Enhancing the meaning of urban biking through implicit interaction

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Abstract

Motivation
Fundamentally, interaction design is about getting in between: Between people and what is important to them. While it often makes sense to make mediated interactions explicit, implicit interactions can integrate harmoniously into the here and now and happen almost unnoticed.

Imagine cycling through the bustling cityscape of Copenhagen. When people are immersed in life, there is a constant stream of signals. As an interaction designer, I think it is important to consider what is already happening as something to add to or integrate into. How can mediated interactions harmoniously integrate into embodied activities like cycling? Interactions that are unrelated to the current activity or context of the cyclist hardly integrate or blend in. They tend to fragment reality or disrupt the flow. Imagine cycling through a busy intersection and suddenly your mother calls.

Proposal
In this master thesis I explore different approaches to harmoniously integrate interactions with mobile and wearable devices into cycling. Cycling can be treated as a modality. It can influence the behaviour of the operating system or provide considerations for the design of applications. Rather than adding to the existing flow of signals, I propose to tap into that flow and even take it a step further: I explore ways to add meaning to what people are already doing, as if there were no interface.

I introduce two concepts where activity shapes the interaction model:
- Bubbles proposes cycling as an indicator of a person's capacity to engage with, receive messages from and respond to an interface. Rather than being indifferent to the activity of the receiver, the interface adapts and responds for a more considerate composition and delivery of messages.
- Nectar proposes an implicit way of recording and enhancing memories, rather than explicitly capturing them as we do when we press the shutter button of a camera. Inspired by cross-pollination, people spread and collect music as they move through the city and spend time in crowds.

Conclusion
Wearable devices, such as the current Apple Watch, can provide comprehensive insight into ongoing activities. The name “smartwatch” suggests that this device is meant to be attended to, but the greater opportunity lies in sensing and adding meaning to what is already happening. This allows people to immerse themselves in their ‘natural’ environment with their heads up and their hands free.

This project makes it possible to expand the meaning of activities for interaction design. Some of the considerations made with the example of cycling as an embodied activity can also be applied in other situations. What are the implications of entering a room where a hybrid video call is taking place?
Introduction

The rise of wearable technology began when aristocratic women first commissioned wristwatches, bracelets with watches and ring watches. Caroline Bonaparte is pictured on the right wearing a wristwatch at a time (1810-1812) when aristocratic men still preferred pocket watches. In the military and in sports, men eventually began to wear wristwatches (Barnebys, 2023). In 2015, Apple released the first generation of its smartwatch. The name Apple Watch refers to the tradition of wearing timepieces, which helped establish a category of devices that can do much more than tell the time at a glance.

Watches have introduced temporal registration as the first pillar of mixed reality. Smartwatches include spatial registration, the second pillar. They are capable of sensing location and movement and overlaying contextual information that is interactive in real-time. Currently, human augmentation is shifting from the first wave, “Overlay”, to the second wave, “Entryway” (Papagiannis, 2017, p. 5). A third pillar of mixed reality seems to be manifesting itself: The personalisation of context.

The constant presence of technology can be both a gift and a burden. In this project, I am pursuing the goal of enhancing a person’s ability to interact with their surroundings, other people and things of interest as if they were a part of themselves. Instead of demanding a person to consciously attend to and explicitly interact with a digital interface, their ‘natural’ behaviour gains meaning as it is virtually registered. “The term implicit interaction is often used to denote interactions that differ from traditional purposeful and attention demanding ways of interacting with computers. However, there is a lack of agreement about the term’s precise meaning” (Serim & Jacucci, 2019).
Let’s take this example as a starting point to understand the requirements for the design framework. Imagine you are in this situation:

You are cycling through a busy intersection and suddenly your mother calls.

It is an inconvenient situation for you to answer a call. Since your mother is unaware of your situation, she calls nevertheless. Your mobile operating system, for example iOS16, lets the call through. This is a fairly simple situation, but it is not so easy to design the mediated interaction for this situation in a constructive way. I need a design framework that registers what a person is doing, represents that activity by agency, and enables to conceive a preferable dynamic and relationship.

Today’s operating systems and apps for mobile and wearable devices are complex software with far-reaching implications. They can be described as fluid assemblages (Redström & Wiltse, 2019). The attempt to solve one problem can cause another. Instead of attempting to solve problems, I propose and discuss beneficial relationships and dynamics.

Unlike tools, today’s operating systems, such as Apple’s Watch OS 9, are not passive, idle or turned off by default. The sensors, processors and algorithms allow designers to register what a person is doing and respond accordingly. An activity such as cycling can be represented by agency, as iOS 16 represents sleep or work as focus modes (Apple, 2023d). Wearable devices augment humans. Your mother is not calling a human. Your mother is calling a cycling human crossing a busy intersection.

The following three layers describe how humans become ‘more than humans’, drawing on the theory of Design for Extended Reality.

### Shifts

#### Towards Augmented Humans

Humans have been shifting from distinct entities towards augmented humans (Papagiannis, 2017). This transformation manifests in wearable technology, that acts as prostheses. Humans relate through this pervasive layer of their existence as hybrids and socio-technical beings. This shift can be traced back through anticipatory art or popular culture references, such as cyborgs. The Surrealist movement provided a foreshadowing moment, which resonates with contemporary digital art. “Parreno’s works (...) liberate the viewer from the common belief that the world is neatly divided in two spheres: us humans and things out there. Time to rethink” (Birnbaum, 2018, p. 21). Subject and object are merging into one.

#### Towards Blended Reality

Blended reality increasingly permeates everything we do. Our “attention and other cognitive resources are often split between dealing with the physical world in which we are located and interacting with the digital (...). While we are physically in one place, we are often mentally in another, or more than one place.” (Waterworth & Hoshi, 2016, pp. 3–4). It is challenging to integrate presence across different realities and blend them harmoniously.

