DIGILOGIC

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D4.1 Challenges: Scope and Objectives

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Abstract	In 2022, the DIGILOGIC project will launch a call for proposals for teams of innovators in Africa and Europe to address four Challenges related to the improvement of logistics on both continents. Twelve teams will be selected from the proposals to participate in a one-year programme of mentoring, coaching, and access to specialist facilities. In this document, which is Deliverable 4.1 of the DIGILOGIC project, the scope and objectives of the one-year programme are described.
Keywords	Africa, Europe, Digital Innovation Hubs (DIH), Logistics, Innovation, Startups, Challenges

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NATURE OF THE DELIVERABLE	R*	
DISSEMINATION LEVEL		
PU	Public, fully open, e.g., web	✔
CL	Classified, information as referred to in Commission Decision 2001/844/EC	
CO	Confidential to DIGILOGIC project and Commission Services	

*** R:** Document, report (excluding the periodic and final reports)
DEM: Demonstrator, pilot, prototype, plan designs
DEC: Websites, patents filing, press & media actions, videos, etc.
OTHER: Software, technical diagram, etc.

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EXECUTIVE SUMMARY

- The vision of the EU-funded DIGILOGIC project is to boost the cooperation and partnership between African and European Digital Innovation Hubs (DIHs) and foster innovation especially of SMEs, young innovators, startups and mid-caps so paving the way to the development and uptake of digital innovations for the promotion of competitive, inclusive and sustainable prosperity in both continents.

- Work Package (WP) 4 of the DIGILOGIC project, IMPLEMENT, contributes to fulfilling the DIGILOGIC vision through DIHs working together to support innovators in addressing logistics *Challenges*.

- WP4 seeks to establish networks between European and African innovative entrepreneurs and potential investors to foster an enabling environment for start-ups.

- Through its five tasks, Work Package 4 (WP4) encompasses definition of *Challenges*' scope and objectives, formulation of the call for proposals to address logistics challenges, assessment of proposals, a boot camp for selected proposal teams, and a year-long programme of support for selected teams.

- In WP4, the scope of logistics *Challenges* and of associated objectives for addressing logistics challenges are defined in Task 1, and are reported here in this deliverable (D4.1).

- In this document, Deliverable 4.1., scope is explained in terms of logistics *Challenges* topics, *Challenges* participants, and *Challenges* technologies. Scope is related to the overall goal of the EU that the digital transformation must work for all people. No one should be left behind.

- Objectives are explained in terms of future-proofing startups. This is appropriate as the survival rate of startups is very low generally, and logistics amidst climate-change related events in Africa and Europe is a particularly challenging setting for startups.

- Also, objectives are explained in terms of nature-based solutions, high reliability organizations, and generative learning.

- Throughout, *Challenges* scope and objectives are related to the overall objectives of the whole DIGILOGIC project.

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ABBREVIATIONS

5G	Fifth generation of broadband cellular networks
AGV	Automated Guided Vehicles
AI	Artificial Intelligence
AR	Augmented Reality
AU	African Union
DIH	Digital Innovation Hub
DLT	Distributed Ledger Technology
EU	European Union
HLAB	High Level Advisory Board
HRO	High reliability organizations
ICT	Information and Communication Technology
IIB	Innovation and Impact Board
ML	Machine Learning
VR	Virtual Reality
Wi-Fi	Wireless network protocol for local area computer networks
WP	Work Package

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1 INTRODUCTION

This DIGILOGIC deliverable (4.1) is based on work carried out in Task 4.1 of Work Package 4. First in this section, an overview of the DIGILOGIC project is provided in order to relate WP4 to the overall project and its other Work Packages. Next, a summary of the five tasks in DIGILOGIC's WP4 is presented in order to relate Task 4.1 to the other tasks. Then, an overview of the deliverables from WP4 is provided in order to relate Deliverable 4.1 to further deliverables that will follow within WP4. Subsequently, the structure of this document is set-out.

1.1 DIGILOGIC PROJECT

DIGILOGIC is a project funded by Horizon Framework Programme to boost cooperation and partnership among European and African Digital Innovation Hubs (DIHs). Within the DIGILOGIC project, DIHs aim to support innovators, start-ups, and SMEs to jointly develop smart logistics solutions in close cooperation with industries and ventures. DIGILOGIC sees the horizontally connecting logistics industry at the converging point of interest and priorities for digital innovation for social and business development, a crucial node for Europe's and Africa's sustainable prosperity.

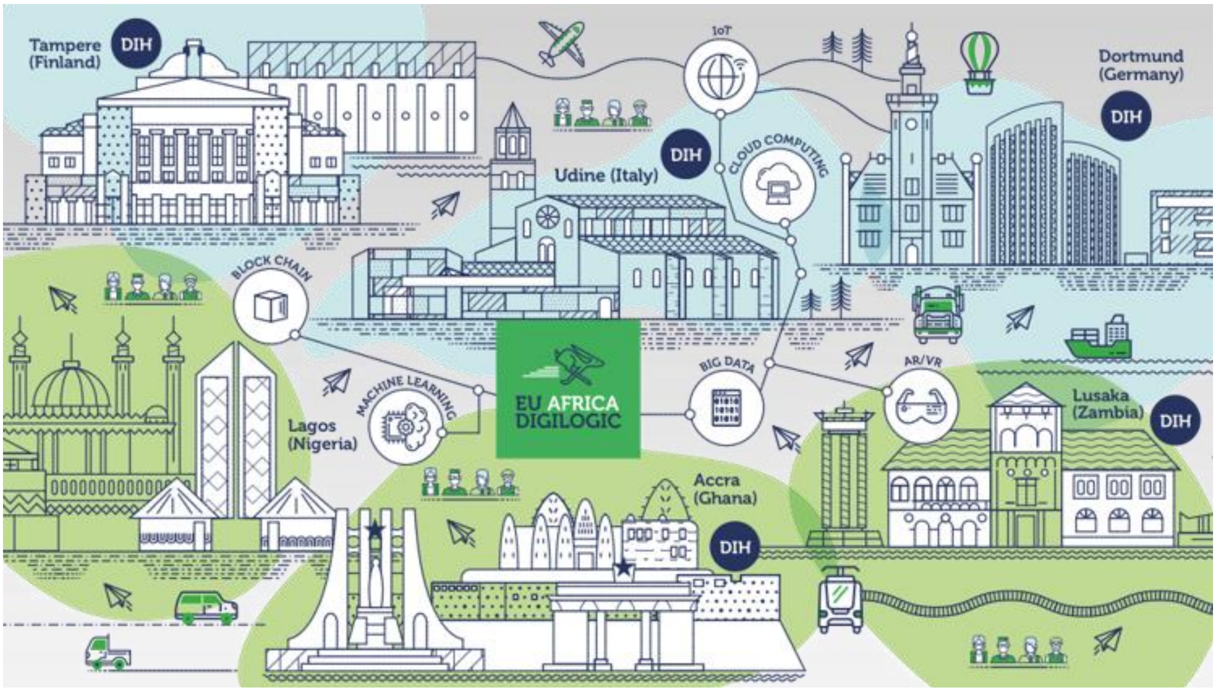

FIGURE 1: DIGILOGIC OVERVIEW

As summarized in Figure 1, the objectives of the DIGILOGIC Project are listed below.

- To establish a Pan EU-Africa network of initially five DIHs focused on the topic of smart logistics and achieve seamless collaboration between the hubs and their pool of emerging technology innovators.
- To strengthen the DIHs technology transfer capabilities to advance African innovators and ICT professionals for better job opportunities.
- To empower African youth, especially women and vulnerable groups with entrepreneurial and digital literacy skills to significantly increase good quality employment opportunities, including self-employment.

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- To demonstrate the market relevance of DIGILOGIC network of DIHs engaging at least 200 innovators in the call for *Challenges*, to participate in the collaborative projects, and value creation in different use cases suggested by stakeholders needs.

- To ensure post project sustainability and growth of the DIGILOGIC ecosystem.

As summarized in Figure 2, the DIGILOGIC project is structured into six work packages, and WP7 that covers ethics requirements. The objective of WP1 CONNECT is to create long-lasting partnerships between the engaged EU-AU DIHs to achieve concrete, tangible, and sustainable impact on digital innovation in Africa. WP2 GROUND aims to establish a common knowledge base on the logistics value chain as well as to transfer knowledge on digitization for the logistics cases addressed by DIGILOGIC. The goal of WP3 LEARN is to develop an enabling environment managed by EU-AU DIHs for digital start-ups in Africa. These start-ups are to be supported by market driven peer learning and consequent upskilling in digital and entrepreneurship domains. **WP4 IMPLEMENT's objective is to foster an enabling environment for digital start-ups as well as to establish networks between European and African innovative entrepreneurs and potential investors**. WP5 BOOST covers the planning and implementation of the project's dissemination, communication, and exploitation activities. WP6 MANAGE is the project management work package of the DIGILOGIC project.

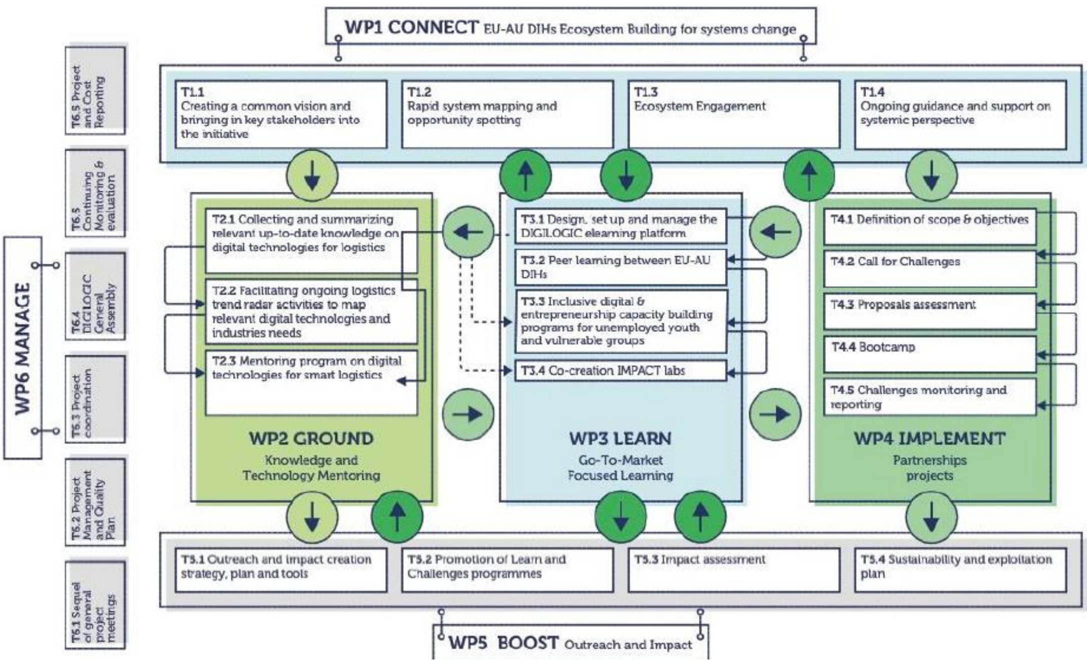

FIGURE 2: DIGILOGIC WORK BREAKDOWN STRUCTURE

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1.2 WP4 TASKS

A summary of the five tasks in WP4 is shown in Table 1. As can be seen in Table 1, Task 4.1 (T4.1) provides the basis for the subsequent four tasks. In common with all WP4 task, T4.1 is led by VTT in collaboration with B-Hive and MEST in Africa, and DHM in Europe.

TABLE 1: WORK PACKAGE 4 TASKS

Task No.	Task		Lead	Duration
T4.1	**Challenges Scope and Objectives.**	Based on the work in and collaboration with WP1 and WP2 will define the overall scope and objectives of the four Challenges, as input to the documentation describing the "Call for Challenges". Contributors: B-HIVE, DHM, MEST.	VTT	M6 - M12
T4.2	Call for Challenges	The outcome from this Task is the "Call for Challenges" set of comprehensive documentation to inform the formulation and evaluation of proposals to address the challenges. Contributors: B-HIVE, DHM, FINN, MEST.	VTT	M13 – M20
T4.3	Proposal Selection Report	The purpose of this Task is to select 12 logistics projects from the submitted proposals for progression to T4.4. Boot Camp. Contributors: B-HIVE, DHM, FINN, MEST.	VTT	M21 - M22
T4.4	Boot Camp	This task will involve organization of a 3-day Boot Camp that brings together the proposal teams selected in T4.3. Contributors: All.	VTT	M23 – M24
T.4.5	Monitoring and Reporting	The selected teams will receive tailored mentoring, coaching, and facilities access in order to carry out their projects. This will involve in-process joint assessment and on-going formulation of team-specific support. Contributors: B-HIVE, DHM, MEST.	VTT	M25 – M36

A timeline for WP4 is shown in Figure 3. This encompasses the definition of logistics challenges to be addressed in T4.1; the launch of call for proposals in T4.2; evaluation of proposals in T4.3; the boot camp for 12 teams selected from the proposals in T4.4; and the implementation of projects by the 12 teams in T4.5. The implementation projects will involve tailored mentoring, coaching, and facilities access provided by the DIGILOGIC consortium, boards, and other experts. Also, the timeline highlights that projects will be invited to showcase their results at the DIGILOGIC Final Demonstration Day, which is scheduled for October 2023.

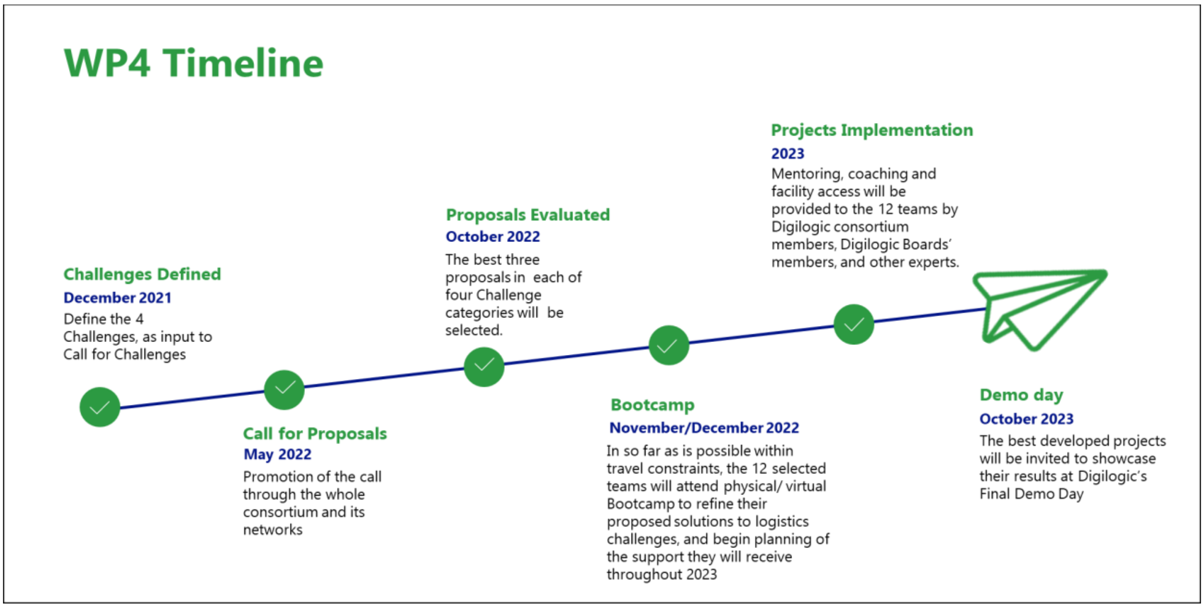

FIGURE 3: WORK PACKAGE 4 TIMELINE

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1.3 WP4 DELIVERABLES AND MILESTONES

A summary of the four deliverables from WP4 is shown in Table 2. Deliverable 4.1 (D4.1) provides the basis for the subsequent three deliverables. In common with all WP4 deliverables, D4.1 is led by VTT and is a public report.

TABLE 2: WORK PACKAGE 4 DELIVERABLES

Del No.	Deliverable
D4.1	**Challenges Scope and Objectives** (R, PU, M012, Leader VTT). This Deliverable defines the overall scope and objectives of the logistics Challenges, as input to Deliverable D4.2, describing the "Call for Challenges"
D4.2	Call for Challenges (R, PU, M17, Leader VTT) This Deliverable is a set of documentation, which describes all the requirements and procedures relating to the Call for logistics-focused projects.
D4.3	Proposal Selection Report (R, PU, M22, Leader VTT). This deliverable provides a summary of the Challenges proposals and teams that were selected following the evaluation process. It includes statistics regarding the number of proposals submitted, net value of the total number of proposals and the cost of funding the selected proposals.
D.4.4	Challenges Conclusion Report (R, PU, M34, Leader VTT). This Deliverable is a compilation of the individual projects reports that are made as the projects progress.

As shown in Table 3, two of the DIGILOGIC project's milestones are within WP4. These are the launch of the call for proposals to address logistics *Challenges* at M17, and the completion of the Boot Camp at M24.

