Steps to a Sustainable Mind : Explorations into the Ecology of Mind and Behaviour

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Steps to a Sustainable Mind

Explorations into the Ecology of Mind and Behaviour

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Abstract

This transdisciplinary doctoral thesis presents various theoretical, methodological and empirical approaches that together form an ecological approach to the study of social sciences. The key argument follows: to understand how sustainable behaviours and cultures may emerge, and how their development can be facilitated, we must further learn how behaviours emerge as a function of the person and the material and social environment. Furthermore, in this thesis the sustainability crises are framed as *sustain-ability* crises. We must better equip our cultures with abilities to deal with the complexity and uncertainty of socio-ecological systems, and use these cultural skillsets to survive in and adapt to an increasingly unpredictable world.

This thesis employs a plurality of ecological social sciences and related methodologies—such as ecological psychology, ecological rationality and agent-based modelling—to enlighten the question of how the collective adoption of sustainable behaviours can be leveraged, particularly by changing the affordances in the material environment. What is common to these ecological approaches is the appreciation of 'processes' over 'products': we must understand the various processes through which sustainable forms of behaviour or decision-making emerge to truly locate leverage points in social systems. Finally, this thesis deals extensively with uncertainty in complex systems. It proposes that we can look to local and traditional knowledge in learning how to deal adaptively with uncertainty.

Tiivistelmä

Tässä poikkitieteellisessä väitöskirjassa esitetään lukuisia teoreettisia, metodologisia ja empiirisiä näkökulmia, jotka yhdessä muodostavat ekologisen lähestymistavan sosiaalitieteelliseen tutkimukseen. Tutkielman keskeinen argumentti on: jotta voimme oppia, miten kestävät käyttäytymismallit ja kulttuurit syntyvät ja miten niiden kehitystä voi edesauttaa, meidän täytyy ymmärtää, miten ne syntyvät ihmisen ja (materiaalisen sekä sosiaalisen) ympäristön funktiona. Tässä väitöskirjassa kestävyyskriisiä tulkitaan käyttäytymistieteellisestä ja kulttuurievoluution näkökulmasta. Sopeutuaksemme yhä hankalammin ennustettavaan tulevaisuuteen, kulttuurimme on opittava ja mukauduttava hallitsemaan epävarmuutta sekä tietoisesti ohjaamaan kulttuurievoluutiota kestävään suuntaan.

Tässä väitöskirjassa hyödynnetään lukuisia teoreettisia ja metodologisia tulokulmia, esimerkiksi ekologista psykologiaa, ekologista rationaalisuutta sekä agenttipohjaista mallinnusta. Yhdessä näiden tulokulmien kautta pyritään ymmärtämään, miten voimme paikantaa yhteiskunnista vipupisteitä kestäviin käyttäytymismuutoksiin esimerkiksi materiaalista ympäristöä muokkaamalla. Väitöskirjan tulokulma painottaa erityisesti käyttäytymismuutosten taustalla olevien prosessien tulkintaa: jotta voimme ymmärtää, miten kestävät käyttäytymismallit tai päätöksenteot syntyvät, meidän on ymmärrettävä miten ne syntyvät lukuisten monimutkaisten ja kytkennäisten sosiaalisten prosessien kautta. Tässä väitöskirjassa tutkitaan myös epävarmuutta kompleksisissa järjestelmissä. Väitöskirjassa esitetään, että paikallisesta ja perinteisestä tietämyksestä voi olla paljon opittavaa sopeutuessamme epävarmaan tulevaisuuteen.

Contents

List of Original Publications

This dissertation is based on the following publications:

1. Kaaronen, R. O. (2018c). Reframing Tacit Human-Nature Relations: An Inquiry into Process Philosophy and the Philosophy of Michael Polanyi. *Environmental Values*, 27(2). https://doi.org/10.3197/096327118X15162907484466
2. Kaaronen, R. O. (2017). Affording Sustainability: Adopting a Theory of Affordances as a Guiding Heuristic for Environmental Policy. Frontiers in Psychology, 8. https://doi.org/10.3389/fpsyg.2017.01974
3. Kaaronen, R. O., & Strelkovskii, N. (2020). Cultural Evolution of Sustainable Behaviors: Pro-environmental Tipping Points in an Agent-Based Model. One Earth, 2(1), 85–97. https://doi.org/10.1016/j.oneear.2020.01.003
4. Kaaronen, R. O. (2020, In print). Mycological Rationality: Heuristics, Perception and Decision-Making in Mushroom Foraging. Judgment and Decision Making, 15(5). https://doi.org/10.31234/osf.io/7g8er

The publications are referred to below by the numbers above (e.g., Article 1).

All articles were written solely by Kaaronen except for Article 3, which was co-authored with Dr. Nikita Strelkovskii at the International Institute for Applied Systems Analysis (IIASA). Kaaronen was the main contributing author for the manuscript, model, and analysis of Article 3. Strelkovksii supervised Article 3 and oversaw the development of its manuscript, model, and analysis.

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For a thesis whose core arguments include the idea that we behave in ways which our environments afford, it is only appropriate to note that the present text would never have become if it were not for the caring and support from my family, friends, and colleagues.

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can be a tiresome business from time to time, and support from peers has proved to be absolutely crucial. I am glad to have so many colleagues that double as brilliant friends.

Not all of the present work as done at Helsinki, and a particular thank you goes to all my international colleagues. I thank all members of the Young Scientists Summer Program 2019 cohort at IIASA, as well as the staff at IIASA, for some of the most intellectually rich experiences I have ever had the pleasure to experience. I thank Nikita Strelkovskii for having the faith in supervising my work at IIASA, and for all the creative collaboration. I thank Liam Satchell for the endless discussions we have had on ecological psychology and other research-life related concerns.

I thank the Faculty of Social Sciences at the University of Helsinki for trusting me with funding and organizational support—in this I have been very fortunate. I also thank everyone at the Helsinki University Library for maintaining such wonderful libraries, whose collections have sparked most of the ideas within this thesis. I used to speak of how having 'random walks' along library aisles has led to the research ideas I most value, but upon further inspection I realised these walks are not random at all: they are all guided by great curation and research infrastructure.

1 Introduction

1.1 Prologue: *Sustain-ability*

Etymologies

I begin with a digression: I am tremendously partial to etymology, the study of the history and origins of words. Admittedly, some of this affection is by its nature pedantic—I enjoy the trivia of knowing the details of everyday things, and particularly the sharing of such information with others. But I wish to make the argument here that there is a more profound aspect to etymology, one which will reverberate throughout this text. This is the notion that histories of words can afford insightful commentaries on how they are currently used; how they might have lost some of their meaning or gained new ones. Etymologies can reveal political or geographical histories—such as the case of 'rhubarb', which derives from the Greek *Rha barbaron*, or the Scythian name for the river Volga (*Rha*) and the foreigners (*barbaron*) who exported the product to Ancient Greece—or have epistemological or even metaphysical dimensions, such as the etymology of 'person', from the Latin word *persona*, a mask or role in a drama. Whilst I maintain that words are often just words, and at that, quite detached from practice, sometimes, to look to the future, it is necessary to understand how the current state of affairs emerged, and etymologies can be helpful here.

Environment – that which environs, that which surrounds

Given the dismal state of global environmental concerns at the time of writing this text, it is perhaps unremarkable to find that the very word by which we conceptualise our calamitous state of affairs is a misnomer. Environment, or *that which environs (surrounds) us*, is one of the more misplaced nouns in modern English, and unfortunately, has found its way more or less literally translated into several other languages (e.g., my native language, Finnish, *ympäristö*). Here is the gist of my argument, one which shall be elaborated throughout the present text: the system we label

the 'environment' is not something that *surrounds us*, it is something we *emerge from* along with other forms of life. To find that much, if not most, of modern sciences that deal with 'environmental' issues regard the environment as something 'out there' is unsurprising. Environmental psychology mainly deals with how we perceive the environment or our attitudes toward it, placing much less emphasis on how we—our patterns of cultures and behaviours—actually emerge from, act upon and act within the natural system. Environmental economics, in turn, seems to have an obsession of its own on with putting a price or utilitarian value on that which 'environs us' (the discourses on 'ecosystem services' and calculations of 'externalities' prove the point), rather than fundamentally serving to safeguard the ecological processes wherefrom we emerge. And so on.

Thus, I argue in the following work, we must foster a move from environmental social sciences to *ecological* social sciences. Fortunately, in doing so, one need not start from scratch, as theoretical frameworks with dealing with ecological human or social sciences, or indeed socio–ecological systems, are plentiful, and have a long history dating to work directly inspired by Charles Darwin (Heft 2001; Wilson 2020). Curiously, Darwin (1859) himself did use the word 'environment' once in the Origin of Species and spoke instead, among other things, of how 'circumstances' shape our individual and collective lives—a much more comprehensive notion which expands to social and cultural forms of life. As we will see below, the challenge with developing ecological social sciences is mainly one of cultivating symbiotic relations between socio–ecological theories that have previously engaged in little exchange of information.

Ecology – the study of our house

The word 'ecology' was first coined by the influential German polymath and artist Ernst Haeckel (also known, regrettably, for his radical eugenicist views) as *Ökologie*, derived from Greek *oikos* (house, dwelling place, habitation) and *logia* (study of). Thus, ecology is the study of our house or

home—a much more favourable framing of the system wherefrom we emerge. The matter of fact that ecology has been traditionally accepted as the branch of science that deals with the relationships, networks, or systems between organisms and their environments, provides a more coherent framework to study mutualistic human–nature relations and socio–ecological systems than any 'environmental' science. This is mainly due to the fact that if we do not understand the networks, systems and relations—the 'extraordinary combination of circumstances', to quote Darwin (1859)—by which human societies and cultures emerge, there is, I fear, little hope that we are capable of maintaining these systems within *sustainable* limits.

Sustainability – the ability to sustain

Sustainability is another concept which, curiously, seems to have lost much of its meaning in its overapplication. Thinking about sustainability today, one is quickly reminded of global catastrophes, or perhaps of individual 'green' behaviours, or the flashy icons of the Sustainable Development Goals. Yet sustainability is not, or at least is not synonymous to, any of these. Sustainability (*sustain + -able*) is the *ability* of a system to maintain a sustained state. Sustainability is *sustain-ability*, and in the context of humans, any such ability implies capabilities to perceive, cognise and act in ways which promote our capacity to sustain within defined boundaries, much like any homeostatic system. An ability is nothing other than a set of skills related to, individual or collective, perception, cognition, and action. Thus, sustain-ability is a set of cultural skills, or capabilities, and if we wish to live sustainably it is our utmost duty to make best use of our human capacities to foster the skillsets that keep us within planetary boundaries.

I know—framing sustainability as capabilities reeks of individualism. But this is only true if one regards capabilities as individual features, which is simply not the case. This is another core argument in this thesis. In fact, despite its focus on psychological processes such as action, cognition and perception, the present text is in fact antithetic to individualism. This is because

capabilities do not emerge from nowhere: they are products of various cultural, social and ecological processes. Capabilities are, among other things, a function of social and individual skills and learning, cultural niche construction, and available action-opportunities in our socio–material environments. Sustain-abilities should thus involve nothing less than leveraging these factors for collective good, non-human life included. Learning to become sustain-able requires leveraging the potentialities that make us human: (re)designing cultural institutions, social behaviours, norms, and environments to shape or direct our cultural evolution towards a more sustainable state.

Ecology of Mind and Behaviour

The title of this work, of course, pays homage to Gregory Bateson's (2000) great collection of essays, *Steps to an Ecology of Mind*. Considering how influential Bateson's way of thinking has been to the present thesis, it is curious how little Bateson's work appears in its actual content—Bateson's name seems to most often appear in the context of fleeting quotations or aphorisms (at which, I must say, Bateson did excel). But there is something which appealed to me in particular in Bateson's way of parsing together theoretical frameworks from various disciplines, cultivating a genuine systems approach for studying human and cultural sciences, that I always found tremendously inspiring. If we truly wish to understand how sustainable cultures might emerge, it is inevitable that we must look into various theoretical frameworks, and in doing so adopt some kind of pragmatist or pluralist perspective when facing the difficulties of multidisciplinary conversation and theorising.

This thesis includes four research articles, all representing unique theoretical or methodological frameworks. What connects them, retrospectively, is a joint attempt at understanding the *ecology* of the human mind and behaviour, and the implications of this for ongoing sustainability, or *sustain-ability*, crises. Together, these articles ask: How do sustainable ways of collective thinking

and doing emerge, as a product of cultural, cognitive or even philosophical processes? In the following summary, I present my attempt at answering this question.

Figure 1. Exploring the ecology of mind entails the blurring of boundaries between human and natural systems, as well as alternating focus between the two when generating explanations for behaviour.

1.2 Abstracts of Articles

Next to the present summary, this thesis consists of four research articles, whose abstracts are presented below. Articles 1–3 have, at the time of writing, been published. Article 4 is currently in print. The research articles discuss several themes related to sustainable dwelling, cognition, and ecological theories of mind and behaviour. In this summary I seek to parse together the key themes of these articles, with particular focus on discussing how they overlap in ways which might not be obvious at first inspection.

For a variety of reasons, not all of my work has been included within the covers of this thesis. These include a research paper on some cognitive mechanisms, particularly cognitive dissonance, which underly most ecological crises (Kaaronen 2018a), an essay on creating resilient systems of scientific inquiry (Kaaronen 2018b), and various more popular scientific chapters and texts on ecological approaches to cognition and behaviour (e.g., Kaaronen 2019c; 2019b). The reader is also pointed to these texts for a more detailed picture of the ecological approach to social sciences built in this summary.

All four articles below are available Open Access. This means that they (or pre-publication versions of them) are free for reading and sharing by anyone. Hyperlinks are provided after each abstract. If the articles, for whatever reason, cannot be accessed, please contact the author at roope.kaaronen@gmail.com or roopekaaronen.com.

