Thinking (about **Reality**) through **Making**

December 2023 · Lukas Moro · Umeå Institute of Design

Abstract

This pictorial is a summarisation of the making- & thought process during the "Sensorium" project. Firstly it dissects the applied thought principles the work is based on, namely first-principles thinking, clarity of mind and thinking through making. Secondly it goes into details on process, education and craft with examples from the project. It maps out what game engines are and how they can be used in designerly context, why spatial computing is a paradigm that changes the way we interface with technology far beyond the form-factor of mixed-reality goggles, how the prototype of the Sensorium project works in detail and what makes it a digital twin, why “wizard of oz” prototyping should not be over-used and why interaction design needs more engineering and less strategy focus. Thirdly the meaning of the project is analysed through an industry lens. In this chapters questions are asked about if real-time interfaces are enablers for a multitude of meaningful and positive experiences or wether they are the ultimate tool for consumption in times of surveillance capitalism, why cars are entry-points into different realities and why our understanding of privacy is antiquated and needs reconsideration towards transparency and facilitating mindfulness about information streams. Finally the project is viewed from a philosophical angle in terms of reality, cognition and simulation.

Thinking and making

Applied “first” principles thinking

The field of design suffers from notorious over-usage of bucket words. This manifests in post-it walls and mood boards, examples are words like shared economy, sustainability and immersive experiences, which are high-level notions that contain a lot of meaning, however they are not precise enough to apply them to a tangible product. Designers through those words are reasoning about the decision making throughout their process. “I want the interior experience to be immersive!” or “Our product is sustainable, because it is a car sharing service!” are sentences that fell multiple times during the project. Those sentences argue for a specific lower-level decision with the higher-level value ingrained in this idea. They fail in both, making the idea an experienceable reality as well as taking part in solving the intended higher-level problem they are revolving around. This reasoning and decision-making chain leads to unfeasible, not thoroughly thought through projects and is not effective in driving innovation. High-level values should be ingrained in every design project, but the decision-making must be informed by functional and tangible prototypes, then there needs to be a loop that evaluates how those solutions fit into the high-level values. Prototyping is the act of confronting yourself with the meaning of your ideas, while simultaneously creating a proof-of-concept. Designers should ask themselves what the underlying functional principle of their idea is, what the underlying functional principle of this functional principle is and so forth. The deeper once ability to drill here, while advocating for the best possible product experience, the more value someone can bring into a team. This process also transform initial idea as it creates more clarity.

Clarity of mind as a designer

If first (or early) principles thinking is applied to the design process in the form of idea dissection (prototyping) throughout the entire process, concept and story will get precise as they are continuously challenged by the boundaries of reality as well as the experienceable manifestations of the story. There is no tolerance for unrefined ideas anymore. The prototypes act as an effective medium of communication to convey a product experience, while words and imagery can describe it to a certain point but fail at making it experienceable. This results in an environment where there is no place for empty words. If it does not work, it does not work. If it feels bad, it feels bad. If it feels right, it feels right. One can only understand what one can build, one can only build what one can understand! During the development of a product, initial research and conception are too bloated. They are essential to the process, but too often used as an excuse to not start actually designing and building. This delays the process of sense-making and leaves a lot of room for un-refined and faulty ideas. The most important research is not done at the beginning of a project it is done by being a person that walks through the world with open eyes and is passionate about topics, this will guide what someone brings to a project far more than any research done in the short term. Camille Mousette's notions of sketching and prototyping, where sketching is the act of creating an artefact that is meant for internal evaluation of an idea, while prototyping is the act of building an artefact to communicate a concept to the outside should be central to every design effort. [1] To implement a technical sketch or prototype, one has to go through the process of dissecting big problems into smaller sub-problems & then come up with a logical chain to solve those in order to solve the bigger holistic problem. This process is extremely effective in order to gain clarity of mind over the quality of a specific idea. Ideas in general are of low value as they are easy to generate and usually neither good nor bad, it is the implementation which makes them a construct that adds or subtracts value from society. When sketching or prototyping there are several pitfalls that need to be avoided. One of them is to get attached to a built artefact, which can lead to moving down a direction that is not adding value to the product. Another one would be to sketch or prototype in a resolution that is not suitable for the current stage of the product development, which can lead to inhibiting creativity later on if the resolution is too product-like too early or bad communication if it is too vague late on in the process. Another pitfall is that one can get obsessed with implementation beyond making something experienceable, this can lead to missed deadlines however if successful it lets someone create an holistic product from scratch.

