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Reinventing the Wheel : The Future Ripples Method for Activating Anticipatory Capacities in Innovation Teams

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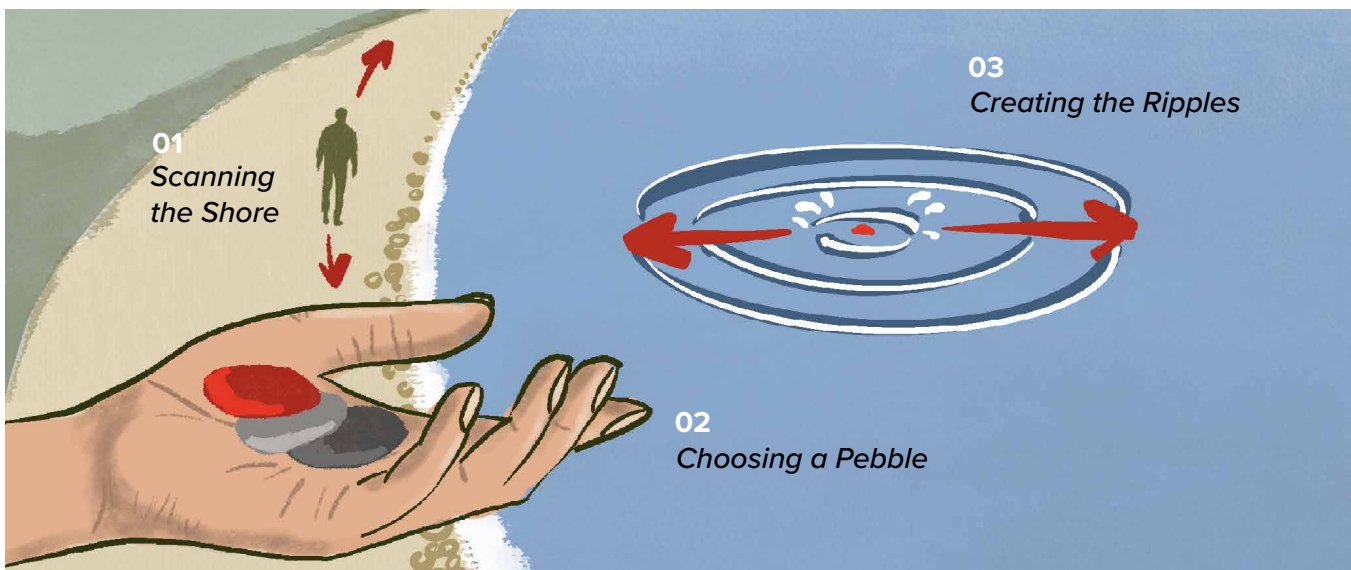idil.gaziulusoy@aalto.fi
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Figure 1: A metaphorical visualisation of the Future Ripples process – scanning the shore for indicators of change (01); choosing a 'what if' scenario as a pebble (02); and, finally, throwing the pebble into the water and mapping out its consequences as ripples (03).

ABSTRACT

Global and systemic sustainability challenges increasingly require innovation teams to incorporate holistic, long-term thinking into their ideation. Since a comprehensive foresight process would prove too burdensome, faster methods are needed. The Future Ripples method was devised to meet this need through reflective practice in four consecutive workshops. It builds on the well-known Futures Wheel foresight method, which offers a collaborative process for brainstorming consequences and impacts. Additionally, the new approach encompasses scanning for weak signals and trends while catering to innovation teams. Analysis of the workshop activities and outcomes suggests that the Future Ripples method can nurture the anticipation skills of innovation teams and help them develop diverse, novel, yet plausible futures. The paper also discusses the role of reflection, metaphors, and the balance between critical and creative thinking in developing holistic futures.

CCS CONCEPTS

• **Human-centered computing** → **Scenario-based design**; **HCI theory, concepts and models**.

