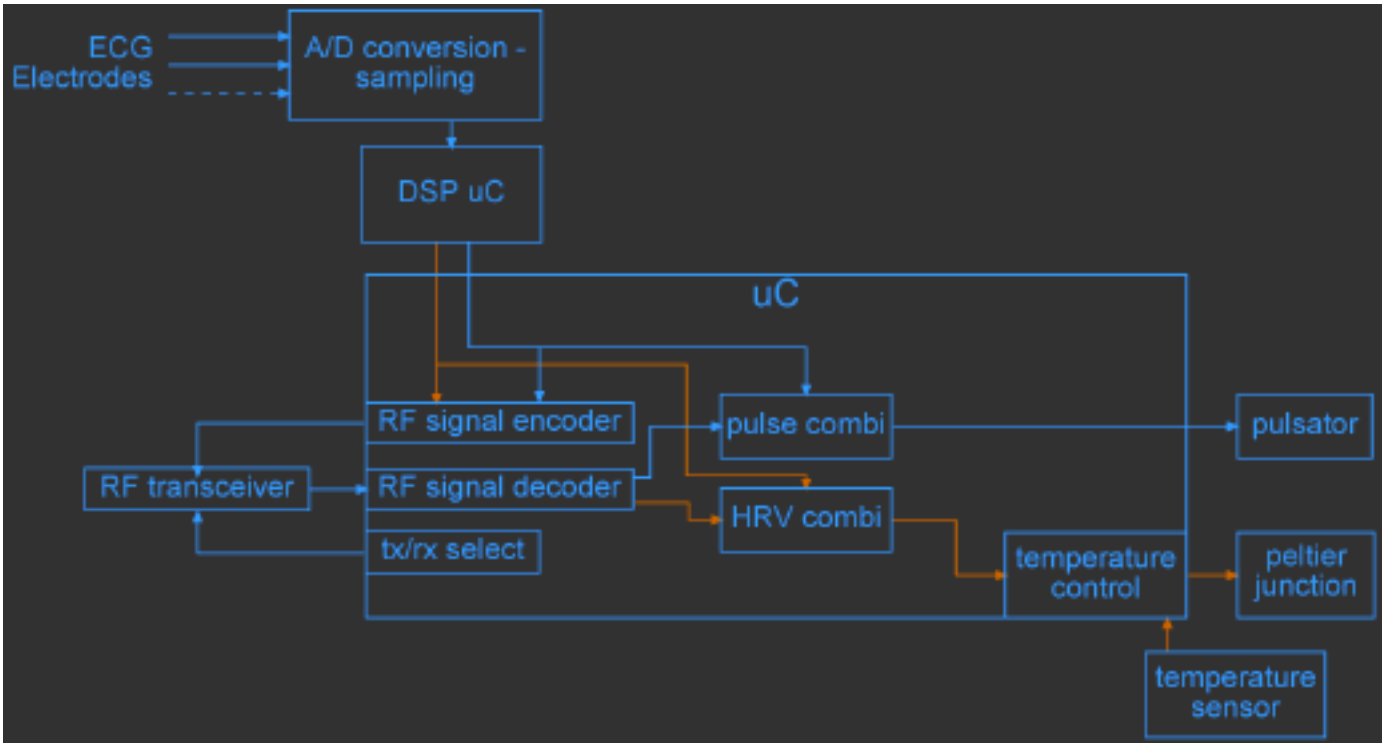
Transceiver

All products in each other's vicinity will have to exchange data wirelessly.
Best option with regard to communication medium for this is radio communication, which avoids line-of sight problems of infrared communication and other problems of e.g. ultrasound. The amount of data exchanged is relatively small. The required bandwidth of the communication channel therefore is rather small.
For the prototypes a transceiver module from Radiometrix was selected: the BiM2 – 433 Mhz, 64kbs (maximum raw data). This module uses little power and has good range specifications and some limited functionality to ensure data-integrity. The unit can either send or receive, not simultaneously, so only half-duplex communication is possible.