TABLE 3: WORK PACKAGE 4 MILESTONES

Milestone No.	Milestone Name	Means of verification	Due Date
MS6	Launch of DIGILOGIC Challenges	DIGILOGIC Challenges published	M17
MS7	Bootcamp	Bootcamp held	M24

1.4 DOCUMENT STRUCTURE

The remainder of this deliverable document comprises four further sections. Next, in section 2, the methodology for work carried out in T4.1. is described. Then, in section 3, the scope of the logistics challenges to be addressed in terms of topics, participants, and technologies. Subsequently, in section 4, the objectives of one-year programming of support for the 12 teams selected in T4.3 are discussed. In the concluding section, 5, a summary of T4.1. work is provided, and next steps in WP4 are outlined.

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2 METHODOLOGY

As described below, the method of work in T4.1 has been to carry out multiple iterations of reference to multi-vocal literature and obtaining expert inputs from DIGILOGIC consortium partners, from DIGILOGIC High Level Advisory Board and Impact and Innovation Board, as well as from grass roots organizations.

2.1 MULTI-VOCAL LITERATURE

Multi-vocal literature reviews encompass formal academic literature and other types of publications [1]. Reference was made to peer-reviewed academic literature about innovation entrepreneurship in scientific journals. For example, the scientific journal paper “Predicting entrepreneurial success is hard: Evidence from a business plan competition in Nigeria”, which is published in the Journal of Development Economics [2], provides rigorous analyses of alternative methods for evaluating entrepreneurs’ business plans. In doing so, the paper reveals the profound difficulties of evaluating which start-ups will go on to be successful. Other types of publications include publicly available online information produced by businesses, communities, institutions, governments, and/or NGOs. Such publications are not necessarily peer reviewed and controlled by commercial publishers, but can provide clear representations of practice information. For example, the online publication from Fortune magazine, Why Startups Fail, According to Their Founders https://fortune.com/2014/09/25/why-startups-fail-according-to-their-founders, provides insights into the reasons why start-ups have such a low success rate.

2.2 EXPERT CONTRIBUTIONS

Expert inputs have been obtained through iterations of discussions with DIGILOGIC consortium partners. Also, expert inputs have been obtained through discussions with members of DIGILOGIC’s High Level Advisory Board (HLAB) and DIGILOGIC’s Impact and Innovation Board (IIB).

In particular, DIGILOGIC organised the first High-Level Advisory Meeting on Wednesday 21st July 2021, which included Flora Tibazarwa, Programme Director SAIS Programme, Mark Mwangi Founder CEO Amitruck, Fabio Scala Director at BNI - Banco Nacional de Investimento, Professor Olayinka David-West, Associate Dean, Lagos Business School, Pan-Atlantic University, Professor Rajkumar Roy, Dean, School of Mathematics, Computer Science and Engineering City, University of London, Holger Schneebeck Global Innovation Manager for Deutsche Post DHL, Chuka Alumona Franklin Alumona, Director - Global GTM Transformation and Distributor operations, Procter & Gamble, Mark Allison, Supply Chain and Logistics Executive, RTT Steven Gray Director Wardour Global and Eric Lwao Manager Postal Services for the Zambia Information and Communications Technology Authority (ZICTA).

During the meeting, a preliminary formulation of the *Challenges* Scope and Objectives was presented, and HLAB members provided feedback. Subsequently, there was a follow-up meeting with Flora Tibazarwa and Olayinka David-West, which involved very in-depth discussion.

In addition, DIGILOGIC organised its first Impact and Innovation Board Meeting on Wednesday 18th of August, with the participation of six expert Board members, Nanko Madu Senior Programme Manager of AfriLabs, David Coleman Founder and CEO of Cole Collective, Sesinam Dagadu Founder of SnooCode, Onyekachi Wambu Executive Director at the African Foundation for Development (AFFORD), Juha Kunnas Head of Product at Vakava Technologies, Obaro M. Osah AGM, SME South, SME Group at the Bank of Industry.

Again, during the meeting, a preliminary formulation of the *Challenges* Scope and Objectives was presented, and IIB members provided feedback. Subsequently, there were two follow-up meetings with David Coleman.

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These interactions with HLAB members and IIB members informed further development of the *Challenges* Scope and Objectives. Furthermore, they involved obtaining agreement from HLAB and IIB members that they could contribute to evaluating proposals in T4.3, and to providing coaching support in T4.5.

As well as obtaining inputs from experts in the DIGILOGIC consortium and its boards, discussions have also been carried out with experts involved in African grass roots innovation and entrepreneurship including International Development Innovation Network-Southern Africa Developing Countries (IDIN-SADC) and South Africa's Grass Roots Innovation Programme. This is important to address the aim of the European Union, as summarized by Jutta Urpilainen, the European Commissioner for International Partnerships, "The digital transformation must work for all people. No one should be left behind".

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3 SCOPE

In this section, the scope of logistics *Challenges* encompassed by WP4 is described in terms of topics to be addressed, geographic and demographic inclusivity, and breadth of technological options to be considered.

3.1 TOPICS

As summarized in Figure 3, building on work carried out at the beginning of the DIGILOGIC project in Task 1.1 Creating a common vision and bringing in key stakeholders into the initiative, and in Task 1.2 Rapid system mapping and opportunity spotting, scope of topics for the *Challenges* are defined as warehousing, transportation, point of sale, and end consumer.

FIGURE 4: CHALLENGES TOPICS

3.1.1 Warehousing

The topic of warehousing encompasses issues such as the automatization, cold chain storage, the pooling of resources, and the tracking of inventory.

3.1.2 Transport

The topic of transportation includes issues such as cold chain monitoring, driver safety, environmentally-friendly vehicles, load matching, routing, tracking, vehicle safety.

3.1.3 Point of sale

The topic point of sale covers issues such as addressing, inventory technologies for distributors and retailers, ordering technologies for distributors and retailers, routing, smart payment, and tracking.

3.1.4 End consumer

The topic end consumer encompasses issues such as addressing, biometric identification (ID), know-your-customer (KYC) analytics, smart lockers, and tracking.

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3.2 PEOPLE

3.2.1 Roles

Roles are being members of the 12 C*hallenges* teams and being providers of support to the 12 *Challenges* teams. Support will be provided as team-specific mentors or as subject-specific coaches. Support can be provided by members of the DIGILOGIC consortium; members of DIGILOGIC Boards; and experts from outside of DIGILOGIC. All team-specific mentors will be members of the DIGILOGIC consortium. Team-specific mentors will provide each team with its main point of contact throughout the one-year support programme. Subject-specific coaches will provide expert support for the transfer of specific technologies or for the transfer of specific methodologies to several teams. Subject-specific coaches can be from within the DIGILOGIC consortium and from DIGILOGIC Boards. In addition, they can be from outside of DIGILOGIC: for example, from government offices interested in start-up initiatives and/or from large companies interested in connecting with start-ups. Coordination of roles will be carried out via the DIGILOGIC Community Platform.

3.2.2 Geographical inclusivity

In accordance with the EU's priority that "The digital transformation must work for all people. No one should be left behind", proposals to address logistics *Challenges* will be considered from teams with participants from the widest geographical scope within the reach of the DIGILOGIC consortium. In particular, *Challenges* team members can come from urban areas and from rural areas of the following countries: Ghana, Nigeria, Zambia, Finland, Germany, Italy. Also, from Botswana, Kenya, Malawi, Mozambique, Namibia, South Africa, Zimbabwe. As illustrated in Figure 5, participants from rural areas can be involved through rural innovation centres, such as those in Botswana, which are connected to the wider International Development Innovation Network-Southern Africa Developing Countries (IDIN-SADC) [3]. This is consistent with the primary objective of the DIGILOGIC project to boost the cooperation and partnership between African and European innovation hubs.

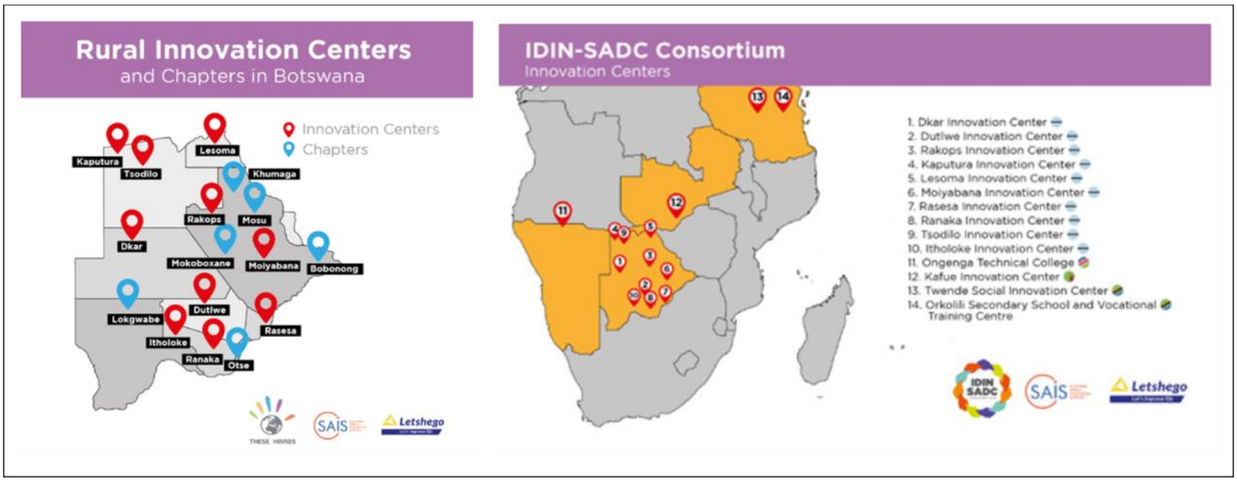

FIGURE 5: GEOGRAPHIC INCLUSIVITY

3.2.3 Demographic inclusivity

There will be diversity among members of the 12 *Challenges* teams and among providers of support to the 12 *Challenges* teams. As one of the overall objectives of the DIGILOGIC project is to empower African youth, especially women and vulnerable groups, proposals to address logistics challenges will be considered from teams that are at the idea-stage. Moreover, in accordance with the EU's priority that "The digital transformation must work for all people. No one should be left behind", idea-stage start-ups will be considered from rural areas, as well as urban areas. This can be facilitated through collaboration with grass roots organizations such as International Development Innovation Network-Southern Africa Developing Countries (IDIN-SADC) and South Africa's Grass Roots Innovation Programme. In addition, proposals to address logistics challenges will also be considered from scale-stage start-ups. This is because they can also be important to another of DIGILOGIC's

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overall objectives: to strengthen the DIHs technology transfer capabilities to advance African innovators and ICT professionals for better job opportunities.

3.3 TECHNOLOGIES

As summarized in Figure 6, comprehensive detailed technology analyses will be carried out using rigorous methodologies in order to determine which technologies can bring significant net benefits reliably [3-5].

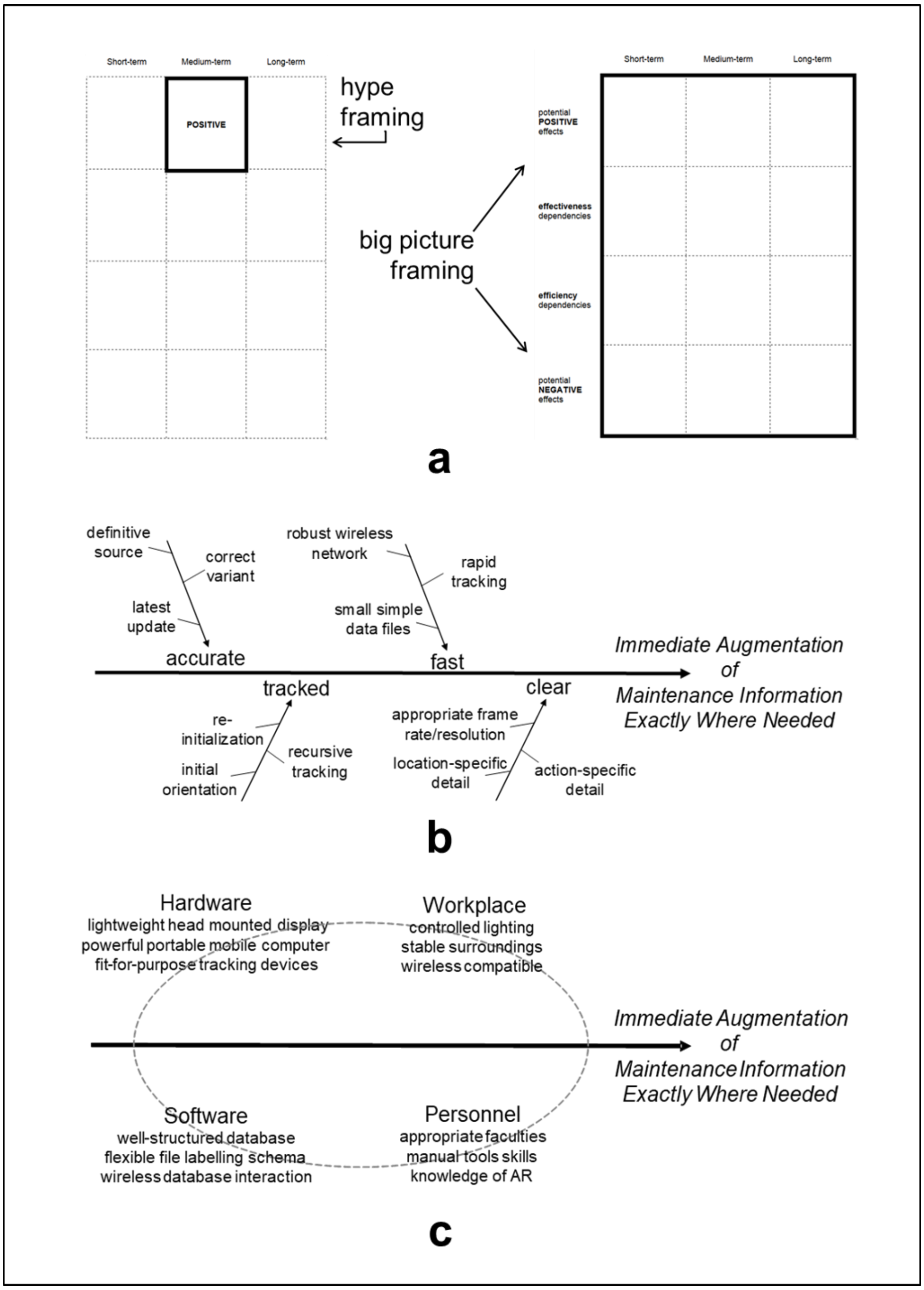

FIGURE 6: COMPREHENSIVE DETAILED TECHNOLOGY ANALYSES [4-6]

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For example, as summarized in Figure 6a, technology analyses will encompass potential negative effects as well as potential positive effects. At the same time, the dependencies upon which effects depend will be analysed in detail in terms of causal mechanisms (Figure 6b) and the causal contexts (Figure 6c) upon which those mechanisms depend. Technology analyses, which will be led by VTT, begin during the evaluation of proposals, continue during bootcamp, and throughout the 12 projects as necessary.

Solutions to address logistics challenges can take into account the potential of a wide range of technologies, including: artificial intelligence, augmented reality, big data analytics, digital twins, distributed ledger, e-vehicles, Internet of Things, next generation wireless, platforms and marketplaces, secure data exchange and data sovereignty, smart payment, virtual reality, 3D printing. From the outset, the potential of alternative technological options will be evaluated in terms of their general readiness level and their situation readiness level. For example, their readiness level in rural African situations compared to urban Europe situations. This will serve to address another of DIGILOGIC's overall objectives: To strengthen the DIHs technology transfer capabilities to advance African innovators and ICT professionals for better job opportunities.

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4 OBJECTIVES OF CHALLENGE SUPPORT PROGRAMME

In this section, the objectives of the programme of support for the 12 *Challenges* teams selected are described in terms of future-proofing, nature-based solutions, generative learning, and high reliability.

4.1 OVERVIEW

As explained in more detail in the following sub-sections, the objectives of the WP4 one-year programme of support to the 12 teams selected to address logistics challenges are as follows:

- to add to the capacity of the 12 *Challenges* teams to grow sustainably by co-development of their **future-proofing** [7] expertise (section 4.2);
- including principles from **nature-based solutions** for high performance adaptation (section 4.3) e.g. active inference (for example, please refer to DIGILOGIC news pieces in Annex 2 and Annex 4; introductory DIGILOGIC journal paper in Annex 3 [8]; and detailed DIGILOGIC paper in Annex 5 [9]);
- together with methodologies with proven potential to increase life spans e.g. **high reliability** organizations (section 4.4) [10,11] through-life engineering [12,13], total quality management and associated methodologies such as six sigma [14,15];
- with tailored mentoring / coaching / facilities access based on joint in-process co-design, monitoring, evaluation, and **generative action learning** [16] for continuous improvement (section 4.5).

4.2 FUTURE-PROOFING

Start-ups are founded by entrepreneurs with the aim of developing scalable enterprises. However, despite start-up founders aiming for growth, the average failure rate of start-ups is approximately 90 percent [17,18]. Thus, rather than grow, nine out ten start-ups do not even survive. Moreover, predicting which start-up will be successful is so difficult that it can be more effective to allocate start-up funding randomly rather than on the basis of analyzing start-ups' plans [19,20]. Accordingly, new perspectives are needed to better enable start-ups' survival and growth. This is particularly important for start-ups that will need to move goods amidst physical shocks / stresses caused by widespread climate-related environmental changes [21-26]. Thus, in DIGILOGIC, as explained further in sections 4.3, 4.4., 4.5, we aim to develop the future-proofing capacity of the 12 Challenges team start-ups. Future-proofing involves anticipating future shocks / stresses and applying methods to minimize their effects [7,9].