#### Towards Embodied Mobile Mixed Reality Applications

Mobile mixed reality apps have been around for many years: Snapchat, Instagram or Tiktok are good examples of AR apps that follow the “Overlay” wave. These applications offer virtual filters that superimpose physical reality. What makes them mixed reality applications is spatial registration in combination with real-time interactivity. Often these apps depend on a camera and a screen, and demand a lot of attention. Calm technology can serve as a source of inspiration for the development of MR/AR applications that require less attention and blend more harmoniously into physical reality. “We are entering a second wave of AR, which I call “Entryway”, creating a more immersive, integrated and interactive experience. (...) You are the context that defines the experience” (Papagiannis, 2017, p. 5).
A different take on More-Than Human Design

Human Centred Design reaches its limits when dealing with complex software. “From a perspective of dealing with complexity, human-centered design (...) is conceptually grounded in the relationship between a person and a tool” (Giaccardi & Redström, 2020). ‘More-Than Human Design’ is an emerging framework that indicates how to constructively deal with today’s complex realities. I am approaching the ‘more’ in ‘More-Than-Human Design’ with concepts from Design for Extended Reality to shape the relations and dynamics of human augmentation through wearable technology.

Extended Reality

Extended Reality can be thought of as a continuum that spans across a spectrum (Milgram, Takemura, Utsumi, Kishino, 1995). On the left side is the real environment and on the right side is the virtual environment. Digital twins originate in either side, from where they augment reality towards the other side. An AirTag can give any physical object a virtual presence.

Mixed Reality

I define mixed reality as a medium in which “real” and “virtual” things or surroundings blend. They are spatially registered and interactive in real-time. This definition shares the key characteristics with Ronald T. Azuma’s definition of Augmented Reality (Azuma, 1997).

Augmented Human

In this project I am interested in two particular aspects of human augmentation: Treating the body as an interface and registering the layers of analog and digital means of augmentation. Embodied behaviour can be treated as meaningful input for mediated interactions. With layered augmentation, visualised as ripples, I intend to capture the things that embrace and surround a person, that enhance their ability to self-actualise or relate to things, other beings and surroundings. These layers can feel like a part of themselves: The clothes they wear, the sun glasses, the earbuds. These layers can act as shields, membranes or prostheses. Instead of speaking indifferently of humans, I distinguish a walking human from a biking, or skating human.
Process Preview

FOUNDATION STAGE

The goal of the foundation stage is to research, analyse and draw conclusions from the design material and prepare it for concept development.

Material
In this phase I am unpacking and analysing the design material. The goal of this phase is to grasp the realities of the topic.

Methods:
• Auto-Ethnography
• Desktop Research
• Interviews
• Self-Trial

Incubators
In this phase I find, peg out and prepare the breeding ground for concept embryos to grow out of. The goal of this phase is to identify and describe design spaces and opportunities.

Methods:
• Staging, Illustration

Framing
In this phase I put the design material in a framework and examine the relations and dynamics of this composition. The goal of this phase is to find approaches, strategies and principles for how to work with the design material, for how to develop the relations of the core components (human–product–context) and for how to frame the interaction model.

Methods:
• Adaptation of theory in Human Computer Interaction

CONCEPT STAGE

The goal of the concept stage is to ideate and develop design proposals and assess their potential for further product development.

Concept Embryo
In this phase I grow ideas out of the incubators. The goal of this phase is to explore and reimagine the design spaces through ideas about how to shape preferable relations and dynamics.

Methods:
• Sketching with pen and paper
• Sketch-modelling with cardboard & play dough
• Interface mock-ups
• Enactments & one-shot videos

Concept
In this phase I transform the composed design material into interactive components. The goal of this phase is to develop the ideas and model them into interactions that come together as a whole and integrate into a scenario.

Methods:
• Interface mock-ups & wireframes

PRODUCT STAGE

The goal of the product stage is to refine and deliver a design proposal to convey a grade of detail that makes the concept believable, come alive, and enable a discussion of practical implications.

Application
In this phase the ideas flourish, grow, and mature into a product. The goal of this phase is to deliver a productive and constructive design proposal, that could be commercialised or marketed with further development.

Methods:
• App Development in SwiftUI
• Storytelling & Videography
• Illustration
Activities

Material

Framing

Concept

Incubators

Concept Embryos

Application
In this phase I am unpacking and analysing the design material. The goal of this phase is to grasp the realities of the topic.
The idea for this personal project came at the end of a gap year, which I spent in Amsterdam and Copenhagen. During this time I explored both cities by bicycle. In parallel, I was studying Design for Extended Reality and started reflecting on my experience from the perspective of human augmentation and blended reality.

**Method**

In this piece of auto-ethnographic research, I stress test mobile interactions. I uncover detailed findings that indicate how mediated interactions could be more harmoniously integrated into cycling.

**Interaction with the smartphone while biking**

When I moved to Copenhagen, I worked part-time for a last-mile cargo bike logistics company called ‘Velo’ (Velo, 2023). As a Rider and Shift Manager I deliver parcels all over the city. This included the preparation for the ride, the delivery and the post-ride routine.

For the shifts, I mounted my smartphone to the bike’s frontend. During the delivery trips, I am multi-tasking with 3–4 apps. Google Maps (Google, 2023) serves for navigation, the Velo app for reporting the trip, the service provider’s app for registering deliveries and occasionally Slack, Whatsapp, or the phone app for communicating with fellow riders and recipients.

I encountered many challenges when performing mobile phone interactions while biking. Touch screen gestures are not robust enough for biking in the rain or on uneven terrain such as a cobbled street. I cannot wear gloves in freezing temperatures. I switch apps and interact with them as I cycle. This makes it harder to remain aware of the traffic and the surroundings. I need to divide my attention and shift focus.