Networking

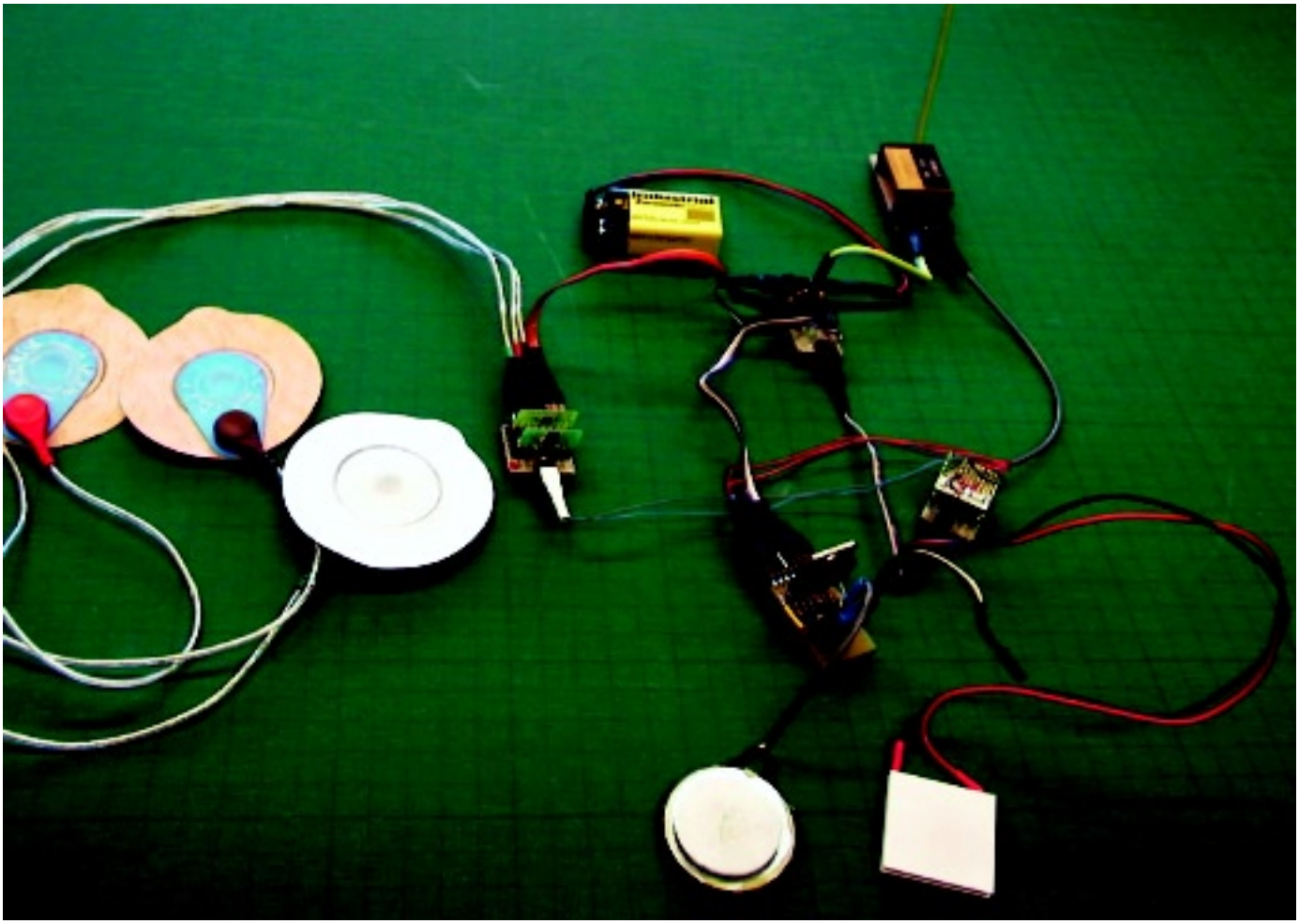
Each device can be seen as a node in a communication network. The structure of this network is ever-changing as people move around. A problem arises in the communication: each device should get information, in digital form, from all others: they might all 'talk' at the same time and would not know how to make sense of each others babble. This problem is a classical networking problem.
A simple solution is to make one unit a 'base station' or 'clock'. In an initial exchange all units identify themselves; the unit with the highest id number becomes the base station (clock). Based on signals from the 'clock' the other units know when to listen and when to broadcast (type of token-ring network protocol).
Schematically this looks like the diagram below.

Much more clever networking protocols may be developed, e.g. Bluetooth functions roughly as described above but is much more robust and efficient.



above
schematic overview of individual system

below - hardware for prototypes
battery - transceiver
ECG electrodes - ECG amplifyer - voltage regulator
output driver - Pushpin
tactillator - Peltier element



Total System

On the facing page a schematic representation of the system is presented as well as a picture of the prototype hardware

Summary

In this chapter the necessary elements for a functional system have been discussed separately and an integration of the elements in a (prototypical) system has been shown. This is the design in the technological and functional sense: “What the system does” and “How it does it practically”.
The product will take a person’s heartbeat, derive heart rate variability from the beat and exchange this information with similar devices in its vicinity. The heartbeats are mapped to a tactile pulsing sensation and heart rate variability values (rather, change in IBI) are averaged and mapped to tactile change of temperature.

A next step is to turn this technology into a physical product, which, once again, resonates with the vision developed.

6. Design: visceral channel of communication

The process of this thesis is aimed at creating new products, which are human centered and offer a context of experience to the user rather than pure (technical) functionality. Therefore the actual development process was initiated with the definition of qualities of the product-user interaction and the qualities of the product that may give rise to the conjured vision of the interaction.
The subsequent steps therefore were aimed at realizing the qualities of the vision. Grounding and elaboration of the vision was found in sociology and psychology. The technology in the previous chapter forms a physical system that may support, afford and realize the vision. However, the core of what has been developed so far is that which the system may give rise to when used by people in a group: On the one hand the experience for an individual and the influence of this on the experience of the group. On the other hand the resulting influence on the social interaction and dynamics of the group.
Therefore the actual product developed is immaterial.

Taking this one step further, it's not so much the qualitative performance of the system (what the system does) that forms the product developed. The experience elicited by the process of interaction between users and the system is the subject and object of design.

On this level the system designed forms a context in which a process of learning, on an intuitive level, may occur.
Steps in this process are:

1. Learn from the biofeedback with regard to your own body. This may raise awareness of your individual mind-body interaction and the roles played by emotions in this interaction.

2. Learn how and to what extent, you, your body-and-mind, respond different when you are around other people. Learn how your social (and physical) environment influences you.

3. Learn what physiological signals of others may mean and to what extent those signals may influence each other in a group context: social-biofeedback.