4.3 NATURE-BASED SOLUTIONS

In 2021, it is argued that, in order to avoid exacerbating climate change and to develop the resilience of human enterprises to climate change, nature-based solutions are preferred [27,28]. Nature-based solutions are very relevant for addressing uncertainties in logistics. This is because success in logistics involves addressing uncertainties about natural science fundamentals: matter, information, and energy. For example, uncertainties about goods to be transported (matter), about route instructions (information), and about fuel consumption (energy). Moreover, reference to natural sciences can be especially important for start-ups, and for large organizations, where uncertainties are introduced into logistics unpredictably by extreme weather events and other disruptions emerging from nature. One nature-based framework that can be applied for logistics start-ups is the active inference framework. This is focused on taking action in the world in order to reduce uncertainty about how to survive. Importantly, active inference is applicable to all levels of life from brain cells to individual people to large enterprises. Hence, it is very relevant to start-ups that want to grow from one person with an idea to a small team to a large organization [7,29].

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4.4 HIGH RELIABILITY ORGANIZATIONS

High reliability organizations (HRO) [10,11] have reliable and effective operations amidst the dynamic complexity of inter-related technologies operating in unpredictable environments. HROs employing five main principles as follows: (1) high awareness of the state of operating systems and processes; (2) acceptance that the work to be done is complex with the potential to fail in new and unexpected ways; (3) preoccupation with the potential for failure, which recognizes near misses and uses them as opportunities to improve; (4) deference to the expertise of those who do the work rather than those who manage those who do the work; and (5) practicing for resilience by training for potential operating disruptions. These HRO principles are very relevant to logistics start-ups that seek to grow from an individual to an organization, using new combinations of technologies, amidst environmental and competitive uncertainties. Furthermore, HRO principles and practices can be complemented by reference to methods in through-life engineering [12,13] and total quality management [14,15], which can make market-offerings and companies more resilient amidst change.

4.5 GENERATIVE LEARNING

Generative learning is the process of transforming incoming information into usable knowledge. Generative learning involves actively constructing meaning from to-be-learned information by mentally reorganizing it and integrating it with one's existing knowledge. Within generative learning, the mind is not a passive consumer of information. Rather, the mind actively constructs its own interpretations of information and draws inferences on those interpretations. This form of active cognitive processing enables learners to develop an understanding of the material that they can apply in new situations. Accordingly, the one-year programme of support for the 12 challenge teams will be based on joint in-process co-design, monitoring, evaluation and improvement of mentoring, coaching, and facilities access for generative action learning. In particular, the 12 challenge teams will be active in the tailoring of their own programme to suit their own needs as they emerge throughout the year. This will involve selecting and tailoring from support options including the following options:

- sustainable business design (e.g. customer, end-user, and beneficiary journey; go-to-market strategy for flexible growth including new technologies and business models for digital logistics);
- critical evaluation and implementation planning for new technologies;
- continuous improvement methodologies for high-reliability in changing times including set-based design;
- financial sustainability, including opportunities to access funding in AU and EU;
- growing as resilient teams: mentoring co-designed with each team for each team (e.g. purpose and resilience as founders and teams in Africa and Europe);
- physical and mental well-being for high-performance;
- storytelling and pitching skills;
- developing pivoting skills as a core competence in relation to new technologies and business models for digital logistics;
- planning team building for different growth trajectories, and developing team supporting skills;
- Africa/Europe ecosystem development/navigation (e.g. community building through identifying important shared stakeholder networks for each team);
- initiating and managing investor relations;
- resilient value chain management;
- operating within different regulatory environments;
- Africa - Europe unique selling proposition.

To foster generative learning throughout the one-year programme, there will be monthly reviews during which each team will give rating of the jointly co-designed mentoring and of access to facilities used the previous month. Also, the 12 teams will give feedback about how much impact on the development of their capabilities they anticipate the mentoring / facilities they have participated in will have (no effect; small effect; large effect: with narrative examples of types of impact anticipated). In addition, each team will make suggestions for improvements to the support already provided and make predictions of consequent improvement to development of capabilities (e.g. from no effect to small effect; from small effect to large effect; from large effect

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to huge effect). This is important for future applications within and beyond DIGILOGIC. Furthermore, each team will provide a review of its market relevance status, what support is needed next, what resources they may need to change, what practical challenges on the ground are getting better/worse.

Based on this review, there will be co-design of support for the coming month. These monthly activities are consistent with best practice in generative learning, which involves learners being active in summarizing learning and envisaging future use [16].

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5 CONCLUSIONS

5.1 SUMMARY

Work Package 4 of the DIGILOGIC project, IMPLEMENT, is focused on carrying out actions with 12 teams of innovators that address logistics challenges. In accordance with the first overall objective of DIGILOGIC, this will contribute to increasing collaboration with the DIHs and emerging innovators across Africa and Europe.

Also, WP4 will strengthen the DIHs technology transfer capabilities to advance African innovators and ICT professionals for better job opportunities. In addition, work done in WP4 will contribute to empowering African youth, especially women and vulnerable groups with entrepreneurial and digital literacy skills to significantly increase good quality employment opportunities, including self-employment.

Furthermore, WP4 will involve value creation in the different use cases of the 12 teams as suggested by stakeholders needs. Moreover, WP4 will contribute to ensuring post-project sustainability and growth of the DIGILOGIC ecosystem, through interaction with experts in other networks of hubs such as those in IDIN-SADC. Thus, WP4 makes contributions to all of DIGILOGIC's overall objectives.

In this deliverable, 4.1, the scope of logistics *Challenges* and of associated objectives for addressing logistics challenges have been described. In particular, scope has been explained in terms of logistics *Challenges* topics, *Challenges* participants, and *Challenges* technologies. Scope has been related to the overall goal of the EU that the digital transformation must work for all people. No one should be left behind. Objectives have been explained in terms of future-proofing start-ups. This is appropriate as the survival rate of start-ups is very low generally, and logistics amidst climate-change related events in Africa and Europe is a particularly challenging setting for start-ups. Also, objectives have been explained in terms of nature-based solutions, high reliability organizations, and generative learning through joint in-process tailoring of DIHs' support for the 12 start-up teams.

5.2 NEXT STEPS

This document, deliverable 4.1, will provide the basis for further work in WP4 that leads to deliverable 4.2 Call for *Challenges* (R, PU, M17, Leader VTT). This next deliverable will be a set of documentation, which describes all the requirements and procedures relating to the call for logistics-focused projects. It will include text explaining what type of projects are expected, how (and by when) to submit a proposal, the maximum time duration, maximum funding, reporting scheme, etc. Also, it will explain procedures and criteria for the evaluation of proposals. An important feature will be the necessity to be associated with a local DIH that is willing to mentor and monitor the projects. This deliverable will be publicized widely by WP5 via many different media channels.

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6 ANNEXES

There are four annexes: the bibliography; future-proofing startups newspiece; introduction to active inference nature-based solution paper: and future-proofing startups paper.

ANNEX 1: BIBLIOGRAPHY

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ANNEX 2: STARTUP FITNESS NEWSPIECE

Startup Fitness

In 2022, the DIGILOGIC project will make a call for proposals from innovators to develop novel solutions to address challenges in logistics in Africa, in Europe, and between the two continents. From the proposals, 12 teams will be selected for a one-year programme of expert mentoring and access to the facilities of the project partners. The expert mentoring will address the need to future-proof startups. This is essential because the current survival rate of startups is very low.

Dr Stephen Fox, of DIGILOGIC project partner VTT, draws upon decades of natural sciences research in his new journal paper, which relates business survival to fundamental principles for the survival of living things in changing environments.

Dr Fox explains these principles in terms of charts that are widely used in business practice. In particular, radar charts, process control charts, and bar charts. These are used to explain the essential need for businesses, as other living things, to continually reduce information gaps between themselves and environments as both change. In particular, it is imperative for businesses to reduce information gaps by paying continual attention to signals from the external environment and by updating their business models as they do so. In other words, businesses always need to maintain their fit with the changing environments in which they intend to survive: i.e. maintain their ecological fitness. In the opinion of two co-founders of DIGILOGIC project partner, BongoHive, Silumesii Maboshe and Simunza Muyangana, these findings from natural science research are relevant to BongoHive itself and to the many startups that it supports through its wide range of programmes.

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ANNEX 3: ACTIVE INFERENCE INTRODUCTION PAPER

entropy MDPI

Communication

Accessing Active Inference Theory through Its Implicit and Deliberative Practice in Human Organizations

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Abstract: Active inference theory (AIT) is a corollary of the free-energy principle, which formalizes cognition of living system's autopoietic organization. AIT comprises specialist terminology and mathematics used in theoretical neurobiology. Yet, active inference is common practice in human organizations, such as private companies, public institutions, and not-for-profits. Active inference encompasses three interrelated types of actions, which are carried out to minimize uncertainty about how organizations will survive. The three types of action are updating work beliefs, shifting work attention, and/or changing how work is performed. Accordingly, an alternative starting point for grasping active inference, rather than trying to understand AIT specialist terminology and mathematics, is to reflect upon lived experience. In other words, grasping active inference through autoethnographic research. In this short communication paper, accessing AIT through autoethnography is explained in terms of active inference in existing organizational practice (implicit active inference), new organizational methodologies that are informed by AIT (deliberative active inference), and combining implicit and deliberative active inference. In addition, these autoethnographic options for grasping AIT are related to generative learning.

Keywords: active inference; autoethnography; business models; environment; free energy principle; gap analysis; generative learning; joint agent-environment systems; process control; radar charts; survival; variational free energy

check for updates

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1. Introduction

Many human organizations do not survive [1,2]. Apropos, it is recognized in organizational studies that better understanding is needed of interactions between inference, action, and learning [3–5]. Active inference theory (AIT) is relevant to this aim, as AIT encompasses interactions between inference, action, and learning at all levels of life from cells to societies [6]. In addition, AIT is applicable to automation technologies, which are becoming more widely used by human organizations [7].

However, AIT comprises specialist terminology and mathematics from theoretical neurobiology [8,9], which can obscure that active inference is an everyday experience in human organizations. In particular, active inference encompasses three interrelated types of actions, which can be carried out to minimize uncertainty about how organizations will survive. The three types of action are updating work beliefs, shifting work attention, and/or changing how work is performed. Accordingly, an alternative starting point for grasping active inference, rather than trying to understand AIT specialist terminology and mathematics, is to reflect upon lived experience. In other words, grasping active inference through qualitative autoethnographic research, which involves self-reflection on personal experience and connecting those reflections to wider contexts [10].

In this short communication paper, autoethnography is related to wider contexts through a common method in organizational practice: gap analysis with radar charts [11,12]. This is done to illustrate accessing AIT through common practice in human organizations. Next, in Section 2, an introduction to major constructs in active inference is provided in terms of radar charts. Then, in Section 3, a description is provided of active inference

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within established methods in organizational practice (i.e., implicit active inference). Subsequently, in Section 4, combination of implicit and deliberative active inference is discussed, with deliberative active inference being explicit application of AIT in the development of organizational practice. In conclusion, in Section 5, generative learning of AIT is related to autoethnography involving reference to active inference practice in human organizations.

2. Active Inference Constructs

2.1. Varying Survival Information Deficit (i.e., Variational Free Energy)

Living things aim to minimize their uncertainty about how they will survive in the environments in which they are situated. Uncertainty comprises information gaps between living things' models of themselves in the environment and their actual selves in the real environment, for example, an information gap between an organization's sales forecast and its actual sales (e.g., forecast sales of 120 products per week versus actual sales of 100 products per week). One information gap can be related to another. For example, sales forecasts and actual sales are related to cash flow forecasts and actual cash flow (e.g., 120,000 euros income per week versus 100,000 euros income per week). A technical term used in theoretical neurobiology for such information gaps is surprisal.

As illustrated in Figure 1, which uses the radar chart gap analysis format, information gaps combine in the survival information deficit. This varies as living things change and as environments change. In neurobiology terminology, the varying survival information deficit can be described as variational free energy. The bigger the survival information deficit, the worse the fit with the environment. As illustrated in Figure 1c, there is an upper limit to survival information deficit beyond which survival is not possible. In neurobiology terminology, this maximum survival information deficit can be described as variational free energy upper bound [13,14].

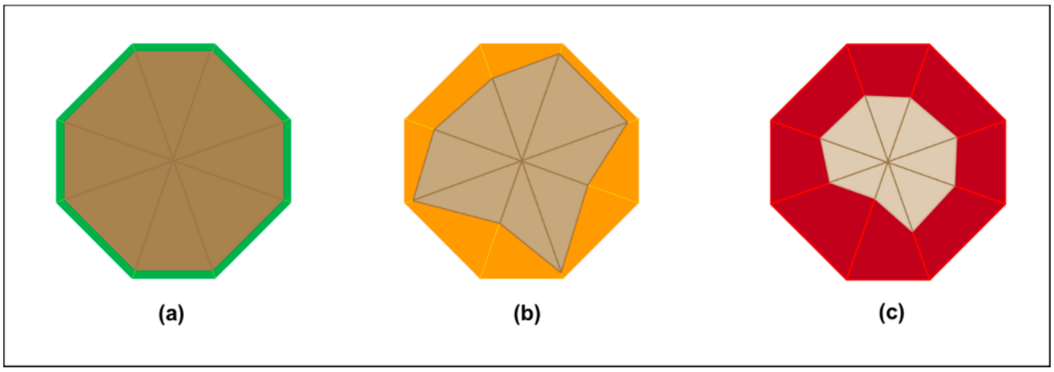

Figure 1. Varying survival information deficit. (**a**) Organization (inner shape) has good fit with the environment (outer shape) due to minimal survival information deficit (green): organization can prosper in the environment. (**b**) Survival information deficit increases but is tolerable (orange): organization can survive in the environment. (c) Survival information deficit increases further and is not sustainable (red): organization cannot survive in the environment unless it improves its fit with the environment. The red area illustrates the maximum survival information deficit for the organization in its current environment.

As with other living things, different human organizations have different maximum survival information deficits at different times as they change and as environments change. For example, an organization with large cash reserves can survive the information gap (i.e., surprisal) of slightly fewer sales than it forecast. Subsequently, however, when the company has used up all its cash reserves, the same company may not be able to survive lower sales than it has forecast because its financial outgoings (i.e., costs) will be more than its financial incomings (i.e., revenue).

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2.2. Forecasting Errors (i.e., Prediction Errors)

As summarized in Figure 2, in order to reduce survival information deficit, organizations can take actions along numerous parameters to change themselves and/or the environments in which they are situated. From an ecological perspective, these survival parameters can be described as fitness components [15]. The term generative process refers to the actual structure of the world that generates observations that are made by the organization. Generative model refers to how the organization expects the observations to be generated [14]. In practice, a generative model corresponds to a business model [16].

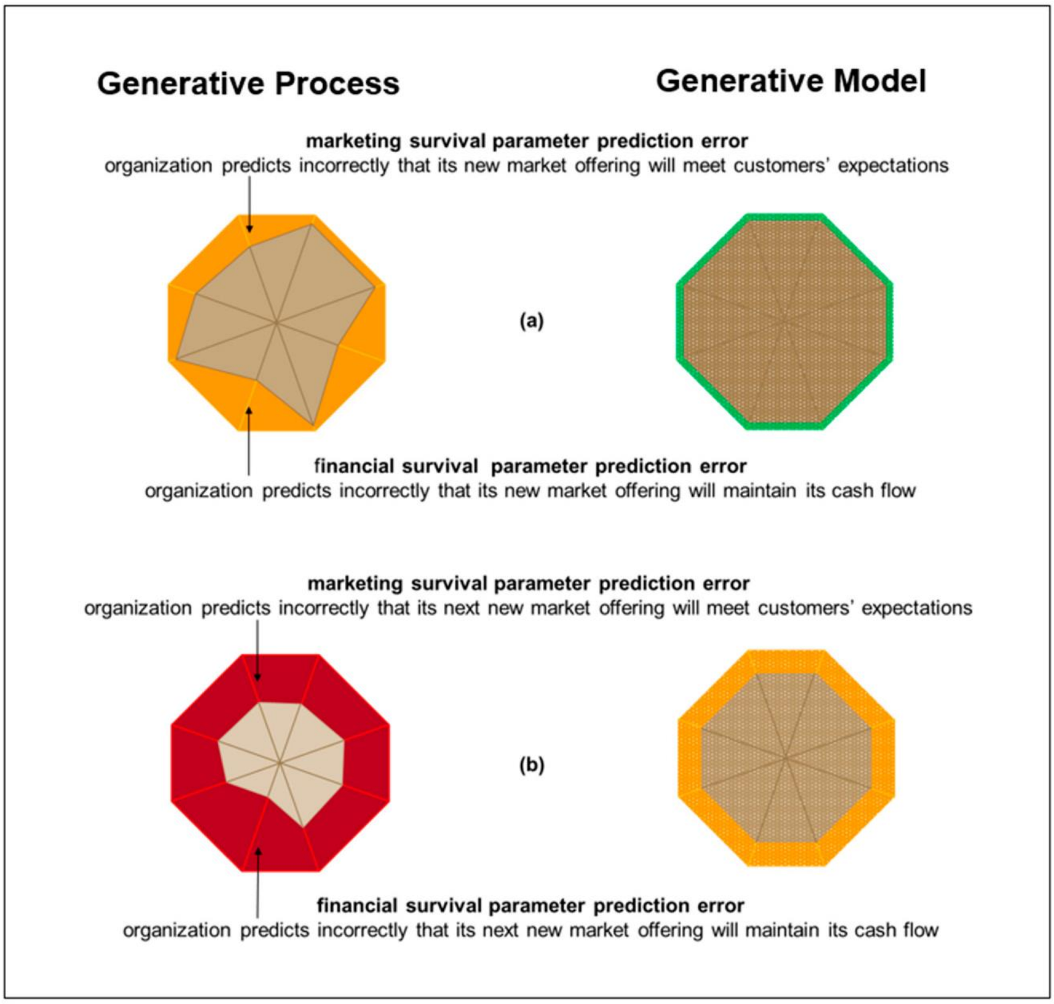

Figure 2. Forecasting errors. (**a**) Expected minimal survival information deficit (green) in the organization's generative model of itself in its environment is increased by forecasting errors about survival parameters to tolerable survival information deficit (orange). (**b**) Expected tolerable survival information deficit (orange) in the organization's generative model of itself is increased by forecasting errors on survival parameters to unsustainable survival information deficit (red).