Article 1. Reframing Tacit Human–Nature Relations: An Inquiry into Process Philosophy and the Philosophy of Michael Polanyi

Abstract

To combat the ecological crisis, fundamental change is required in how humans perceive nature. This paper proposes that the human–nature bifurcation, a metaphysical mental model that is deeply entrenched and may be environmentally unsound, stems from embodied and tacitly-held substance-biased belief systems. Process philosophy can aid us, among other things, in providing an alternative framework for reinterpreting this bifurcation by drawing an ontological bridge between humans and nature, thus providing a coherent philosophical basis for sustainable dwelling and policy-making. Michael Polanyi's epistemology can further help us understand these environmentally-oriented tacit processes of knowing, and also provide a basis for the political and educational implementation of process-philosophical insights, particularly via the nudging of mental models.

Full citation:

Kaaronen, R.O. (2018). Reframing Tacit Human–Nature Relations: An Inquiry into Process Philosophy and the Philosophy of Michael Polanyi. *Environmental Values*, 27(2), 179-201. DOI: https://doi.org/10.3197/096327118X15162907484466

Open Access (preprint):

http://hdl.handle.net/10138/233395

Article 2. Affording Sustainability: Adopting a Theory of Affordances as a Guiding Heuristic for Environmental Policy

Abstract

Human behavior is an underlying cause for many of the ecological crises faced in the 21st century, and there is no escaping from the fact that widespread behavior change is necessary for socio-ecological systems to take a sustainable turn. Whilst making people and communities behave sustainably is a fundamental objective for environmental policy, behavior change interventions and policies are often implemented from a very limited non-systemic perspective. Environmental policy-makers and psychologists alike often reduce cognition 'to the brain,' focusing only to a minor extent on how everyday environments systemically afford pro-environmental behavior. Symptomatic of this are the widely prevalent attitude–action, value–action or knowledge–action gaps, understood in this paper as the gulfs lying between sustainable thinking and behavior due to lack of affordances. I suggest that by adopting a theory of affordances as a guiding heuristic, environmental policy-makers are better equipped to promote policies that translate sustainable thinking into sustainable behavior, often self-reinforcingly, and have better conceptual tools to nudge our socio–ecological system toward a sustainable turn.

Affordance theory, which studies the relations between abilities to perceive and act and environmental features, is shown to provide a systemic framework for analyzing environmental policies and the ecology of human behavior. This facilitates the location and activation of leverage points for systemic policy interventions, which can help socio–ecological systems to learn to adapt to more sustainable habits. Affordance theory is presented to be applicable and pertinent to technically all nested levels of socio–ecological systems from the studies of sustainable objects and households to sustainable urban environments, making it an immensely versatile conceptual policy tool. Finally, affordance theory is also discussed from a participatory perspective. Increasing the fit between local thinking and external behavior possibilities entails a deep understanding of tacit and explicit attitudes, values, knowledge as well as physical and social environments, best gained via inclusive and polycentric policy approaches.

Full citation (Open Access):

Kaaronen, R. O. (2017). Affording Sustainability: Adopting a Theory of Affordances as a Guiding Heuristic for Environmental Policy. *Frontiers in Psychology*, 8, 1974. DOI: https://doi.org/10.3389/fpsyg.2017.01974

Article 3. Cultural Evolution of Sustainable Behaviours: Pro-environmental Tipping Points in an Agent-Based Model

Abstract

To reach sustainability transitions, we must learn to leverage social systems into tipping points, where societies exhibit positive feedback loops in the adoption of sustainable behavioural and cultural traits. However, much less is known about the most efficient ways to reach such transitions, or how self-reinforcing systemic transformations might be instigated through policy. We employ an agent-based model to study the emergence of social tipping points through various feedback loops which have been previously identified to constitute an ecological approach to human behaviour. Our model suggests that even a linear introduction of pro-environmental affordances (action-opportunities) to a social system can have non-linear positive effects on the emergence of collective pro-environmental behaviour patterns. We validate the model against data on the evolution of cycling and driving behaviours in Copenhagen. Our model gives further evidence and justification for policies that make pro-environmental behaviour psychologically salient, easy, and the path of least resistance.

Full citation (Open Access):

Kaaronen, R.O., and N. Strelkovskii. (2020). Cultural Evolution of Sustainable Behaviors: Pro-Environmental Tipping Points in an Agent-Based Model. *One Earth* 2(1), 85–97. DOI: https://doi.org/10.1016/j.oneear.2020.01.003.

Article 4. Mycological Rationality: Heuristics, Perception and Decision-Making in Mushroom Foraging

Abstract

How do mushroom foragers make safe and efficient decisions under high degrees of uncertainty, or deal with the genuine risks of misidentification and poisoning? This article is an inquiry into ecological rationality, heuristics, perception, and decision-making in mushroom foraging. By surveying 894 Finnish mushroom foragers with a total of 22,304 years of foraging experience, this article illustrates how socially learned rules of thumb and heuristics are used in mushroom foraging.

The results illustrate how traditional foraging cultures have evolved precautionary principles to deal with uncertainties and poisonous species, and how foragers leverage both simple heuristics and complex cognitive strategies in their search for, and identification of, mushrooms. Foragers also develop selective attention through experience. The results invite us to consider whether other human foraging cultures might use heuristics similarly, how and why such traditions have culturally evolved, and whether early hunter-gatherers might have used fast and frugal heuristics to deal with uncertainty.

Full citation (Open Access):

Kaaronen, R.O. (2020; In print). Mycological Rationality: Heuristics, Perception and Decision-Making in Mushroom Foraging. Available on PsyArXiv (to appear in the September 2020 issue of Judgment and Decision Making): https://doi.org/10.31234/osf.io/7g8er

1.3 Synopsis of the Argument

> 'There is only one world, however diverse, and all animals live in it, although we human animals have altered it to suit ourselves. We have done so wastefully, thoughtlessly, and, if we do not mend our ways, fatally.'
>
> James J. Gibson (1979, 130)

We are in midst of a crisis perhaps unmatched by any other in the history of humankind. The list of ecological catastrophes has been repeated so many times that it has all but become a 21st century banality: we're experiencing global heating of a scale unwitnessed before by humans, biodiversity has plummeted with disastrous consequences to ecological systems and networks, and planetary boundaries have been breached in numerous other domains (not all of which are known to us) (Steffen et al. 2015). This is all the consequence of human societies, and the fundamentally unsustainable development of human cultures.

We, as human collectives, have lost our ability to live within planetary boundaries. We have failed in *sustain-ability*. Yes, some, and particularly a select few industries (and nations), hold much higher responsibility for this calamity than others. Yes, there are culprits who have (at least, for now) benefited from this mess—much brilliant investigative work has gone to illustrate this (Taylor and Watts 2019). Yet the crisis is also a collective one, a cultural one. Human societies have lost or lacked in capacities to reinforce sustainable patterns of behaviour, to reinforce sustainable habits, norms and institutions. Many, if not most, human cultures have forgotten, or detached themselves, from our intuitions for dealing with uncertainty, and have also, for now at least, distanced themselves from direct environmental feedback. Cultural systems, not the least in the affluent parts of the world, have forgotten how to sustain. If we wish to offer future generations and non-human species an opportunity at life within reasonable ecological conditions, we must regain our capabilities to live in ways which respect the processes from which we ultimately emerge.

As the title of this thesis suggests, this work includes inquiries into the ecology of mind and behaviour. By the word ecological here, I wish to imply that I focus mainly on theoretical frameworks which interpret human cognition, behaviour and cultures as emergent properties of organism–environment and organism–organism systems. That is, to explain cognitive or behavioural processes, we must understand cognition and behaviour as products of the person (and its cognitive faculties) and the environment. As Kurt Lewin (1936) once wrote, behaviour is a function of the person and the environment. Only by understanding this process of emergence can we attempt to leverage it towards a sustainable direction.

That I chose 'ecological' theories of mind and behaviour to interpret ecological crises seems like a curious coincidence. However, I doubt this truly is coincidental. After all, if we understand human behaviour as emerging from both personal and environmental processes (and that focusing on only one half of this equation is insufficient to explain the whole), the conclusion is inevitably one where current forms of culture and behaviour cannot sustain if environmental processes continue to degrade. James J. Gibson, an influential ecological psychologist, whom I quoted in the epigraph of this section, seemed to have grasped this connection. Although not, to my best knowledge, a vocal advocate of ecological or sustainability concerns, Gibson too seems to have come to the inevitable conclusion that should we understand human societies and behaviours as emerging from organism–environment systems, little will remain if we continue to disregard the environmental half of the whole.

This thesis aims to interpret ongoing sustainability crises from a variety of ecological social scientific perspectives, all of which have not previously engaged in much discussion. Echoing the work of some of the forebearers of ecological approaches to cognition, such as William James (1977), the position I take is inherently pluralistic: there is not a single lens the sustainability crises should be envisaged through, and multiple theoretical frameworks will be more of a necessity than an option when attempting to understand the numerous ways in which humans think and behave unsustainably. Theories are tools to analyse relations between objects or subjects, and since such

relations are practically infinite, it is unlikely that one tool will fit all situations. Much like other cognitive mechanisms studied in this thesis (see Article 4 in particular), theories are tools for collectives of human organisms to adapt to their ecological niche, and the availability of multiple theories for selection may be necessary to guide our way through the uncertain environments we now face.

The main title of this thesis is Steps to a Sustainable Mind. It might have as well been Steps to Sustainable Behaviour, or Baby Steps to either of these. The current title was chosen mainly for cosmetic reasons. Commenting on the latter, a bit of epistemological humility is in place. To argue that a single thesis could provide humans with a collective roadmap towards sustainable behaviour would be nonsensical—in fact, owing to the diversity of human cultures, and the diversity of solutions that ensues, such a blueprint most likely does not exist. However, this thesis provides multiple perspectives on how sustainable modes of thought or behaviour might emerge, and in particular, how ways in which we think and behave are related. As the title suggests, a series of steps is suggested:

Step 1. Relocating ourselves in natural processes. We must re-examine the cognitive models by which we conceptualise our relation to natural processes. Although this began as mainly a philosophical endeavour, it eventually found its way into both practice and methodology. If we wish to think or behave in ways which respect ecological boundaries, we must fundamentally shift our understanding to respect the fact that we ourselves emerge from the processes we call by names such as 'ecology', 'environment' or 'climate'.

Step 2. Ecologies of design. Here, I apply insights from and methods influenced by *Step 1* to locating politically feasible leverage points—or, in Donella Meadows' (2008) famous definition, 'places in the system where a small change could lead to large shift' in the system's behaviour—to induce shifts in the ways in which individuals and societies behave. Thus, the target is to reach social tipping points, or *phase transitions*, rapid shifts from one mode of collective being to another.

Step 3. Dealing with uncertainty. Finally, we must learn to apply both traditional and tacit knowledge to gain insights on how to deal with uncertainty, and foster knowledge of sustainable practices through various processes of cultural evolution.

The research articles that constitute this thesis respond to some specific challenges in each of these steps. It is not my intention in this summary to merely rephrase the findings of these research articles. Instead, here, I seek to connect the dots. Some of the articles were not planned to discuss with each other, yet, retrospectively, interesting connections seem to exist. Article 1, *Reframing tacit human–nature relations* (Kaaronen 2018c), sets the ontological and epistemological ramifications for *Step 1*, and its central ideas reverberate—sometimes explicitly, sometimes tacitly—throughout the rest of the thesis. Article 2, *Affording sustainability* (Kaaronen 2017), sets out to tackle *Step 2*, and in doing so, provides the necessary theoretical background for the formal computational model presented in Article 3, *Cultural evolution of sustainable behaviors* (Kaaronen and Strelkovskii 2020). Article 4, *Mycological rationality* (Kaaronen 2020), applies insights from local and traditional knowledge to inform ways of dealing with uncertainty, and illustrates how cultural know-how is born from ecological interactions between organisms and their environments. These are all elaborated below in section 3.

However, before embarking on this task, a brief overview of the theoretical nomenclature and methodology is in place. The purpose of this is not to give a thorough introduction to each theoretical framework, which would be an exhaustive task (and which is done better by others elsewhere), but rather to give an overview of the ways of thinking which led to the four research articles at hand. Attempts are also made to weave these theoretical frameworks together, although as noted below, some conflicts in theoretical assumptions almost inevitably remain.

2 Ecological Approaches to Social Sciences

> 'In psychology one can begin to describe the whole situation [from which behaviour (B) emerges] by roughly distinguishing the person (P) and his environment (E). Every psychological event depends upon the state of the person and at the same time on the environment, although their relative importance is different in different cases. Thus we can state our formula [...] as B = f(P, E). [...] Every scientific psychology must take into account whole situations, i.e., the state of both person and environment. This implies that it is necessary to find methods of representing person and environment in common terms as parts of one situation.'
>
> Kurt Lewin (1936, 12)

This thesis builds upon several ecological theories of human behaviour and cognition. Therefore, to begin with, it is necessary to define what I mean with ecological theories in this context, and what precisely these theoretical frameworks consist of. Even though ecological theories of mind and behaviour have experienced something of a resurgence in recent years—for instance, in the development of dynamical systems approaches (Chemero 2011; M. J. Richardson and Chemero 2014) and so-called 4E (Embodied, Extended, Enactive and Embedded) approaches to cognitive science (Newen, De Bruin, and Gallagher 2018)—these are by no means new ideas.

Tracing back to the origins of psychological science itself, many of the ideas that constitute an ecological approach to behaviour can be found in the pragmatism and radical empiricism of William James (who, in turn, was greatly influenced by Darwin; see Heft 2001; R. D. Richardson 2007). That is, the central insights from pragmatism that meaning should be associated with both function and context, and that to understand the meaning of a thing or an environment we must understand how it *relates* to the observer, are by no means new (Dewey 1958; James 1975). Yet,

perhaps a consequence of the cognitive revolution and the computational metaphors that ensued, ecological theories of cognition have been somewhat hibernating.