4. The previous learning steps raise awareness on a gut-feeling level of head-body interactions especially with regard to affect and similarly of interactions between the mind, the body and the social. Once such awareness has been raised, it may become unnecessary for the product to perform the feedback. The product / system may become redundant.

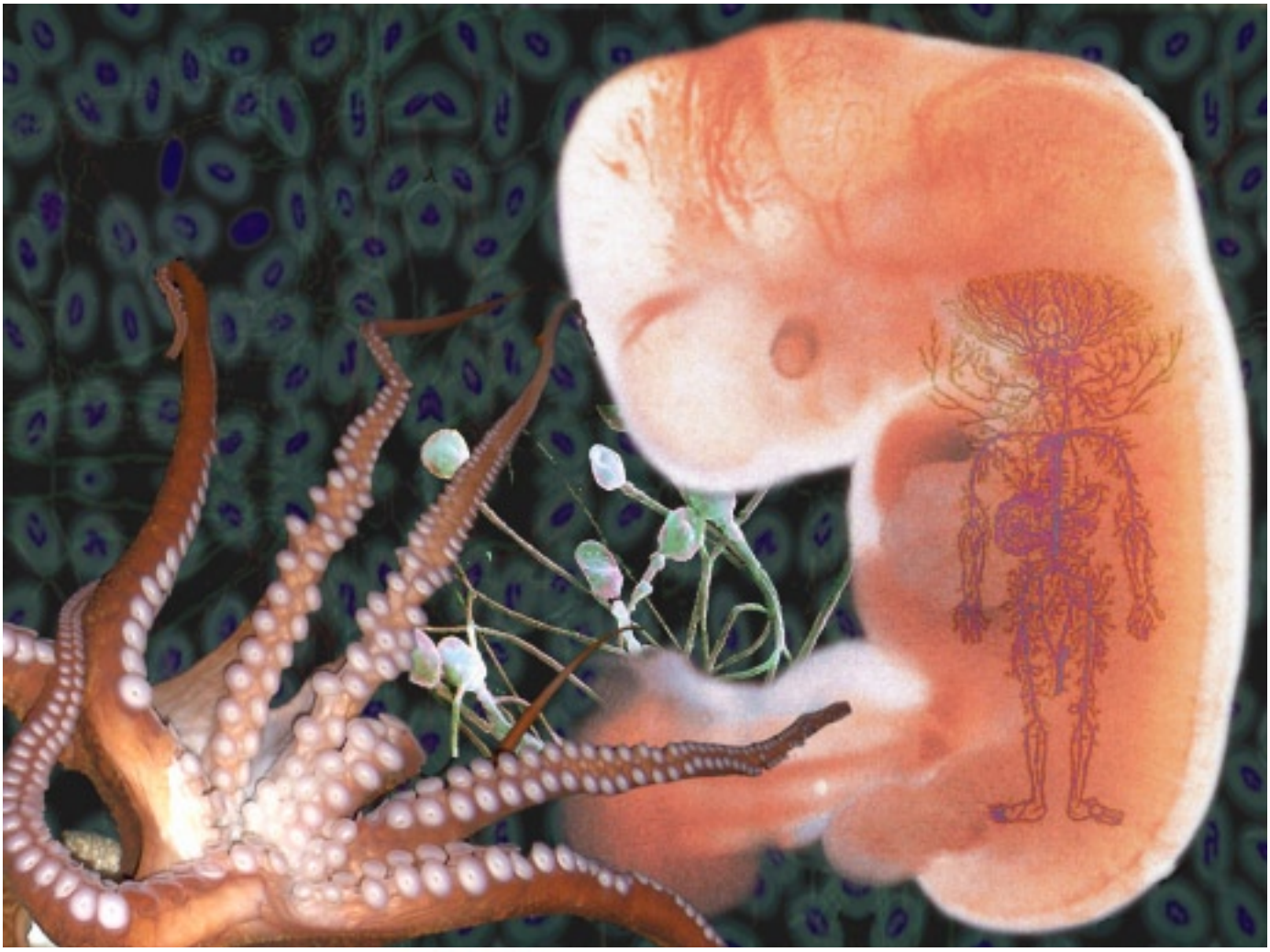
In a way of course the product is redundant from the outset. Biofeedback and social-biofeedback occur to some extent naturally. However, the products we use and the world-view in our western society make us forget –at least be less aware- of these aspects of our interactions with the world, as has been explicated in the chapter 'Conception'.