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Organizations' actions are based on their forecasts about the effects of their actions on their survival parameter information gaps. These parameters can include, for example, marketing, product development, procurement, production, delivery, finance, etc. Together, parameters can comprise an organization's business model [16], which can be described as a generative model in the context of theoretical neurobiology terminology. Forecasts are statements of survival preferences. For example, a preference for surviving in competitive markets through high volume sales of economy goods. Forecasts are predictions of future observations rather than plans that will be inevitably realized. This is because organizations cannot know all causal factors in the environment that can affect their preferred observations, such as preferred observations of high-volume sales. Rather, many causal factors are hidden from the organization. They can be hidden because of the general difficulty of acquiring perfect information. In addition, they may be hidden because of deliberate concealment, such as competitors keeping secret their rapid development of new products. Apropos, in the context of theoretical neurobiology terminology, factors that contribute to causing observations are referred to as hidden states.

Actions are taken iteratively to reduce differences between what is forecast to be observed and what is observed (i.e., to reduce prediction errors). Actions can involve making use of existing information (i.e., exploiting existing information) and/or searching for other information (i.e., exploring for new information). Attention and work can be based more on internal beliefs than information coming from the environment if an organization has more confidence in internal beliefs than in information coming from the environment; or vice versa. Actions can be updating beliefs about how to survive, shifting focus of attention in trying to survive, and/or changing work performed in order to survive. Actions can involve changing self and/or environment in order to improve fit between self and environment.

Figure 2a illustrates an organization making forecasting errors in marketing and in finance. In particular, the organization forecasts incorrectly that its new market offering will meet customers' expectations, and that sales from its new market offering will maintain its cash flow. Consequently, its actual survival information deficit is more than its expected survival information deficit. Figure 2b illustrates that the organization does update its generative model so that its expected survival information deficit is larger but tolerable. However, the organization does not take the needed action of shifting its attention to pay closer attention to customers' expectations. In addition, the organization does not take the needed action of changing its work to provide a new market offering that better meets customers' expectations. Hence, the organization's actual survival information deficit in the generative process of the environment is more than its expected survival information deficit and increases beyond tolerable to unsustainable.

2.3. *Organizational Identity (i.e., Expected Free Energy)*

As illustrated in Figure 2a, forecasting errors can combine to increase actual survival information deficit. Then, as illustrated in Figure 2b, actual survival information deficit can lead to an organization updating its expected survival information deficit. In the context of theoretical neurobiology terminology, expected survival information deficit can be described as expected free energy. It is important to note that while forecasts can be made for survival parameter information gaps, forecasts cannot be made for expected survival information deficit.

In the context of theoretical neurobiology, explanations of why expected free energy cannot be predicted involve specialist mathematics. By contrast, those working in organizational practice can make reference to everyday experiences to understand why expected survival information deficit cannot be forecast. For example, from an internal perspective, different survival parameters involve different types of information, such as product sales in product units and cash flow in financial currency. Accordingly, survival information gaps cannot be added together into an overall amount. From an external perspective, market responses are different on different survival parameters. For example, competitors

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may introduce new products and banks may change financial arrangements. Again, these changes cannot be added together into an overall amount. Moreover, there can be unpredictable interactions between different external organizations and other causal factors in the environment that are hidden from the organization. For example, sudden weather events can disrupt both supply into the organization and demand for its products.

Hence, rather than being a forecast, expected survival information deficit is an expectation of the impression that an organization will make on its environment. This can be considered in terms of organizational identity, which encompasses how an organization prefers to see itself and would prefer to be seen by others [17,18]. For example, an organization could prefer to be seen as an organization with a strong financial base that provides its customers with good value products. As observations of an organization will be different among different people, expected survival information deficit can be considered as an average.

3. Implicit Organizational Active Inference

Active inference is implicit in some existing practices in human organizations. In this section, a short summary is provided that goes beyond extant literature [19] by relating process management charts to AIT surprisal and to countervailing preferences for suprisal minimization within human organizations [20]. As shown in Figure 3, organizations can plan and monitor survival parameter actions using bar charts, such as Gantt charts [21]. These charts are widely used in project activities, such as product development. Figure 3a illustrates that the bars on such charts can provide summaries of preferred, expected, tolerable, and unsustainable outcomes from actions. The forecast is that the action outcome will be within the expected range. There is a forecasting error because, as shown in Figure 3b, the actual action outcome is outside the expected range on the survival parameter.

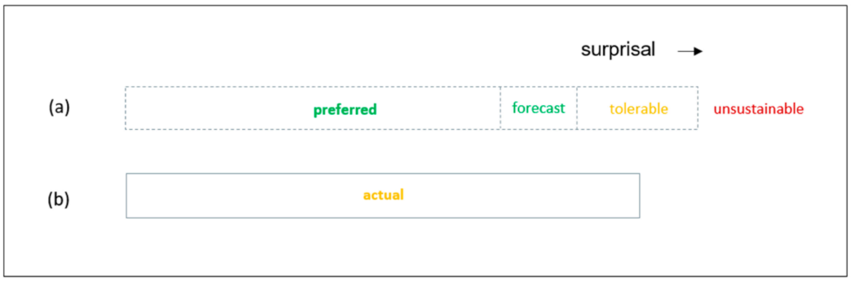

Figure 3. Gantt chart style activity bar. (**a**) The planning bar shows the preferred, forecast, tolerable, unsustainable ranges for the activity. The term surprisal is applicable to the tolerable range and unsustainable range. (**b**) The bar shows the actual activity outcome, which is more than expected but within tolerable limits.

As shown in Figure 4 below, organizations can also plan and monitor survival parameter actions using statistical process control charts [22]. These charts are widely used in repetitive activities, for example in mass production. Figure 4 shows that such charts can have upper control limits (UCL) and lower control limits (LCL), within which are upper warning limits (UWL) and lower warning limits (LWL). UWL and LWL indicate the limits of expected deviation from the mean that represents the preferred process outcome. UCL and LCL indicate the limit of tolerable deviation from the mean. The forecast is that the process will stay within the expected deviation from the mean, i.e., between the UWL and the LWL. In Figure 4, the actual processes have been operating within the expected deviation from the mean (i.e., between UWL and LWL) but have begun to drift outside the expected range. Thus, there is a forecasting error.

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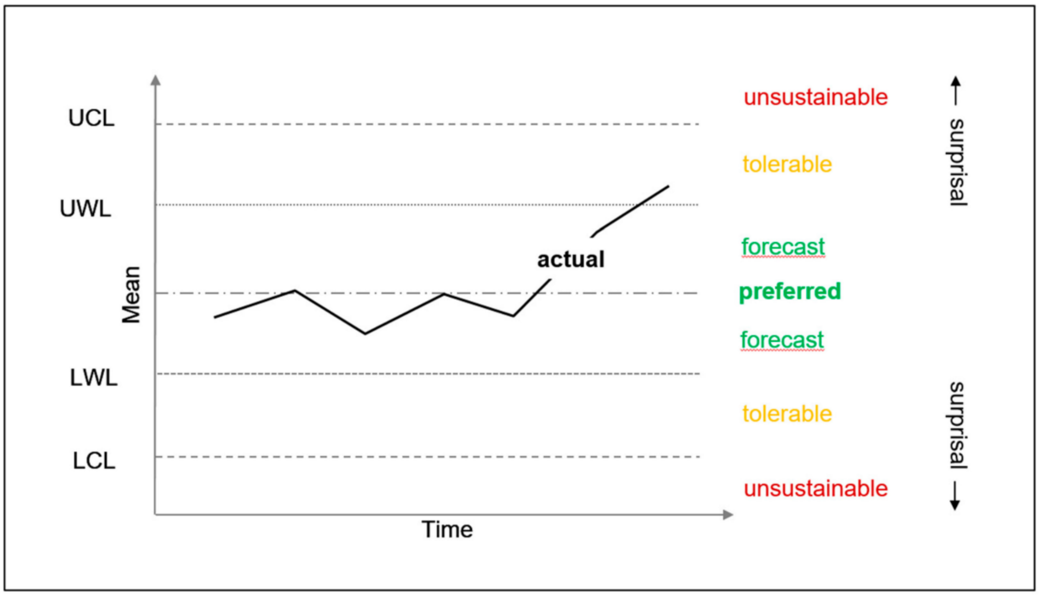

Figure 4. Statistical process control chart. The forecast is that the process will stay within the expected deviation from the mean. UWL (upper warning limit) and LWL (lower warning limit) indicate the limits of expected deviation from the mean that is the preferred process outcome. UCL (upper control limit) and LCL (lower control limit) indicate the limit of tolerable deviation from the mean. The actual processes have been operating within the expected deviation from the mean (i.e., between UWL and LWL) but have drifted outside the expected range. Thus, there is a forecasting error. The term surprisal is applicable to the tolerable range and unsustainable range.

It is routine for organizations to make precise forecasts about survival parameter actions. These can include sales forecasts for a new market offering and forecasts of cash flows from those sales (Figure 2). They can also include durations for product development projects that are intended to bring new products to market before competitors (Figure 3). In addition, they can include manufacturing dimensions for new product parts (Figure 4). As illustrated in Figure 2, predictions errors on individual survival parameters are interrelated in affecting survival information deficit. However, their interactions are characterized by dynamic complexity between each other and as they interact with the environment. For example, launching a new product later than predicted during product development planning can give competitors an advantage. Also, manufacturing outside of predicted dimensions can lead to poor product operation, which leads to potential customers buying competitors' products. Both of these can lead to lower than predicted sales and lower than predicted cash flow. However, effects on sales and cash flow are also dependent upon the actions of competitors. Thus, survival information deficit cannot be predicted precisely. Rather, process charts are applied to individual internal processes on individual survival parameters. They do not enable organizations to control the environment, which can exert determining influence over survival information deficit. Hence, predictions about the outcome of an action, or a series of actions, on a survival parameter are not predictions of survival information deficit. Rather, they provide a basis for expectations about the survival information deficit.

Within active inference theory (AIT), there are not process management constructs such as those in Gantt charts and SPC charts. Rather, there are preferred observations and the fundamental goal of surprisal minimization. Accordingly, there are not gradations such as tolerable and unsustainable in AIT. However, organizations need process management charts in order to manage countervailing preferences within organizational silos [20]. For

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example, a product development department may prefer to spend more money and take more time than competitors to minimize product surprisal. In other words, to minimize the gap between the product to be offered by the organization and potential customers' ideal product. By contrast, the sales department would prefer to introduce a new product at a lower price and before its competitors. This being preferred to minimize sales surprisal, i.e., to minimize the gap between sales forecasts and actual sales. Apropos, process management charts are used to address the potential for organizations' personnel to minimize the source of surprisal that is most important to them, but to increase another source of surprisal that is less important to them. In addition, process management charts address the potential for causes beyond the control of the organization to affect processes. For example, SPC charts used in manufacturing address the potential for the properties of natural materials to affect the accuracy of their machining. Consider, for example, the potential for knots in hardwood to decrease the precision of their machining into furniture components. This can lead to machining drifting above warning limits towards control limits. This can happen despite the best efforts of personnel to keep machining within warning limits: i.e., to minimize machining surprisal. Here, there can again be countervailing preferences that need to be managed. For example, machining surprisal could be minimized by the organization buying hardwood that has far fewer knots. However, such hardwood could be far above the financial budget for manufacturing the furniture components. Thus, machining surprisal could be minimized at the expense of budget surprisal. So it is that minimizing surprisal in human organizations can involve managing multiple countervailing preferences with the aid of process management charts.

4. Combining Implicit and Deliberative Organizational Active Inference

Deliberative active inference involves making reference to AIT literature in the development of new organizational practice. One detailed example of deliberative active inference is reported in [23]. As summarized in Table 1 below, there can be five generalizable characteristics of deliberative active inference. First, there is an aspect of organizational survival that is not addressed successfully already by implicit organizational active inference. Second, AIT literature suggests new directions for addressing the issue. Third, AIT can be related to other theoretical resources from research in the natural sciences. Fourth, new methods based on deliberative active inference can be related to established constructs from organizational studies. Fifth, new methods based on deliberative active inference can be related to established organizational practice. The remainder of this section describes a new example in which these five characteristics are considered, and in which there can be combination with implicit active inference from the outset. In particular, implicit active inference in the use of radar charts [11,12].

Table 1. Characteristics of Deliberative Active Inference.

Characteristic	Example
Issue in organizational survival not addressed successfully by implicit active inference in extant methodologies	Reciprocal synchronicity of organizations and their environments
AIT literature suggests new directions for addressing the organizational issue	AIT studies concerned with joint agent-environment systems
AIT can be related to other theoretical resources from natural science research	Natural science research concerned with joint learning and development of agents and environments
New deliberative active inference method can be related to established constructs from organizational studies	Organizational lifecycles and organizational design
New deliberative active inference method can be related to established organizational practice	Business model design and set-based design

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As summarized in Table 1, an aspect of organizational survival that is not addressed successfully by implicit organizational active inference is the fit of organizations with the environments in which they intended to survive and grow. In particular, fit is not addressed in terms of the reciprocal synchronicity of organizations and environments as they jointly learn to adapt to each other into order to co-exist successfully. AIT literature suggests new directions for addressing this issue through studies concerned with joint agent-environment systems [14] and model structure learning [24]. AIT can be related to other theoretical resources from research in the natural sciences concerned with joint learning and development of agents and environments [25]. New methods based on deliberative active inference can be related to established constructs from organizational studies, for example, organizational lifecycles [26] and organizational design [27]. New methods based on deliberative active inference can be related to established organizational practice in business model design [16] and set-based design [28].

In order to survive, organizations need to adapt their business models, which set-out their what (e.g., market offerings), their how (e.g., operating processes) and their why (e.g., value proposition). Here, it is important to note that notion of business models being generative models is established in organizational studies. For example, it has been argued that business models generate virtuous cycles, or feedback loops, that are self-reinforcing [16]. However, this notion does not address the fundamental problem that self-reinforcement of a business model can lead an organization not learning sufficiently about environmental changes in order to undertake necessary business model adaptation. For example, it is possible for a global provider of instant photographs to recognize that its technology would be superseded by digital photography. Nonetheless, failure to carry out work to adapt in order to provide digital photography can lead to the organization not surviving [29]. More generally, an organization may not survive if its attention and its work are based more on its out-of-date internal beliefs than on new information coming from the environment [30,31]. This fundamental problem is addressed directly in studies concerned with joint agent–environment systems, for example, with formulations such as a stubborn agent might persist in its behavior despite contrary evidence [14]. From an organizational perspective, contrary evidence could be, for example, falling product sales, decreasing revenues, cash flow problems, and other contractions that can lead an organization into a so-called death spiral [32].

AIT literature concerned with model structure learning provides important insights into how organizations can keep themselves open to learning from the environment, rather than learning only to reinforce their existing internal model. In particular, AIT literature encompasses a generative model being equipped with open slots for learning about new concepts. These open slots facilitate model expansion, which can be followed by model reduction in order to prevent models becoming overly complex [24]. Similar in organizational practice is set-based design. This is an approach to design that involves being open to multiple design options simultaneously, rather than successively criticizing and modifying a single design option [28]. However, set-based design is focused on product development and business model design can be focused on reinforcement. Apropos, changing business models from one to another often involves the abrupt change of so-called pivoting [33] rather than continual synchronous adaptation with the environment. By contrast, reference to AIT literature highlights the need for continuous learning with the environment [14] and the need to keep open slots for model expansion together with procedures preventing models from becoming overly complex [24]. Thus, reference to AIT stimulates consideration of set-based business model design in practice in accordance with fundamental active inference questions: should we change our work, should we shift our attention, and/or should we update our current generative model in accordance with new learning from the environment. Throughout, radar charts can be used to regularly map both the organization and the environment as shown in Figures 1 and 2 above.

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5. Conclusions

Theoretical neurobiology terminology and mathematics used in AIT may not be the best starting points for explaining AIT to the widest range of potential beneficiaries. An alternative is for explanation to begin with individuals engaging in autoethnography, i.e., self-reflection on personal experience and connecting reflections to wider contexts [10]. This may be a better alternative for many because all living things that survive are already practitioners in what is intended to be described by AIT terminology and mathematics. In particular, AIT is concerned with the daily experiences of trying to minimize uncertainty about how to survive by updating beliefs, shifting attention, and performing work, which may or may not be influenced by information from the environment depending upon confidence in beliefs. Thus, understanding of active inference can begin by reflecting upon lived experience, such as poor marketing leading to cash flow problems that undermine organizational survival (Figure 2). Then, that lived experience can inform selection and application of AIT constructs when seeking better explanation and improvement of efforts to survive amidst changing environments.