An ecological approach to human behaviour should deal with what Kurt Lewin (1936) labelled *whole situations.* To understand how dynamical systems of human behaviour emerge from human–environment interactions, we must account for parameters on both sides of the skin (Chemero 2011): personal factors and environmental structures. In Lewin's now famous equation, behaviour (B) is defined as an emergent function (f) of the person (P) and its environment (E), or

$$B = f(P, E).$$

In Article 3, I go to considerable lengths on elaborating on this equation, complementing it with numerous feedback loops, but this much suffices for now. In James' (1912) words, if we wish to explain the human mind and behaviour, we must learn to be 'subjective and objective both at once.' We must account for the (universal) environmental structures that afford a given behaviour, and the faculties and intentions of the observer that actively guide the subject to interact with its environment selectively and in specific ways.

An ecological approach to studying human behaviour thus assumes at least the seven following propositions:

1. Humans are active organisms that develop varying interests, intentionalities and skills, which dispose them to engage with the world with selective attention. All perception is active and a result of movement and interaction in and with the world.
2. All behaviour and cognition is contextual and should be studied in appropriate context. Behaviours, cognitions, meanings et cetera arise from *relations* between the observer and that observed, and context can therefore not be disregarded.
3. The environment is not passive. The environment itself is in constant flux, and reflects various meanings which we can interpret and interact with. We also actively shape the environments we behave in.

4. Human rationality should be understood in ecological context. Rationality itself—if we choose to understand it in terms of functional success in the world—is a product of both the organism and its environment.
5. The focus on studying behaviour should be on *processes*. If we wish to understand behaviour—and even more so if we wish to affect it by means of interventions—the relevant targets of study are the complex dynamical processes by which behaviours emerge, which include not only intentional, but also environmental and social processes.
6. No behaviour is free from causal mechanisms that extend far to (and beyond) the social and material world they are embedded in. All definitions of systems boundaries should be understood as pragmatic choices, although some make more sense than others.
7. The study of human behaviour should be systemic and focus on nested levels and feedback loops. Collective sets of human behaviours create environments and institutions that, in turn, define the state space of possible human behaviours within that system. In Bateson's (2000) terms, 'the river molds the banks and the banks guide the river'.

In the following sections I discuss briefly the main theoretical frameworks and methods used in the research articles that form this thesis.

2.1 Ecological Psychology and Affordance Theory

Ecological psychology (not to be confused with either *environmental psychology* or *ecopsychology*) is a psychological scientific study of perception-action. Broadly speaking, ecological psychologists—originating mainly with the work of James J. Gibson (1979; 1966)—assert that perception and action should always be studied in tandem. There is no such thing as a passive human observer, and the baseline for studying human behaviour should assume humans to be active agents exploring the material world that they inhabit. Moreover, ecological psychology posits—explaining its curious name, and partly following from William James' radical empiricism

(Heft 2001)—that the world is not meaningless for the active perceiver. Instead, by moving about in the environment, an organism is capable of harvesting and interpreting *ecological information*, the sets of structures and regularities in our environments, such as patterns of light or sound reflected by the physical environment, that allow us to engage and interact with our environments. In other words, the ecological niche we inhabit is permeated with potentialities for interpretation and meaning. By actively moving about in this environment, and interpreting the statistical regularities and information within it, organisms need not create meaning 'inside their heads', but are able to actively encounter the world and experience it directly (Reed 1996). Meanings thus arise from organism–environment relations.

Much debate has gone into discussing how far this direct perception can be taken (Chemero 2011). That is, how much of human cognition can be explained merely through studying our active interaction with the information afforded by the physical environment without resorting to explanations relying on cognitive processing or mental representations? Although this is an interesting and lively (and, at times, heated) debate, I shall not engage in this debate in detail within the scope of the summary of this thesis, since, for one, detailed accounts exist elsewhere (e.g., Chemero 2011; Golonka and Wilson 2019), and second, this discussion is not necessarily directly pertinent to the research questions at hand.

For present purposes, however, I assume a position that is, at the least, heavily influenced by ecological psychology. If we wish to explain the emergence of human behaviour, we must take into central account the structure of the material (and social) environment and the ecological information within our ecological niche. For this purpose, a specific aspect of ecological psychology, *affordance theory*, deserves further focus. Acknowledging that varying definitions of

affordances exist (and that the definition of affordances is itself subject to vehement debate[1]), affordances are here defined as relations between abilities to perceive and act and features of the environment (Chemero 2003; 2011). More specifically, in a forthcoming article (Satchell, Kaaronen, and Latzman 2020), we define an affordance as a bundle of ecological information sufficiently rich enough to offer behaviours for a perceiver. Affordances are thus the functional meanings of environments for an organism and are specified by the ecological information available in an ecological niche. In its association of meaning with function, affordance theory bears considerable resemblance to the philosophical tradition of pragmatism: the meaning of an environment or object is the function that it affords.

Thus, our environments consist of not merely passive objects to be acted upon, but instead objects and environments actively specify action-opportunities for the observer. The environment is imbued with meaning available for the observer. When humans, a bipedal and mobile species, perceive a chair, for instance, we do not merely observe a passive object, but an opportunity for sitting (Heft 2001). The chair *affords* sitting. Thus, affordance theory is an attempt at overcoming the subject–object dichotomy in psychology by studying the *relations* between the perceiver and that perceived. Note that this does imply that perceivers have (socially and individually learned) skills and bodily capabilities: a bicycle will only afford cycling successfully for those who are able to cycle. Importantly, the concept of the affordance invites focus on the whole dynamical situation from which behaviour emerges, the reciprocity between organism and environment.

Affordances were originally conceived in the field of ecological psychology, where Gibson (1979) and others used the concept to emphasize the functional significance of perception and perceived ecological information. 'The affordances of the environment', writes Gibson (1979, p. 127) in a

[1] John Dewey (1958, 47) writes, I believe correctly, that philosophical feuds tend to be 'family quarrels', and that the most heated debates are often between those who *almost, but not quite,* agree with each other. Dewey continues: these feuds 'go on within the limits of a too domestic circle' and are best settled 'by venturing out of doors'. Even though I risk omitting some important debates, I choose not to engage here in these terminological debates in order to move 'out of doors' with my core argument.

famous passage, 'are what it offers the animal, what it provides or furnishes, either for good or ill.' The concept of the 'affordance' derives from earlier work in Gestalt, phenomenological and behaviour field psychology, with the neologism explicitly borrowed from Kurt Lewin's '*Aufforderungscharakter*' or 'valence' (Käufer and Chemero 2015, 88–89). Therefore, the similarities between affordances and Lewin's (1936) 'whole situations' are also non-coincidental.

Whilst Gibson (1979) did not exclude 'social affordances' from his original treatment, they received merely a very brief mention and only recently have the notions of social or cultural affordances—the affordances provided by social interactions and culturally designed environments—reached broader popularity (Costall 1995; Ramstead, Veissière, and Kirmayer 2016). More recently, affordance theory has also found interest in broader studies of human–environment relations, including (among other things) design (Norman 2013), architecture (Rietveld and Brouwers 2017), embodied cognitive science (Chemero 2003), child behaviour (Kyttä 2004, Heft, 1988), urban design (Marcus, Giusti, and Barthel 2016) as well as cognitive anthropology (Ramstead, Veissière, and Kirmayer 2016). My research, in turn, has emphasized the role of the intentional design of affordances as a 'leverage point' for sustainable system transitions (Kaaronen 2017; Kaaronen and Strelkovskii 2020; 2019).

Common to these approaches is the underlying assumption that it is insufficient to restrict a study of human behaviour, on the one hand, to environmental *form* (Heft and Kyttä 2006), and on the other, to mental or cognitive representations (Chemero 2011). Instead, behaviour is understood to emerge from a non-decomposable dynamic brain-body-world system (i.e., one which also evolves over time). Environmental form is thereby understood as a part of this ecological behaviour system which solicits, invites or *affords* certain behaviour for an individual organism embedded in the enculturated 'form of life' of a human society (Rietveld and Kiverstein 2014).

Interpreting our everyday environments from this ecological perspective, we are better equipped to study critically the 'psychology of everyday things' (Norman 2013)—the meanings and functions afforded to us, often unconsciously, by our everyday material environments. Moreover,

these meanings and functions are not isolate entities, but are together embedded in the societies and institutions that so thoroughly shape our behaviour. In Rietveld and Kiverstein's (2014) terms, we inhabit a 'rich landscape of affordances', where a landscape of affordances refers to the totality of action opportunities in our environment. As skilled and active perceivers, our material and cultural environments afford for us a rich variety of potential behaviours, and if we wish to understand why we behave in ways which we do, these opportunities for behaviour, these affordances, deserve critical inspection. This latter notion, in particular, is a focal point of this thesis.

2.2 Cultural Evolution: Niche Construction and Social Learning

Affordance theory is a very promising basis for studying the emergence of (sustainable) behaviours, but somewhat notoriously has lacked in at least two respects. Firstly, although attempts at defining 'social' or 'cultural' affordances have been numerous and, at times, promising (Ramstead, Veissière, and Kirmayer 2016; Costall 1995), affordance theory and ecological psychology have traditionally lacked in accounting for the social dimension of humans. Yet in explaining behaviour we must also explain the processes through which humans learn their skills for perception and action, forming traditions, norms and institutions through processes of cultural transmission and social learning. Second, although ecological psychologists have documented in detail how physical environments afford behaviours to humans—which, famously, include studies on how we perform everyday activities such as stair climbing (Warren 1984)—they have paid less attention on the processes by which humans culturally *construct* the environments which afford behaviours (although, again, notable exceptions do exist, such as in Reed's (1996) work, which documents how humans create clusters of affordances, forming 'fields of promoted action' in the process). I envisage an ecological theory of social science and psychology where these frameworks

could be in fruitful discussion which each other, and have already embarked upon doing so particularly in Article 3, although much work remains to be done.

The scientific field of cultural evolution, broadly, deals with applying Darwinian evolutionary theory to the sociocultural domain. It is therefore an evolutionary theory of social change, and primarily seeks to explain how cultural traits spread in societies vertically (from one or both parents), obliquely (from unrelated elders), and horizontally (within generations) (Mesoudi 2011). Culture, in this context, can be defined as 'information that is acquired from other individuals via social transmission mechanisms' (Mesoudi 2011, 2–3). Ecological information, which we encountered in the previous section, would also often fall under this category, at least in cases when it is reflected by cultural infrastructures or artefacts; affordances of this kind are sometimes referred to as 'cultural affordances' (Ramstead, Veissière, and Kirmayer 2016). The reader is referred to general works on the topic such as Mesoudi (2011) or Laland (2018) for more comprehensive discussion on cultural evolution. For present purposes, I shall discuss merely two presently important drivers of cultural evolution: social learning and (cultural) niche construction.

A feature which sets humans perhaps most apart from other species is our capacity for social learning and cultural development (Laland 2018; Henrich 2015). Therefore, any ecological attempt at explaining human behaviour must also account for the social organism–organism and organism–environment interactions which so thoroughly define our collective emergent behaviour patterns. Social learning refers to processes where learning patterns are 'facilitated by observation of, or interaction with, another individual or its products' (Hoppitt and Laland 2013). The notion that 'products' of human behaviour are included in this definition is important: we do not only learn from each other, but learning (and any consequent behaviour) is also facilitated by engaging with environments and artefacts which other humans have designed.

Although claiming this much would come naturally to most social scientists, the precise definition of the processes and patterns of social learning and cultural transmission are nontrivial endeavours which form much of the basis for studies on cultural evolution (Laland 2018; Hoppitt and Laland

2013). Indeed, much of the variation in behavioural patterns between societies can be explained by processes of cultural transmission (Mesoudi 2011, 15), and a grasp on how social and cultural networks operate is crucial in understanding how societies behave. For the context of the present purposes, it suffices to say that any study of *whole situations* of human behaviour, or any study which seeks to explain how human behaviours emerge ecologically from organism–organism and organism–environment interactions, must first explain how a behavioural trait is influenced by social and cultural circumstances. This is returned to in much detail particularly in Article 3.

As suggested above, humans (and, indeed, other animals) do not only encounter affordances in their ecological niche, but actively construct and *design* the affordances within their niche, thus imposing directional non-random pressures on the selection of any future behaviours. The process by which this occurs is called *cultural niche construction* (Laland 2018), another concept which deserves more specific focus.

Whilst Charles Darwin is most popularly appreciated as the father of the theory of evolution by natural selection, he also had an affinity for studying niche construction, even though he was not wholly able at the time to explicate this conceptually. In his experimental studies on earthworms (Darwin 1892), some of his final work, Darwin noticed that earthworms, 'through their burrowing activities […] change both the structure and chemistry of soils,' which results the alteration of selection pressures within their niche (Odling-Smee, Laland, and Feldman 1996). Although these ideas gained initial popularity, they seemed to escape later mainstream attention, and have only been revived *en masse* since the late 20th century, when several thinkers have made the case for accepting niche construction as a bona fide evolutionary force (Constant Axel et al. 2018; Odling-Smee, Laland, and Feldman 2003; Laland 2018). Hereby niche construction is taken to refer explicitly to the process involving the modification of selective environments by organisms. In other words, according to niche construction theory, organisms are not only objects of natural selection but also active designers of the conditions for natural selection. As a consequent, adaptive fitness is no longer understood as organisms merely adapting to their environment, but rather as

a 'two-way process' involving organisms both responding to challenges presented by their environments, as well as creating new opportunities and challenges by altering their environments through niche construction (Laland and O'Brien 2011, 193).

