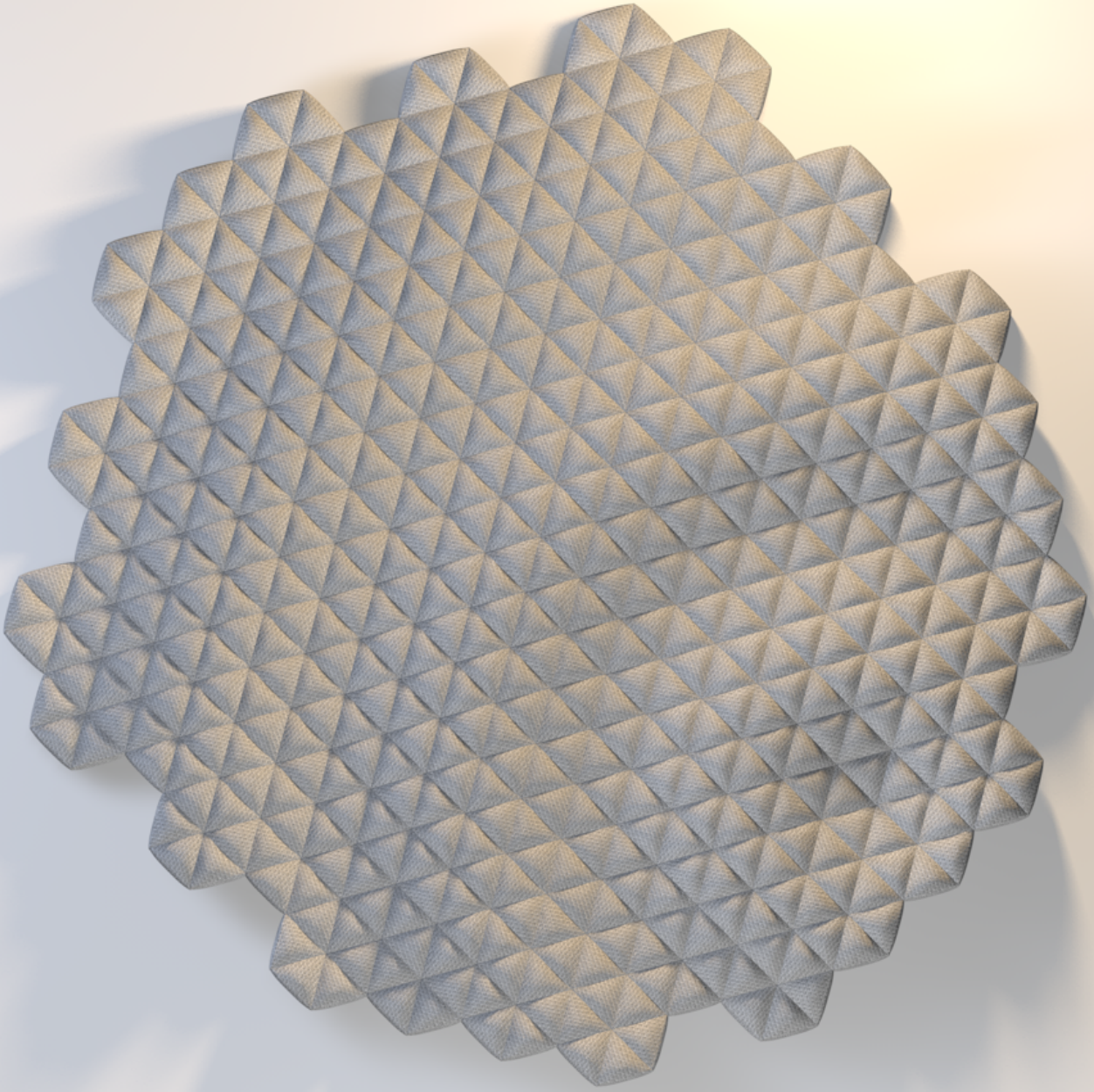

Soft Robotics for Health & Mobility

GRADUATION PROJECT PROPOSAL 2021

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Introduction to the Context

Well Being Resides in Balance

Survival & healthy living are a battle against the forces of pressure & time. We have evolved to counter this tremendous pressure and optimally distribute these forces throughout our bodies (bones, muscles, joints) & over time (movement). The constant positioning & balancing of the body to counter the forces of gravity is what we call posture.

Balance through movement is an essential part of our evolutionary blueprint.

When there is a 'deviation' beyond our evolutionary threshold (habit/deformity/injury), the body moves differently from the way it was designed to. But since the body is also designed to find balance, our posture adapts to this deviation to stay in balance. And clinically speaking, a postural change begins a cascade of compensating cause and effects (in the body's physiology) [5].