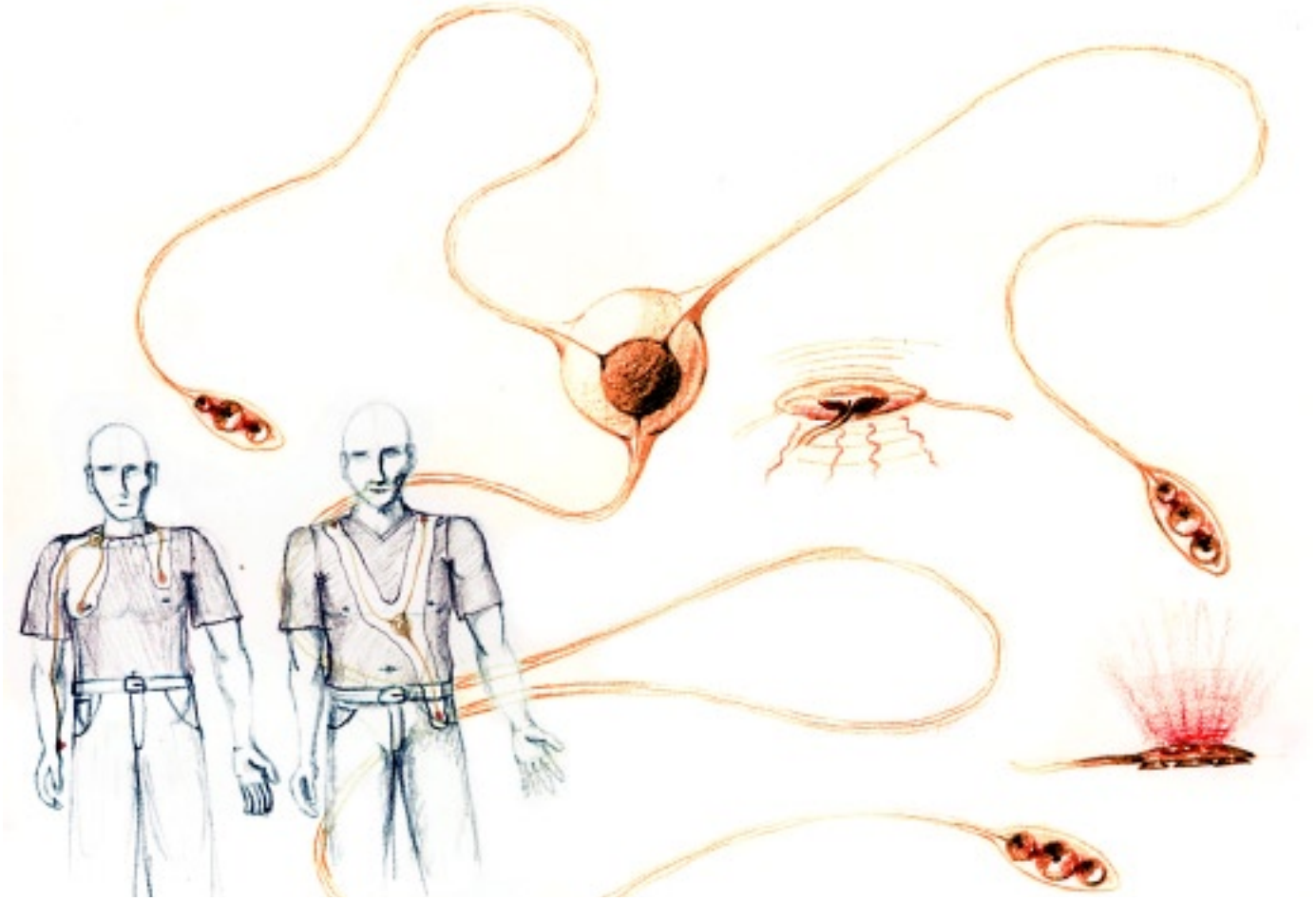
The design is a possibility, a physical hypothesis.
On the one hand it is important to find out what the effect is of the system, e.g. the fitting of the mapping of beat to pulse and the way several sources are combined. Therefore prototypes need to be built, which are a simplified system that may entail at least some of the implied aspects and answer some questions: e.g., feedback of certain information; can it move into periphery? Can we start to make sense of what it does? What is the effect of introduction of such a system in social interaction?

On the other hand, just pondering the idea of the system and what it may do evokes questions and doubts with regard to ethics and values. Once again this stresses the multiple roles of products, hence their designers, may play in our perception of the world.

These philosophical exercises form a scaffold and positioning for the design. The technology developed in the chapter ‘Synthesis’ forms part of a physical support for testing the ideas put forward throughout this thesis.
The appearance of the product is just as important for the perception of the product as a whole. The appearance may amplify or refute the perceived workings of the system as well as the underlying ideas and vision.

In this light no final design will be presented. Rather, possible directions for the appearance will be proposed and their merits and deficits discussed.





Cellipus

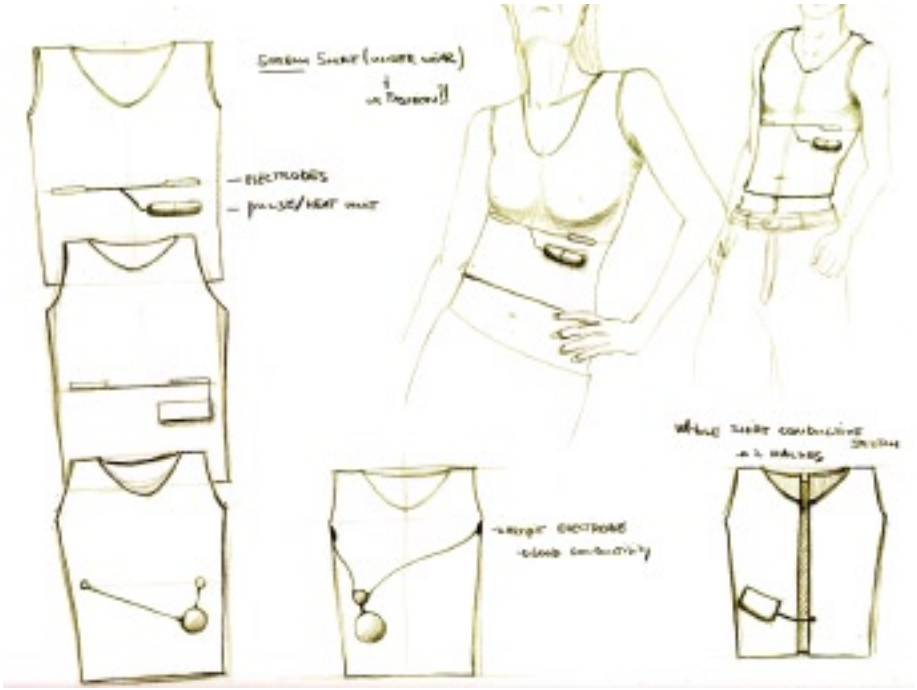
Cellipus is a guise of the system that underscores the scary, ambiguous and autonomous qualities of the vision as well as the networked, liminal character of the product. The product appears to be a hybrid between an octopus and a nerve cell.