The repetitive performance of explicit interactions frustrates me: every time I head to a new address, I have to select “navigate by bike” in Google Maps; the delay for the phone camera to adjust to light settings before a photo can be taken; the need to unmount and remount the phone at every stop. Each delivery has to be documented involving a sequence of several touch gestures and a photo, all while moving around. The wish arose for more actions to be implicit and in harmony with the flow of physical movement.
LITERATURE REVIEW

Considerations for integrating mediated interactions into biking
In their publication Ubikequitous computing: designing interactive experiences for cyclists (Rowland, Flintham, Oppermann, Marshall, 2009), the authors share 8 lessons for the design of bike-based interactive experiences. This paper does not cover interactions with smartphones or smartwatches. However, it does provide important general considerations.

“Cyclists have a close relationship with their surrounding environment. Cycling is a visceral experience, with riders being physically connected to the underlying terrain, its surface details, the weather, and other environmental factors that have a profound impact on their experience.”

“Cyclists enjoy the freedom of movement offered by cycling; one can travel a long way compared to pedestrians and yet enjoy relatively free access to the city when compared to cars.” Audio signals support the "heads up" nature of biking, minimise the problem of distractions by looking at the screen. But "audio is sensitive to external interference and there remains the risk of not being able to hear traffic and pedestrians". Where "visual interfaces are used or direct manipulation is required then the experience should encourage participants to stop before interacting". The authors conclude: "Digital media must adapt to cycling".

Cycles are a part of the interface hardware as well as computers and therefore need to be carefully integrated into the overall hardware design. An important decision is whether to mount the computer technology to the rider or to the bicycle.

Situational Awareness & Stream of Signals
In his dissertation 'Faster. Stronger. Better?' (Zarin, 2017) Rouien Zarin takes sport as a canvas to explore how people can heighten their environmental and self-awareness with mediated technology. He emphasises the importance of remaining aware of the situation. "Situational awareness (SA) can be described as the perception of environmental elements and the comprehension of their meaning. (...)"

In an interview, he highlights the significance of signal flow. When cycling, the rider takes in information with all his senses: He looks at the road, hears the wind, the traffic, feels the vibrations when riding over uneven terrain, feels the balance.

It is a constant flow of analogue signals, like a data stream. If an interface can somehow tap into this data stream that is already happening naturally, then it is less likely to disrupt. The introduction of digital signals needs to be considerate of the ongoing analogue signal stream. Any additional signals will blend into the existing stream of signals. The addition of vibro-acoustic feedback will blend with the vibrations of cycling on uneven terrain.

Heidegger's concept of ready-to-hand (Heidegger, Stambaugh, 1996) describes how knowledge about the world is acquired through interaction. Interaction during cycling is about layering complementary pieces of information to enhance the knowledge of the world that readily exists. When the perception of additional information diverges from an embodied experience, it affects the overall experience. Latency can ruin the whole experience.

The spatial and social qualities of biking
Biking is a social activity, in many regards (te Brömmelstroet, Nikolaeva, Glaser, Skou Nicolaisen, Chan, 2017). The immediate experience of the surroundings, of people and places, makes it social. Cyclists are structurally very open to interaction as all their senses are exposed and they are in no way visually or physically shielded. Bikes have no inside and outside. There is a general potential to immediately experience nature, people, places, and everything that makes a city vibrant.

When cycling, there is:
- the direct immediate way of socialising, with people who are present,
- the mediated interaction, through apps or phone calls,
- the indirect social implication of biking as a means to reach places and meet people.

"Being connected to people and places means moving around, exploring, using all senses and interacting" (te Brömmelstroet, Nikolaeva, Glaser, Skou Nicolaisen, Chan, 2017). The embodied nature of biking, the sensory and affective dimensions are central in mobility choices and experiences. Mobility is not individualistic and disconnected. Different modes of transport provide a rich understanding of social and spatial context, but none trumps them all.
INTERVIEWS

Method
In this phase I interviewed five citizens about mediated interaction in the context of biking. The interviews were semi-structured and I prepared a map of their city and photos as conversation starters. I asked them about their weekly routines, how they differ between work and leisure, preparations for cycling, their relation to the different areas of the city and mediated interaction through mobile and wearable devices.

I gained insights into the emotional qualities of biking, transitions, what comes before and after cycling, what people wear, their attitudes towards situational awareness, battery management, housing situation, companionship, quality of life, navigation, bike sharing, and more. The quotes have been edited for clarity.

The panopticon of possibilities (Tom, London)
Tom highlights the role of cycling in everyday adventures and visits to past memories. Factors such as current location, photo memories, mood, weather, events, and navigation route can be combined to provide real-time suggestions. The map of London appears as a ‘panopticon of possibilities’.

There is the potential to harness knowledge of the cyclist’s situation, and predict the likelihood of where the cyclist will want to go next. The bike is a browser for the urban environment. Unlike a web browser, where people collect bookmarks, the cyclist collects and retrieves memories. The cityscape becomes an emotional map on which past experiences and current opportunities are laid out.

“In a 15 min. radius in London you can do a lot. Many events, exhibitions.”

“I would like to increase the level of intelligence, from harvesting all my data. Here, I have taken many pictures, romantic point, sad spot. Spotify could adapt.”

“You commute every day. Under the week it is more about efficiency.”

“Endel connects to your heart beat and the music syncs with you.”
The two-wheeled office (Lyna, Amsterdam)
Lyna works as a rental agent. In her work, she relies on the bike as a fast means to visit flats all over Amsterdam. She rides a 'VanMoof' (VanMoof, 2023), an e-bike that she charges in her flat. With her headset, she can regulate the volume or skip back and forth when listening to music.

As she cycles, Lyna transitions from work mindset to leisure and back again. Lyna's bike is her office, but also her life companion. She expects her bike to be comfortable to enjoy the city, but also fast to rush to an appointment. Her mobile ecosystem is not adapted to cycling. Her professional reality requires her to flexibly reschedule, call, and message on the go. Her seemingly endless contact list cannot be easily filtered while biking. Mobile apps do not blend smoothly into biking. They require her to divide her attention between cycling and communication. Lyna talks about the bike as a companion to her Amsterdam lifestyle.