"The human bipedal posture is extremely effective and the most economical of antigravity mechanisms once the upright posture is attained."

- Steven P. Weiniger (2016)

We Have Tipped the Balance

The environments that we have created for ourselves, have made our lives immensely convenient. We have progressed from satisfying our needs to fulfilling our desires. Somewhere down that road, the obsession with convenience, comfort, efficiency & economic sense fogged our judgement to a point wherein the requirements of our natural state, long-term thinking & consequence were sidelined. Hence, affecting our notions of progress, health & well being.

"Over the last 200 years, ambulatory Homo Sapiens became sofa-seduced, slothful Homo Sedentarius"

- James A. Levine (2014)

Systemic, technological and environmental factors of modern society (starting from the mid-20th century) have contributed to a deviation in our daily living and working environments, that takes us beyond our evolutionary threshold. This deviation is 'Physical Inactivity'. This is even more so in the digital age as technology chips away at physical activity. When habit becomes a guiding sociological mechanism, it percolates into a lifestyle which, in our case, is increasingly sedentary. The statistics are disturbing & we have substantial research proving that now more than ever, all age-groups are affected by the, "Sitting Disease". The COVID-19 pandemic has only tightened that noose.

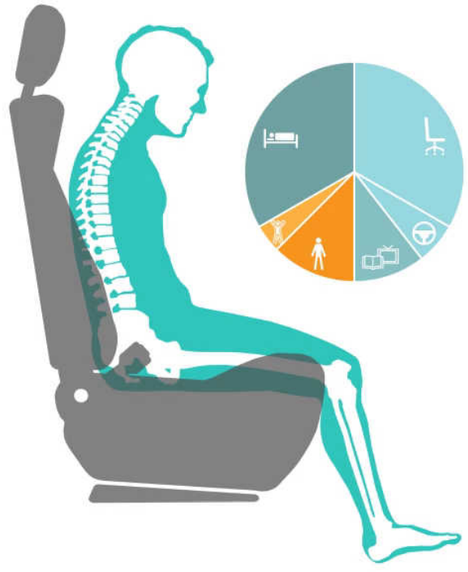
Posture is:

Holistic
Postural observations are organic; that is, they deal with the whole organism.[5] A myriad of interdependent physiological & psychological systems are at play in achieving a balance for function & survival.

Architectural
People come in various shapes & sizes. Every individual learns to balance the body's unique architecture. [5]

Dynamic
Posture is not a position, but a dynamic balance of reflexes, habits & physical responses that keep you upright against gravity and allow you to function. Posture is fluid. It is about balance & moderation than "spinal neutral" [10].

Adaptive
People live unique lives, causing individual postures to differ. Posture comprises an accumulation of adaptations & compensations from an individual's lifestyle (habits, injuries). [5]



Sitting Disease is a term coined by the scientific community, commonly used when referring to metabolic syndrome & the ill effects of an overly sedentary lifestyle [11]

The **4th leading** risk factor for global mortality is physical inactivity [11].

A Global Burden of Disease study shows low physical activity accounted for **152000 deaths & 2.1 million Disability-Adjusted Life Years** (DALYs) in 2017 (EU).

The estimated economic burden was **80.4 billion Euros** through 4 major non-communicable diseases (coronary heart disease, type II diabetes, colorectal & breast cancer) & the indirect costs of inactivity related mood & anxiety disorders (ISCA 2015).

The irony of our fast-paced, mobile context is that we are increasingly static.

The average person spends 8.5 hours (median-adult) [22] of the day in a seated position. The sedentary lifestyle limits us to static posture sets that, over time, have devastating effects on the whole body. "Growing evidence suggests that the health impact of sitting may overall be greater than that of smoking" (Levine, J. 2014)[12]. And to make matters worse, this negative impact is amplified in combination with our tendency to assume poor posture in daily life.

Opportunities for sedentary behaviours are ubiquitous and likely to increase with further innovations in technologies [16]. Sedentary behaviour is shown to increase with age and so are disabilities. The ageing population is projected to be 22% of the world's population by 2050 [21, 20] and the public health burden associated with sedentary behaviour is therefore emerging as an important public health concern.

To make matters worse, we don't see it! Self-report estimates tend to underestimate sedentary behaviour time, suggesting the need for consistent object measures in population studies. The median self-report for sedentary behaviours among adults was 5.5 hours/day but was 2 hours/day longer for objectively measured sedentary behaviours (median 8.5h/day) [22] This means that we are not consciously aware of this issue and its magnitude.