Process, education and craft

Game engines

A game engine is a software framework designed to develop video games, however it is increasingly used for several industry applications like cars, robots and consumer electronics and use cases like user interfaces, synthetic data generation as well as controlling of spatial computing experiences. Game engines provide the toolsets to simulate world space, physics and complex behaviours of objects while simultaneously enabling a direct interface to most kinds of hardware actuators as well as sensors. With the rapid advances and distribution of compute performance they can increasingly be embedded on all types of chipsets which enables to transform human-machine interfaces towards real-time experiences occupying human perception with increasingly similar cues like physical reality does. This makes them a powerful tool for designers as they enable a multitude of workflows previously unthinkable, like building centralised controlling mechanisms for hardware systems or immersive experiences catering both actuation output as well as sensor input in a spatial context, while early on in the process using virtual reality to evaluate a system intended for physical reality, which keeps development cost low.

Spatial computing as a new paradigm for user experience

Currently spatial computing applications are mostly understood in the context of head-mounted displays. An interesting thought experiment is to count the microcontrollers within a radius of 3m around oneself and then to think of experiences that would be possible if all those chips would have one centralised controlling mechanism that allows using all the generated data from attached sensors for one curated behaviourally optimised experience facilitated by all the attached actuators. Later in this pictorial the case is made for spatial computing outlets to intertwine the realities we populate.

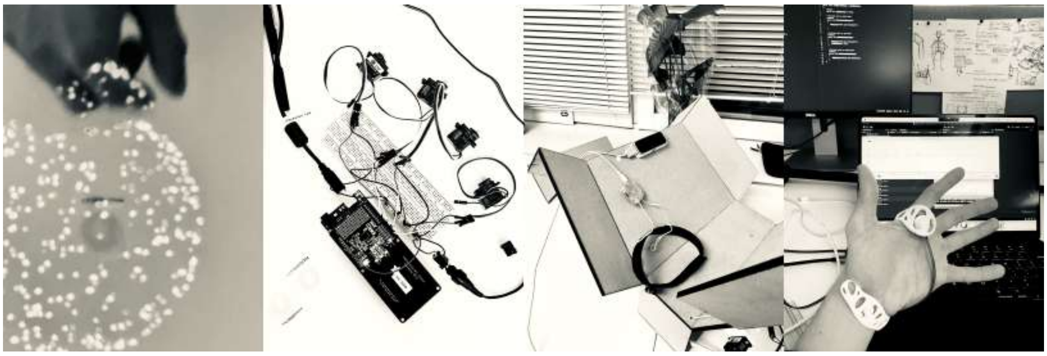
Critical questioning of design methodologies & story-telling

There is a notion in the industry, especially but not exclusively in big design agencies and consultancies that design is about generating a multitude of ideas, aesthetics or concepts that are then hand-over to other teams for implementation. This leads to the rise of design methodologies such as design-thinking, ethnographic research, wizard-of-oz prototyping and many more. A common denominator of those techniques is that they are used to generate and somehow visualise ideas and stories a product should have, without going into technical detail. This leads to a gap between the story and the actual manifestation of the product. The more one understands the materiality of their creation, the smaller this gap becomes, which increases the impact of designerly motivations for creating a product.