It is perhaps not surprising that ever since niche construction gained mainstream attention, it has been widely studied in various species, particularly those which are most active at modulating their ecological niches, such as ants, wasps, spiders and beavers (Laland and O'Brien 2011). Contrasting with the conventional perspective of natural selection, which takes an asymmetrical approach to organismic adaptation (organisms adapt to the environment), niche construction theory puts symmetrical emphasis on the capacity of organisms to modify environmental states and thus selective pressures (Laland and O'Brien 2011). *Cultural niche construction*, which pertains particularly to cultural and behavioural selection, is a particularly relevant concept here. Broadly speaking, cultural niche construction refers to the process where an organism modifies environmental states in non-random ways (i.e., culturally) and thus imposes systematic biases on the behavioural and cultural selection pressures generated by the environment (Laland 2018). Notably, this effect is also transgenerational. The design of cultural niches defines not only the selective pressures of current generations, but also alters the 'ecological inheritance' of subsequent generations (and thus the ecological information they encounter).

In this regard, it is perhaps even less surprising that the niche constructive behaviour of the ultimate 'ecosystem engineer,' *homo sapiens*, has sparked inquiries in archaeology, biological anthropology and psychology. Humans, after all, live in 'designer niches,' where we construct our ecological niche—our homes[2] and everyday (urban) environments—to afford the perceptions and experiences we cognitively expect and socially strive for (Clark 2015).

[2] In fact, this idea of niche construction as retrofitting our home has a quite literal connection to the etymology of the word 'niche' itself. Deriving from the Latin nīdus ('nest'), niche construction indeed is the process of reconstructing our nest or home.

In the social sciences, this idea of self-induced feedback can be traced at least to the cyberneticians, who, fronted by the likes of Norbert Wiener and Gregory Bateson, emphasized the ecological dimensions of human existence. Here, cultural development was best described by an analogy: 'the river molds the banks and the banks guide the river' (Bateson 2000, 83). I argue in this thesis, and particularly in Articles 2 and 3, that these biases are transmitted in particular through the conscious and unconscious design of affordances—note that similar arguments have previously been made by Reed (1996) in particular.

In an essay for the independent philosophical journal *The Side View,* I call this process the 'Ecology of Design' (Kaaronen 2019c). By designing and redesigning our everyday environments, we have the potential to tap into curious feedback loops, where 'design breeds affordances, affordances breed behaviours, behaviours breed ideas, and ideas breed design.' As discussed later, in Article 3 I go on to formally define this process and the emergent phenomena that ensue with an agent-based model.

2.3 Ecological Rationality

When analysed from an ecological perspective, that is, as a function of a person and their environment, even our definition of rationality can (and arguably, should) be redefined. In the following section, I discuss in brief the notion of ecological rationality. More comprehensive introductory accounts can be found in, e.g., Todd and Gigerenzer (2012) and Marewski et al. (2010).

Ecological rationality stems from polymath Herbert A. Simon's work, who from the 1950s emphasised that the capacity of human decision-making is necessarily bounded by uncertainty, cognitive limitations and the time and resources available at the moment of decision-making (Simon 1957; Callebaut 2007). Decision-making, and thus rationality, is necessarily *bounded*, and

consequently, humans are *satisficers* who, for reasons of efficiency—and surprisingly, sometimes also accuracy—use varieties of cognitive shortcuts to make decisions.

Ecological rationality builds upon Simon's work, and, much like ecological psychology (although the field of ecological psychology rarely deals explicitly with decision-making processes), has an ambition of putting the human subject back into their ecological context. In ecological context, proponents of ecological rationality argue, rational decision-making and behaviour should be understood in terms of cognitive success in the world: the fitness between the mind and the environment (Kozyreva and Hertwig 2019; Gigerenzer and Todd 1999; Todd and Brighton 2016).

However, the study of ecological rationality goes far beyond this descriptive statement, and seeks to explain the processes through which, by leveraging ecologically valid cues in the environment (i.e., reliable statistical regularities), decision-makers are able to circumvent complex optimisation processes and, instead, use simple and efficient 'fast and frugal' heuristics when making decisions. Sometimes, as is discussed in more detail in Article 4, these simple decision-making rules can even systematically outperform more complex cognitive (or statistical) processes. Thus, ecological rationality seeks 'to explicate the mind–world interactions underlying good decision making' (Todd and Gigerenzer 2007, 167).

Heuristics are adaptive cognitive tools, and are particularly sensitive to context. Therefore, it comes as little surprise that local processes of cultural evolution (and cultural selection) can lead to the development of particularly robust heuristics. However, this connection between cultural evolution and heuristics is a less charted one. In Article 4, I contribute to this topic by describing how a traditional foraging society, Finnish mushroom foragers, uses culturally evolved heuristics to adapt to their local uncertain environment. Foragers, Article 4 argues, use socially learned rules of thumb to make robust and safe decisions at the face of uncertainty, and need not bother much with utility calculations (or other optimisation processes) when making efficient decisions. An efficient heuristic is not a general-purpose algorithm, but rather a contextual one, and as illustrated

in Article 4, heuristics can be a product of long-term local cultural evolution and traditional knowledge.

Much unlike our risk- and probability-obsessed world, ecological rationality deals primarily with *uncertainty* and uncertain complex systems. Unlike the hypothetical creature *homo economicus*, the real-world human (or homo heuristicus, as per Gigerenzer and Brighton 2009) does not live in a world where decisions can be fully optimised or where probabilities and utility functions can be optimally calculated. As Simon (1957) has noted, three modes of uncertainty in particular impose limits on optimisation. Firstly, due to temporal constraints and limited individual histories, humans can only account for select alternatives when making a decision—it is rarely the case that all options are known to the perceiver. Second, the state space of possible events is unknown. Simply, as is illustrated with the case of mushroom foraging in Article 4, knowledge about the consequences that would follow from each alternative choice are not directly available to the human. These consequences might include unanticipated ones, which in the case of mushroom foraging, include extreme events such as death, which further complicates calculations of costs or benefits. Third, real world environments are unforgivably complex, and even with high degrees of knowledge, the optimal solution may be practically intractable (Kozyreva and Hertwig 2019).

Thus, it follows that 'the laws of logic and probability are neither necessary nor sufficient for rational behavior in the real world' (Gigerenzer 2008). Or, as Egon Brunswik (1955, 1) eloquently writes, 'the crucial point is that while God may not gamble, animals and humans do, and that they cannot help but to gamble in an ecology that is of essence only partly accessible to their foresight'. Uncertainty is therefore an unavoidable feature of a real-world organism–environment system, and thus any real-world—or *ecological*—rationality must find robust methods to deal with this uncertainty.

Such methods, proponents of ecological rationality argue, include heuristics: simple strategies that ignore information as much as they make use of it (Marweski et al., 2010). This 'selective industry

of the mind' (James 1890)—or selective attention—has a long history in the study of psychology. In the context of heuristics, selective ignorance can protect us from overfitting our cognitive models, that is, avoid tuning our decision-making models so precisely to past data that our adaptability to an uncertain future is endangered. Sometimes, simplicity might be key to robustness and resilience, and it might be better to be systematically biased than attempting to be optimal. This theme is discussed in detail in Article 4.

Echoing other mutualistic ecological theories of mind and behaviour, such as ecological psychology, Herbert Simon (1990, 7) used his famous scissor analogy: 'Human rational behaviour is shaped by a scissors whose blades are the structure of task environments and the computational capabilities of the actor.' That said, there are clear theoretical tensions here between the anti-computationalism of ecological psychologists and the computational metaphors preferred by proponents of ecological rationality who, e.g., speak of 'algorithms' used for decision-making. Attempts at reconciling these two theoretical frameworks do exist, but are unfortunately uncommon; e.g., Carvalho and Rolla (2019) suggest that perceptual learning and skilled engagement with affordances themselves (as studied by ecological psychologists) are processes for minimising uncertainty, an idea which resonates strongly with research in ecological rationality. At the least, notwithstanding the debate on computationalism, both theories explicitly study successful action in the world as a product of organism–environment mutualism.

The study in Article 4 can be interpreted as a preliminary attempt at reconciling these two theoretical frameworks, with its focus on skilled, selective and active perception (as so often studied by ecological psychologists) and 'fast and frugal' cognitive decision-making processes (as studied traditionally by ecological rationalists). However, the two approaches may be reconciled also by adopting less extreme positions on either end. For instance, the empirical data in Article 4 suggest that heuristic decision-making might rarely be as 'algorithmic' as some ecological rationalists suggest: decision-making processes in messy real-world contexts such as mushroom foraging seem to less commonly resemble clear-cut 'algorithmic' processes, and foragers rather actively inspect

multiple sensory cues (ecological information) and use of various forms of expertise, (culturally evolved) traditional knowledge, simple heuristics and intuitions to guide their practice. Reality is often messier than theoretical frameworks, and, once again, a plurality of lenses to view socio-ecological phenomena might be more of a richness than a hindrance.

2.4 Modelling Ecologies of Behaviour

Above, I have advanced the idea that ecological social sciences should deal with the mutualistic relations between organisms and their environments, and that this mutualism should be a starting point in our studies on human behaviour, culture, cognition, and decision-making. Thus, it is quite appropriate to point out methodologies that are explicitly mutualistic, and which focus specifically on modelling complex engagements between agents and their environments. I am speaking, of course, of *agent-based modelling*, the methodological approach taken in Article 3.

Agent-based models, a class of computational models, are used to model agent–agent and agent–environment interactions, usually with a particular focus on the evolution of such systems over time (Railsback and Grimm 2019; Wilensky and Rand 2015). Agent-based models are particularly useful for modelling dynamical systems which include heterogeneous populations and emergent collective behaviour patterns arising from relatively simple interactions (Grimm et al. 2005). Agent-based modelling has become a standard method for studying complex, dynamical and adaptive systems, with a specific focus on studying the evolution of such systems *as a whole*. Whilst many if not most statistical methodologies aim to *reduce* systems to study them (by, e.g., controlling and isolating variables), the aim of agent-based modelling is to understand systems by *growing* them. This is often done by the pattern-oriented approach, modelling patterns at various hierarchical levels, ranging from cognitive, individual to social and ecological dimensions (Grimm et al. 2005). The consequent form of research, generative explanation, is summarised by the

following quote accredited to Joshua M. Epstein: 'if you haven't grown it, you haven't explained it'—although I am perhaps less adamant about this, as I discuss below.

At the time when Kurt Lewin (1936) defined his famous equation for studying 'whole situations', B = f(P,E) (recall section 2), it is unlikely that he had even an inkling that a methodology so well-suited for studying his idea would emerge in the future. Whilst Lewin dwelled on the lack of methods suitable for studying 'whole situations', we are now arguably equipped with much better facilities for studying the functions between persons and environments. As user-friendly and accessible software for agent-based modelling, such as NetLogo (Wilensky 2010), have emerged, so has the interest grown in studying complex and emergent patterns of socio-environmental interactions by means of computational modelling.

This should not, of course, come without critical introspection. Firstly, formal definitions of real-world processes—and, to be clear, formal definitions and logical operators are precisely what agent-based models 'eat'—are often either too 'poorly defined or nebulous' (Wilensky and Rand 2015) to be modelled formally, or simply too complex to be defined by algorithms to begin with (Kauffman 2019). It is often distasteful to formally define complex social patterns by simple lines of code, but, again, I wish to emphasise a pragmatic notion here. Studying and gaining data of complex social phenomena in the real-world is a tricky business. Firstly, the numerous feedback loops which define, for instance, the assumptions of Article 3, would be nigh impossible to study with any traditional empirical methodology. Data are, simply, too noisy and complex to interpret, and more than often we lack sufficient means to guard our system of interest from external influences (and indeed, studying the effects of these external influences might itself be interesting—and is possible with agent-based models!). Moreover, studying a complex system in the real-world almost necessary means studying its component parts separately. Yet what makes complex systems so interesting are their emergent properties when their components interact.

Second, when we study real-world complex processes, we only have access to one *unique event* in world history. As Karl Popper noted in *The Poverty of Historicism* (Popper 1957), unique events

are not sufficient to make reliable inductive inferences or predictions. Agent-based modelling, on the other hand, gives us the opportunity to play a divine creator and simulate a practical infinitude of alternative scenarios, generating rich amounts of data that would otherwise be impossible to collect (Epstein 2008). At the least, this spares us much of the burden of dealing with small datasets and often unreliable statistical methodology. Another caveat on prediction is in place here: agent-based models deal primarily with complex systems, and as we know from decades of studies with complex systems and social systems in particular, these systems are particularly sensitive to initial conditions[3] and unforeseeable (cultural) evolutionary mechanisms, and are thus inherently unpredictable in the long run (Kauffman 2019; Mitchell 2009). For this reason, I typically assume scenarios represent some possible states of the studied system, but I dare not claim they afford us with predictions.

Finally, relying merely on verbal models, such as those provided in Articles 1 and 2, is insufficient if we really want to put our theory to test. This is where the joy of building comes in. How can we be sure that we haven't omitted any crucial functions or phenomena unless we can see familiar and concrete results emerging from our assumptions? How do we know we have defined a system's crucial components if we have not built it ourselves? How do we know what parameters or initial conditions the model described verbally is particularly sensitive to? Personally, I learned this the hard way. When formalising the processes defined verbally in Article 2, for instance, I noticed numerous factors I had formerly disregarded: one such case is the role of the structure of social networks in the social transmission of sustainable behaviours. However, more on this later (and particularly in the lengthy Supplementary information of Article 3).

I therefore tend to give slack to the incompleteness of formal models; incomplete and sometimes stupid, yes, but certainly not impractical. As Smaldino (2017) writes, 'models are stupid, and we

[3] Sensitivity to initial conditions, a feature of chaotic systems, simply means that an arbitrarily small change in the initial parameters of a phenomenon can lead to fundamentally different future behavior. This, particularly, renders complex and chaotic systems—to which basically all social systems belong—unpredictable.

need more of them'. I personally value agent-based models as extremely useful tools to think with, and view the process of modelling itself as a philosophical conversation with code and model output. In fact, I have come to regard agent-based models as thought experiments on steroids. Thinking out how social or socio-ecological processes might evolve is all fine, but putting these ideas to the test isn't possible without formally defining their assumptions. I noticed that agent-based modelling is not only hard manual work (with all the coding, protocols, sensitivity testing and whatnot), but also an intellectual and theoretical challenge: never before have I had to lay out my theoretical assumptions so thoroughly in public.