According to Levine, designing a chair-based world was a mistake. To a large degree I would agree, but argue that the object may not be to blame. If we examine the object as an embodiment of all the systems crucial to its relevance, we realise that we missed important overlaps with our evolutionary system. What I mean is, our evolutionary system floats the component of time; because the rate at which technology can evolve is substantially different from the rate at which our biology does. Then perhaps our approach to designing our objects (in this case, the chair) is flawed or imcomplete! Hence it might be valuable to ask: If the human body is meant to be moving, then why on earth is the object we spend 50-60% [23] of our time in so static?

The technology with which we build our environments can & should be used to put cues in our environments that trigger our natural state!

Problem Definition

The Problem Space: Sedentary Behaviour

The Sedentary Behaviour Research Network (SBRN) defines Sedentary Behaviour as any waking behaviour characterised by an energy expenditure ≤ 1.5 metabolic equivalents (METs), while in a sitting or reclining posture (Tremblay et. al. 2017) [13]. Tremblay et. al. also note:

> The definition of 'Sedentary Behaviour' highlights two primary components of sedentary behaviour: energy expenditure & posture.

It is important to differentiate between "physical activity" and "sedentary behaviour" [1]. This shows that the problem within the energetic component of sedentary behaviour lies in prolonged, uninterrupted sitting time. To make matters worse, the longer a person is seated, the more likely they are to let their posture slide. The compounded effect of the two aspects of sedentary behaviour: prolonged static posture sets (translating to large timeframes of low energy expenditure) and poor posture wreak havoc on our health and wellbeing.

The Energetic Component

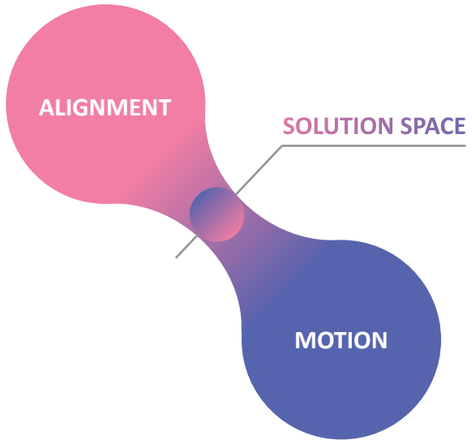
> "It is not enough to just have good posture. In fact, being stationary for long periods with good posture can be worse than regular movement with bad posture."
>
> - Murat Dalkilinç (2015)

Prolonged sitting or any activity with static posture sets triggers the biologic mechanisms of "inactivity physiology" [16, 17]. This effect occurs on the molecular level, which means that the problem runs deep. The consequence is increased risk of obesity; cardiovascular disease; abnormal glucose metabolism & metabolic syndrome causing type-2 diabetes; & some cancers [16]

The Postural Component

> Our posture, as fluid as it is, forms the foundation that represents the configuration & alignment of different biological systems

(musculoskeletal, nervous, sensory motor, circulatory, tissue & organ systems). Poor alignment of these systems disturbs optimal distribution of stresses by creating overactive & underactive areas. This strains these systems over time, resulting in functional impairment. The short term effects range from soreness to decreased flexibility & inhibited muscle groups [19, 15]. This misalignment can have serious, debilitating long term effects like musculoskelatal degenration, poor blood circulation, nerve constrictions and organ malfunctions. Additionally, studies show that posture is also linked to the emotional state & pain sensitivity [27].



[1] This is because 'inactivity physiology' is separate from 'exercise physiology'. "In theory, this may be in part because non-exercise activity thermogenesis is generally a much greater component of total energy expenditure than exercise or because any type of brief, yet frequent muscular contraction throughout the day may be necessary to short-circuit unhealthy molecular signals." [16] Our perception of physical activity lays the focus on deliberate 'exercising for health', which becomes the key feature of most public health guidelines. The American College of Sports Medicine and American Heart Association emphasise the participation in at least 30-minutes of moderate-intensity physical activity, 5 days a week. [14] But studies show that even the people who met the physical activity guidelines are at risk for the same consequences as those who didn't! [15] It implies that the time spent exercising and sitting are separate factors for health risks. This is because even though the hypothetical "physically active" adult achieves this 30 to 45-minute, minimum level of purposeful exercise during the day, a large portion of the remainder of the day is spent sitting. Hence the term "active couch potato" is appropriate.[16]

Mental Health
Foggy Brain, focus & productivity loss [11, 26],
Depression, Mood disorders.