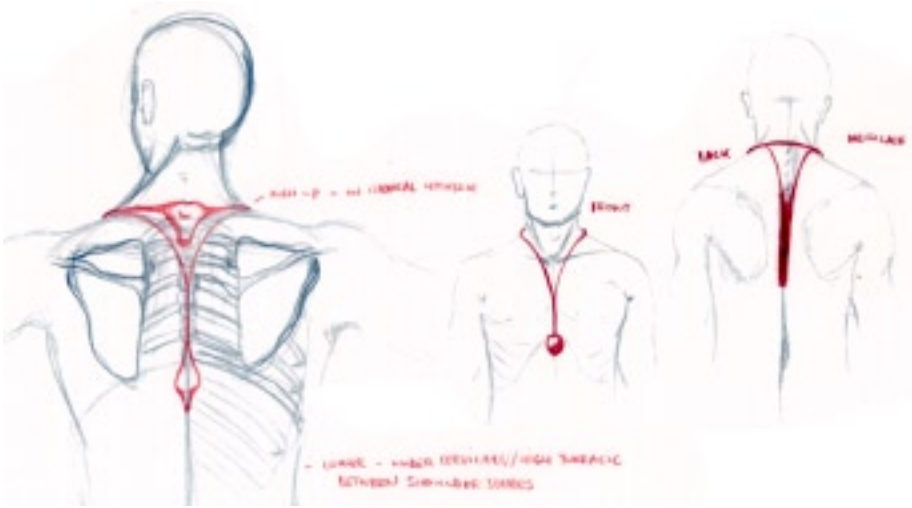
Cellipus is worn against the skin, under clothing. The three tentacles function as the ECG electrodes as well as the points from which Cellipus is suspended on the wearers' body. The ends of the electrodes are suction cups made out of electrically conductive silicone rubber.
The central body of Cellipus houses all electronics. Cellipus rests against the wearers skin. The device conveys temperature change to the skin and pulses (vibrates) on the beats detected and received.

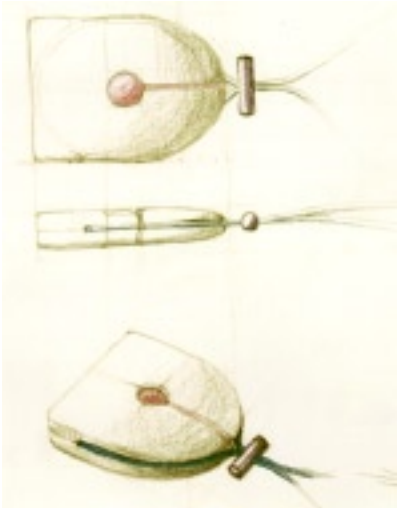
The wearer may decide to position Cellipus anywhere on the trunk, front, back or sides. However, the placing of the electrode-tentacles has to be roughly correct: two of the electrodes each on a side with regard to the heart, the third should be placed away from these two.
The guise of the device elicits an off-hand slap-on movement for donning it, with some more focus for positioning the electrodes.
Cellipus may be worn under any kind of clothing, or even on a bare trunk.

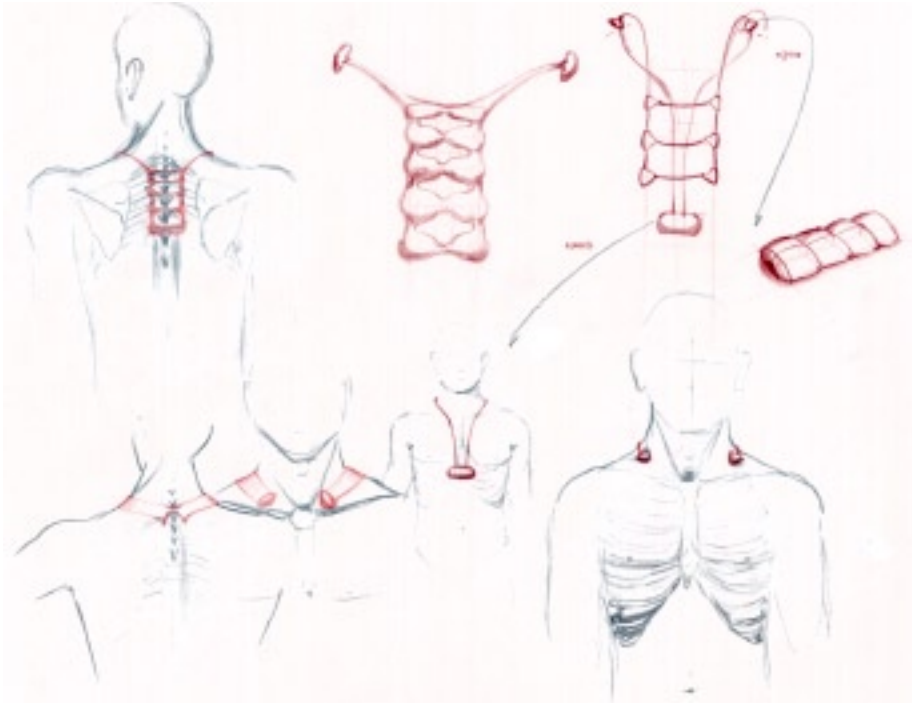
Cellipus' material is silicone rubber. The ductility of the material is slightly tougher then that of the silicone gels found in wrist-rests for mouse- or keyboard operation. This material is similar to that of breast-implants and feels very like real body and skin.
The material is milky translucent, the innards, electronics and wires, can be just made out as faint shadows in this milky substance. The tentacles are stretchy but will not tear.