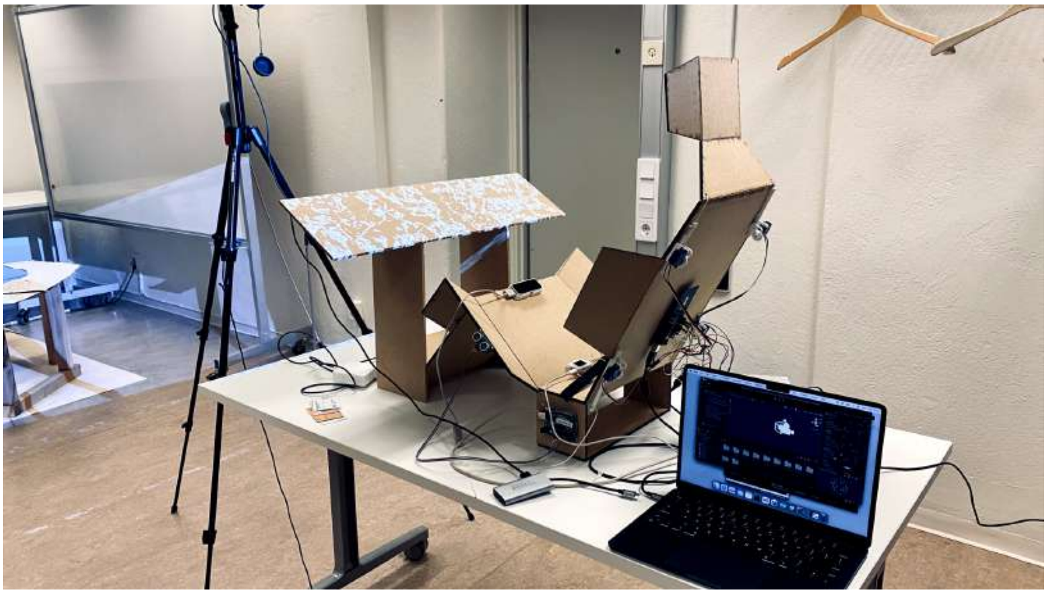
Interaction design and engineering focus

As written in the chapter above design is often manifested as something that is meant to come up with a product vision to inspire other teams for implementation. This disconnection from implementation is negatively impacting the quality of the final product and the impact design can have. It is easy to generate seemingly "good" ideas through telling stories guided by qualitative research and own biases, however as long as these ideas do not go through the test bench of basic technical feasibility and user testing with concrete data collection it is not clear if it is a good idea or not. In order to generate artefacts that enable this process designers must acquire knowledge about the underlying technologies on a level that enables functional non-scalable prototyping. What happens in the future, stays in the future.

Sketches



I sketched and prototyped experiences throughout the project to evaluate, illustrate and communicate the meaning of ideas we came up with in the group. Early illustrating and evaluating sketches included the need for an artefact personalising the experience via a RFID tag, physarum as visual output, triggering haptic feedback on belts and wearable in real-time, interacting with a car through hand-tracking and gestures and biometric data input through the wearable. My final prototype consists of the seat with seatbelts including a RFID reader, one ambient projection, one body projection, one functional UI projection, the wearable giving haptic feedback and measuring heart rate as well as an additional camera view rendering the digital twin. The organic shape as well as the detailed haptic feedback signals of the actuators in the wearable and the flows for the UI layer were created by Regina Gensinger. The seatbelt was sewn by Charlotte Phillipe. The car interiors styling as well as the 3D model for the digital twin view was created by Rohit Dongre.



Prototype

Software

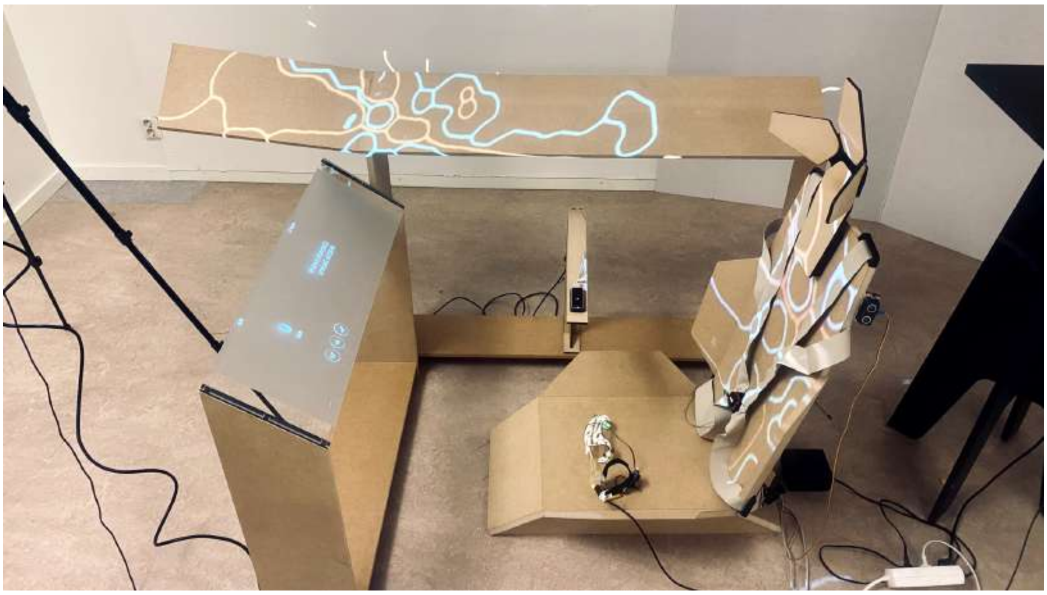
- Unity (C#, multiple SDKs, Figma Unity Bridge, HLSL and compute shaders)
- Blender
- Figma
- Arduino
- GPT-4