Metabolic Health
Impaired respiration circulation & digestion, Obesity, Varicose Veins/
Deep Vein Thrombosis (DVT) [26], organ malfunctions,
112% increase in the risk of diabetes [23]
147% increase in risk of cardiovascular disease [23]
upto 66% increase in risk of cancer [24]

Neuromusculoskeletal Health
Spinal Deterioration, Muscle, bone & joint degenration,
Scoliosis [27], Osteoporosis [11], Pressure Injuries & Sores

Injuries, Disabilites, Pain, Chronic Diseases, Loss in Function
71% increase in mortality rate (US)[25]

The Solution Space

> "Sit when you need to;
> stand when you want to;
> walk or move when you can."
>
> - Aviroop Biswas, Peter Smith (2018)

Postural Awareness and Reducing/breaking up the time that we spend in sedentary behaviours are seen as a possible solutions. Several recommendations are being issued in the form of national and internations physical activity guidelines.

Plenty of studies show the need for recommendations for sedentary behaviour that support healthier lifestyles [2]. But this study has its limitations for analysis and shows that with better testing tools & longitudinal analysis, we may find more robust and compelling results that could lead to more meaningful randomised control trials or policy change [18].

Communicating this perspective to the public & policy makers will require ingenuity & clarity in message [16] along with proof based solution proposals that call for action. Research through design can tackle the challenge to understand and effectively intervene in acting upon the opportunities to trigger sedentary behaviours within healthy limits. What better point for behavioural intervention can we find than the very object in which we display sedentary behaviours?

The chair represents the positioning system in which we spend a large portion of lives. The need for dynamic and user-friendly positioning systems for health and well-being presents a valuable opportunity to explore the scope of soft-robotics & AI.

This could potentially contribute to solving many of the ergonomic problems associated with Sedentary behaviour and managing/delaying/preventing the its deleterious effects. In addition to solving ergonomic problems, the considerable contact area provides value in an ecological approach. This opens up possibilities to explore Human-Computer Interaction through our sense of touch. Explorations in Haptic Interaction Design in this context would allow for the insertion of effective cues in the environment (or positioning system) to trigger behavioural change.

[2] Studies by Hamilton et. al. conclude that with a clearer understanding of the unique determinants of sedentary behaviour beginning to emerge and relavant conceptual models being developed, the field is now ready for behavioural intervention trials on the feasibility and health outcomes of changing sedentary behaviours [16].

Assignment

"Assessing the merits
of soft-robotic surfaces for sedentary behaviours,
health & well-being"

Focus of Development

Due to considerable amount of ongoing research in the sensing aspect, the focus of development for this assignment will be the actuation of soft-robotic surfaces with the aim to provide dynamic ergonomic support and room to explore haptic interactions through seating & positioning systems..

Aim of Project

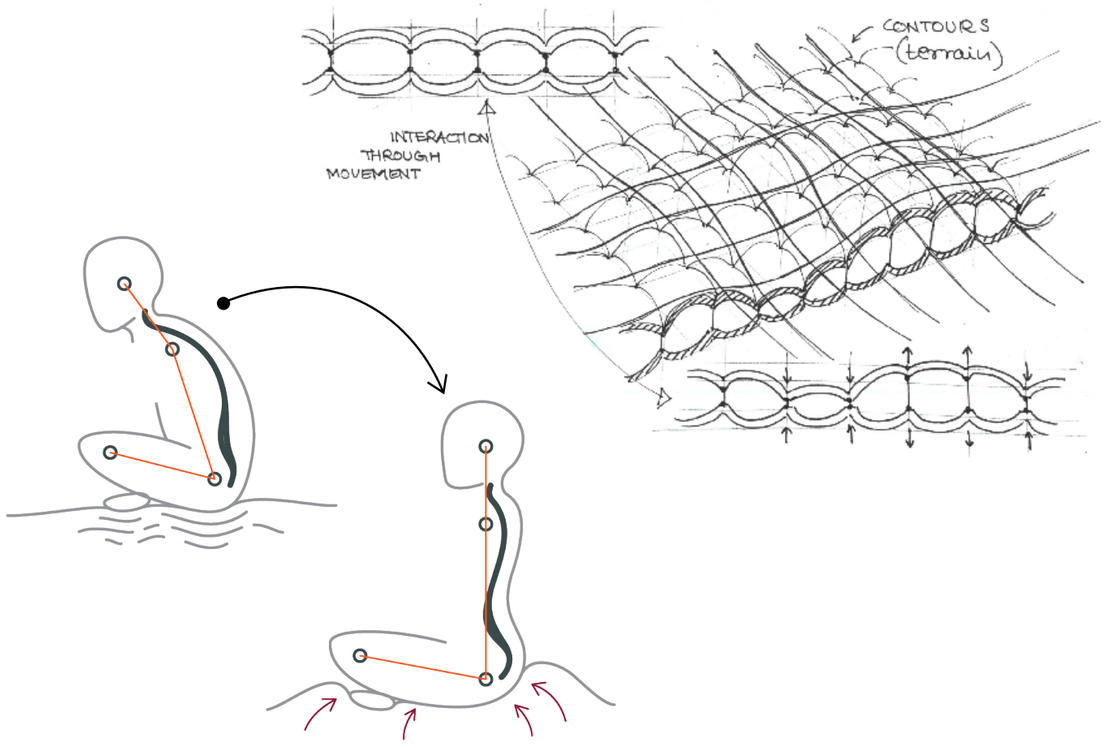
The aim of this graduation project is to contribute to the body of research that supports ergonomic & haptic interaction desiderata through soft-robotics for sedentary behaviours based on an empirical approach for research & analysis.