Autoethnography can involve consideration of implicit and deliberative active inference in organizational practice using common methods such as radar charts. Importantly, relating AIT to widely used methods such as radar charts has potential to facilitate generative learning of AIT by people who do not have a background in theoretical neurobiology. Generative learning is the process of transforming incoming information into usable knowledge. Generative learning involves actively constructing meaning from to-be-learned information by mentally reorganizing it and integrating it with one's existing knowledge, for example, existing knowledge of methods applied in organizational practice. Within generative learning, the mind is not a passive consumer of information. Rather, the mind actively constructs its own interpretations of information and draws inferences from those interpretations. This form of active cognitive processing enables learners to develop an understanding of incoming information that they can apply in new situations [34]. For some, the specialist AIT terminology and mathematics used in theoretical neurobiology may provide the best format of incoming knowledge to transform into usable knowledge. For many others, charts and other methods used in everyday organizational practice may provide a better starting point.

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ANNEX 4: FUTURE-PROOFING STARTUPS NEWS PIECE

Future-proofing startups

In 2022, the Digilogic project will make a call for proposals from innovators to develop novel solutions to address challenges in logistics in Africa, in Europe, and between the two continents. From the proposals, 12 teams will be selected for a one-year programme of expert mentoring and access to the facilities of the project partners https://digilogic.africa/the-challenges/. The expert mentoring will address the need to future-proof startups. This is essential because the current survival rate of startups is very low. Future-proofing involves anticipating future challenges and applying methods to minimizes their effects.

One major challenge facing startups is how to deal with stress caused by multiple uncertainties. In order to provide a sound basis for future-proofing related to stress management, Dr Stephen Fox, of Digilogic project partner VTT, draws upon decades of natural sciences research in his new journal paper: https://www.mdpi.com/1099-4300/23/9/1155 Future-proofing startups: Stress management principles based on adaptive calibration model and active inference theory. Active inference involves taking action in the world in order to reduce uncertainty about how to survive. Importantly, active inference is applicable to all levels of life from brain cells to individual people to large enterprises. Hence, it is very relevant to startups that want to grow from one person with an idea to a small team to a large organization.

Eminent neuroscientist Professor Dr Karl Friston, who leads active inference research globally, has witnessed increasing interest in findings from his research that reveal fundamental natural processes. In particular, fundamental natural processes that can have determining influence over human actions and their outcomes. Professor Friston considers that natural sciences research can be very relevant for addressing uncertainties in logistics. This is because success in logistics involves addressing uncertainties about natural science fundamentals: matter, information, and energy. For example, uncertainties about goods to be transported (matter), about route instructions (information), and about fuel consumption (energy). Moreover, reference to natural sciences can be especially important for startups, and for large organizations, where uncertainties are introduced into logistics unpredictably by extreme weather events and other disruptions emerging from nature.

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ANNEX 5: FUTURE-PROOFING STARTUPS PAPER

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Future-Proofing Startups: Stress Management Principles Based on Adaptive Calibration Model and Active Inference Theory

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Abstract: In this paper, the Adaptive Calibration Model (ACM) and Active Inference Theory (AIT) are related to future-proofing startups. ACM encompasses the allocation of energy by the stress response system to alternative options for action, depending upon individuals' life histories and changing external contexts. More broadly, within AIT, it is posited that humans survive by taking action to align their internal generative models with sensory inputs from external states. The first contribution of the paper is to address the need for future-proofing methods for startups by providing eight stress management principles based on ACM and AIT. Future-proofing methods are needed because, typically, nine out of ten startups do not survive. A second contribution is to relate ACM and AIT to startup life cycle stages. The third contribution is to provide practical examples that show the broader relevance ACM and AIT to organizational practice. These contributions go beyond previous literature concerned with entrepreneurial stress and organizational stress. In particular, rather than focusing on particular stressors, this paper is focused on the recalibrating/updating of startups' stress responsivity patterns in relation to changes in the internal state of the startup and/or changes in the external state. Overall, the paper makes a contribution to relating physics of life constructs concerned with energy, action and ecological fitness to human organizations.

Keywords: active inference theory (AIT); adaptive calibration model (ACM); double-loop learning; conservation of resources; free energy principle; physics of life; startups; stress; triple-loop learning

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1. Introduction

Startups are founded by entrepreneurs with the aim of developing scalable enterprises. However, despite startup founders aiming for growth, the failure rate of startups is approximately 90 percent. Thus, rather than grow, typically only one out of ten startups survive. Moreover, predicting which startup will be successful is so difficult that it can be more effective to allocate startup funding randomly rather than on the basis of analyzing startups' plans [1–4]. Accordingly, new perspectives are needed to better enable startups' survival and growth: especially amidst the challenges introduced by widespread climate-related environmental changes [5–10]. Here, future-proofing is relevant. This involves anticipating future challenges and applying methods to minimizes their effects [11–15].

A long established method for improving the performance of organizations is the definition of principles that can guide operations successfully in a wide variety of settings [16,17]. In 2021, it is argued that, in order to avoid exacerbating climate change and to develop the resilience of human enterprises to climate change, nature-based methods are preferred [18,19]. Hitherto, however, underlying principles that guide the organization of nature have not been considered as a basis for providing principles for future-proofing startups. This is despite the nature-based term, ecosystem, being widely used in connection with startups [20,21]. By contrast, in this paper, the Adaptive Calibration Model (ACM) [22] and Active Inference Theory (AIT) [23] are related to the future-proofing of startups.

ACM addresses the allocation of finite time and energy by the stress response system to alternative options for actions, depending upon individuals' life histories and changing external contexts [22]. ACM is relevant to organizational life cycles from an entrepreneur with a startup idea through to the few startups that grow to become large organizations. For example, the need to manage stress is recognized in literature concerned with entrepreneurs [24,25] and large organizations [26,27]. Active Inference Theory (AIT) is a physics of life process theory [23], which is a corollary of the Free Energy Principle (FEP) [28]. Within AIT, living things, including humans, implement internal generative models in order to survive. This involves humans surviving by taking action to align their internal generative models with sensory inputs from external states. In accordance with FEP, this is done to address the existential need for active systems to minimize the long-term average of unwanted surprise from external states: i.e., from the world [28]. Within stress studies incorporating AIT, stress arises from existential information entropy in trying to align the internal state with the external state: i.e., stress arises from uncertainty about survival [29,30]. Apropos, stress can lead to the collapse of higher goals in internal generative models [29], and stress can lead to the formulation of maladapted internal generative models with negative prior expectations that override positive sensory inputs [30].

As explained in the following sections, ACM and AIT can provide physics of life principles for addressing the potential of the stress response system to support or to undermine survival through action. ACM and AIT are related to future-proofing startups in the five remaining sections. In Section 2, ACM is related to life cycle phases of startups. In Section 3, ACM and AIT are related to business model development and marketing. In Section 4, ACM and AIT is related to startup practice in terms of the need for living things to maintain non-equilibrium steady states (NESS). In Section 5, stress management principles for the future-proofing of startups based on ACM and AIT are proposed. In Section 6, principal contributions are stated and directions for further research are proposed. ACM and AIT are applied together in this paper because under active inference, self-organizing systems must select between alternative courses of action based upon their expected potential to align sensory data predicted by the internal generative models with those data generated by external states. However, AIT does not define what are the sequences of stress management actions (i.e., policies) that the self-organizing system can select between. Hence, ACM complements AIT by offering a defined set of stress responsivity patterns that do offer stress management policies that a startup can select between.

Three contributions are intended from the paper. First, to make a contribution to addressing the need for future-proofing methods for startups. Second, to relate ACM and AIT to startup life cycles in order to provide principles for recalibrating/updating stress response patterns to changes in startups' internal states and changes in the external state within which startups seek to survive. This is different to previous studies that have focused on particular stressors [24–27]: rather than on recalibration/updating of stress responsivity patterns. Third, to provide practical examples that show the broader relevance ACM and AIT to organizational practice. Previous research has explained the relevance of AIT to human organizations that offer high volume low variety goods and/or services: e.g., mass production organizations deploying quality management systems. However, previous research has highlighted the need to for further investigation of AIT's relevance to human organizations [31]. Overall, the paper makes a contribution to relating physics of life constructs concerned with energy, action, and ecological fitness to practice in human organizations.

2. Adaptive Calibration Model (ACM): Startup Life Cycle

ACM addresses ways by which living things deploy stress response systems to allocate finite time and energy throughout their life cycle in order to survive [22]. Startups can have four lifecycle stages: business model development, transition, scaling, and exit. During business model development, organization is typically informal. During transition, the loosely structured informality of the initial stage changes to a more structured form that can facilitate rapid scaling. During the scaling phase, functional specialists take roles once covered by generalists, and formal procedures replace ad hoc decision making. At some

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point, an "exit" is undertaken through initial public offering of shares, private sale, merger, or acquisition [32]. In terms of ecological fitness, these four stages can be considered as two phases: arrival of the fittest and survival of the fittest [33]. In particular, the arrival of the species with the highest ecological fitness for an environmental niche is brought about by natural innovation processes. Subsequently, the survival of the fittest takes place through preservation of fittest through natural selection of useful adaptations. Ecological fitness is the potential of living things to survive in environmental niches through competition, cooperation, and/or construction that changes the environment [34].

At the outset of a startup when it is one person with an idea, the startup's stress response system can be its founder's stress response system, which will involve interactions between the person's the sympathetic system, parasympathetic system, and hypothalamic-pituitary-adrenal axis (HPA). The sympathetic nervous system prepares the body for the "fight or flight" response during any potential danger. This is complemented by the parasympathetic nervous system that inhibits the body from overworking and restores the body to a calm and composed state [35]. Meanwhile, the HPA controls reactions to stress and regulates many body processes, including energy storage and expenditure. As the life cycle of a startup progresses, these functions need to be replaced by well-resourced formal operating procedures [27,36].

The allocation of time and energy during life cycle stages is crucial as both are limited. Hence, there are trade-offs between their allocation to different components of ecological fitness. For example, between investing in exploitation of existing information to promote current market offerings versus investing in exploration for new information to enable new market offerings. Within ACM, each trade-off is a decision node in allocation of resources, and each decision node influences the next decision node, which opens up some options while closing off other options, in a chain over the life course [37].

Within ACM, there is no one best life course. Rather there is adaptive developmental plasticity that involves interaction between internal and external variables. With regard to internal variables, the stress response system acts as an integrative mechanism, which mediates the development of alternative life strategies that are adaptive in different environmental conditions. This leads to conditional adaptive developmental variation through what is described in organizational studies as double-loop learning [38]. In particular, information encoded by the stress response system during development feeds back on the long-term calibration of the system itself. This double-loop learning results in adaptive patterns of stress responsivity, stress appraisals, and consequent individual differences in life history-related behavior. With regard to changing external variables, at different locations at different times there can be changing resource availability, environment characteristics, and uncertainty. The purpose of adaptive developmental plasticity is to maximize ecological fitness [22]. In terms of ACM, the move from one life cycle stage to the next can be switch points for the calibration of stress responsivity. For example, in the life cycle of startups when there are crises of leadership and bureaucracy during moving from informal to formal structure [32].

Through the stress response system, Adaptive Calibration Model (ACM) addresses the coordination of allostatic responses. Allostasis is the process of achieving internal stability through physiological or behavioral change—in contrast with homeostasis, which maintains internal stability by maintaining the organism's internal state at a set point [22]. Also, ACM encompasses the encoding and filtering of information from the environment, thus mediating openness to environmental inputs. In particular, the stress response system continuously "samples" the environment, and its pattern of activation over the years provides a representation of key dimensions of the environment, which can then be used to orient the individual's developing life history strategy. Different strategies may require different calibrations of the stress response system. In addition, ACM encompasses the regulation of traits and behaviors that can affect ecological fitness [22].

Within ACM, four prototypical patterns of stress responsivity are posited: sensitive (I), buffered (II), vigilant (III), and unemotional (IV). Sensitive pattern (I) is characterized

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by openness to the physical and social environment, which enable rapid adjustment to temporary perturbations in the environment through low risk cooperative life history strategies. Buffered pattern (II) is characterized by low-to-moderate stress responsivity in active engagement with the social environment involving long-term relationships. Buffered pattern is distributed widely across environmental conditions compared to sensitive pattern that is more likely in protective, low-stress developmental contexts. Vigilant pattern (III) develops in stressful contexts, where they enable people to cope effectively with dangers and threats in the physical and social environment. In the vigilant pattern, psychological resources are employed to monitor and cope with possible sources of threat and/or social competition, rather than to maximize learning and relaxed exploration as in the sensitive pattern (I). In the unemotional pattern (IV), there is generalized unresponsivity that inhibits social learning and sensitivity to social feedback, which can also increase risk-taking by blocking information about dangers and threats in the environments. Different stress responsivity patterns can lead to different appraisals of the same event: i.e., different stress appraisals of the same event [22].

A summary of ACM for startups is provided in Figure 1. Based on [22], this diagram shows that the stress response system (SRS) filters and/or amplifies unpredictable/uncontrollable events and threats/dangers in relation to support system that can offset them. At the same time, SRS filters and/or amplifies novelties in the environment and social feedback. Filtering and/or amplification regulate life history traits in terms of decisions about allocation of time and energy to competitive actions, cooperative actions, and/or construction actions. Initially, SRS is situated amidst psychomotor characteristics of founders. Subsequently, SRS is situated with organizational characteristics such as policy statements. Throughout, these include stress responsivity patterns (I, II, III, or IV), which affect and are affected by the SRS as it is calibrated through double-loop learning during active inference. In the following sections, adaptive calibration through active inference is related to startup lifecycle stages.

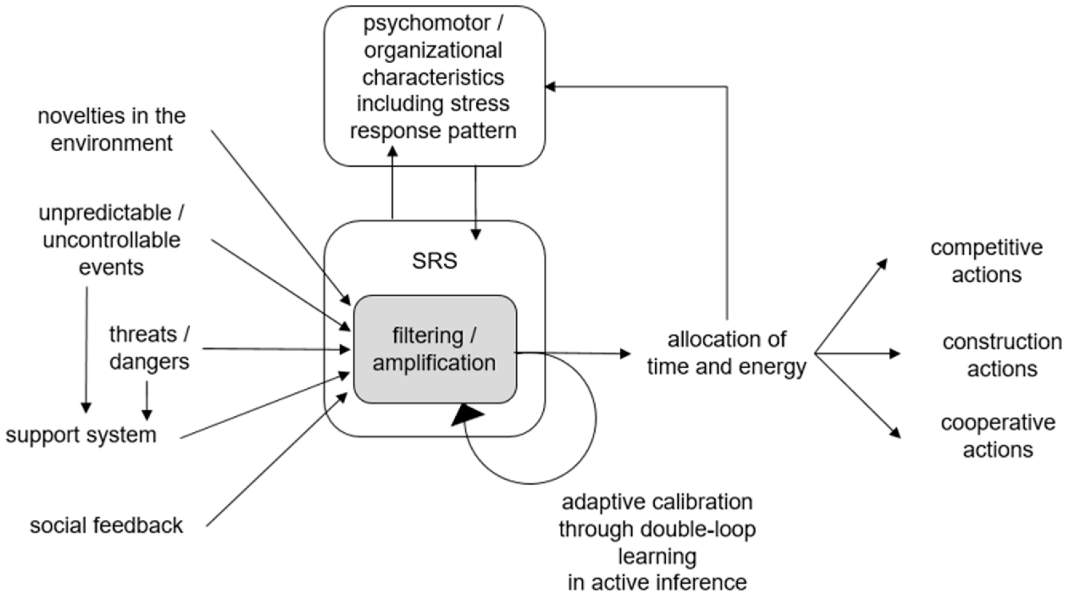

Figure 1. Adaptive Calibration Model for Startups.

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3. Business Model Development and Transition: Arrival of the Fittest

3.1. Business Model Development: Formulation of Internal Generative Model

The first phase of a startup can involve five activities [39]. First, formulating falsifiable hypotheses about a startup idea. Second, embedding these hypotheses into a designed business model. Third, developing a minimum viable product in order to test the business model. Fourth, customer development through identifying "earlyvangelist" customers from whom to receive feedback that can inform discovery and/or creation of many more customers. Fifth, running tests with multiple iterations to make decisions about whether or not to persevere with the startup idea. Together, these five activities span build-measure-learn-feedback that can lead to the startup having a well-defined business model encompassing its value proposition, market segments, cost structure, revenue streams, etc., [39]. Common across the five activities are opportunity creation, effectuation, and bricolage. In startup scholarship concerned with opportunity creation, opportunities for entrepreneurial profit are formed endogenously through action amidst uncertainty where outcomes are difficult to determine [40,41]. Similarly, within scholarship concerned with effectuation, opportunities are often endogenous to actors who focus on what can be done to move toward a yet-to-be-determined near-term future end point [42,43]. Additionally, within scholarship concerned with bricolage, actors are creative. In particular, they use whatever is at hand to create new solutions to problems as they arise [44,45]. The need for action is common across lean startup, opportunity creation, effectuation, and bricolage. The importance of action is further emphasized in scholarship that reports on action theory and action learning [46,47].