“I hold the phone in my hand, texting. The other hand is on the steering.”

“If I am late for a viewing, I will call the agency to let them know. When I am calling different agencies, I have a huge list of agencies to go through. If there was a way for me to just access them, rather than scroll down the whole list, that would be very helpful.”

“I love to bike. If I were ever to leave Amsterdam, that is one thing that I would miss. The freedom. It is such a personal experience.”

“A lot of the people who like Oud-Zuid, I know right away that they might like Plantage as well. They offer a similar vibe and energy.”
**Velove Mode (Bruno, Copenhagen)**

When Bruno started working as a Rider for the bicycle logistics company Velove, he created a custom focus mode on his iPhone and called it 'Velove'. He created a home screen with all the apps that he needs while biking and he cancels out notifications from Facebook and Snapchat while cycling. When he starts his shift, he switches to 'Velove' mode. Apps like Velove, Budbee, Slack, and Spotify are displayed on the home screen.

He wears an Apple Watch that can detect when he is cycling, but he cannot take advantage of this function. He has to manually enter Velove mode, when he starts a shift as Rider, as there is no way in iOS to activate a mode that is triggered by cycling activity. Each time he navigates to a new address, he has to select "navigate by bike" in Google Maps. He has to do that 30–50 times during a shift.

He carries out deliveries and he is ready to receive calls and messages. He thinks the mobile ecosystem's integration into bikes lags behind integrations, such as Apple CarPlay, where the phone is automatically and directly connected.

"When you are riding, the Apple Watch switches mode and goes to handsfree mode, since it recognises that you are biking. (...) But it doesn't do it automatically and it sucks. I don't have the time to put it on."

"My frustration is that on cars, a lot of progress has been made. Now we have Apple CarPlay, that improves the user experience. (...) That is lacking in bikes."

"Before I became shift manager, I was not using my AirPods. I was not listening to music either. Since I became shift manager, I have been wearing them all the time. If I receive a phone call, I need to take it right away."
**Trial**

**bike OS: Adaptation of Bruno’s setup**
I am exploring bike mode as an way to overcome the current limitations of mediated interaction taking bike navigation as an example. After the interview with Bruno, I set up a custom iOS focus mode and call it bikeOS. When configuring the focus mode, there is the possibility to configure notification settings and create a custom home screen. This allows me to select the apps that can notify me and the apps that come to presence on my mobile home screen while cycling. The phone is mounted to my bike’s handlebar with a ‘Quad Lock’. I ride without gloves, so I can perform touch gestures.

**Findings**
Before I hop onto the bike, I manually enter bikeOS mode. As of February 2023, WatchOS can recognise cycling as an activity, but iOS does not offer activities as a trigger to switching modes. Google Maps categorises navigation by means of transport. After searching for a destination, I have to manually select ‘navigate by bike’. The reporting function allows the cyclist to report stalled vehicles and mobile speed cameras. It does not seem to adjust to the ongoing biking activity. It does not offer any functions that are particularly beneficial for cycling.
In this phase I find, peg out and prepare the breeding ground for concept embryos to grow out of. The goal of this phase is to identify and describe design spaces and opportunities.
Currently, the mobile ecosystem is not integrated with cycling. There is no 'Apple BikePlay' or mode triggered by cycling. In absence of digital technology, sitting on the bike and can be the biking mode. The cyclist enters biking mode by approaching the bike and hopping on. The cyclist exits biking mode by hopping off and leaving the bike. Presence and movement can imply modal shifts.

Instead of integrating the mobile ecosystem into the bike, biking could be integrated into the mobile ecosystem as a mode triggered either by the presence of the cyclist in relation to the bike, or by cycling as an activity.

Lyna is biking in the same outfit in which she walks or enters the underground. She bikes in high heels, skirt and does not wear a helmet. Ideally, biking requires no preparation. The cyclist’s relationship to the bike changes, when there is no lock, or when it unlocks automatically.

What role does the reason for the switch in modality play? Bruno expressed the need to imagine a different experience for transitioning from cycling to public transport. He wants to know if he should speed up to reach the train.

How does biking mode affect others? Would rental agents who text Lyna receive a heads-up message to become aware she is biking?

There are nuances to biking, that change depending on mindset, emotional state or situation, whether someone is commuting or on a weekend trip. Is the biking mode discrete or gradual, like blinds that open and close? How could Tom’s experience of listening to music adapt?
A bike does not have an integrated dashboard. Applications are spread out:

- **Mobile apps** can be downloaded from the app store and installed on the smartphone and smartwatch. Phone mounts bring mobile apps to hand, but do not compensate the operating system's lack of adaptation to biking. What other ways are there to integrate existing apps into biking?
- **Bike functions**, such as the bell, lights or lock are either embedded into the bike or can be controlled from a companion app, such as VanMoof. It allows you to customise the sound of the electric bike bell or unlock the bike by tapping the lock in the VanMoof app (VanMoof, 2023). What should e-bike companies do next?

I envision **bike-specific apps**: Apps that are designed with biking as an embodied activity in mind. These apps are not meant for sport or professional bike riding, but for everyday scenarios. What would the design guidelines be for adapting Spotify or Google Maps for biking? What are the particular opportunities and challenges of designing apps for integration into biking? What would it be like to design an app from scratch? What particular experiences can be created when apps make the most out of the particular qualities of cycling, such as the possibility to spontaneously immerse oneself in different socio-spatial contexts within a short period of time?

Which mobile experiences are relevant in the context of daily biking? How might a cycling dashboard look and behave? Like a stream deck, a home screen, a companion app?

If there were a guideline for designing apps for the context of biking or adapting existing apps to biking, what would need to be considered? What complexity of interaction model and wireframe is appropriate?

How can the cyclist navigate through the dashboard? What is the experience of staging and switching apps?
Conventional gestures for mobile apps are too delicate and attention-demanding for biking. What considerations are necessary, for interactions, gestures and interaction models to be integrated into biking?