Figure 2. Much like photography: a pattern-oriented approach to modelling focuses on describing and discovering patterns on a variety of scales, alternating focus between the macro and the micro. What looks like disorder on one level (above) may give rise to order on another (below).

3 Steps to a Sustainable Mind

> 'It is often neglected that the words animal and environment make an inseparable pair. Each term implies the other. No animal could exist without an environment surrounding it. Equally although not so obvious, an environment implies an animal (or at least an organism) to be surrounded.'
>
> James J. Gibson (1979, 4)

Bruno Latour, in his work *We Have Never Been Modern* (Latour 2012), contemplates on a conundrum we often face when discussing human–nature relations: if nature is to be understood as constructed by humans, it appears as artificial—plastic, lawless, fabricated, or counterfeit. Yet if it is not, nature appears as remote, foreign and hostile. But what if this distinction itself is a false one? What if, as Latour puts it, 'we have never been modern', or never truly lived in an ecosystem where humans should be analytically separated from their natural environment? It is this last conviction the theoretical framework of this dissertation builds upon; a framework where ecological niches are both constructed by humans, and where human activities, collective and individual, emerge from ecological processes. As Gibson writes above, no organism can exist without its environment—but environments are also defined and shaped by organisms, and indeed the word 'environment' itself suggests some perceiver, centre for observation, to be environed. This dynamical and mutualistic framework is what I will elaborate below in the form of *ecological constructionism*, the study of how behaviours and cultures are ecologically constructed, as emergent products of organism–environment relations.

I will begin this task in section 3.1 by uncovering the ontological premises of ecological constructionism in the form of a process-relational metaphysics. Here I summarise the key ideas presented in Article 1 and draw connections to my other research where appropriate. In section 3.2 I extend the theoretical framework to ecological psychology and niche construction theory, discussing in more detail how this applies to the emergence of collective sustainable behaviour

patterns, drawing particularly from the work in Articles 2 and 3. In section 3.3, in turn, I elaborate on relational theories on decision-making, with a particular focus on survival under uncertainty and Article 4.

3.1 Step 1: Relocating Ourselves in Natural Processes

> 'Nature considered *rationally*—that is to say, submitted to the process of thought—is a unity in diversity of phenomena; a harmony, blending together all created things, however dissimilar in form and attributes; one great whole animated by the breath of life. The most important result of a rational inquiry into nature is therefore to establish the unity and harmony of this stupendous mass of force and matter, […] and to analyse the individual parts of natural phenomena without succumbing beneath the weight of the whole.' Alexander von Humboldt (1856)

We begin with a metaphysical move—one which is spelled out in detail particularly in Article 1, but which ultimately resonates throughout all articles within this dissertation. This is the assumption of a process-relational, or process philosophical, stance to studying human–nature relations and socio-ecological systems (Rescher 1996; 2000; Whitehead 1957; Mesle 2008). The crux of the argument is this: as long as we categorise, conceptualise or demarcate human systems separately from the natural processes that afford their becoming, we are more or less bound to make decisions and actions which undermine the process of adaptive human emergence from and within natural systems.

As an 'environmental social scientist' (a concept I quite dislike, owing to reasons already discussed above) and as a person who is somewhat vocal in discussing ecological concerns in the public domain, it is quite often that I hear remarks such as that I am 'concerned about the environment',

as if this was just one political cause of many to identify with or be worried about. But the position advanced in this thesis, I hope, should clear the air: it is not the 'environment' I am concerned about per se, but the current interplay between complex social, ecological and climatic systems, which will without a doubt lead to wildly unexpected consequences if the deeply disturbing status quo is maintained. And it is not the 'environment', as some external entity, that should be our concern, but the potential collapse of the life support systems that enable the existence of human cultures and non-human life forms to begin with. We desperately need alternative ways to conceptualise our relation to and emergence from natural systems, and Article 1 is an attempt at outlining one potential approach. I acknowledge that I am not the first to suggest such a position. For instance, recently, Jeremy Lent (2017) has developed a convincing argument that the root metaphors that cultures use to construct meaning in their world have longstanding effects on how cultures deal with their natural (and social or political) environments. However, paraphrasing an old adage, repetition—in different forms and contexts—is key to cultural learning.

The core argument is this: to develop collectively sustainable states of mind, we must take a relational stance. This relational stance, or process philosophical position, is defined in detail in Article 1, but is also at the least tacitly present in the relational theories used in Articles 2, 3 and 4 (affordance theory, ecological psychology and ecological rationality), and thoroughly influences the methodological approach in Article 3—agent-based modelling, after all, deals particularly with modelling complex emergent processes arising from agent-environment relations.

Descriptions of process philosophy, primarily a metaphysical approach with particular similarities to (and influences from) the American tradition of pragmatism (Dewey 1958; James 1975), often begin by quoting pre-Socratic philosopher Heraclitus' famous teaching that 'everything changes' or 'everything flows' (*panta rhei*). Whilst many strains of process philosophy exist—some insist on near-literal interpretations of the sometimes esoteric work of Alfred North Whitehead, whilst others, such as Nicholas Rescher (2000; 1996), adopt a more pragmatist approach—the commonality between process philosophical theories is the focus on the ontological or

epistemological primacy of *process* over *substance*. My personal taste for process philosophy is mainly influenced by Rescher (1996; 2000), whose pragmatist approach I also find the most practical from the various process philosophies. Here, *things* are what they *do*, and cannot, and arguably should not, be defined otherwise. In this approach, processes, captured by words such as flux, dynamics, change, action, movement, temporality and other 'items better indicated by verbs than by nouns', are taken to be the primary units of interest in both philosophical and scientific inquiry (Rescher 2000, 4).

This involves primarily the study of how 'things' *become*, how they are connected, and how they emerge from (and relative to) larger macroprosesses or smaller microprosesses. At times, this might involve the blurring of the traditionally accepted boundaries of things—as is illustrated in Article 1 with the case of the coastline paradox—and at others, it involves pragmatic choice and agency in defining systems boundaries for some particular practical purpose. Processes, by their fundamental nature, are causally incomplete (Rockwell 2016): unlike traditional 'objects' or 'things', they, or rather their emergence from interconnected systems, can be traced in back in time and out in space, to the point where this can become rather cumbersome. As Humboldt, an early advocate of wholistic science, observed (see quote above), the whole can quickly become too heavy to study rigorously. Therefore, assuming a process-relational philosophy also implies embracing what Amartya Sen (1992) has called 'pragmatic incompleteness': learning to define systems boundaries in ways which are particularly useful for some specific function.

Affordance theory presents us with one such pragmatic boundary. In focusing the target of our study from human 'individuals' or 'societies' to studying the relations between abilities to perceive and act and features of the environment (Chemero 2011), behavioural scientists—and as I argue in Article 2, even policy-makers and designers—are provided with a more wholistic (recall Lewin's *whole situations*) approach to studying how behaviours actively emerge in the process of human–environment interaction. In this framework, the focus is specifically on flux, movement, change and activity: human behaviour is assumed to arise from actively moving about in the world,

altering the perceptual environment we behave in, and the unit of interest is the organism–environment relation, the affordance.

That ecological psychology and affordance theory (Gibson 1979; Gibson 1966) go so well hand-in-hand with process-relational metaphysics and epistemologies is no coincidence. As Harry Heft (2001) has masterfully illustrated, the history of ecological psychology can be traced in particular to William James' work, who in turn is often described as a process philosopher (and, of course, pragmatist) and who had a particularly direct influence on the most famous of process philosophers, Alfred North Whitehead (preface in Whitehead 1957; Rescher 1996; 2000).

Although discussion on process philosophy is most often found in speculative metaphysics, somewhat detached from real-world concerns or applications (although welcome exceptions do exist[4]), the process-relational dimension of this thesis is put to practice. For instance, in Article 4, the focus of inquiry is on the processes of how human foragers actively move about and make decisions in uncertain real-world environments, and particularly, how they make *relational* decisions by utilising various environmental cues. In Article 3, the focus is on modelling the multiple processes (five major feedback loops, to be precise) that arguably precede the collective adoption of sustainable behaviour patterns. These are all relational approaches, with a specific focus on studying the *processes* through which human behaviour, and particularly sustainable behaviour patterns, emerge from organism–environment interactions.

3.2 Step 2: Ecologies of Design

Any theory of human behaviour or cognition will come unfortunately short if it cannot account for how humans behave in and design their most common niche today—the City. Today, over half of the world's population live in urban areas or cities, with this number expected to rise to two

[4] See, e.g., the work of Arran Gare (1996).

thirds by 2050. If we truly wish to change human behaviour to become more sustainable, regenerational instead of degenerational, we must understand how humans interact with the city and how they design the functions it affords.

Now, begin with imagining a typical walk in an urban environment—perhaps your home city, or a global metropolis. What does the city invite you to do? What kinds of behaviours does it primarily solicit? What are the functional meanings of its form? What kind of information do you encounter, and what are the action opportunities it specifies? These are all questions pertaining to the perceptual ecology of the city, or the study of how we encounter the urban niches we construct.

Evidently, the answers to the above questions mostly include activities revolving around consumption or transport. Thus, the prime activity a 21st century city solicits, it seems, is consumption of some sort. As cities grow denser and denser, these urban consumption arenas grow in density and in height, until little of the cities historical or organic form remains. Instead, what we encounter is a mechanistic Global Mall tuned for ecological destruction, a fundamentally unsustainable playground for encountering and consuming, next to life's necessities, things we don't need, things which harm us and destroy the ecological systems which, for now, keep the cogs of society turning. We have designed our local ecological niche to suit ourselves, to respond to our culture and to reinforce it—but as James J. Gibson (1979, 130) writes, we have done so wastefully and thoughtlessly, and perhaps fatally. And so, we have lost our sustain-ability, our cultural skill to maintain our local and global ecosystems at a sustained state.

Generally, I like to open my presentations of affordances and urban landscapes with the following analogy (I have previously written about this in both Finnish[5] and English[6]). Close to my university department lies the Metsätalo building, which (ironically, as we will later see) represents the architectural principle of functionalism. One day during the first year of my PhD, I was organising

[5] Kaaronen (2019a): https://wiseproject.fi/kestavyyskriisi-on-myos-suunnittelukriisi/

[6] Kaaronen (2018d): https://www.theconventions.com/articles/society/the-ecology-of-ecological-behavior

an event in the third-floor hallway, sitting at the reception desk by the entrance. To my amusement, many, if not most, of the guests were incapable of entering through the door. First, they tugged the large vertical handle on the door. Then they repeated this in frustration. Finally, after a contagious moment of embarrassment, they slowed down, read the politely imperative instructions by the door handle ('☑ **PLEASE TURN THE HANDLE!** ', in *three languages* and *capital letters*, just to be clear!), and finally twisted the smaller horizontal handle behind the large vertical one they were instinctively pulling before. The morale of the story? We rarely stop to read instructions if the affordances in the environment, in this case the large vertical door handle, primarily invite us to behave otherwise.

This is a well-known fact in the field of design (Norman 2013)—to the extent that such malfunctional doors are a common joke and even have a colloquial name, 'Norman doors' (99pi 2016)—yet this seems somehow to escape us when discussing large scale societal behaviour change. An obvious analogy to the (non-)emergence of sustainable behaviours is to be made here. Why would we assume, for instance, that humans would stop to read instructions on how to behave pro-environmentally if the affordances in our directly perceivable environment solicit us to behave otherwise? How can we expect humans to behave sustainably, when most, if not all, the new affordances we fit our urban environments with (think: ads, shopping malls, visual displays, audio commercials, etc.) are ones which primarily invite us to behave unsustainably?

Figure 3. A typical 'Norman door' in Metsätalo, Helsinki. Imagine encountering this door: Which would you grab first: the wooden vertical handle or the brass horizontal handle? Would you tug the handle before slowing down to read the instructions?

To more thoroughly understand the ecology of perception in a city, we must begin with some premises of perceptual systems. A central concept in the ecological approach to visual perception, as formalized by Gibson (1979), is the *ambient optic array*. The ambient optic array is the structured light in a given environment, with respect to a point of observation. In other words, the ambient optic array is the structure of light which reaches the eye, or the visual information available at the retina. As light reflects on and off the surfaces of an environment, it conveys information about these surfaces, allowing an active organism to harvest, pick up or leverage this information for its use. Furthermore, Gibson posited, this ambient optic array contains in itself enough information and invariant properties so as to specify actions, such as the walk-on-ability of a horizontal plane or the climb-on-ability of a set of stairs.

Consider then the ambient optic array of your typical urban environment and the actions it affords. In this hectic lightshow, the information flow is more than often specified so as to maximize the likelihood of humans engaging with consumptive activities: buy this, fly there, drive that and lust for those. In the urban three-dimensional ambient optic array exist very few points of view which enable us to escape this ecologically unsound information flow. I feel like I risk repeating the obvious here, but it seems clear to me that this is not emphasized nearly enough. Consider the following: private advertisement is generally allowed in urban arenas on the basis that it takes place on private or rented property. Billboards, neon signs, bus stop ads—these are mostly found on rented space or privately-owned property. Relatively few advertisements, for example, are directly placed on areas which we consider truly public (such as roads, the pavement or public lawn), or if they are, they are often considered illegal and removed. However, for the system of visual perception, it is not the placing of the object we are necessarily concerned about, but rather the *information* it conveys in the ambient optic array, and the location where this information reaches the observer.

Thus, an ad might be placed in private space, but the invariant information it conveys and the functions (affordances) this structured information specifies, for good or for ill, thoroughly

pervade public space. And it is precisely this information which matters. This is not merely light pollution or visual pollution, but a more specific form of information pollution, which reaches our subjective perceptual realms, and which is practically unavoidable in our everyday encounters with our urban niche. Less and less public space, it seems, is free from consumption solicitations. As malls become the new urban living rooms and public space privatised, it is increasingly arduous to escape the flow of ecologically harmful information. Yet for some peculiar reason, we take this 'pollution of the idea space' (Lovelock 2000) almost for granted, adapt to it, and become perpetuators of this new norm in what seems like a self-reinforcing destructive cycle. Yet, as I will discuss below, it is precisely this self-reinforcing cycle which we can, with appropriate and thoughtful design, leverage to our benefit.