Similarly, action is at the core of AIT [48]. In particular, humans survive by taking action to reduce information gaps between their internal models and reality [30]. This involves actions being taken with the aim of aligning the sensory data predicted by the internal generative models with those data generated by external states. Better aligning includes formulating new internal generative models through insights gained via curiosity in exploring new external states [49]. For other livings things, such exploration may require being physically present in the new external state. By contrast, humans can undertake curiosity-driven exploration without being physically present in the new external state: for example, through discovery via the World Wide Web. Moreover, beliefs about the new external state can exist, at least partially, only in the mind of a person who envisages a future external state: for example, a future external state in which a startup has been founded and has grown into a large organization with global reach. Thus, the formulation of an internal generative model can involve imagining a future external state. In particular, a person can imagine themselves in the future within the imagined future external state [50]. Through this sophisticated active inference, a startup founder can consider simultaneously "what would happen if I did that" and "what I would believe about what would happen if I did that" [51]. Additionally, through theory of mind, the startup founder can consider what other people think about the action taken and what other humans would think about the startup founder for taking the action [52]. Thus, a startup founder can formulate internal generative models that can encompass alternative potential startups situated in future external states. These internal generative models can encompass alternative courses of action, such as market offerings of goods/services, founder's own feelings about those market offerings, founder's estimate of potential customers' feelings about the market offerings, and founder's estimate of the feelings of society about the startup founder and the startup.

Compared to detailed internal generative models for routine daily life, nascent internal generative models for alternative potential future startups can be lacking in detail. They can be conceptual models that need more sampling from the external state to become schematic models that can provide the basis for beginning lean startup by formulating falsifiable hypotheses about the startup ideas. Further sampling from the external state is required to embed these hypotheses into a business model. Then, more sampling is required to enable development of a minimum viable product in order to test the business model. By

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the fourth stage of lean startup, alignment of internal generative models with external states begins to involve actions in the external state. These actions in the external state encompass opportunity creation, effectuation and bricolage. In particular, interaction with earlyvangelist customers to get iterative feedback in development of the minimum viable product. That is, a version of the startup's proposed marketing offering with just enough features to be usable by early customers who can then provide feedback for future product development. Subsequently, in the fifth state of lean startup, running tests, can involve aligning what has become a detailed internal generative model with the external state through changing what is sampled from the external state and through changing actions in the external state. For example, changing what is sampled by eliciting feedback from a wider range of potential customers about the minimum viable product, and changing actions in the external state by modifying the minimum viable product in response to their feedback. Subsequently, in order for the startup to survive through enacting its business model, the founder will need to exploit information gained through the preceding exploratory active inference [53] carried out during the five phases of lean startup activities.

As shown in Figure 2 below ideally, after a startup has gone through the lean startup activities, it will have a meta generative model that is aligned with descriptions of its intended potential customers. Meta generative models encompass characteristics that are applicable to many different activities in many different situations. For example, the meta generative model of an individual person can include personality type, which underlies prior expectations during many different situations [54]. Meta generative models for startups' potential customers can encompass descriptions of goals that they are attempting to accomplish, and their related needs for the startup's good/service. Descriptions can include visual images that can distill multiple details including demographics, locations, occupations, hobbies, levels of digital literacy, disposal income, etc. As summarized in Figure 2, meta generative models are autopoietic models of self in the world and provide the basis for *why* actions are taken in the world. Activity-specific generative models provide the basis for *how* actions are taken in the world. For example, generative models for marketing management activities or generative models for operations management activities. Together with sensory inputs, these generative models, influence *what* sensory inputs are experienced from actions taken in the world. Such multi-level generative models are often referred to as being hierarchical in accordance with the notion of top-down expectations and bottom-up sensory inputs [54].

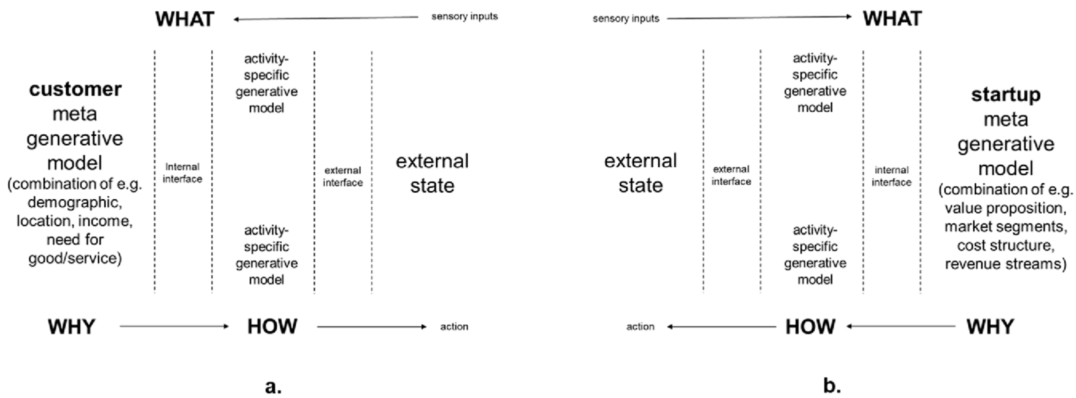

Figure 2. Meta generative model for intended customers as defined by startup (**a**) are aligned with (**b**) the startup's own meta generative model developed during lean startup activities.

This model is hierarchical in the sense that the *why* states predict the *how* states, which themselves predict *what* sensory data. The inversion of this model (i.e., inference) then

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involves passing the *what* messages back up the hierarchy to infer the *how* states and, in turn, the *why* states. As is appropriate for a practitioner paper, the term meta generative model is used here colloquially. It is used to refer to an additional hierarchical level or factor in the generative model. The prefix 'meta'- is used in the sense of 'next to'. This can be regarded as a superordinate hierarchical level that is 'next' to the penultimate level in a hierarchical generative model. Alternatively, it can be regarded as an additional factor that is 'next' to the remaining factors that constitute the generative model. This meta level is meant to convey the inclusion of latent or hidden states that are conserved over time and contextualise (activity-dependent) state transitions in other parts of the generative model. Accordingly, meta generative model is used here to summarize the multitude of inter-related variables that can exert *why* influence over the *how* of activity-specific models. Overall, the more likely prior expectations in the meta generative model are considered to predict a sensory input (i.e., the higher the prior probability), the more attention will be paid to the prior expectation and the more influence the prior expectation will have on what is experienced. By contrast, the lower the prior probability, the more attention will be paid to the sensory input and any prediction error between prior expectation and what is actually experienced [54].

From the perspective of ACM, the startup meta generative model comprises decisions about the allocation of finite time and energy that begin the life history strategy of the startup. To the extent that the startup meta generative model is developed by one founder, it can be an expression of that person's stress responsivity pattern (I, II, III, or IV), which reflects the life history strategy of that person so far. As the formulation of the startup meta generative model involves creative exploration of potential for survival and growth in future environments, it can involve filtering and/or amplification of opportunities and/or threats in those imagined future environments as they are sampled by the stress response system. If only one founder is involved, business development can involve only that person's stress appraisals of alternative imagined future environments.

3.2. Transition: Interface between Internal State and External State

Interactions between the internal generative model and the external state takes place across the interface state (i.e., Markov blanket state [31]). For startups, transition towards scaling up takes place across the interface state through marketing that involves analyzing market characteristics, formulating market offerings, and adapting market offerings in relation to market responses. Ideally, marketing will lead to the situation summarized in Figure 3 below, where there is zero prediction error and zero relative entropy between sales forecast (i.e., what is predicted to happen) and actual sales (i.e., what happens). Probabilities can be allocated to predictions and probabilities can be allocated to events as they are happening. For example, the final value of some sales orders may only be definite months after the initial order has been received: meanwhile probabilities can be allocated to the total sales values. Relative entropy (D), sometimes referred to as Kullback–Leibler divergence, is a measure of differences between a reference probability distribution (e.g., a sales forecast) and a related probability distribution (e.g., total sales values). Zero prediction error and zero relative entropy can be achieved through the marketing of the startup's good/service matching the specification for the good/service. This can lead to the situation where market sales match the startup's sales forecast. However, poor marketing, such as poor pricing of market offerings, is often a cause of startup failure [2].

AIT can be related to the failure of startups offerings to survive in markets in terms of expectation disconfirmation [55]. In particular, the startup's marketing can lead to potential customers having positive beliefs about the startup's offering. Potential customers' positive beliefs can lead to them having positive expectations about trying the startup's offering. Their belief-based positive expectations can lead to them make specific positive predictions about what they will experience when trying out the startup's offering. However, if their positive expectations are not confirmed when they take action to try the startup's offering, they experience an unwanted surprise from the prediction error about would

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be experienced. The resulting actions of the customer, which are contrary to what the startup's internal model predicted, in turn causes unwanted surprise for the startup. In particular, it is unwanted surprise for the startup because the startup believes in its market offering and has predicted positive cash flows from its market offering because it expects potential customers to try it out and want to experience it again in the future. Moreover, many potential customers experiencing unwanted surprise from the startup's offering threatens the startups survival because it will not have incoming revenue from sales to cover outgoing costs from its operations. Rather, the startup will have unsustainable negative cash flow.

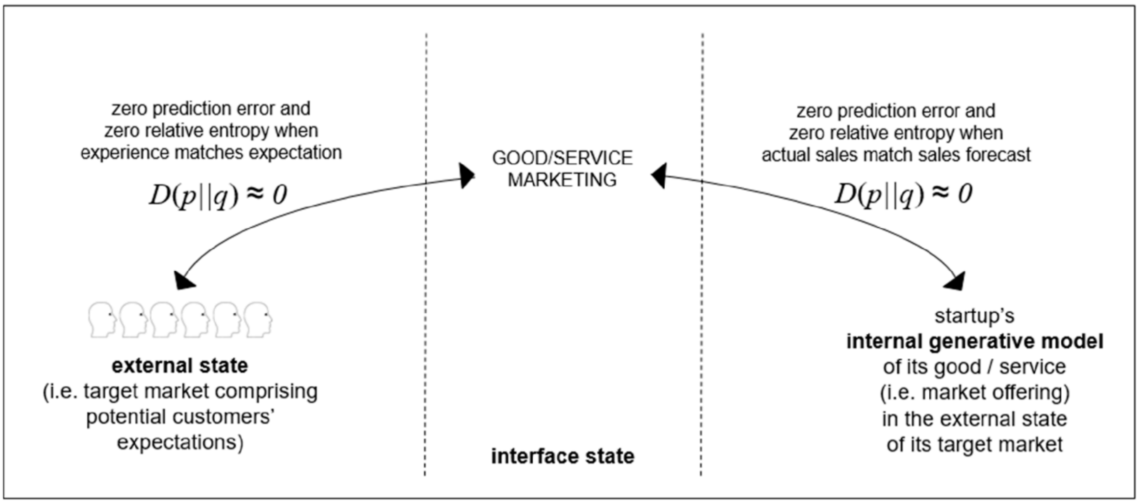

Figure 3. Startup interface state. Within the interface between the startup and its potential customers are the startup's advertising of its good/service. If what is advertised is the same as what is produced by the startup, as defined in its good/service specification, there can be zero prediction error and zero relative entropy as customers' experiences match their expectations from the startup's advertising, hence actual sales match startup's sales forecasts: i.e., internal generative model is aligned with the external state.

As shown in Figure 4 below, the limit of tolerable expectancy disconfirmation can comprise two sources. First, expected difference between preferred sensory inputs from the startup's market offer and actual sensory inputs from the startup's market offer. Second, some additional tolerance for unwanted surprise, which can be described as float or slack on an action [56]: in this case, the action of trying out the startup's market offering. If an action is carried out many times, limits of tolerable expectancy disconfirmation can be defined in statistical process control (SPC) charts [31]. However, if the action is a one-off, for example, during the trial of a startup's good/service by a potential customer, then the limit of tolerable expectancy disconfirmation is a one-off. If the potential customer expects there to be no difference between preferred sensory inputs and actual sensory inputs, then the expected difference is zero. Moreover, the potential customer does not expect there to be any information gap between her internal generative model for using the startup's market offering and actually using it in the external state of the world.

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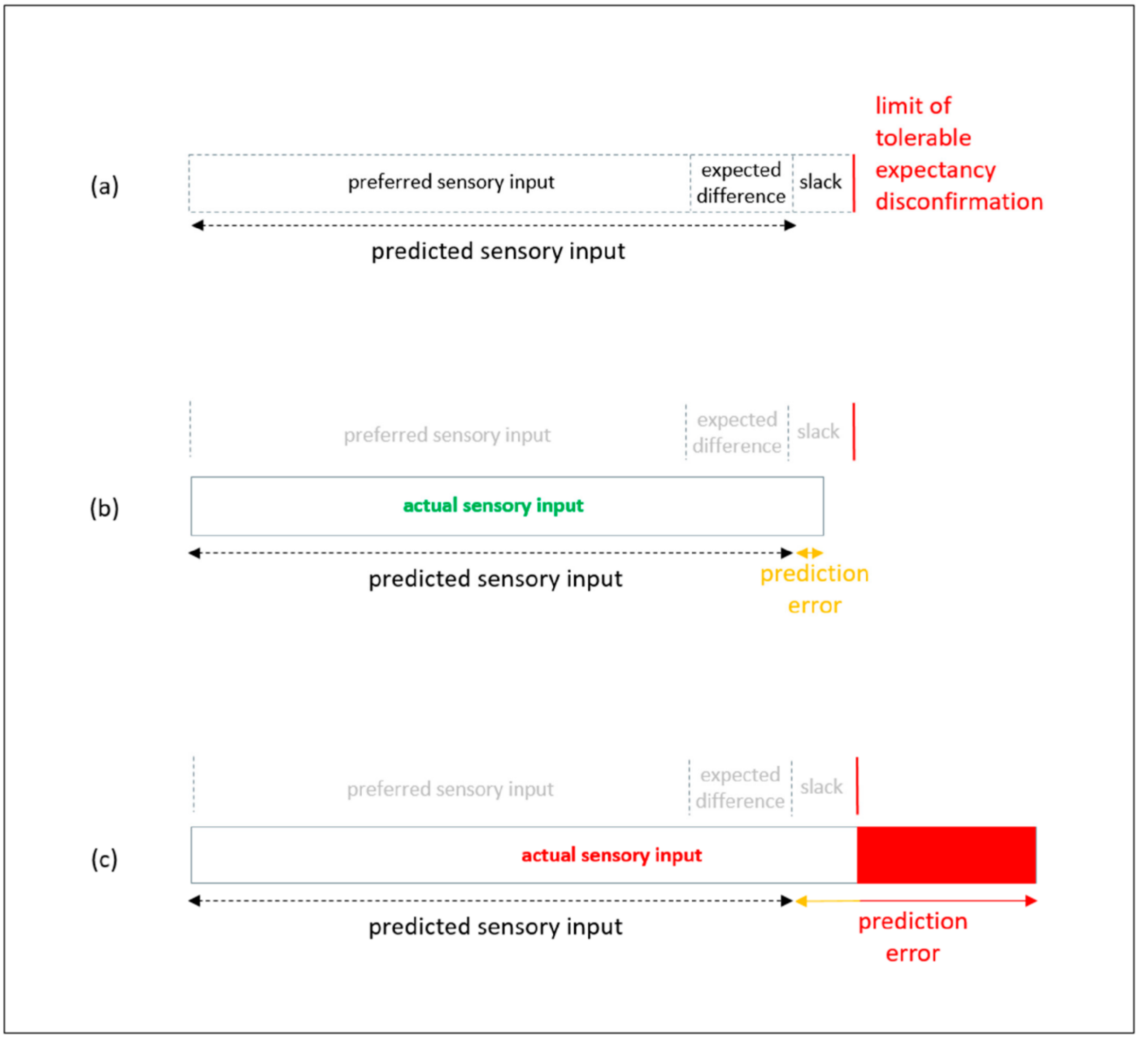

Figure 4. Limit of tolerable expectancy disconfirmation from startup's market offering. (**a**) predicted sensory input (preferred sensory input plus expected difference between preferred sensory input and actual sensory input); (**b**) tolerable prediction error as sensory inputs are farther from preferred than expected but are within limit of tolerable sensory input from unwanted surprise; (**c**) not tolerable prediction error as sensory inputs are farther from preferred than expected and are beyond limits of tolerable sensory inputs from unwanted surprise.

Expected difference and limit of tolerable expectancy disconfirmation can be related to AIT in terms of expected free energy (EFE) and variational free energy (VFE) upper bound. VFE can be considered as information gap between agents' internal models and reality [30], which varies as internal states change and/or external states change. If the VFE upper bound, evaluated at some sensory input, is very large the information gap between internal model and reality can be too wide to be sustainable. Accordingly, within AIT, loosely speaking, agents select sequences of actions (i.e., policies) that will bring about future observations that minimize VFE. As future outcomes are yet to be observed, actions need to be selected that can minimize expected free energy (EFE): i.e., expected information gap between internal model and reality after action has been taken. Conceptually, the EFE can be related to the VFE by noting that VFE can be expressed as complexity minus accuracy (i.e., minimizing free energy leads to the most accurate but minimally complex explanation of the world). In the EFE the accuracy term of the VFE is replaced by a negative ambiguity, and the complexity term is replaced by risk. This means that the expected free energy favors minimally ambiguous and minimally risky futures. Action selections intended to minimize EFE seek to resolve uncertainty and to maximize reward. Actions will tend to be exploratory when beliefs about states are very uncertain. Conversely, action selections will tend to exploit information, which has been gained during exploration, in order to maximize reward when confidence in beliefs about states is high. It is important to note that VFE, and related constructs, such as EFE, do not have the same measurement units as sensory inputs. Rather VFE is a function of sensory input in the space of log probabilities.