Hardware

- MacBook Air 2022 with 16GB of RAM and the M2 with 10 core GPU
- 4x HS422 servos + Arduino Uno
- HC-SR04 ultrasonic sensor and ID-12LA RFID reader with SparkFun breakout board + Arduino Uno
- Pulse sensor + Genuino MKR 1000
- Two haptic engines + Hapticlabs (ESP 32 with two haptic engine drivers)
- Leap Motion

Architecture

The system architecture of the final prototype consists of one Unity main application receiving all sensorial input and facilitating all actuation and display outputs. It has four peripheries for controlling sensors and actuation and streams to a total of 4 display outputs simultaneously including the digital twin camera view.



Sub-system 1 is for handling local sensors in the car. It consists of one HC-SR04 ultrasonic sensor for understanding the passengers distance from the vehicle and ID-12LA RFID reader with a SparkFun breakout board for letting the passengers personalise their experience. Those sensors are communicating with an Uno that is connected via serial into the main application where their signals trigger certain events in real-time.

Sub-system 2 is for handling local actuators in the car, namely four HS422 servos. The servos have hard-coded events on their Uno micro-controller that receives input triggers facilitated from the main application via another serial port. The events are soft pull (as welcoming gesture from the car), hard pull (as protective signal in emergencies), left and right pull (when actively driving to emphasise the feeling of the curve) and release (as indicator that a passenger is now controlling the car).

Sub-system 3 is handling the hand-tracking. It is a Leap Motion device that is directly integrated into the Unity application via Ultraleap's SDK. Hand-tracking is the main interaction point with the vehicle. Main interactions are consisting of tracked poses at within certain volumes in world space defined by colliders, as well as global X translation and local Y rotation of the left hand.

Sub-system 4 is the wearable. It uses a Genuino MKR1000 with a pulse sensor to wirelessly stream via a TCP connection into the Unity main application. This biometric signal is one of the inputs of the generated visual for the projections. For the haptic feedback on the wearable a Hapticlabs satellite (ESP32 with two on-board haptic drivers) is used with two different linear resonance actuators positioned on the wrist and between index and middle finger. The Hapticlabs satellite is also connected with the main application through serial which facilitate the driving signals at certain trigger points. Haptic feedback is supplied to the passengers at points of direct interaction with the car, namely approaching it, activating collective experiences and at steering angle maximums. Unfortunately the Hapticlabs satellite is a closed system and the firmware does not allow to enslave it to the MKR 1000. A point for improvement in the prototype would be to use two haptic engine drivers directly from the MKR1000 which would allow to stream the haptic signals from the main application via TCP and make the wearable fully wireless. However there was not enough time to implement that.

The Unity main application is both the centralised facilitator for haptic and visual output as well as processor interpreting all sensory input. Having the whole input and output act and react in real-time in a spatial environment creates a user experience continuously blending virtual and physical realities to a unified experience where content reacts in immediate response to behaviours and situations in and around the car in a holistic manner. In case of the prototype this manifests in the following interactions:

1. Haptic feedback on the wearable that differs based on how close a passenger is to his shared ride and acts as a guiding signal to the right car.
2. Launching and personalisation of the visual parts of the experience. Haptic feedback on seatbelts when unlocking the experience creating a feeling of embodied intelligence of the vehicle.
3. Gesture and hand-position based activation of the ambient experience. First a gesture of grabbing ca. 10-20 cm in front of the torso acts as a metaphor for establishing a data stream between the users personal data activating haptic feedback on the wearable that suggest holding something. Then a release gesture paired with a forward movement of the hand ends haptic feedback on wearable and launches ambient experience, which consists of music starting to play which is also reflected in the functional UI layer (Spotify Jam), part of the compute shader starting to react to the specified music (average base frequencies of the song) and other parts of it starting to react to the raw pulse signal of the passenger (saturation changes based on maximum amplitude).
4. Gesture and hand-position based activation of the driving mode (passenger want to steer the vehicle). Open palm is positioned close to the ambient canvas the result is pulsating haptic feedback on the wearable and partial release of the seatbelt. After 4 seconds holding this pose another haptic feedback is triggered on the wearable, the busy distracting part of the ambient canvas (reacting to music) fades out and the part reacting to the pulse signal remains. The UI layer changes its behaviour towards a interface that has an indicator for current steering angle and maps for navigation.
5. While in driving mode at peak steering angles there is haptic feedback on the hand as well as the seatbelt, which pulls the passengers into the curve

> asymmetrically to emphasise the feeling of the curve. The steering angle indicator changes its direction based on the translation of the left hand on the global x-axis and the speedometer updates based on the local y-axis rotation of the left hand.

In order to achieve a blend in behaviour of objects in physical and virtual reality and breaking down friction in interacting with virtual objects we need machines/vehicles with deeply integrated sub-systems of sensing and actuation guided by centralised main-applications that define holistic behaviour of the system as a whole, comparable to a central nervous system and brain. This main-application defines the holistic interaction paradigm of the system, which can in this sense also be seen as a hyperphysical system as defined by Crawford perceived by our cognition as an extension of unified reality. [2]

Physarum transport networks and why they were chosen as a visual output of the application

Jones observes the pattern formation emerging from particle-like agent's behaviour in physarum slime molds. [3]

> *Using simple local behaviours based on chemotaxis, the mobile agent population spontaneously forms complex and dynamic transport networks. By adjusting simple model parameters, maps of characteristic patterning are obtained.*

The emergent behaviour of those molds has synergies with parallel processing in modern GPU architecture as it can only be described by calculating every agents position continuously in parallel on every frame and passing data back into the main application executing on the CPU in order to generate trail map and data map that then defines the agent behaviour on the next frame. This synergy from an artistic standpoint makes physarum a life-form that behaves and works identically no mater if defined in virtuality by bits or in physicality by atoms. It makes one reflect about substrate independence.

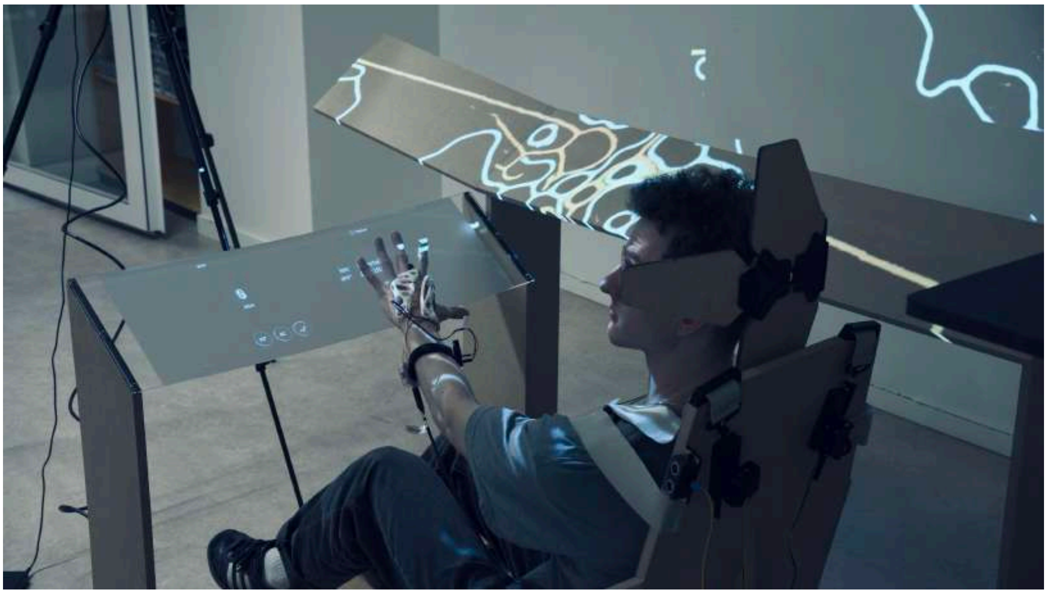
The project in industry context

New real-time user interfaces: Enabler of meaningful experiences and systemic change or ultimate tool for surveillance capitalism