Journalist and activist George Monbiot (2016) once noted the saddening irony in the fact that despite all the calls by global leaders to curb carbon dioxide emissions, very little actual effort is put into keeping carbon in the ground. What exactly are we expecting, Monbiot asks, to happen to all the oil and coal once it is drilled or mined—to magically disappear? The exact same applies to consumption. We must 'Ensure sustainable consumption and production patterns', or so declares the United Nations' Sustainable Development Goal #12, yet most of the growth of urban centres and the information flows they reflect seems to scream at us for more unsustainable consumption and production. We are failing miserably at designing the proper ecology for the behaviour we wish to achieve. No amount of environmental consciousness is sufficient if the ecology of behaviour does not afford sustainable behaviour patterns to begin with. Thus, it seems, we need to radically redesign the urban niches which most of us humans today inhabit. Note that it is not necessarily a 'smart' city I advocate for—a 'dumb' or traditional city might well do the trick if it has less information pollution and less opportunities for ecologically destructive consumption patterns (Fleming 2020; Watson 2019). This need also not mean a return to the proverbial 'stone age'; the reader might entertain themselves by looking at motion pictures from most urban landscapes in

as late as the 1960's, and notice how much the information landscape in urban environments has changed since.

The discussion on altering the choice architecture in urban environments has more recently been revived in the form of nudge theory, or more colloquially, 'nudging'. I am somewhat critical of this approach, for reasons stated below. A nudge here is 'any aspect of the choice architecture that alters people's behavior in a predictable way without forbidding any options or significantly changing their economic incentives' (Thaler and Sunstein 2008, 6). Thaler and Sunstein (ibid.) continue: 'To count as a mere nudge, the intervention must be easy and cheap to avoid. Nudges are not mandates. Putting the fruit at eye level counts as a nudge. Banning junk food does not.'

To begin with, let me be clear: nudge theory has resulted in some interesting behavioural interventions and discussion on the ethics of sustainable design (see, e.g., (Hukkinen 2016)). However, I believe nudge theory is, as a behavioural science, quite misled. This is mainly because it is not an ecological approach to perception or action. Without digressing to a lengthier critique, I wish to point out two things. Firstly, in the real world which human beings inhabit, the structure of the environment *always* affords or constrains some kind of behaviour. Nudge theory focuses on specific, isolated 'nudges', but in the real world of action-perception the ambient optic array and other sensory cues continuously specify new predictable action opportunities and forbids many others. Easy and cheap interventions here and there are of very little use if the rest of our everyday life consists of a bombardment of unsustainable solicitations. Simply, little changes in specific environments are not enough: we need a radical restructuring of our perceptual environment.

Second, nudge associates the forbidding of behavioural options with loss of liberty. This is not the case if we take into account more complex cognitive or temporal dimensions. To begin with, consider the game of chess, where establishing systemic boundaries does not entail the loss of freedom, but rather is the *prerequisite* for both freedom and creativity. A relatively simple set of 91 rules leads to a practically inexhaustible lower bound of 10^{120} possible games (Claude Shannon's estimate—for what it's worth, this is quite a large number: there are an estimated 10^{78} to 10^{82} atoms

in the observable universe). Similarly, the establishment of certain boundary conditions (such as regulating outdoor advertisement) does not necessarily entail loss of liberties, and contrarily the altered information landscape might open up new action opportunities, liberties and avenues for alternative or creative self-organising forms of life or patterns of emergent behaviour (Alexander 1979). Nudge theory, it seems, can only account for losses of liberties, whereas a systemic theory of behaviour (such as affordance theory) also accounts for the emergence of liberties. This is not to even mention the intergenerational aspects of liberty (such as: what negative implications do our liberties to consume today have on the liberties of future generations?). Much important work has been done with nudges, but importantly it underemphasizes the crucial notion of the ecological construction of freedoms: establishing boundaries need not reduce freedoms, and contrarily, it can create them. Through thoughtful and even participatory and democratic design procedures we can construct our everyday environments to afford altogether new liberties and forms of life.

In other words, to more comprehensively understand our dynamical relations to our environments, we need more wholistic approaches than mere nudges. But a critique should not be presented without an alternative. Thus, I propose that ecological accounts of human behaviour, such as those promoted by ecological psychologists and niche construction theorists, offer more viable windows into analysing the behaviour of humans in their 21st century econiches. I also argue that this helps us find ways to leverage collective patterns towards a more sustainable trajectory. Together these present a framework which I have called elsewhere (Kaaronen, 2018) the Ecology of Design.

The design of sustainable urban niches is a bidirectional process. If we wish to lead lives which respect ecological boundaries, we need to design niches in which this is the path of least resistance—or rather, the path of maximum affordance. This entails identifying the relational and functional relevance of these areas with respect to their users. In such a relational conception, the environment is not just a uniform box in a flowchart. Yes, the environment affects behaviour—this much has been obvious in the psychological and social sciences since their conception in the

19th century (indeed, it is mere common sense). But how this happens, how it leads to emergent feedback loops between organisms and environments, is a much less charted territory. Instead, we are drawn to ask, as environmental policymakers, urban designers, philosophers or behavioural interventionists, *how* the environment affords prescribed patterns of behaviour. In other words, what are the processes and feedback-loops in cultural and behavioural systems that lead to sustainable behaviours?

One of the most persistent barriers to pro-environmental or sustainable behaviour is the gap that lies between personal states (such as environmental values, knowledge or attitudes) and actualized behaviour (Kollmuss and Agyeman 2002; Jackson 2005). Simply, 'it is easier to be concerned about the environment than it is to act on one's convictions' (Vining and Ebreo 1992, 1604). There are, to my mind, two ways to go on about this so-called attitude–action gap. One is to chastise those who are not acting accordingly with their internal moral drive, and trust in the power of increased information or guilt-tripping to leverage these people into acting as they by all means should. Given the incredibly wide prevalence of the attitude–action gap, I would not bet my money on this working. The other is to adopt a dynamical or ecological stance, or understanding human behaviour as emerging from the feedback loops of continuously evolving human–environment interactions, attempting to actualize the potential for behaviour change by complementing pro-environmental 'personal states' (individual traits) with appropriate environments. It is, of course, the latter for which I argue in this thesis, particularly in Articles 2 and 3. For such a relational task, it is helpful to use a relational concept as a tool for analysis: the affordance (recall section 2.1).

Humans, of course, are by far the most efficient species in altering affordances to suit their needs—in other words, we are arguably the ultimate *niche constructors* (Laland, 2017). We construct the worlds in ways that fit with our mental models (Clark, 2016), and shape natural and urban form to conform with whatever is the current cultural trend. And most of all, whatever affordances we fit our environments with will propagate new behaviours and design efforts in what is evidently a

self-reinforcing feedback loop. Thus, quoting from my essay *The Ecology of Design* (Kaaronen 2019c),

> 'Design is the bootstrap by which animals, humans in particular, become capable of lifting themselves up to novel levels of existence. It is how culture ratchets its growth, how social systems encode what they learn, and how people navigate through a near-chaotic world riddled with uncertainties.'

And so, we have the potential to revert the ongoing death spiral by identifying one particularly important leverage point for collective behaviour change: the structure of ecological information in our urban environments and the affordances that they convey. This is the argument put forward in Articles 2 and 3. If we wish to achieve the radical behaviour change the current predicament requires, we must begin by redesigning the affordances within our (urban) environments so that the path of least resistance is sustainable. Arguably (and unlike top-down interventions such as 'nudging'), this is best achieved by polycentric and participatory forms of governance (Ostrom 2010), which are responsive to local demand, capabilities and mentalities. This, I hypothesize in Article 2, could potentially trigger a positive feedback-loop, where the new behaviours afforded by the environment help people 'actualize' their behaviour potential (e.g., growth in pro-environmental attitudes or awareness), leading to pro-environmental habituation, social learning and even further pro-environmental niche construction.

In other words, we must understand the mutualism between organisms and environments to maximise the *fitness* between pro-environmental personal states (attitudes, awareness, intentions, etc.) and environments that afford salient behaviours. Importantly, doing so might result in self-reinforcing feedback loops, as is proposed in Article 2. At the stage of writing Article 2, however, much of this idea was theoretical and hypothetical. The next step was to formalize the mechanisms and study their effects on the emergent socio-ecological system. This is precisely what is done in

Article 3, together with Nikita Strelkovskii at the International Institute of Applied Systems Analysis in Laxenburg, Austria.

In our agent-based model in Article 3, we define five key processes that underlie an ecological approach to studying human behaviour:

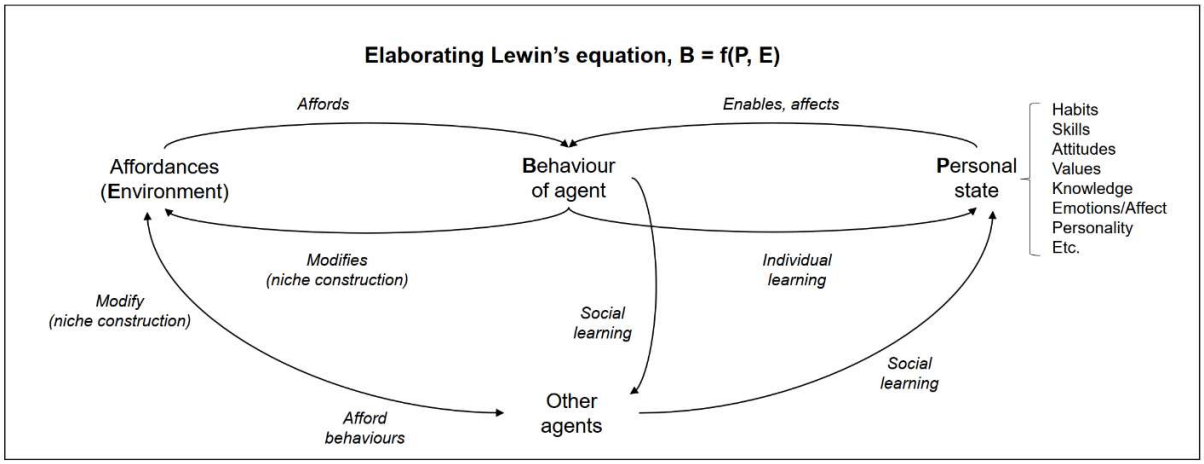
1. The ecological information in the material and social environment specifies affordances for behaviour.
2. The ways in which we behave modulate our personal states (e.g., skills, knowledge, attitudes and whatever traits dispose us to engage with specific affordances) through processes of habituation and individual learning.
3. Personal states direct our individual behaviour patterns.
4. Our collective behaviour alters the environment and its 'landscape of affordances' (Rietveld and Kiverstein 2014) in non-random ways via processes of cultural niche construction.
5. All behaviours occur in social networks and result in social and cultural transmission of information (through, e.g., imitation, teaching or copying).

As one can imagine, studying such an amount of feedback loops in the real-world would be tricky, to say the least. Therefore, as described in section 2.4, we chose to analyse this system and its emergent phenomena by means of agent-based modelling. At its core, the system we model can be considered an elaboration and formal definition of Lewin's equation, $B = f(P,E)$, where, recall, behaviour (B) is a function (f) of the person (P) and their environment (E). As we argue in Article 3, however, Lewin's equation is insufficient in its detail to formally model all the processes that underly this function, so instead we looked to various theories of cognition, ecology and behaviour for inspiration.

Our results show, as agent-based models often do, unexpected emergent behaviours. In Article 2 I entertained the idea that changes in the 'landscape of affordances'—changes in the constitution of available pro-environmental affordances in an (urban) environment—might have nonlinear

effects on the adoption of sustainable behaviours (Figure 3). According to the results in Article 3, and the associated sensitivity tests (see the Supplementary information of Article 3), changes in the landscape of affordances can have radical effects on collective behaviour patterns, which presents urban designers and policymakers with a particularly strong leverage point. Changing the 'personal states' (e.g., attitudes, intentions…) of agents, on the other hand, proved to be a less reliable leverage point: the case is simply that if sufficient opportunities to behave do not exist, one cannot behave pro-environmentally even if one had the noblest intentions or attitudes.

Figure 4. A nonlinear dynamical system of human behaviour: the conceptual model underlying Article 3.



As the results in Article 3 illustrate, even a linear (or near-linear) introduction of pro-environmental affordances to a social system can have a nonlinear effect on the collective uptake of pro-environmental behaviours, to the extent that this can be characterised as a tipping point or 'phase transition' (the transition of a system to a notably different state). In Article 3, we use the case of bicycling in Copenhagen to empirically validate our model: in Copenhagen, for instance, the introduction of cycling-related affordances (the construction of cycling infrastructure) has likely triggered the accelerating nonlinear adoption of pro-environmental cycling behaviours. However, we maintain that the core argument is a more general one than the case of cycling alone would suggest (the case was chosen mainly due to the convenience of easily available empirical

data): where potentialities for sustainable behaviour exist (in forms of 'personal states' such as ecological awareness, pro-environmental attitudes, etc.), they can quite rapidly be actualised by providing the fitting affordances or infrastructures. Moreover, collective behaviour change can be faster in speed than isolated individual behaviour change. More precisely, this phenomenon would fall under the definition of a 'social tipping point', where

> 'a small quantitative change inevitably triggers a non-linear change in the social component of the [socio-ecological system], driven by a self-reinforcing positive feedback mechanisms, that inevitably and often irreversibly lead to a qualitatively different state of the social system.' (Milkoreit et al. 2018.)