As shown in Figure 4a, a potential customer for the startup's offerings may expect some difference, and also have some additional tolerance for more than expected difference: i.e., some additional float/slack for unwanted surprise from an action. The term, tolerance, is not an integral feature of AIT. Rather, it is a term that is widely used in industry. Here, tolerance means the difference between the prediction and maximum permissible error. In SPC charts for repetitive processes, tolerance is between process mean and process control limits. Tolerance corresponds to the difference between prediction and what can be described, in AIT terms, as maximum negative evidence for the internal generative model [31]. This additional tolerance for unwanted surprise can arise from the startup's competitors' existing market offerings not providing the potential customer with preferred sensory inputs. Consider, for example, a potential customer in Africa who survives by making deliveries with rented old bicycles [57]. This is extremely strenuous work involving thousands of peddling and pushing actions that can consume thousands of calories of energy. The person survives through a precarious daily balancing of energy expenditure and energy consumption. Survival depends on earning more money from making deliveries than is needed to pay bicycle rental charges and is needed to buy food calories for peddling and pushing the rented bicycle.

The person may have mixed expectations about a startup's market offer of rental cargo bicycles that are powered by electric batteries (e-bike) [58]. In particular, the person may predict rental costs to be higher but predict this to be more than off-set by reduction of current costs from buying food to get energy to peddle and push conventional bicycles. As summarized in Figure 4a, tolerance for unwanted surprise is minimal. This is because the person has minimal surplus resources available to cope with unwanted surprise [59].

In Figure 4b, sensory inputs from trying out the e-bike are not as expected but within tolerable limits: e.g., better than fatigue from making the same deliveries with the conventional old rental bicycles. This is because the same deliveries were made and the same money paid, but the amount of peddling and pushing was less. By contrast, in Figure 4c, sensory inputs from trying out the e-bike are worse than tolerable limits: e.g., worse than the fatigue from making the same deliveries with the conventional old rental bicycles. This is because use of the e-bike did not reduce the amount of peddling and pushing actions sufficiently to offset its extra rental costs. Hence, there was almost the same amount of peddling and pushing but less money available to buy food calories. Thus, tolerance for expectancy disconfirmation can involve comparisons between alternative internal generative models. In this case, internal generative model for continuing with renting old bikes versus internal generative model for beginning to rent e-bikes. However, when life takes place in a precarious balance between energy input and energy output, the limit of tolerable expectancy disconfirmation is existential: i.e., survival is not possible beyond the limit.

As the person survives through a precarious daily balancing of energy expenditure and energy consumption, any additional energy consumption involved in making the same deliveries can threaten the person's survival through a vicious cycle in which not being able to complete deliveries due to exhaustion will result in being paid less and having less money to buy food. This example illustrates that survival can depend upon resolving information gaps between internal generative model and external state. In which case, the information gap between preferred sensory input and limit of tolerable expectancy

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disconfirmation can be described as survival information deficit. Uncertainty about the ways in which this survival information deficit could be addressed are a source of existential information entropy. For example, the delivery person may speculate about different ways that the e-bike could be otherwise be used to increase deliveries made and/or reduce energy expenditure from peddling and pushing. However, any speculative probabilities assigned to these speculative options are associated with mismatches between energy input and energy output that cannot be survived.

If the majority of potential customers experience prediction errors about the startup's e-bike offering no worse that as summarized in Figure 4b, that offering can provide the basis for transition towards scaling. By contrast, it cannot provide the basis for transition towards scaling if the majority of potential customers experience prediction errors that are beyond their limits of tolerable expectancy disconfirmation as summarized in Figure 4c. In which case, the startup should update its meta internal generative model through double-loop learning [38] informed by its first-loop learning from negative customer feedback. For example, its value proposition should be revised.

At the same time, through ACM double-loop learning, the startup may re-calibrate its stress responsivity pattern. For example, a startup founder with stress responsivity pattern I, sensitive, may move towards stress responsivity pattern III, vigilant, due to the perceived threat to survival in the intended business environment. However, this could lead to exaggerated stress appraisals. Moreover, if permanent, this could be counterproductive because in the vigilant pattern (III), psychological resources are employed to monitor and cope with possible sources of threat and/or social competition, rather than to maximize exploration and learning as in the sensitive pattern (I).

4. Scaling and Exit: Survival of the Fittest

4.1. Scaling: Maintaining Non-Equilibrium Steady State (NESS)

The internal states of startups need to survive in the external states of the world around them by the startups maintaining a non-equilibrium steady state (NESS). Maintaining a steady state involves a startup's internal state not dissipating into the external state. For example, a startup can maintain a steady state through its operations management ensuring that its internal resources are not scattered into the external state by being taken into the possession of external creditors via bankruptcy proceedings. Maintaining a non-equilibrium steady state involves the startup being able to continually adapt internally in relation to changes in the external state. Internal adaptations can be reactive in response to changes in the external state and/or proactive to bring about changes in the external state. Non-equilibrium steady states can range from near-equilibrium, which is maintained by homeostasis, to drifting towards far-from-equilibrium, which is addressed by allostasis [29]. Survival as the ecologically fittest depends upon making adaptations that are better than those of competitors in the same environment. For a startup, internal adaptations can include improving business processes, and external adaptations can include improvements to enabling infrastructures for the operation of its market offerings.

Homeostasis can be described as being a first-order feedback loop that regulates essential variables in near-equilibrium steady states. For example, a startup ensuring that outgoing costs are at least matched by incoming revenues through diligence in routine actions such as sending out invoices. In terms of organizational studies, refinements to processes such as, for example, sending out invoices, come from single-loop learning [38]. Allostasis can be described as a second-order feedback loop that reorganizes a system's input–output relations when first-order feedback has failed, and the steady state is moving towards far-from-equilibrium. Allostatic reorganization being done to restore a near-equilibrium steady state by reestablishing stability of essential variables. In terms of organizational studies, allostasis is analogous to double-loop learning [38]. Allostasis involves the stress response system which coordinates allocation of time and energy to different activities that are intended to promote ecological fitness [60]. That is, promote the compatibility of a living thing with the environmental niche in which it

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intends to survive [61]. It is very important to avoid allostatic overload arising from second-order feedback loops being continually overtaxed. This is because allostatic overload can contribute to burnout [62], which is a common cause of startup failure [2,63]. Moreover, allostatic overload can contribute to the collapse of higher goals [29]. Apropos, there are many ways that a startup can reorganize its input-output relations, including changing its markets by pivoting to another business model [64].

However, the homeostasis and allostasis of startups can be affected by biases [65]. These can include initial overconfidence followed by escalation of commitment to failing courses of action. Such biases are examples of an internal generative model determining attention, expectation, and action irrespective of sensory inputs coming from the external state [54] such as negative sensory inputs from market analyses. Importantly, internal generative models can be affected negatively by stress [30], and stress is common among startup founders [63]. In accordance with ACM, and within AIT, updating the internal generative model can be based on the action of changing what sensations are sampled from the external state. For startups, this can include stopping paying attention to sources of negative market signals and carrying on with the same course of action based on the erroneous expectation, which has been generated by the biased internal model, that this will lead to survival. In terms of ACM, this could involve re-calibration to stress responsivity pattern IV, unemotional. If permanent, this would be counterproductive because pattern IV involves generalized unresponsivity that inhibits social learning and sensitivity to social feedback, which can also increase risk-taking by blocking information about dangers and threats in the environment. Negative market signals can include lack of interest among potential customers for the startup's market offering.

In the e-bike example, there could be several reasons why the e-bike did not reduce the amount of peddling and pushing sufficiently. For example, it could be because the e-bike is not suitable for hilly terrain in a country such as Burundi [57]. Also, additional peddling and pushing could be required to get to battery recharging center where empty batteries are returned and charged batteries are collected. Accordingly, the startup could try to survive by preventing dissipation of its non-equilibrium steady state (NESS) through allostasis involving reorganizing its input–output relations. This could involve niche construction and participation in wider ecosystem engineering. In other words, allocating finite time and energy primarily to construction actions.

Niche construction involves adaption of the environment to better enable survival [66]. This can involve adaptive preferences [67] where people forego a first preference in order to survive. For example, people prefer to live above ground, but people will adapt this preference and modify the environment by building underground settlements if that can fulfil their primary goal of surviving [68]. On a wider scale, ecosystem engineering can involve more far-reaching changes to the environment that alter survival pressures positively for the ecosystem engineers but negatively for others [69]. Thus, there can be eco-evolutionary feedbacks in ecosystem dynamics [70]. This can lead those that are negatively affected to disperse. This happens when the expected ecological fitness benefits of moving outweigh the expected ecological fitness costs of moving [71,72].

In the e-bike example, niche construction by the startup could include moving its operations to a region with flat terrain and setting up one e-bike center from which its e-bikes are rented and repaired, and where the e-bike batteries are recharged and replaced. Then, in order to reduce the time and energy spent by customers in travelling to a from the one e-bike center, the startup could extend its niche construction by arranging for some of its services to be carried out at small roadside shops. For example, the startup could deliver charged batteries to the roadside shops and collect empty batteries left by their customers. Wider ecosystem engineering could involve the startup working with other organizations involved in introducing battery power for other machines to setup multi-machine battery charging points at multiple locations. Additionally, the startup could work with other organizations to support the introduction of renewable energy sources for battery charging points [73,74]. Such allocation of time and energy to construction and cooperation in

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competition against established vehicle rental companies could lead to maintaining NESS and scaling of the startup's operations towards the exit stage of its life cycle.

4.2. Exit: Relative Ecological Fitness

Ecological fitness can be absolute and relative. Absolute fitness refers to ability to survive in an environment. Relative fitness refers to ability to survive better than others in an environment. Numerically, relative fitness ranges from anything above 0 to 1: with best relative fitness being 1 [61]. For the most favorable initial public offering of shares, private sale, merger, or acquisition, a startup needs to show that it is on its way to establishing best relative fitness.

For example, e-vehicle niche construction and ecosystem engineering could lead to the dispersal of established vehicle rental companies to other regions, such as hilly regions where the electric power of e-bikes may not be adequate. However, as there are already established vehicle rental companies in those regions, survival may not be possible through geographical relocation. Rather, the favorable landscape for established vehicle rental companies can first become fragmented by the niche construction of e-vehicle companies. Then, further niche construction for e-vehicles can lead to loss of favorable habitat for established vehicle rental companies as their landscape splits into patches, which little by little shrink and become more isolated from each other [75].

By contrast, as e-vehicle technology improves, wider ecosystem engineering can lead to the new e-vehicle niches becoming less isolated and more interconnected into a new e-vehicle landscape that encompass hilly as well as flat terrain. Hence, the NESSs of established vehicle rental companies becomes harder to maintain, and it becomes more likely that their internal resources will be scattered into the external state by being taken into the possession of external creditors via bankruptcy proceedings. However, while the landscape and NESSs of established vehicle rental companies may have survived many previous decades, the landscape and the NESSs of e-vehicle rental companies may be more short-lived as niche construction for bikes powered by hydrogen fuel cells begins [76].

As summarized in Figure 5 below, market incumbents, such as established vehicle rental companies, and possibly e-vehicle rental companies in the near future, may not change in response to new market expectations because people working in market incumbents can have biases that lead to them only sampling inputs from the external state sensory that support their biases [77,78].

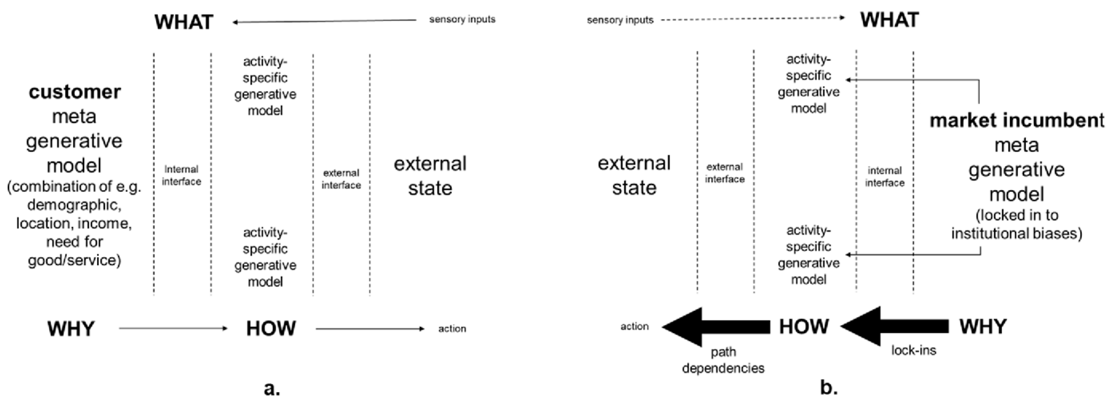

Figure 5. Evolving meta generative model of (**a**) customers is not matched by (**b**) market incumbent's meta generative model that is locked-in to its biases.

Biases throughout the organizations being based on, for example, lock-ins to past investments that lead to persisting with path dependent actions even when there is sensory evidence that they are no longer effective [79,80]. People and organizations may not recognize their own biases, and their biases can be difficult to reduce even when they are recognized [81,82]. Consequently, maintaining the internal state in the external states of the world can be undermined by the market incumbent's actions in the world being determined by an out-of-date meta generative model rather than sampling from the external state of the changing world. Importantly, this can prevent a favorable exit if electric power is already perceived as going to be superseded soon, for example, by hydrogen power.

Accordingly, to avoid loss of relative fitness that can undermine the exit stage, it is important to maintain stress responsivity pattern I, sensitive, or stress responsivity pattern II, buffered, in order to enable openness to the physical and social environment as it changes. Rather than the fight/flight responses predominating in the vigilant pattern (III) or the unresponsivity of the unemotional pattern (IV). Neither of which, if permanent, may enable balanced stress appraisals and learning needed to update internal generative models in changing environments.

5. Future-Proofing Principles for Startups

ACM and AIT are based on living things that have evolved through many millennia to survive within a few types of natural environments that change little from one generation to the next. By contrast, human niche construction and ecosystem engineering can bring many environmental changes within one generation. Some of these changes are unintended, negative, and difficult to control [83]. Moreover, climate-related environmental changes are becoming more widespread [5–10]. Accordingly, maintaining the NESS of human organizations in the 21st century and beyond can depend on changing the ratio between exploration for information and exploitation of that information. In particular, more time and energy may need to be spent on exploration followed by there being less time to exploit the information gained during exploration. Moreover, maintaining the NESS of human organizations in the 21st century and beyond can depend on being able to cope with shorter periods of homeostasis and more instances of allostasis.

Hence, a first organizing principle for future-proofing is for startups to carry out formal definition of their stress responsivity patterns. This can begin with startup founders defining their own ACM stress responsivity patterns. This can be carried out, for example, during SWOT analyses that define strengths and weaknesses in relation to opportunities and threats [84]. There is no one best stress responsivity pattern. Rather, a stress responsivity pattern can be a strength or a weakness depending upon the opportunities and threats in the environment. Accordingly, startups need to assess the compatibility of their stress responsivity pattern with the opportunities and threats in the environment. As shown in Figure 1, the stress response system filters and/or amplifies threats in relation to support that can offset them. However, either too little or too much support can undermine the potential for the stress response system to enable ecological fitness [22].

A second organizing principle is for startups to address the potential of their stress response systems to exert determining influence over sampling from the environment during business model development. This can be addressed by making AIT an explicit process in which the relationship between internal generative models and sampling from the environment is recognized. In particular, as summarized in Figure 6 below, the potential for founders' internal meta generative models, including their stress responsivity patterns, to lead to motivated cognition and wishful seeing [77,78], should be recognized. This is important because it can lead to their startup's business models being based on biased sampling that confirms their founders' preconceptions and their habitual stress appraisals. Rather than being based on alignment with the expectations of potential customers as shown in Figure 2.

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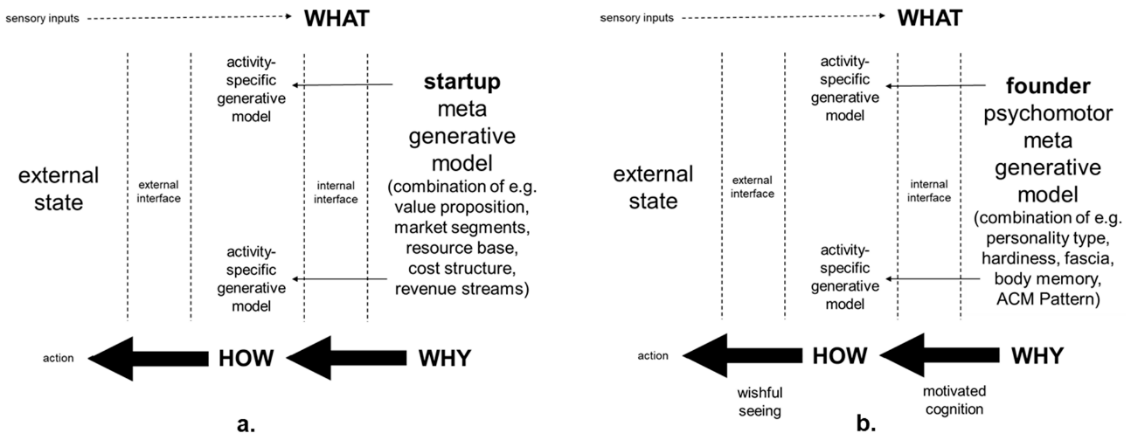

Figure 6. Startup meta generative model (**a**) based on motivated cognition and wishful seeing arising from (**b**) startup founder's psychomotor meta generative model including ACM stress responsivity pattern (I, II; III or IV).