As Cellipus looks and feels somewhat alien and scary, it may only convince specific people to wear it because of its weirdness. Many people may find it repulsive, even if wearing it may open interesting possibilities for experience in group interaction.


– ELECTRODES







Smartclothing and -Jewelry

Clothing

In this proposal the functionality of the system could be integrated in a piece of clothing, especially underwear for the upper body parts. (For women it is possible to completely 'hide' the system in a bra).
The electrodes and leads are part of or embroidered on the fabric of a shirt, making use of smart-materials such as conductive yarn. For loose fitting shirts the electrodes may be positioned on the shoulders so that the weight of the shirt presses the electrodes on the shoulders, for tight, stretchy shirts they can be nearly anywhere on the trunk.
The feedback elements for pulse and temperature are quilted in-between two layers of fabric or, e.g., molded in rubber onto the fabric. The whole of the system thus becomes a nearly graphic design, which is visible to others depending what other clothes are worn.

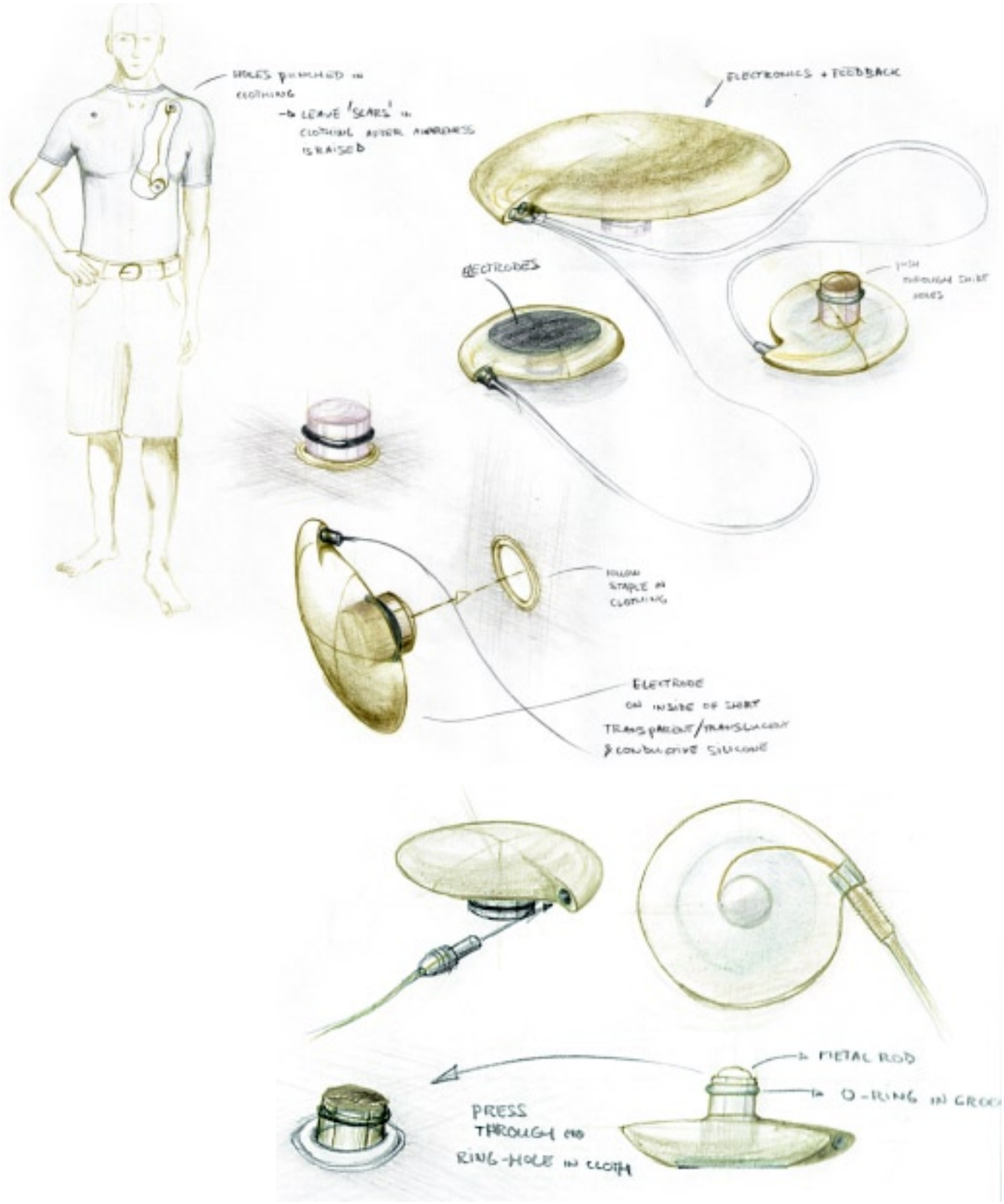
The electrodes are integrated with the clothing; therefore the positioning of the electrodes is relatively fixed.
Donning the product is the same as donning other pieces of clothing. The choice of wearing the product is similar to picking other things you wear when you dress.