The term real-time in the context of user interfaces is relating to user facing systems in which input data from the user or other data streams are processed in a timespan that is so small that the system's feedback through display outputs and actuators is virtually immediately. This enables immediate adaption of the whole system to the current context the user is in at every given point in time. With increased availability and miniaturisation of compute performance the possibility arises of calculating interactions in world space, simulating physics and having advanced interpretations of data input through machine learning algorithms on high-end as well as embedded hardware. This adds great flexibility to the possible behaviour of virtual objects, while simultaneously increasing the bandwidth of information streaming into and out of the system calculating those objects. As a result the perceived meaning and status virtual objects occupy in the lives of people changes and desire and other feelings for those objects are sparked. Early examples for this trend are video games such as Fortnite, Hearthstone and League of Legends which are mostly free to play but give the possibility of buying virtual objects that signal status and add functionality. They are still bound to old platform archetypes like consoles, mobile and personal computers, however with the rise of digital outlets and sensors in every domain of life this consumption behaviour is increasing in relevance. Virtual objects are easier to produce, scale and distribute which gives them systemic advantages. They are also far more fluid in their gestalt, which adds the possibility of updating and personalising them very immediately as well as over time.

With digital outputs occupying a big junk of the human perceptive apparatus while human behaviours and environments are sensed and interpreted in intricate ways by machines a scenario is thinkable where corporations are able to trigger consumption behaviours in near real-time by hijacking evolutionary grown systems focussing on short term gratification rather than long term sustainable gratification. This could enslave us to the universal machines defining our realities and ultimately disrupting us as a species by making consumption our priority neglecting all of our natural needs and duties.

Privacy, transparency and mindfulness about information streams
Regulation of information technology is often focussed on regulating data collection. Those interventions are important, they also lead to a strategy where companies try to get consent to collecting as much data as possible through in-transparent consent forms with dark UI patterns. Richer interactions involving haptics, sound and hyper-physical behaviour of UI elements can convey more meaning than conventional user interfaces. This can be leveraged to be honest and more intuitive about data collection and information streams into and out of the system.



In the example of the prototype this manifests in the physarum compute shader as well as the gestural hand-over of personal data. The gesture reverses the stream of information complimented by haptic feedback on the wearable suggesting the feeling of holding data in one's hand and passing it to the machine.

The turquoise physarum whose saturation is controlled by the biometric data of the user can be seen as a constant feedback monitor communicating the level of stimulation the passenger is experiencing by the rest of the experience through its colour saturation. If consent for facilitating ambient experiences tailored to the individual is given by the gesture the orange physarum starts reacting to the transmitted content (in case of the prototype a shared music session on Spotify) signalising the increased data footprint of this service's recommendation algorithm as well as a reversal in the direction of the information stream as the experience now starts stimulating the passenger which is also reflected in the turquoise physarum again.

Finally if driving mode is launched the orange physarum fades out to not distract the driver and emphasise on the turquoise physarum that again shows the level of stimulation the driver is experiencing, now by the thrill of driving the car.

Usage data is precious for increasing the quality of output of algorithms that power personalised experiences. Today's user interfaces try to trick users into giving consent to as much data exchange as possible to then stimulate them with instant gratification to bind them to the service. The physarum project suggests an alternative approach by making information & data streams more visible to make technology usage more mindful, while not neglecting or hiding the need for data collection.