- How can the designer account that the cyclist’s is immersed into an analogue stream of signals, which reduces their capacity to engage with an interface? Certain occasions, such as a red light, could serve as an exception to introduce more demanding interactions.
- Touch screen gestures are not robust enough for biking. How can robustness be increased? How can information density and complexity be reduced?
- How can concepts from human computer interaction be adapted to biking and vice versa?

While biking, the human has a limited capacity to attend to a separate interface. How can the complexity be reduced? How can the interface accommodate for both dedicated and contextual interactions?

A smartwatch can eliminate the inconvenience of interacting with a handheld device, such as the smartphone. How can a bike-mounted tangible interface and smartwatch complement each other?

To what extent are concepts of Human Computer Interaction and biking compatible? What is the difference between shifting gears and holding shift on a keyboard? What interactions feel intuitive in the context of biking?
In this phase I am framing the design material, examine the relations and dynamics of this composition. The goal of this phase is to find approaches, strategies and principles for how to work with the design material, for how to develop the relations of the core components (human–product–context) and for how to frame the interaction model.
Method
I identify and examine approaches, principles, and strategies that support a more harmonious integration of mediated interaction into biking. In the context of urban biking, the need to attend to a virtual environment risks to dividing attention, disrupting flow and fragmenting reality.

Mentality
The design of traditional graphic user interfaces relies on explicit interactions. Operating an interface is a cognitive task. Michael Kay sought ways to reduce the cognitive load of interacting with interfaces, by drawing on research from cognitive science. “Human cognitive facilities are made up of a doing mentality, an image mentality, and a symbolic mentality” (Kay, 1989). He coined the slogan for a more intuitive and efficient interface design:

Doing with images makes symbols
• enactive: know where you are, manipulate – mouse
• iconic: recognize, compare, configure, concrete – icons, windows
• symbolic: tie together long chains of reasoning, abstract – Smalltalk

This approach to interface design starts with the concrete, moving a mouse cursor, builds on the recognition of icons and containing applications in windows, and extends to the abstract, such as the chain of reasoning required to export a file.

Implicit interaction can reduce the cognitive load even further. Instead of attending to a virtual interface with windows, the real environment can serve as the view. Instead of moving a cursor on a separate screen with a mouse, a wearable device can sense natural body movement and presence in relation to the natural environment.

Embodied activities such as biking resemble the doing mentality. While biking, it can be difficult to perform interactions that demand high cognitive capacity according to the image and symbol mentality. As Lyna said, it is a challenge to scroll through a contact list while cycling and find the agency contact she needs to call. In designing interfaces that better integrate into with the scenario of biking, it might be beneficial to find ways to remove iconic and symbolic components from the interaction model.

Principles
During the interviews, I gained insights into the circumstances in which interactions do not integrate harmoniously into biking. In summarising the insights, I identified three core principles that are worth considering:

Synchronicity is the coincidental occurrence of events that seem related but are not explained by conventional mechanisms of causality (Merriam-Webster, 2023). Such experiences can be caused by design. There is a convenient or inconvenient time for certain interactions to happen.

Calm technology engages both the centre and the periphery of our attention. Calmness allows us to gently shift focus back and forth between the two, while remaining aware of surroundings and staying in the flow. (Weiser, Seely Brown, 1996). “Calm technology can be summarized as invisible and natural to use; it doesn’t interrupt or get in the way of life. It happens in the background, and it appears when you need it.” You can think of apps as a mental space. When you open an app, you enter another mental space. Ideally, this transition feels continuous, like moving through an open space.

Immediacy means the ability to follow spontaneous impulses, that enable us to realise ourselves, to experience the world around us and to connect with others (own definition, cf. Burning Man, 2023). It requires that interfaces feel second to nature. When interactions lag or get in the way, we tend to become aware of digital mediation.

Strategy
When the interaction model of an app is detached from the context, the real and virtual environment are not integrated. Instead, an app can be designed on the foundation of mixed reality:
• Relate: Instead of displaying a map or app gallery with all possible items, a personal choice can constrain what is expressed. This approach is based on knowledge of people’s identity and personal preferences.
• Situate: Instead of displaying a map with a search bar that allows to virtually travel to any place, the person’s current location is registered to enhance the here and now.
• Imply: Instead of relying on a variety of explicit interactions, such as touch gestures, constrain them to ‘natural’ embodied behaviour.
In this phase I grow ideas out of the incubators. The goal of this phase is to explore and reimagine the design spaces through ideas about how to shape preferable relations and dynamics.
**Dock**

I am exploring the idea of making a selection of apps readily accessible, by integrating a dock into the watch face. The dock is loaded with bike mode. Bike mode is triggered either by the physical presence of the cyclist on the bike or by recognising the movement pattern typical of biking. With WatchOS 9 the customisation of watch faces is very limited. It is neither possible to add a custom selection of apps as a complication nor to integrate a modal dock.

**Remote control**

In this exploration I attempt to make mobile interactions more robust by complementing a wearable interface with a bike-mounted tangible interface. This raises the question of how these two interfaces relate to each other. I repurposed an Apple remote as a peripheral for the Apple Watch and mounted it on the handlebar of the bike. Spotify (Spotify, 2023) is one of few apps that synchronise all instances: desktop, mobile and wearable. I assign the keys for play/pause, previous/next and volume up/down to the five buttons in the circular array. The remote control covers the essential functions of the music player. This test setup works well, sometimes it lags.

Spotify depends on the mental model of the screen interface. It is not possible to change the playlist without looking at the screen and performing touchscreen gestures. The wireframe can only be navigated on the watch, not remotely. It has three pages, two of which are scrollable.