As startups move to their transition stage, they move from informal structure towards formal structure. Apropos, a third organizing principle is for startups to move from its stress response system being that of its founder to it being a set of well-resourced work procedures [27,36], which can emulate the roles of the sympathetic system, the parasympathetic nervous system, and HPA.

Beginning during the transition stage, a fourth organizing principle for startups is to check the compatibility of their stress responsivity patterns with changing external environments. In particular, check the extent to which double-loop learning has led to the stress responsivity pattern being well aligned with the current environment or has led to it being badly aligned by being fixated on past environments [85]. In terms of organizational studies, explicit consideration of the effects of implicit double-loop learning can be described as triple loop learning [86]. In doing so, startups can consider what is their own limit for tolerable expectancy disconfirmation. As summarized in Figure 4, like their customers, startups can expect some disconfirmation and can have some slack resources to deal with expected disconfirmation and unexpected disconfirmation [87,88]. However, startups cannot have infinite slack resources and need to recognize that unwanted surprise from the environment that exceeds limit of tolerable expectancy disconfirmation will undermine survival.

As startups begin their scaling stage toward exit stage, during which functional specialists take roles once covered by generalists, a fifth organizing principle is to check that the formal stress response system that is documented in work procedures is not superseded in practice by the human stress response systems of the functional specialists who are appointed during crises of leadership and bureaucracy [32].

During exponential growth of scaling towards the exit stage, it is essential to ensure that the resources required to do work in accordance with customer expectations does not exceed the resources available to the startup. This is important to prevent organizational stress that can lead to the collapse of higher goals such as ethical standards [89]. The amount of resources required to do work in accordance with customer expectations can be exceeded if an accumulation of individually small organizational errors leads to the startup being overwhelmed by what can be described as firefighting: in other words, becoming trapped in a quagmire of deadline pressure, overtime working and energy depletion [31,90]. This represents a failure of homeostasis' first-order feedback loop that regulates essential variables in near-equilibrium steady states. It also represents a failure of stress response system's co-ordination of allostasis' second-order feedback loop that reorganizes input–output relations when first-order feedback has failed. This is because

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organizational firefighting moves organizations closer to, rather than away from, far-from-equilibrium. Accordingly, particularly during exponential growth of scaling towards the exit stage, startups need to have stress response systems that can address emergent weaknesses of internal operations. Especially, emergent weaknesses that can undermine the stability of essential variables, such as cash flow, which are needed to regulate traits and behaviours affecting ecological fitness [22]. Hence, a sixth organizing principle is that the stress responsivity pattern needs to be updated through explicit AIT processes to ensure it can address emergent weaknesses of internal operations during exponential growth.

A seventh organizing principle, which encompasses all stages of the startup lifecycle, is to avoid toxic stress that can lead to stress response system maladaptation. In particular, maladaptation through not recalibrating/updating stress responsivity pattern or maladaptation from recalibrating/updating to a stress responsivity pattern that is not congruent with the environment. In order to avoid toxic stress, it is necessary to maintain at least the minimum resources required to enable ecological fitness: i.e., to enable survival in operating markets. This involves the response to the loss of resources, for example from prediction errors, being to carry out resource development to replenish and/or enhance resource stocks. Resource development to prevent toxic stress need not involve large financial expenditure. For example, it can include taking rest, social support, and/or refreshing skills [91,92]. This proactive response to resource loss can be formalized as an explicit policy for active inference by the startup: initially by its founder and subsequently by its management. This can be done with the rationale that replenishing resources reduces potential underlying stress about survival. Thus, while there can be uncertainty, and associated information entropy, about the ways in which resources will be deployed in order to survive, this is not uncertainty about survival itself and the associated information entropy is not existential information entropy that can lead to maladaptive stress. As summarized in Figure 7 below, maintaining resources is necessary to reduce potential for expectancy disconfirmations to take stress beyond positive stress and tolerable stress towards toxic stress [93]. Figure 7a summarizes actual sensory inputs being within expected difference from preferred sensory inputs: i.e., sensory inputs are within the expected range. In such scenarios, information entropy arises from specific uncertainties about particular work tasks [94]: not from uncertainties about survival. There is no need for the startup to draw upon its spare resources (i.e., slack), and stress can be positive involving brief mild stress responses. Figure 7b summarizes actual sensory inputs going beyond expected range but within the scope of the startup's spare resources. In such a scenario, stress can be tolerable if it is intense but temporary. Figure 7c summarizes actual sensory inputs going beyond expected range and beyond the scope of the startup's spare resources that have already been reduced by previous prediction errors. In such a scenario, stress can be toxic if it is prolonged. Figure 7d summarizes actual sensory inputs going beyond expected range after all the startup's spare resources have been consumed by dealing with its previous prediction errors. Loss of resources can increase stress because there are fewer resources available to enable ecological fitness [91,92]. The more prediction errors that are made and the more resources are lost, the more uncertainty there will be about the startup's survival and higher potential for existential information entropy that can lead to maladaptive stress [29,30]. In such a scenario, stress can be more likely to lead to a counterproductive calibration of the stress response system.

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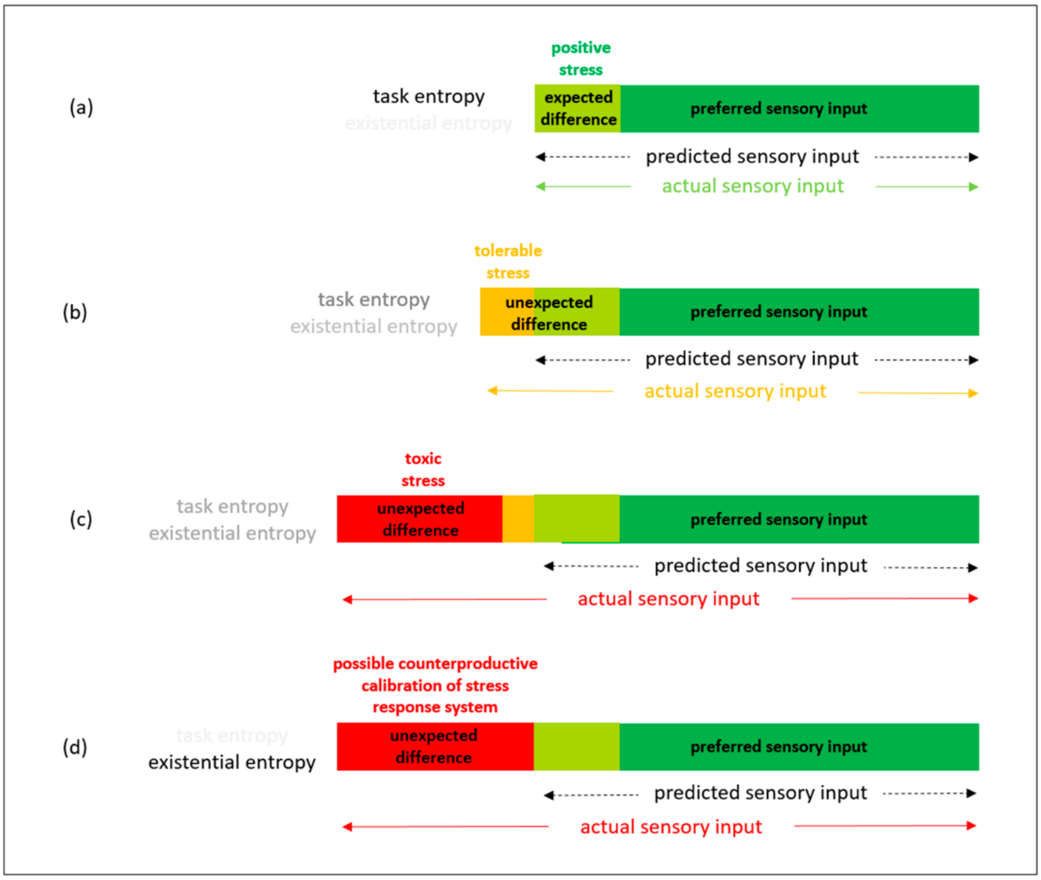

Figure 7. From task entropy to existential entropy. (**a**) Expectancy disconfirmation within range of expected difference: information entropy arises from work tasks. (**b**) Within limit of tolerable expectancy disconfirmation: information entropy arises from work tasks but with more uncertainty. (**c**) Beyond limit of tolerable expectancy disconfirmation: information entropy arises from survival uncertainty. (**d**) Beyond limit of tolerable expectancy disconfirmation: existential information entropy arising from increased survival uncertainty can lead to counterproductive calibration of stress response system.

As summarized in Figure 8 below, an eighth organizing principle, which also encompasses all startup lifecycle stages, is to manage expectations. In particular, to align external expectations with internal expectations in order to avoid, what can be described as expectancy discrepancy/violation/disconfirmation [55,95,96]. For example, align customers' expectations for good/service with startup's specifications for good/service. Also, to align financial backers' expectations for sales growth with startup's plans for sales growth. The alignment of expectations can minimize the startup's uncertainty about how it will survive. This is because there is minimal information gap between the startup's internal generative models and the external state. When there is minimal information gap, any prediction errors will be within the range of expected difference from preferred sensory inputs, and stress will be minimal [29,30]. In terms of organization studies, the startup will not be stressed commercially or financially because sales forecasts will be reached, and cash flow forecasts will be within expected range of deviations. In terms of AIT, this corresponds to actual posteriors (e.g., sales income) matching expected posteriors (e.g., sales forecast) with free energy related to actions in the sales policy matching expected free energy, and being less that the variational free energy upper bound [31]. When there is

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minimal information gap, which is within expected range of deviations in sales forecasts and cash flow forecasts, any stress that is experienced in dealing with sensory inputs from customers and funders can be brief mild stress that can be described as positive stress [93]. Expectations should be updated and realigned in response to the loss of resources and/or the development of new resources in order to minimize potential for future expectancy discrepancies/violations/disconfirmations [55,95,96].

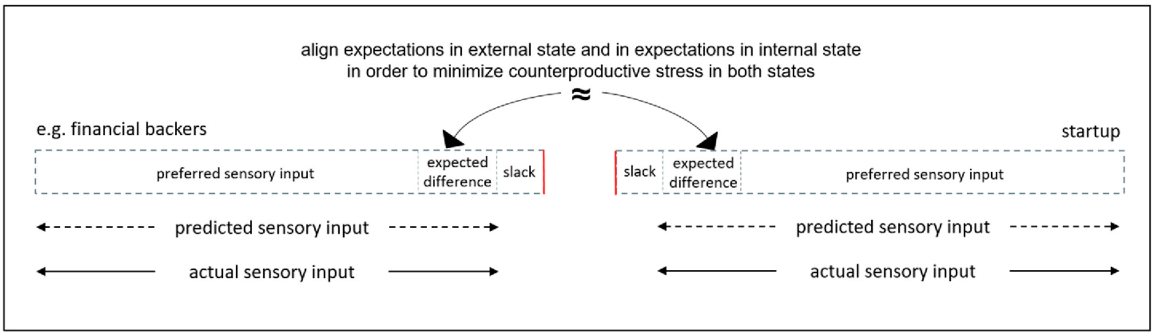

Figure 8. Manage expectations between internal state of the startup and the external state including, for example, financial backers, to minimize stress that can arise from survival uncertainty.

6. Conclusions

6.1. Principal Contributions

There are three contributions from this paper. The first contribution is to address the need for future-proofing methods for startups. This has been done through the definition of the eight organizing principles based on ACM and AIT that are summarized in Table 1 below. Together, these eight stress management principles go beyond previous literature concerned with entrepreneurial stress and organizational stress. In particular, rather than focusing on particular stressors, the principles are concerned with the recalibration/updating of startups' stress responsivity patterns to changes in the internal state of the startup and/or to changes in the external state: instead of stress responsivity patterns being based on previous internal states and/or external states. In doing so, the eight principles address startups' two fundamental growth challenges amidst dynamic environmental change [5–10]: arrival as the fittest and survival as the fittest.

A second contribution is relating ACM and AIT to four life cycle stages of startups. In doing so, overlaps between ACM and AIT are apparent. In particular, both encompass internal models that can have a determining influence over sampling from the external state and actions taken in the external state. Furthermore, both encompass internal models being changed by what can be described as double-loop learning [38]. Within ACM, this is the recalibration of stress responsivity patterns (I, II, III, IV). Within AIT, this is the updating of internal generative models. Within both ACM and AIT, double-loop learning does not necessarily lead to better alignment of the internal state with the external state. Rather, double-loop learning can be maladaptive [22,29,30]. From an organizational practice perspective, both ACM and AIT are pertinent to phenomena such as motivation cognition, wishful seeing (Figure 6), lock-ins and path dependencies (Figure 5) [77–80], within which preconceptions in internal models can override sensory inputs from the external state. When individuals and/or organizations get so stuck in their preconceptions, interventions can be required to get them unstuck [30,81,82]. This can involve reflection that can lead to triple-loop learning [86].

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Table 1. Future-proofing principles based on ACM and AIT.

Startup Stage	Principle
Business model development	1. Define stress response system in terms of ACM stress responsivity patterns and assess strengths and weakness in relation to opportunities and threats 2. Address potential of stress responsivity pattern to exert a determining influence over sampling from the environment by making AIT an explicit process
Transition	3. Move from stress response system being that of its founder to it being a set of documented work procedures with sufficient allocation of resources 4. Check the extent to which double-loop learning has led to the stress responsivity pattern being well aligned or badly aligned with the current environment
Scaling towards exit	5. Ensure that the documented stress response system is not superseded in practice by the human stress response systems of human functional specialists 6. Through explicit AIT processes, ensure stress responsivity patterns can address emergent weaknesses of internal operations during exponential growth
All stages	7. Avoid stress response system maladaptation from toxic stress by always counteracting loss of resources through development of new resources 8. Align expectations in external state and in expectations in internal state in order to minimize counterproductive stress in both states

The third contribution is to provide practical examples that show the broader relevance ACM and AIT to organizational practice. This has been done with examples across the life cycle stages of startups, which are also relevant other types of organizations. These include examples related to business model development (Figure 2), marketing (Figure 3), customer experience (Figure 4), and organizational firefighting (Figure 7). In addition, the examples illustrate the congruence between life science theories and practice in human organizations. For example, the congruence between survival through minimizing long-term average surprise and organizations minimizing expectancy discrepancy, expectancy violation, and expectancy disconfirmation [55,95,96]. Here, it is important to note that there is ongoing debate about the exact meaning of terms, such as EFE and VFE, and interrelationships between them [97] Accordingly, there is not fixed exact correspondence between technical terminology and practice examples [98]. Overall, the paper makes a contribution to relating physics of life constructs concerned with energy, action and ecological fitness to practice in human organizations.

6.2. Directions for Further Research

Further research can encompass action research focused on implementation trials for the eight principles summarized in Table 1. Particularly relevant are startups that involve individuals and organizations that have developed in very different environments to have different stress responsivity patterns, and so can make different stress appraisals of the same events. For example, very different environments in northern Europe, where resources are plentiful, and southern Africa where resources are scarce. Particularly relevant are startups that involve the conversion and/or transportation of physical matter amidst the physical challenges brought by climate change. This is because of the potential for increased incidence of uncontrollable events that unpredictably increase expenditure of energy needed to survive. For example, increased energy required to survive as a startup involved in the delivery of physical goods by e-vehicles. As summarized in Figure 7, when

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the expenditure of energy and other resources repeatedly exceeds expectations, it is more likely that toxic stress will lead to counterproductive calibration of stress responsivity patterns. This could be particularly problematic when startups involve individuals and organizations that have different stress responsivity patterns that lead to different sampling and stress appraisals from the same situations.

As well as enabling contributions to the future-proofing of startups, such action research could lead to findings relevant to research into stress appraisals in new environments [99], interactions between resource depletion and stress appraisals [100], and dynamics between uncertainty and anxiety [101]. More broadly, such action research could lead to findings that are relevant to research into joint agent-environment systems where environments change alongside agents—often due to the action of agents themselves [102]. In particular, there could be relevance to research that encompasses the influence of agents' prior beliefs over their inference. For example, the potential for prior beliefs that poorly represent the environment to lead to false inferences [103], which could undermine survival. In turn, advances in these life science fields have potential to further inform the future-proofing of startups. For example, research into dynamics between uncertainty and anxiety suggests that adoption of belief structures and clear goals can constrain experience of uncertainty. Also, it suggests that the formulation of clear explanatory narratives can support transforming uncertainty into understanding [101]. Thus, action research into future-proofing startups could encompass the formulation of narratives that explain how belief structures and concrete goals relate to markets in which startups intend to survive. Such an exercise can be framed as an explicit updating of startups' internal generative models with belief structures encompassing the definition of stress responsivity patterns.

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