Integration of the device in clothing rejects its envisioned independence and autonomy. It becomes much more of a fashion statement. This does not resonate with the vision, even if the workings –what is felt– do. The reason to wear the system should be interest in mind-body interaction and the physical changes in collocated people, not so much to show off the device itself like a cool accessory.

Jewelry

A similar proposal is to integrate the device with jewelry.
Designs were made that look like new kinds of jewelry that do not explicitly connote the character of the workings. Contrary to the clothing, only the wearer knows and feels the behavior of the device, other people may see (part of) an aesthetic accessory. The wearer would show off a beautiful piece, not a cool gadget.

The clothing and the jewelry proposals both provide relatively straight-forward possibilities for making contact with the wearers skin and avoid a threshold for the wearer to put it on.
These proposals have some merits but fail to fully encompass the vision.


HOLES PUNCHED IN CLOTHING
→ LEAVE 'SCARS' IN CLOTHING AFTER ANDROGENS IS RAISED
ELECTRONICS + FEEDBACK
ELECTRODES
1cm THROUGH SHIRT HOLES
FOLLOW STAPLE IN CLOTHING
ELECTRODE ON INSIDE OF SHIRT
TRANSPARENT/TRANSLUCENT
CONDUCTIVE SILICONE
METAL ROD
O-RING IN GROO
PRESS THROUGH END RING-HOLE IN CLOTH

The previous examples can be seen as extremes in shape-connotations for the system developed. Cellipus shows the dark side of the proposed device, whereas the clothing and jewelry tries to hide and/or integrate the character of the product with the functions and character of objects people normally wear.

Buttonhole consists of a number of elements –electrodes and feedback elements– that fit into rings in a piece of clothing from the inside. The rings are pierced through the cloth of, e.g., a shirt. The rings and the studs that are visible on the outside elicit wonder in a spectator, but hardly give away what they are.
The elements are connected to one another with wires that run underneath the garment.
The material of the elements is similar to that of Cellipus, milky-transparent silicone rubber, but slightly clearer. The innards therefore can be made out in detail. The rings that are punched into the clothes are silver, but could be chosen in a color that matches the garment and preference of the wearer.

At the time of purchase of Buttonhole, the rings are punched in whatever the person is wearing. Extra rings are available for preparing other garments as hosts for Buttonhole. Similar to Cellipus the owner is free to choose the specific positioning of the elements within the constraints of detecting ECG.

Buttonhole is an appearance of the developed system that keeps its autonomy and character without becoming scary in itself. In this form the device is not a gadget, not a piece of clothing nor a piece of jewelry. Buttonhole constitutes another class of object altogether.
Buttonhole needs clothes to be worn but does not integrate into it. Rather, it rides clothing. It is controllably invasive.

An additional feature of the system is the ‘scars’ it leaves in the owners clothing when the product is not worn (anymore). The scars reflect the learning steps implied at the start of this chapter and may reflect the hypothesized final achievement of awareness of the interaction of the mind, the body and the social context.

Buttonhole is a proposal that closely resembles the vision of a channel for visceral communication between collocated people.

During this project a set of prototypes are built. The hardware has not been optimized with regard to size and power consumption. After an engineering iteration, it should be possible to fit the system in two or three elements, each the size of a pocket watch.
In this project, due to constraints in resources such as time, skill and money, concessions had to be made for the construction of the prototypes.
There are three small electrode elements, to elements for the two forms of feedback each. All electronics and batteries are placed in a generic block or blob that can be placed in a pocket. All elements have a wire leading to this central unit. The elements however are still positioned on the wearers body as described above.

7. Conclusions

A primary goal of this thesis is to explore a possible alternative approach to the development and design of consumer products.
The subject of the project, the product developed, is a response to the way things are with regard to products and society in the western world, as has been discussed previously. In a sense the product developed is an illustration of an alternative approach to design.

The Product

A product was developed which augments insight in and experience of group interaction for group participants. The product is a medium for social-biofeedback.

A vision was projected rooted in, on one hand, the author's view of western society and, on the other hand, an analysis of the media used and being developed for social interaction in this society.
Handles that provide grounding for this abstract vision were found in social psychology and psychophysiology, perception and emotion theory.
In order to realize the vision in a physical product, technology was selected and developed. The technical system developed was primarily aimed at realizing prototypes, which afford evaluation of the experience – the process of user-product interaction.
The physical appearance of the product is an integral part of the elicited experience. Designs were presented which explore the different connotations appearance may give to the perceived workings of the system.
So far, individual systems perform the detection of physiological signals and map them to tactile sensations. The exchange of physiological information between a number of individual systems has been simulated as proof-of-concept on a (digital) logic level.