**Findings**

Overall, I find that it is necessary to reduce complexity and density of information, in order not to monopolise the cyclist's attention. Distinct actions and reactions, such as picking up an incoming phone call, can be externalised to a button. Complex interactions that rely on the mental model of the screen or touch gestures are harder to translate and externalise. Mobile apps face accessibility and inclusion challenges, which make it difficult to interact without attending to a screen. A more inclusive approach to app development can benefit activities such as cycling. The integration of a tangible interface into the handlebar is only beneficial while biking.

Instead of integrating interactions into the bike, it might be better to integrate biking and other activities into app behaviours.
APP AS APPLET

Spotify for Riders
In this exploration I am reimagining Spotify as an applet in order to reduce the cognitive load of performing interactions. I take away functionality and redesign the interface. The wireframe is constrained to one page. The typeface and icon size are meant to be readable while moving. The bike symbol represents the operating system's mode that the app responds to.

→ The first wireframe shows WatchOS 9 watch face, app view and Spotify for WatchOS in March 2023.
→ The second wireframe shows my design: Watch face incl. bike mode dashboard, ‘Spotify for Riders.

Findings
The app becomes more quickly accessible, when placed on a watch face. The possibility to customise watch faces and add complications from a complete choice of apps can benefits activities like cycling. This is not possible in WatchOS 9.

‘Spotify for Riders’ reduces the wireframe to a single view. Previously, swipe gestures were needed to switch views, and scroll gestures were needed to scroll down lists. Such delicate gestures are less suitable while biking with environmental factors such as rain and vibration. This eliminates the possibility to switch a playlist, in convenient moments. When the cyclist is waiting at a red traffic light, the possibility to switch playlists may be welcome. The responsiveness to modality comes with a loss of consistency.
APP AS EXTENSION

Vibe Catcher
In this exploration, I extend the functionality of an existing app by biking. Biking in itself is a meaningful and sufficient input for the interaction model. I design a journalling app, as a means to record trips, capture and map out memories. The photo app in iOS already offers the possibility to browse photos based on location or time. Photography requires the introduction of a camera, that needs to be installed or held in the hand. How might an explorer capture the memories of a bike trip hands-free?

Vibe Catcher extends an app for listening to music, like Spotify, and introduces spatial registration and motion tracking as a feature for generating new playlists. It registers the alternating pattern of moving and dwelling. When the explorer spends time in a crowded place, such as a park or café, the vibe catcher gets exposed to the soundscape of that particular place. A soundscape represents the combined music taste of a social group. As long as the explorer stays present, vibe catcher picks up the crowd’s most recent music taste and automatically generates a playlist. The longer the stay, the longer the playlist.

Findings
Vibe Catcher takes away the necessity to attend to an interface. While biking, interactions happen implicitly. It combines the defining properties of a mixed reality application, spatial and temporal registration, with the property of music taste. Could music taste describe places and create anticipation as the cyclist decides where to go next?

The app depends on the people’s willingness to share their current music taste, through an existing platform as Spotify, or through a stand-alone app. How does people’s music taste relate to where they go and spend their time?

It could be interesting to harness the time and location metadata to link photos with soundscapes and present memories in a novel way. Would the playlists rather enrich and enhance memories, or cause disharmony or fragmentation? How might Vibe Catcher change the way people revisit, relive and share memories?
TRANSITIONS

In this exploration, I am reimage the transition from walking to biking. Presence and movement can imply common interactions and changes in modality. How smooth can it be to hop on, ride and hop off?

**Watch-to-bike communication**
The presence of the cyclist near the bike can act as a trigger. When the cyclist approaches the bike, it can automatically identify the cyclist and unlock. As the cyclist leaves, it can automatically lock.

**Mode for operating system**
The integration of communication technology (e.g. Bluetooth) into the bike opens up new scenarios. As the cyclist approaches the bike the behaviour of the operating system of the smartphone and smartwatch can react. Notification settings can change. A custom watch face can be loaded and the apps that are particularly desirable when biking can be docked. Audio settings can change. When switching to bike mode, noise cancelling can be disabled as a safety feature.

**Mode for apps**
Once the operating system can predict that the person is about to cycle, it can pass this information on to apps, which can then respond. Google Maps can pre-select the bike as a means of transport.

**Findings**
There is Apple Car Play, but no equivalent for integrating iOS and WatchOS experiences into biking. The Apple Watch only notices that someone is biking when the person's movement pattern changes. Currently, iOS and WatchOS only support location and time as triggers for changing focus mode. Activities could be added as triggers. The introduction of activities as triggers poses a challenge for the consistency of the operating system. As with other modes, there is a trade-off between consistency and responsiveness.
In this phase I transform the composed design material into interactive components. The goal of this phase is to develop the ideas and model them into interactions that come together as a whole and integrate into a scenario.
Scenario
Christina makes coffee and takes the last drop of oat milk. She is already at home and sitting comfortably on the sofa while her flatmate Ananyo is on his way back from work. She wants to send him a message so that he can buy some more oat milk on his way back.

Application
I explore how insights into a message recipient’s situation can change the way people compose messages. Bubbles changes the interface and process of message compilation and delivery based on insights about a recipient’s ongoing activity and active devices. The size of the text field scales according to the screen real estate of the recipient’s active device. If Ananyo is wearing earbuds, the option to record a voice message appears. As he is biking, ‘timely delivery’ is selected.

Interaction model: Reality-Virtuality Continuum
I am adapting the reality-virtuality continuum (Milgram, Takemura, Utsumi, Kishino, 1995) and describe activities according to immersion into reality versus virtuality. I assume that someone who is further immersed in reality has a lower capacity to attend to virtuality. Bubbles mediates the gap of immersion.

Findings
In this exploration, I compromise the neutrality of message compilation. I mix the message with the medium. Sharing insights into the mode of transport and active device raises questions of privacy. When Christina takes the photo of the empty oat milk carton, the frame is cropped to the aspect ratio of Ananyo’s device. Before sending the message, Christina previews of how Ananyo is likely to receive it. The ‘Timely delivery’ feature delays the delivery until Ananyo can receive and respond to it at a convenient time, such as when he stops at a red light.
The concept embryo for Vibe Catcher piqued my interest and motivated me to further explore and develop the concept. Vibe Catcher enhances the meaning of gatherings by treating people as pollinators.