The fact that the results of the agent-based model in Article 3 were even more radical than hypothesised in Article 2 illustrates an important lesson: modelling can reveal shortcomings in verbal models. In this case the problem was that Article 2 did not emphasise enough the role of social learning in the adoption of sustainable behaviours. In Article 3, where social networks had to be coded and modelled formally, the effects of social learning on the adoption of pro-environmental behaviours proved to be drastic (and sensitive to modelling choices). However, I maintain that the theoretical framework put forward in Article 2 was essential in helping to formalise the more complex and detailed processes in Article 3.

Before moving on, let us entertain another brief analogy I have previously written about in my essay *The Ecology of Design* (Kaaronen 2019c)—the case of Roman highways. Dalgaard et al. (2018), in their recent study, superimposed maps of Roman roads from 117 CE, the peak of the Roman Empire, onto satellite images of European nightlight density. Their research came to a fascinating conclusion, where Roman road density proved to be a strong causal predictor for contemporary road density and economic activity. In other words, the affordances designed by a distant population two millennia ago have literally paved the way for what now are Pan-European trade networks, giving in the process birth to many of Europe's greatest cities which spawned at

the highway intersections. This is despite the fact that the highways were originally constructed not so much for economic trade as for military expansion. Regardless, this process of cultural niche construction—of affordance design—non-randomly altered the ecological inheritance of future populations so that the environment favoured transport on wheels, resulting in increased trading activities, in the process also creating cultural selection pressures for trade-related behaviours and attitudes, the further design of trade-related affordances, and so on (indeed, the process was likely rather similar in kind to the five feedback-loops defined above). This process, although mostly unconscious, resulted in a self-reinforcing ratchet whose (literally) path-dependent effects still reverberate strongly in everyday life today. Now, imagine if a society had the capacity to knowingly tap into a process of feedback loops this strong, designing the Roman highways (*viae publicae*) of today to bring forth a sustainable urban environment tomorrow. Equipped with the right theories, I argue with many others (e.g., Wilson 2020), we might just well be capable of this.

It is worth emphasising, though, that tipping points, like Roman highways, do not generally come for free, and require both considerable effort and maintenance. I do not therefore suggest that reaching a 'social tipping point' is a panacea for sustainability transitions, or that reaching one would altogether be a simple task with clear-cut implementation. For one, even in our model, the tipping point in the adoption of sustainable behaviours is far from free: The shift in collective behaviour patterns only emerges after sufficient affordances are introduced to the social system *cumulatively*, significantly altering the landscape of affordances. In practice, this would require considerable investment into infrastructure, among other factors that might increase the affordances for cycling (e.g., regulations for air quality, speed limits for vehicles, etc.). Indeed, even much-lauded tipping points in cycling cultures in cities such as Copenhagen and Amsterdam have been products of various policy processes, including hard 'command-and-control' measures such as speed limits, considerable investment into infrastructure and economic support for specific transport mode choices, along with softer policy measures such as education and information (Gössling 2013).

This notion—that transitions rarely come for free—is also one that is repeatedly discussed in the context of sustainability transitions. It is easy to imagine a mechanistic clockwork-world where a tipping point could simply be triggered through smart design, but the real world, as is so often the case, is much messier than this. For a social movement to be transformative and to overcome resistance by existing regimes, it needs continued support (in the forms, e.g., of restructured incentives and financial/political facilitation), maintenance (through formal and informal institutions and social activism) and mutual reinforcement or social coordination (Chenoweth, Stephan, and Stephan 2011; Nyborg et al. 2016; Westley et al. 2011). Whilst even small determined minority groups have been shown to be capable of triggering tipping points in social conventions and norms (Centola et al. 2018), adjusting the landscapes of affordances in urban environments will likely require much political and economic determination and citizen activism if we truly wish to overcome the institutional lock-ins and path dependencies our everyday lives are embedded in.

Moreover, much work remains to be done in integrating behavioural theories such as those discussed in section 2 with theoretical frameworks that are more sensitive to institutional, social, political and economic factors and variations. Undoubtedly, this is also a point that remains underexamined in the research articles that compose the present dissertation. Although, as mentioned, attempts at 'socializing' or 'enculturing' concepts such as affordances do exist (Costall 1995; Ramstead, Veissière, and Kirmayer 2016) and applied work is being done in designing affordances for sociability (e.g., Rietveld, Rietveld, and Martens 2017), some central problems remain in over-psychologizing phenomena that ultimately are more efficiently studied through the lens of social and political theory. Most notably, Gibsonian theories of direct perception generally seem to lack focus on the social values, aesthetics, economics, politics and other individual variation that typically mediate our perception of the world (with the notable exception of variation in physical traits, which ecological psychologists have studied). Here, ending this chapter, I propose some promising ways forward.

A notable candidate for studying human–environment interactions or ecological social science from a more institutionally sensitive point of view would be the Capability Approach, as developed by Amartya Sen (1992; 2009) and Martha Nussbaum (2007). Although I only briefly mention Sen's work in Article 1 and Article 2, I should emphasise that this is far from an afterthought: it was Sen's Capability Approach that originally sparked my interest into relational theories of human behaviour (and this was in fact the topic of my first academic thesis, my Bachelor's dissertation). As its name would suggest, the Capability Approach is particularly well-suited for studying sustain-abilities.

The Capability Approach could be summarised as follows. It sets off with a normative axiom: we should begin the development of policy measures from the assumption that, in human societies, the primary moral importance is in the freedom to achieve well-being (Robeyns 2016). Notably, most theoretical frameworks described in section 2 lack such a moral foundation. For instance, research in ecological psychology generally comments very little on how perception, action or niche construction *should* emerge, or indeed *why* specific behaviours should emerge. In this dissertation, much of the moral foundation was rooted in the notion of sustainability and well-being of human and non-human life, however many more normative axioms could be imagined. The point is that whilst ecological psychology as such may strive to be value-free and descriptive, any applied version of it should be honest and self-reflective about its normative assumptions.

The second basic principle of the Capability Approach is that freedoms to achieve well-being should be understood in terms of capabilities (Sen 1992). Freedoms here are to be understood as a product of 'functionings' (the subjects of our behaviour considered in their totality, such as opportunities to behave or exist, not much unlike the 'landscapes of affordances' as discussed in (Rietveld and Kiverstein 2014) and Article 3), resources (e.g., social, cultural and economic capital), and 'capabilities' (the sets of functionings that are feasible for a person to

achieve, depending on economic, social and personal resources). The crux of the Capability Approach is that even if the totality of functionings and resources—or the landscapes of affordances—were uniform to people in a society, individuals and local populations differ drastically in their capabilities to act upon these action opportunities due to economic, social and political factors. Therefore, whatever functionings we are able to *achieve* are contingent on our capabilities, which vary person by person. In ecological psychological terms, people are selectively attuned to affordances in their environment based on socioeconomic, political and personal or physical variation. This is not much unlike the distinction Bruineberg and Rietveld (2014, emphasis mine) make between the total 'landscape of affordances' and the 'field of affordances':

> 'LANDSCAPE OF AFFORDANCES: The affordances available in an ecological niche. In our human form of life, these are related to **the whole spectrum of abilities** available in our socio-cultural practices.
>
> FIELD OF AFFORDANCES: The **affordances that stand out as relevant** for a particular individual in a particular situation; i.e., the multiplicity of affordances that solicit the individual.'

Indeed, making and emphasizing such a distinction as Bruineberg and Rietveld (2014) and Sen (Sen 1992) do, between 1. The totality of action opportunities in an environment and 2. Those relevant or feasible for a human to interact with, has several benefits for ecological social science. First and foremost it sensitises researchers to consider that even though the material environment were similar for everyone, not all are 'born equal' in their capabilities of utilising its affordances or functionings (Sen 1992). In other words, there are always dimensions of politics and equality at play when designing affordances. Second, connecting the dots between the various relational theories discussed in this dissertation with the vast literature on the Capability Approach could inspire much research on, for instance, how wealth, social status, scarcity (Mullainathan and Shafir

2013), disability (Toro, Kiverstein, and Rietveld 2020), gender and various socio–political factors mediate perception (of, for example, urban environments or urban affordances). Here, modern methods such as PPGIS (participatory mapping systems) and strategic or experimental design interventions (Rietveld, Rietveld, and Mackic 2014) can help researchers identify the capabilities (and lacks thereof) of local populations for engaging with everyday affordances. This could, in the spirit of the Capability Approach, serve to increase human agency to pursue well-being and various freedoms. These ideas are also guiding my current, yet unpublished, research.

Concluding this section, Articles 2 and 3 in particular illustrate how the functionally relevant aspects of our environment, the affordances within our niche and the ecological information that specifies them, have a profound role in shaping our behaviour. Affordances shape the ways in which we behave, and the ways in which we behave are socially transmitted. If we wish to instigate collective behaviour change on the scale that is required to reach sustainable levels of transport, consumption, et cetera, we need to focus much more on the context and infrastructure we behave in. Pro-environmental opportunities for action should be designed to be on the 'path of least resistance', and we should collectively seek to ensure that our environments are not so thoroughly permeated by information that solicits us to behave unsustainably.

3.3 Step 3: Dealing with Uncertainty

Article 4 discusses how a traditional practice, mushroom foraging, deals with uncertainty by using ecologically rational decision-making. I have previously written on this topic from an autoethnographical perspective (Kaaronen 2019b), and in the spirit of ecological psychology and Jamesian radical empiricism I am quite delighted to report that the research questions here were born from direct personal experience. More specifically, Article 4 deals with how Finnish mushroom foragers make ecologically rational decisions under uncertainty (recall section 2.3) by making use of traditional knowledge, heuristics, and precautionary heuristics. In doing so, its focus

is perhaps more restricted than the previous articles'. Article 4 surveys 894 Finnish mushroom foragers with a humbling total of 22,304 years of foraging experience, providing us a representative overview of the art of mushroom foraging. Next to a set of multiple-choice questions and associated statistical analysis, the study included a wealth of qualitative data, providing a comprehensive set of mixed-methods data of decision-making processes in the wild. However, I wish to illustrate in this section that here, too, lie some more universal analogies for skilfully dealing with the sustain-ability crisis.

Article 4 is also a study into tacit, traditional and practical knowledge, a theme previously introduced in the second half of Article 1. Since the definition of tacit knowledge in Article 1 is extensive, it suffices for present purposes to note that Polanyi's (2009; 1974) notion of tacit knowledge assumes that 'we know more than we can tell', and that any formal description of a thing or an event relies on a background of experientially gathered common sense that cannot be explicated at the moment of description. Thus, all knowledge is rooted in tacit knowledge. From Kaaronen (2018c):

> Ultimately, it follows, to know something is to rely on 'common sense' (or a Duhemian *bon sens*) in the face of fundamental incompleteness. Explicit knowing, then, whilst being a 'superb instrument', ultimately 'requires a background of common sense', or tacit knowledge, for its operational basis (Whitehead 1947, 74). Whilst tacit knowledge can be possessed or embodied in itself, explicit knowledge must rely on being tacitly understood: all knowledge is '*either tacit* or *rooted in tacit knowledge*' and a '*wholly* explicit knowledge is unthinkable' (Polanyi 1969, 144).

Dealing with uncertainty, it seems in the case of Finnish mushroom foragers, requires a considerable amount of tacit knowledge. As the results of Article 4 illustrate, foragers often make their decisions regarding where and what to forage based on intuitions and hunches, and their

decision-making is characterised by utilising sets of 'fast and frugal' heuristics—sometimes even without the foragers themselves knowing why they do so.

In Article 4, decision-making is studied as an active practice, where perceivers make use of the environmental cues they encounter to guide even difficult decisions. Article 4 illustrates how mushroom foragers use simple heuristics, such as the rule 'avoid white mushrooms', as precautionary principles to prevent unwanted surprises (such as encounters with the deadly white *Amanita virosa*). Thus, it is a study of how safe decisions can be made under high uncertainty. The uncertainties of mushroom foraging not only include poisonous lookalike species, but also the fact that mushrooms themselves are highly variant in their form and colour. It is common knowledge in Finland that, when mushrooming, it is better to be safe than sorry. Safety, in turn, can be achieved by applying a relatively simple 'adaptive toolbox' (Gigerenzer and Selten 2002) of foraging rules.

Recall that a central feature of ecologically rational decision-making is the use of heuristics, or simple and satisficing 'rules of thumb'. These can include stopping rules for searching through sequences of available alternative behaviours, or task-specific heuristics to aid 'fast and frugal' decision-making, often relying on coarse one-reason judgments (Gigerenzer and Todd 1999). When operating in the context where these heuristics are designed, such rules have repeatedly been shown to deal particularly well with uncertainties, and are capable of outperforming more complex computations and judgments in both effort and accuracy (Kozyreva and Hertwig 2019; Todd and Gigerenzer 2012). Article 4 illustrates several cases where Finnish mushroom foragers use one-reason judgments to make decisions, and curiously, even the most experienced foragers often resort to simple rules to guide their search for mushrooms. For instance, foragers seem to avoid specific subclasses of mushrooms, such as white mushrooms or unrecognised ones, and at other times use simple but reliable perceptual cues (such as the 'white milk' secreted by edible milk-caps) to make safe decisions (see Figure 5 below).

Figure 5. Finnish foragers often tend to altogether avoid white mushrooms, due to possible confusions with the deadly *Amanita virosa*, pictured below. Particularly a young *A. virosa* (bottom left and right) can look similar to many edible white mushrooms, including the champignon and its wild relatives. See Kaaronen *(2020)* on how foragers employ heuristics analogous to the precautionary principle in foraging strategies.

The reason why simple judgments or rules of thumb might outperform more complex cognitive algorithms in uncertain environments has its roots in the bias–variance dilemma (see Kozyreva and Hertwig, 2019). Simply put, in uncertain environments—or environments with large and

unpredictable variance—an organism might have higher cognitive fitness when it is biased than when it is not. This owes to the fact that, in terms of survival, it might be more adaptive to be systematically biased (and avoid fatal large events) than to suspect oneself to high variance (such as unrecognised mushrooms). In such cases, persistent biases (propagated by, e.g., social norms or traditions, or other forms of intuitive or tacit knowledge) can protect communities from uncertainties, unwished events and risk of ruin. Mushroom foraging, it turned out, was a fascinating case for studying such biases. Foragers use systematically biased rules to avoid deadly encounters with poisonous mushrooms, and also bias their search for edible mushrooms by associating specific mushrooms with particular terrains or environments.