A preliminary test was performed with the individually functional hardware.
The two test subjects reported initial surprise at the strength of the sensuous experience and wonder over its meaning. With elapse of time the initial attention drawn to the stimuli of the system was reported to become less demanding: the stimuli of the feedback moved into peripheral perception.
The system was not worn long enough to establish any (other) learning affect of the feedback.
However, opinions were expressed which confirm ambiguity with regard to autonomy ("Does it really respond to my body?") and attraction ("It feels really cool, but it's scary too! It's, like, it's alive…").

The (Near) Future

The creation of a system that establishes social-biofeedback is one thing. However, it may be clear that this project is a work in progress. The product in the stage it is in is a physical hypothesis. Many questions are left unanswered due to time and financial constraints.
An interesting step in a possible short-term continuation is a field test of the set of prototypes.
The experiences of the test-subjects should be evaluated on a psychological as well as a sociological level, e.g., the fit of the mapping of physiological signals to sensory stimuli on the one hand, and, on the other hand, the effect of introduction of such a system on the dynamics of the test group.
Evaluation of the experiences of test-subjects may yield insight for adaptation of the system. Adaptations may range from tuning the intensity of the feedback and varying the way feedback from several sources is combined, to developing other modalities for feedback and even overhaul of the appearance of and technology used in the system.

Looking at a longer period other exploration come to mind.
On a very practical level, electrodes and, possibly, other sensors that are unobtrusive and comfortable –or at least not intrusive– to wear for long periods of time should be developed.
A similar system might be extended with other physiological signals mapped to the same or other sense modalities.
In conjunction with the developing fields of psychophysiology, emotion theory and affective computing as well as wearable- and ubiquitous computing, other levels of 'intelligence' may be embedded in a system. For instance, more signals –Galvanic Skin Response, Electromiogram as well as ECG and HRV– from the wearer could be combined and then mapped to some form of feedback. The product could monitor the information it receives from the wearer and her social environment and provide feedback of a derivative of the social biofeedback process, such as synchronization of heartbeats.

Other directions I see sprouting from the same feeding grounds as this project are plenty.
A similar system could be implemented for non-collocated groups. In this vein, a channel of visceral and tangible communication could form a line between two lovers. Imagine that you could feel how your lover feels.
To take it less extreme, a similar approach, here applied to group interaction, could be applied for medical and health purposes.

Generally speaking, exciting explorations lie ahead concerning the relations of:

- the body, the mind and the social,
- the affective and behavioral dynamics of individuals and groups,
- mental and physical health,
- and the role wearable technologies, miniaturization of electronics and pervasive, ubiquitous computing can play in all of the above.

The Process

As mentioned in the preface to this document, this graduation project was carried out in part at the MIT Media Laboratory, Cambridge MA, in pursuit of a masters' degree in Industrial Design Engineering at the school of IDE, TU Delft, Netherlands.

Looking back at the whole process of the project, I see a clear line from the start to the results presented. The match between initial assignment and designed product is striking.
This is very much due to the approach taken as well as the environment in which I was fortunate enough to work on this project.

The Vision in Product development approach was combined with the human centered, integral approach to product design as the design of a context for experience, advocated by the ID-StudioLab at the school of IDE. This integration served well to marry the personal world of the designer to the professional world of product design as well as the conceptual with the real.
However, especially the conceptual ViP steps of deriving and tuning of interaction vision and product vision proved time-consuming. Once an integral vision had been constructed, it proved difficult to convert it into actual product ideas and design proposals that correspond to the subtleties of the vision.

The Media Laboratory, with its emphasis on proof of concept through technology, proved to provide valuable grounding of the conceptual in feasibility through urging implementation. At the Media Lab, I have found constant inspiration and support to pursue a passion, as well as constructive critique and incentive to find back-up in science and reality. The many fields of study represented by the groups of the Media Lab provided valuable technology as well as in depth knowledge with regard to marrying technology and human-centered aspects.
However, it has taken quite long to find the fit between the IDE and ML cultures.

In the end, the vision construction, conversion of vision into reality with the help of the interaction of the two cultures has proven to be productive. However, the time consumed by finding a match has strongly influenced outcome of this project.

Epilogue

I would like to put the level of realization of the product designed in another light then purely as a marketable, mass producible, consumer product or a tool for scientific research.
I have emphasized before that the product is a context for experience. The core of the design is the qualities of the interaction between user and product as well as the influence the introduction of the product may have on social interaction and people's perception of self in a social context. In this light the product gives rise to a narrative that offers experience. Anthony Dunne and Fiona Raby eloquently express a similar outlook on design:

> *If the current situation in product design is analogous to the Hollywood Blockbuster, then an interesting place to explore in more detail might be its opposite: Design Noir*
> *<…>*
> *Noir Products would be conceptual products, a medium that fuses complex narratives with everyday life. This is very different from conceptual design, which uses design as a medium for exploring what these products might be like. Conceptual design proposals can exist comfortably in book or video form, it is about life whereas conceptual products are part of life. With this form of design, the 'product' would be a fusion of psychological and external 'realities'; the user would become a protagonist and co-producer of narrative experience rather than a passive consumer of a product's meaning. The mental interface between the individual and the product is where the 'experience' lies. Electronic technology makes this meeting more fluid, more complex and more interesting. [Dunne&Raby, 2001]*

This excerpt captures vividly an outlook for the visceral channel of communication developed in this thesis. The time is due for design to fuse with our perception of the social fabric we are part of.

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