Case Study
Umar Hansa’s data visualisation of 1 billion Shazam music recognitions got me thinking about the relation between music and space. He mapped out the locations where iOS and Android users recognised songs as blue and red dots. Over time, the dots accumulate. People’s interest in music creates a map. There is a connection between place, time and music.

Snap Map visualises the activities of its users in a heat map. It is possible to search for any place on the globe. When zooming in and clicking on hotspots, videos that users have uploaded appear. The map view is not constrained by the current position of the person looking at the map. The uploaded videos do not represent the current energy in a place. They remain visible for a few hours after uploading.

Spotify Enhance expands a human-compiled music playlist and fills it up with songs that a machine learning algorithm deems fitting. The algorithm becomes visible as an agent and collaborator. The playlist is made by the person and ‘Spotify’. Each song that was added by ‘Enhance’ is marked with a green spark symbol. The process of enhancing takes one second. The songs seem to appear out of nowhere, without any effort of the person. The activity of the algorithm allows the human to remain passive.

Vibe Catcher
Vibe Catcher is about establishing the connection between the spatial exploration of a city and its memories. The concept combines a real-time vibrancy map with a music-journal.
Compass
Compass maps out social gatherings and represents people's combined music taste as soundscapes. The display is constrained by the here and now. It is intended as a smartwatch application.

Journal
Journal encodes the explorer's journey as socio-spatial exposure to enrich the memory of each journal entry with a generated music playlist. It is intended as a smartphone application.

Interaction Model
Natural human behaviour serves as input:
- Movement is recorded as a journey.
- Being in a crowd's presence means being exposed to their music taste and sharing one's own taste. The vibe catcher collects songs as long as the explorer is exposed to a soundscape.
- Like any compass, the interface follows the rotation of the body. It is not possible to search for places, zoom in or out.

Findings
Life can change at any moment and in any place. Sometimes is is only in retrospect, through memories, that we realise the turn our lives at a particular moment. Vibe Catcher is an antidote to the passivity that 'Enhance' promotes and Google Maps' efficiency mindset, with a pre-determined destination.

Nectar
Vibe Catcher enhances the presence of places as soundscapes when a critical mass of people with a particular music taste come together. People make places come alive, just as bees pollinate flowers. Cross-pollinating seems an apt metaphor to describe the interaction model of this app. That's why I call the app Nectar.

Nectar is your sixth sense for exploring cityscapes and reliving memories.
In this phase the ideas mature to become a product. The goal of this phase is to deliver a constructive design proposal, that could be commercialised or marketed with further development.
Throughout this project, I explored different approaches for prototyping smartwatch interactions. SwiftUI proved to be the best fit to meet my needs.

Mock-up
For the Google Watch there is a ProtoPie Player (ProtoPie, 2023) that makes it possible to build an interactive interface that runs on the watch via this player application. This approach benefits from the ease of using the design tools Figma and ProtoPie. Instead of following the logic of a real app, it follows the logic of ProtoPie, with its constraints. All common functionalities and APIs have to be built from scratch.

Build your own smart watch
All hardware components that are needed to replicate the desired functionality of a smartwatch can be sourced separately and connected via a microcontroller. This process proved to be unpractical for me. Lead times for orders can delay progress by many weeks. This approach makes it possible to break out of the limitations of existing hardware. It can be valuable for prototypes where Apple makes it difficult to intervene, for example when you want to connect an external keyboard to an Apple Watch. It feels like a prototype, not like a finished product.

App development as a design tool
SwiftUI (Apple, 2023b) is Apple’s programming language and framework for app development. It is declarative and makes it easy to integrate components and connect to APIs from the Apple ecosystem. It is the easiest way to work with real-time sensor data from the device. Initially, it does not feel like a design tool. But it enabled me to prototype and design apps and complications. The Apple Watch still works as usual: It displays the time and sends notifications.

Findings
I build ‘Compass’ as a WatchOS app and run it on my Apple Watch. I demonstrated the app during the degree exhibition. It felt real and people related to it as a product that could soon hit the market.
Results

I treated this thesis as a research and development project with a focus on interaction design. The research and development have influenced each other, and each has lead to learnings and outcomes. The primary outcome of development is the interaction model for 'Nectar' that showcases implicit interaction. The primary outcome of research is the collection of 7 Considerations for how to integrate mediated interactions into biking as an example of embodied activity.

The third outcome results from adapting the theory of Design for Extended Reality in the models Layered Augmentation & Reality-Virtuality Continuum and showcasing how to design the interaction model for 'Bubbles'.

DEVELOPMENT

Nectar
Nectar comprises of two applications: Compass and Journal.

RESEARCH

7 Considerations for how to integrate mediated interactions into biking
1. Biking can be treated as a mode that cyclists transition into and out of.
2. Biking is an activity that can be addressed with a doing mentality.
3. Calm technology keeps a cyclist in the constant stream of signals.
4. Instead of integrating an app into an activity, like biking, try vice versa.
5. Wearables support an immediate 'second-to-nature' experience.
6. Implicit interactions can enhance the meaning of 'natural' behaviour.
7. Each activity brings particular qualities, such as socio-spatial exposure.

FRAMEWORK

Models: Layered Augmentation & Reality-Virtuality Continuum
Reflection

Review: From original brief to actual project
The initial spark for this project came from my own experience of biking through Copenhagen while interacting through mobile apps. Originally, I set out with the goal to harmoniously integrate mobile and wearable app interactions into biking. During the project I opened up to understanding biking as an example of an embodied activity and found value in implicit interaction. While Nectar and Bubbles could be perceived as product proposals for messaging or music discovery, they are the result of my exploration of implicit interaction.