The findings of Article 4 suggest that mushroom foragers, equipped with strong intuitions, tacit knowledge and cultural traditions, are not 'probability calculators' or 'optimisers' as much as they are 'satisficers' and 'uncertainty avoiders'. Probability theory only provides the best answers when the rules of the game are certain (Gigerenzer 2015), and this is rarely the case in mushroom foraging. Thus, good intuitions to deal with uncertainty are required, and traditional rules of thumb are necessary to succeed in the practice. For instance, foragers seem to generally prefer a conservative rule similar to the 'minimax' rule (ibid.): 'Choose the alternative that avoids the worst outcome'.

Recall also from section 2.3 that ecological rationality suggests that rational decision-making should always be understood in context: whatever counts as rational or adaptive behaviour is a product of both the organism and its environment. Accordingly, foraging heuristics and rules are *local*: they only work in the context they are embedded in, and the foragers surveyed in Article 4 seem well aware of this. These practices have likely culturally evolved over decades or centuries, and have in the process developed simple rules of thumb to deal with local uncertainties. In Article 4 I also briefly discuss where such local heuristics fail: for instance, populations moving to new countries (e.g., refugees) have faced fatal accidents when using their respective traditional rules in unfamiliar environments.

Given how far studies in ecological rationality emphasise 'context', it is curious how few studies in the paradigm actually study behaviour in natural settings. Most research in ecological rationality seems to be focussed on uncovering 'fast and frugal heuristics' in abstract settings or in the domain of immobile cognising. Therefore, studying how people actually use heuristics in the wild, as Article 4 does, proved to be a fruitful and rewarding endeavour, one which I hope increases our understanding of how humans make decisions in natural environments. Often these decision-making processes were less 'algorithmic' or clear-cut as many studies in ecological rationality might suggest, and the decision-making processes rather involved active movement and use of multiple sensory cues (from olfaction to haptic to gustatory). In my essay *The Art of Mushroom Foraging* (Kaaronen 2019b) I describe these processes from an autoethnographic perspective. With this and the mixed methodology (qualitative and quantitative) used in Article 4, I aimed to broaden the scope of studies into decision-making to include more of what Herbert Simon (2000) called the 'processes of choice' (as opposed to mere 'products' of choice). Indeed, in some of his final work, Simon (2000, 35–36) emphasised in particular the need for a plurality of methods when studying decision-making:

> 'The traditional empirical tool of economics, collection of aggregated data and their analysis by statistical regression, can only provide one weapon in the armory, and that not the most important. One key requirement for forward movement is broadening the training of economists in methods of gathering data. Especially, they need to understand how to carry out field studies on decision making (and field experiments) [using] methods of observing and interviewing, of taking and analysing verbal think-aloud protocols, of extracting information about decision processes from written records, and of drawing conclusions reliably from multiple studies of these kinds. [...] It is especially important that they learn how to use non-numerical data (e.g., verbal and written information expressed in natural language). '

By analysing natural language, reports of experiences from the field, verbal descriptions of decision-making protocols along with numerical data, Article 4 (along with its autoethnographic sibling essay) responds to this call for broadening the scope of methodology in decision-making research.

Article 4 is a specific study of ecological rationality in a specific niche, and the results are presented in Article 4 in enough detail that further discussion on the specifics would be redundant. Instead, I would like to use this space on discussing the generalisability of Article 4 and its potential societal relevance. Article 4 presents a clear case where humans, sometimes intuitively, use precautionary and risk averse heuristics to make decisions when they have 'skin in the game' (Taleb and Sandis 2013)—i.e., when they would experience direct personal consequences from adverse extreme events (in this case, mushroom poisoning and the associated pain, malaise, organ failure, or even death). Mushroom foragers make conservative decisions and seem to generally avoid taking calculated risks. After all, cost-benefit calculations in this domain make little sense if potential costs are infinite (death by poisoning). I am led to wonder whether there might be a valuable lesson to be learned here regarding risks and uncertainties.

It is curious that this tendency to avoid uncertainty, which comes so tacitly and intuitively to us as foragers or practitioners of a traditional culture, should so quickly disappear on the modern large-scale societal level. Risk and uncertainty management seems to differ drastically in situations where there is personal skin in the game (such as mushroom foraging) vis-à-vis situations where institutions, industries and markets have distanced decision-makers from direct environmental feedback. Perhaps there is, therefore, something we can learn from traditional risk management—such as the ample use of precautionary principles—when preparing risk management for the Anthropocene. In fact, I am writing the present summary in midst of a pandemic that might well have been mitigated or avoided with strict precautionary measures. It almost seems like our tacit intuitions for dealing with uncertainty quickly disappear when the challenges get more abstract and collective, and are interpreted through the lens of institutions and not people. Whilst the

precautionary principle is instinctively applied when individuals' personal lives are at direct danger, it is far less often applied when harm is external, time-lagged or an effect of second-order consequences. Part of this undoubtably has to do with the free-rider problem and similar institutional mechanisms—political concerns which are far beyond the scope of this thesis—but I hope Article 4 is read with an eye for applying its insights to the societal scale.

The mismatch between traditional and modern modes of dealing with uncertainty is certainly one that seems to call for further inquiry. Although it should be noted that evidence for truly sustainable traditional socio–ecological management practices is scarce (Smith and Wishnie 2000), and that unsustainable human transformations of the environment can be traced far into the late-Pleistocene (Stephens et al. 2019), perhaps our risk-, profit- and probability-obsessed cultures should seek to learn select lessons from traditional knowledge for dealing with uncertainty in socio–ecological systems. Applying intuitive and conservative rules of thumb, similar to the precautionary measures used by foragers, might just lead us out of harm's way.

4 Concluding Remarks

> '[I]n the industrialized world all of us are largely reduced to consumers. [...] Even in our lives in nature we are reduced to consumers, and our few remaining wild places, to commodities. But the value of these parks is life itself and our participation in it. [...] We of the industrialized world forget that our current value system is only one of a range of choices. We desperately need a global ethic that is richer than our mere concern about ourselves as consumers.' Stuart A. Kauffman (2008, 9.)

This thesis deals with various *sustain-abilities*, examining how we as individuals, societies and cultures can better equip ourselves with skillsets to deal with the many dimensions of the ecological crisis. These skillsets range from learning to conceptualise our natural world in ways which respect systemic interconnectedness, leveraging our capacity to design environments which support sustainable behaviours, and dealing adaptively with uncertainty. Although these perspectives afford merely some windows for viewing the sustainability crisis, they present a uniform attempt at developing an ecological social scientific framework for studying the emergence of sustainable states of mind and behaviour. Similar perspectives are also available in my other work not included within the covers of this thesis (Kaaronen 2018a; 2019c; 2018b). I hope these perspectives afford a more wholistic picture of how human cognition and behaviour is shaped by not only what is inside our heads, but the environmental regularities we find ourselves in.

We are not mere consumers roaming on an unbounded ecological system, although much modern discussion has appropriated the word 'consumer' as a near-synonym for being human. We cannot go on with the process of separating natural systems into compartments more suitable for human consumption.[7] Instead, we must collectively learn to regenerate the synthesis of these parts, and as

[7] Interestingly, the word consumption itself can be traced from Latin, *con-* 'altogether' and *sumere* 'take up', originally meaning 'to destroy by separating into parts which cannot be reunited'. How very appropriate.

Article 1 discusses, to reconceptualise ourselves as an inseparable emergent property of natural systems—or else, I quote Bateson (2000, 501), 'The creature that wins against its environment destroys itself'. Bateson (2000, 509) continues:

> 'I regard the grooves of destiny into which our civilization has entered as a special case of evolutionary cul-de-sac. Courses which offered short-term advantage have been adopted, have been rigidly programmed, and have begun to prove disastrous over longer time. This is the paradigm for extinction by way of loss of flexibility.'

The steps in this thesis illustrate some ways of regaining this flexibility through cultural skillsets to deal with long-term sustainability. For one, we humans are the ultimate niche constructors, and we have the option to use this capacity for good: by designing environments where sustainable modes of behaviour are the path of least resistance—or path of maximum affordance—we would at the least be on the right tracks. We need to design *whole situations* which support and direct the evolution of sustainable cultures. As Articles 2 and 3 illustrate, this has the potential to lead to surprisingly rapid tipping points in collective behaviour patterns. Second, in the process of dealing with unsustainable modes of culture, we can look back at how some traditional societies have dealt adaptively with uncertainties, and learn valuable lessons on how to deal with systems where potential losses are extreme and gains limited. Article 4 sheds some light here, and provides us an analogy on how we should behave when our lives are in direct danger: by applying precautionary principles and other adaptive heuristics.

Retrospectively, much of the process of writing this dissertation has altered how I perceive social and ecological systems. Whilst Article 1 was an attempt at formulating some ideas I had been entertaining for a longer while, the rest of this thesis emerged in the process of writing and tinkering. Modelling, in particular, seems to have left a mark on how I perceive the world. Let us entertain a thought-experiment here. If I were to model the evolution of culture, I should naturally

place us on a timeline of emergent processes. In this timeline, we—the agents of our model—should always find ourselves at nodes at the far edge of this process, poised between an interconnected history and an unforeseeable future. All agents in this model are connected, either by social networks or their common environment, and the future states of affairs are determined by how they emerge *together*. 'We are agents who alter the unfolding of the universe', writes Stuart Kauffman (2008, 113).What a great responsibility it sets on us, to find ourselves at this novel point at the edge of a chaotic system, with the agency and potential for shifting it into a more sustainable phase. My hope is this thesis, and the work that follows it, will provide at least some tools to help us achieve this transition.

I set on the process of writing this doctoral dissertation with the following question in mind: how can we use ecological theories of mind and behaviour to guide a transition towards more sustainable cultures and societies? By focusing on organism–environment systems as the main unit of my study, I employed insights from ecological psychology to understand how cultural systems might be leveraged to learn into more sustainable habits (Articles 2 and 3). In Article 1, I uncovered what I believe are some fundamentally unsustainable mental models, and presented an alternative in process philosophy to reframe how we conceptualise nature in both everyday life and scientific inquiry. In Article 4, finally, I studied a society with considerable traditional knowledge, analysing in detail how they survive in uncertain environments by utilising precautionary measures—a topic I have described above as particularly relevant for our era of uncertain ecological disruption.

Together, these inquiries have contributed to sustainability science and socio–ecological systems research in general, as well as to the more focussed fields of research in which each research article is respectively situated (e.g., ecological psychology, ecological rationality, process philosophy). Articles 2 and 3 make direct contributions to the more politically relevant aspects of ecological psychology, shifting the field's typically descriptive studies to a more normatively oriented approach. Article 3 is also, to my best knowledge, the first ecological psychological agent-based model, and hopefully will inspire others to study affordances with similar computational

methodology. Article 4 presents an attempt to take studies in ecological rationality—which so often deals merely with 'algorithmic' or otherwise sterile laboratory-environment decision-making processes—'into the wild', studying ecological rationality in (appropriately, I would like to think) ecological context. Article 4 also contributes to our understanding of the cultural evolution of foraging strategies. Article 1 is an attempt at bringing process philosophy back to the forefront of philosophical inquiry by applying it to some of our most urgent ecological concerns, and hopefully this will also inspire others to discuss socio–ecological systems in process-philosophical terms.

This thesis therefore also presents multiple new avenues for future scientific inquiry. Article 3 offers a new way into studying ecological psychological phenomena computationally, and I can imagine plenty of work to be done here elaborating the studied mechanisms with interdisciplinary collaboration. Much work can be done in defining the model parameters and processes more precisely, as well as making the model more realistic. Article 3 also presents a novel way to study the phenomenon of social tipping points, which has gained increasing interest in recent years (Milkoreit et al. 2018). Article 4 invites us particularly to study whether other traditional foraging societies exhibit similar decision-making rules (particularly, precautionary heuristics), and also proposes mushroom foraging as a particularly suitable avenue for studying human perception-action. The themes of Article 4 also could be extended to more comprehensive inquiries into the cultural evolution of foraging practices and precautionary heuristics, research topics which I have recently embarked upon.

Article 2 develops a framework for studying policymaking and particularly urban behaviour in terms of affordances, and these ideas could be developed much further by collaborating with, for instance, urban designers and landscape architects. As discussed in section 3.3, there is also much potential in complementing affordance theory with more politically and institutionally sensitive theories, such as the Capability Approach. Process-philosophical approaches for studying socio–ecological systems, such as that presented in Article 1, have recently garnered some momentum (Hertz, Garcia, and Schlüter 2020; Mancilla Garcia, Hertz, and Schlüter 2019; Walsh, Böhme, and

Wamsler 2020), and it remains to be seen whether sustainability science will catch up with the process philosophical mode of thinking which I believe would suit it so well.

Much work remains to be done with creating a synthesis between the various ecological social scientific approaches presented in this thesis. Some obvious theoretical conflicts remain in particular. However, this might not be as much a fault as is it a necessity: we are contextual and complex beings, and capturing the whole of humanity within a single theoretical framework might be akin to forcing a mobile, complex, lively and evolving organism into a rigid and cold mould. Something always dies in the process of forcing the real-world into a model, and perhaps adopting a pragmatic pluralistic perspective would do social science a larger favour than we can currently imagine.

Here, we have embarked on steps to a sustainable mind. My hope is that by engaging with future collaborative efforts, we can pave our way with a higher variety and number of stepping stones, and ultimately develop a pluralistic research program dedicated to the study of sustainable modes of cognition and behaviour, helping us cross and navigate through the treacherous and uncertain rapids of the ecological crises.

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