Reality, simulation and cognition

Cognition, self-awareness and consciousness

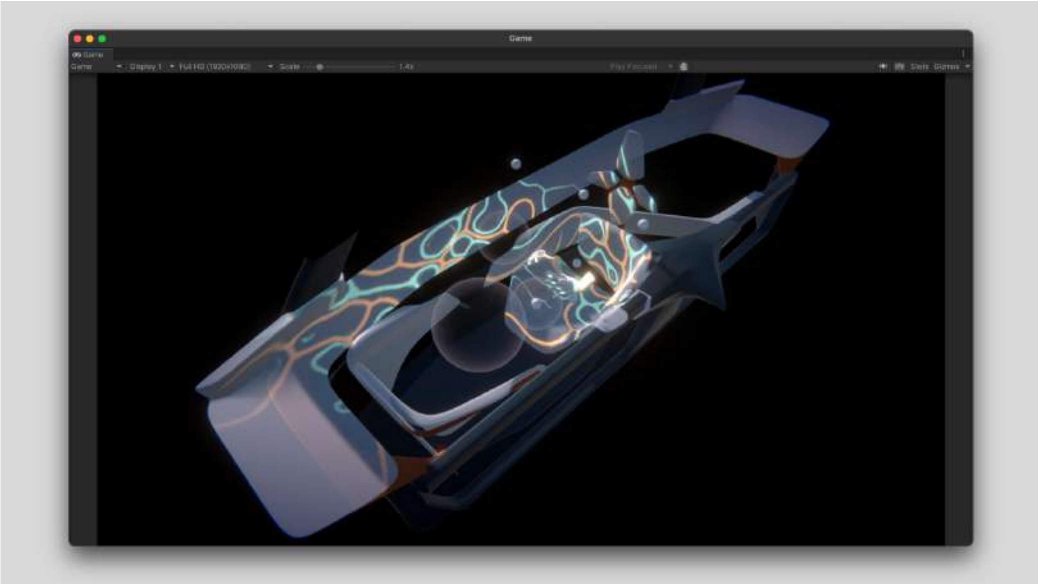
In a conversation with Lex Fridman the cognitive scientist Joscha Bach suggests that we are neither conscious nor self-aware when we are born. [4] As soon as we see the light of the world our perceptive system starts developing some sort of natural game engine that makes it possible to perceive an abstraction of what is happening around us. Then the ability of our brain to memorise and synthesise on those inputs through language enables for reasoning, learning and predicting. The awareness of those processes is where consciousness arises. According to Tegmark [5] the ability to form our thinking based on past memories and future predictions is what distinct us from simpler lifeforms that live their lives after pre-programmed processes. What we call reality therefore is an individual simulation providing our self with information to make sense of the entirety of the data input from our surroundings.

Cars as entry-points into different realities

Cars are architectural products in terms of encapsulating the passengers within them. The availability of new output hardware such as projectors and displays and the automatisation of driving, fundamentally changes their meaning. The primary use case for a modern car is not transporting someone from A to B, but triggering certain feelings and emotions within them. The fully surrounding aspect of a car makes it the perfect product for fully immersing people into different realities by multi-sensory stimulation. The industry must not prioritise creating continuous revenue streams over thinking how those experiences could be meaningful and facilitate presence which is contrary to stimulating people as much as possible to trigger consumption.

How real is reality?

It is a common view that virtual objects are not real but merely fictional or illusory "consensual hallucinations". [6] This is a misconception as the previous definition of reality points out. A computer-generated object made out of bits if it is perceivable and interactive is perfectly real and part of our individual realities as much as an object that is physically defined and made out of atoms. According to Bostrom mind and computation could be substrate independent.[7]



There should not be a clear distinction between virtual & physical reality anymore as they are fundamentally intertwined and influencing each other permanently. In case of the digital twin created for the sensorium project this becomes apparent when trying to point out directions of streams of information into the given systems and their reality of origin.

Conclusion (written by GPT-4)

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The "Sensorium" project encapsulates the transformative potential
of integrating advanced technologies like game engines and spatial
computing in design. This fusion offers innovative, immersive
experiences that challenge our perception of reality. However, it
also brings to the fore critical considerations around privacy,
ethical use of technology, and the impact on human behaviour. As
we venture further into this realm, the key lies in balancing
technological innovation with ethical responsibility and user-
centric design. Our goal should be to harness these technologies
not just for their novelty, but to enrich human experiences and
foster a sustainable, ethical future.
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