Learnings related to the topic
Initially, I was wondering why there is no equivalent to Apple CarPlay (Apple, 2023a) for bikes. I studied how e-bike developers, such as VanMoof (VanMoof, 2023) and Cowboy (Cowboy, 2023) approach the integration of mobile experiences. None of them addressed the issues that come with the reliance on a touchscreen while biking. Unlike a car, a bike has no interior or dashboard to integrate into.

Wearable and mobile devices can complement each other. Today, many WatchOS apps replicate the interaction model of a mobile app, instead of designing an interaction model for a wearable device. As smartwatches become more widespread, the scenarios for embodied interaction will also increase. In the future, leaving the phone at home may become more common again. Smartwatches and earbuds are capable AR devices that often get overlooked when AR is discussed merely as a visual augmentation.

When adapting apps like Spotify to biking, incremental improvements can be made. A more exciting design space can open up when the activity with its particular qualities shapes the interaction model.
- Nectar does not integrate music listening into biking. It integrates biking into music listening.
- Bubbles aims to integrate messages into the flow of cycling rather than impose messages. This approach led to the ’Timely Delivery’ feature.

Many apps, like Google Maps, are designed for efficiency. When a known destination is the goal, the journey and the experience of the here and now can be neglected. Nectar’s interaction model invites serendipity, finding value in things not sought for.

While biking, the smartwatch is often inaccessible, covered by a sleeve. Nectar senses the cyclist’s activity, movement and presence, for implicit interaction, rather than explicitly capturing memories, such as pressing the shutter button on a camera.

If the interactions are unrelated to the cyclist’s current activity, situation or mindset, they are unlikely to integrate harmoniously. Wearable devices, such as the current Apple Watch, can provide rich insights into ongoing activities.

The name smartwatch suggests that this device is meant to be attended to, but the greater opportunity lies in sensing and adding meaning to what is already happening.

Contribution & relevance to interaction design practice
Biking is a head-up hands-down activity (Rowland, Flintham, Oppermann, Marshall, 2009). Nectar provides a way of recording memories without attending to an interface. Bubbles treats biking as an activity with lowered capacity to attend to an interface and seeks to register the right moment for mediated interaction.

Rouien Zarin (Zarin, 2017) highlights the significance of signal flow when designers seek to harmoniously integrate mediated interactions into biking. Rather than adding to the ongoing signal flow, I have shown approaches to tap into the signal flow.

Biking allows cyclists to expose themselves to a diversity of spatial and social settings (te Brömmelstroet, Nikolaeva, Glaser, Skou Nicolaisen, Chan, 2017). Nectar’s interaction model is designed around socio-spatial exposure to enhance memories and find music.
Compass is designed as a smartwatch app. I have combined the concepts of a compass and map. Any real-time map needs to lay out matters of interest in relation to position and time.

The concept of ‘Compass’ builds on three strategies typical of AR apps:
1. Relate: Constrain and filter expressions according to a particular matter of interest. Compass displays soundscapes in real-time as vibrancy and filters based on personal music taste.
2. Situate: Constrain the display based on the current location and immediate reach. Compass centres the view and displays a ring that represents the range. In previous iterations, this range displayed the time it takes to walk or bike.
3. Imply: Constrain personal input to ‘natural’ embodied behaviour. The map view rotates like a compass. There is no need to perform touch gestures.

One month after I presented ‘Compass’ internally at UID, Apple announced WatchOS 10 with an update to their Maps app (Apple, 2023c). The app now features a range ring that displays the time it takes to reach. It builds on the same strategy: to situate the view. This change puts more emphasis on spatial registration. It is a small but notable step towards treating the smartwatch as an AR device.

→ Left to right: Early iteration of ‘Compass’ for WatchOS 9, last iteration of ‘Compass’ for OS 9, Apple Maps for OS 9, Apple Maps for OS 10.

**Learnings as Interaction Designer**

In this project I have explored a challenging design space: Implicit interaction. My take is grounded in ‘natural’ embodied behaviour. It is difficult to define natural behaviour. Touch gestures can be learned and become part of muscle memory. Even if they are designed for the interaction with digital interfaces, they can feel natural, like pinching the fingers to pick up a pebble.

As an interaction designer, I define interaction and influence its consequences. Nectar adds an implication to spending time in the presence of crowds with a particular music taste. When a natural behaviour obtains such an implication, people may become conscious of their behaviour and change with regards to its implications. The line between implicit and explicit behaviour starts to blur. Nectar could encourage people to move through a city, but also to dwell in crowded places. An exciting interplay unfolds between the natural presence of places and its virtual augmentation.
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I realised the need to find a vocabulary that represents the beliefs, relations and dynamics when I talk about interaction design. This glossary is an attempt to clarify the role of concepts in each design framework. I added concepts from Design for Extended Reality to each side.

### Human-Centred Design

<table>
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<tbody>
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<td>solve</td>
<td>live with, regulate</td>
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<td>to use a tool</td>
<td>to augment ability</td>
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<td>tool</td>
<td>organism/ecosystem, algorithm/network</td>
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<tr>
<td>(passive, idle when not in use)</td>
<td></td>
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<tr>
<td>master–slave</td>
<td>agent–agent</td>
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<tr>
<td>afforded: the whole world is</td>
<td>relation, interest, engagement:</td>
</tr>
<tr>
<td>assessed by how it might serve</td>
<td>meet other agents on eye-height,</td>
</tr>
<tr>
<td>humans, everything is assumed</td>
<td>human is part of nature,</td>
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<tr>
<td>to be at disposal: Is this chair</td>
<td>part of technology</td>
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<td>sittable?</td>
<td></td>
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<td>discrete environment</td>
<td>reality-virtuality continuum, blending</td>
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<tr>
<td>surf / window / look at</td>
<td>spheres</td>
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<tr>
<td>‘Overlay’</td>
<td>‘Entryway’</td>
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<td>networked computational device</td>
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<td>cost of development</td>
<td>cost of abstraction</td>
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