Scope & Outcome of Project

To research the contact surfaces of seating & positioning systems in order to build a set of well-grounded criteria against which the solution space can be assessed. The research is to also include a cursory investigation of the feasibility and viability constraints of the context.

The result of this assignment is to be a set of recommendations for actuation maps and their potential applications in the chosen context; based on an empirical assessment of the explored solution trajectories. Furthermore, the result of this assignment is to propose the foundation for further research and explorations in the field of soft robotics for sedentary behaviours.

To keep the integrity of the idea of desideratum, the technical outcomes of this project are to be supplementary to the explorative & experiential qualities of this research.



Planning & Approach

The aim of the project planning was to allow for incubation time to aid the processing of information into knowledge. Considering a 4 day work week, the project of 100 working days extends over 25 weeks.

Week of the Year	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
Project Week	**1**	**2**	**3**	**4**	**5**	**6**	**7**		**8**	**9**	**10**	**11**	**12**	**13**			**14**	**15**	**16**	**17**	**18**	**19**		**20**	**21**	**22**	**23**	**24**	**25**
Work Day (4 d/w)	1	5	9	13	17	21	25		29	33	37	41	45	49			53	57	61	65	69	73		77	81	85	89	93	97
				EVAL.							DAY 40 EVAL.							EVAL.				PRE. SUB. EVAL		DAY 80 GREEN LIGHT				DELIVER	PRESENT
RESEARCH								B							B	B							B						
DESIGN								R							R	R							R						
PROTOTYPE								E							E	E							E						
TEST								A							A	A							A						
ANALYSIS								K							K	K							K						
DOCUMENTATION																													

The approach for this project is inspired by the one used in the materials stream in Project Light.Touch.Matters. [28]. It aims to use soft-robotics to develop a smart material that allows the "product to become the interface"[28]. It involves a set of 'Research Through Design' (RTD) activities for 'Design Driven Material Innovation' (DDMI) since a material is being developed with design input obtained through empirical studies.

The 'material' described here is not a material per se but a combination of materials, components and even software, that in terms of the latter behaves as a single interactive material. [28] According to this understanding a material can be redefined as a scalable object without fixed dimensions or restrictions of shape (Tempelman E. personal communication. 2021 February 16)

I see value in approaching the project from
- technological perspective looking "inside-out" (the material scientist's lens)
- contextual perspective looking "outside-in" (the designer's lens)

The focus of my graduation project is heavier on the contextual perspective and the technological perspective shall be supplementary to the contextual perspective, although it cannot be underestimated in its influence & importance.

During the graduation project, I will be attempting to create vthe architecture of the material. Research Through Design (RTD) activities will be employed to identify and define a preliminary set of desiderata for the further development of this material (Desiderata implies: performance targets, design inputs, development targets, & 'why', to define most promising targets). For this, the material will be examined from the "inside-out" approach, wherein each layer of the material is assessed as well as the "outside-in" approach, in which the material is assessed as a whole in relation to the user & its context. The idea is to find a balance between the two since each affects the other. This approach will be explored over two prototype iteration cycles resulting in recommendations regarding further development.

The problem statement gif shows that each context contributes to the mix of interests in the project that adds weight to the issue and speeds up the research agenda. This preliminary set of desiderata as an outcome of this project are to serve as a basis for their re-examination & revision through targeted research enquires for further development; hence influencing the the direction of future research.

Alongside the expected outcome, which to "showcase what the technology could look like", it is valuable to consider the expected project effort and resources.

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