KEYWORDS

Technology Innovation, Consequences, Futures Wheel, Futures Workshop, Anticipatory Capacity, Future Studies, Foresight, Futures Literacy, Futures Thinking, Speculative Design

1 INTRODUCTION

HCI and design are future-oriented activities. Significant parts of
research and practice in the field are oriented toward informing
future technologies' design and identifying new ways to support
users. Against this background, HCI researchers and practitioners
must be mindful of the futures they consider in their designerly
activities. That requirement has been rapidly gaining obvious per-
tinence with our awakening to global challenges related to social,
economic, and environmental sustainability [40, 52]. Accordingly,
design must address much broader, more systemic considerations
than merely the needs of the product's end users. The dramatic
changes in technology use amid the SARS-CoV-2 pandemic have
clearly shown that HCI researchers and practitioners need to in-
corporate long-term thinking into ideation practices and develop
anticipation capacities.

Regrettably, current HCI practice largely fails to answer the
call for holistic, systemic futures thinking [40, 54]. Irrespective of
the future-studies and futures fields' voluminous production of
methods and frameworks [41], few of these have found their way
into mainstream HCI research. Mankoff and colleagues [36] adapted
the Delphi forecasting technique, which builds predictions by a
group of specialists through a sequence of iterative surveying [35].
For a design team seeking to identify directions, such a process is
likely to prove overly burdensome.

We believe that the reason behind the poor take-up level of
futures-studies and foresight methods is the original methods' ex-
pansiveness. A typical foresight process aimed at scenario-building
takes months to complete [48]. While, in contrast, speculative de-
sign has gained immense popularity in HCI and provided methods
methods for critical futuring these scholars have only recently
started to adapt rapidity-oriented foresight methodology. Wong
and Nguyen [58] created a lightweight world-building activity for
considering the value-related and ethics implications of emerging
developed via traditional foresight.

Our paper contributes to the development efforts by focusing on
innovation teams' work. This was our central question: *What rapid
method could enable innovation teams to improve the anticipatory
capacity of their invention processes?* Through reflective practice
in the four ideation workshops described here, we developed the
Future Ripples process, which can be executed within a half-day
collaborative workshop. At its core is the widely used foresight
method Futures Wheel [19], which, notwithstanding popularity
in its home field, has made relatively limited inroads into the HCI
toolset [34, 58]. The method guides participants to consider the
consequences flowing from a nodal starting point creatively and
account for not purely technological factors that play a part in the
futures' unfolding: society, ethics, environment, politics, and juris-
diction. Akin to a dedicated foresight process, our version encapsu-
lates this brainstorming activity in a holistic process of scanning

for trends and framing the futures to ground the speculation in the
present.

Proceeding from analysis of the workshops, we found that the
Future Ripples method can nurture innovation teams' anticipation
capacities and help them generate a rich set of novel but plausible
futures. We reflect also on the role of metaphors and balancing
different modes of thinking (critical vs. creative, open-ended vs.
output-oriented) in developing comprehensive future scenarios.

2 RELATED WORK

The conditions that societies face now are very different from those
of the twentieth century. Likewise, the range of actors influencing
the futures has broadened. However, human cognitive capacity
to anticipate long-term futures remains just as limited as before,
and even expert knowledge is not entirely reliable for anticipating
futures [52]. The detrimental effects of the attention economy [24]
and reinforced discrimination of facial-recognition applications [2]
are just two examples of technology breeding unintended future
consequences. Carelessly constructed future visions can fail to
factor in significant future events, whereby surprises may emerge
that could have been better prepared for [46]. Focus on incremental
product changes, for example, may draw designers' attention away
from grand societal changes that should be taken into account [13].

The discussion below reviews the potential and the challenges
of integrating foresight into the work practices of technology-
innovation teams – i.e., designers, engineers, and scientists. From
prior literature on foresight, HCI, and design, we pinpoint and
extract the requirements for a rapid process and suitable methods.

2.1 Futures Thinking in HCI and Design

While a user-centred method of product design may be largely
successful especially when products are developed on a near-future
time horizon, the limitations of this approach have become appar-
ent in several ways. For example, participatory design approaches
have highlighted designers' disproportionate role in the product
development and called for democratising the design process via
co-design [8, 10].

Another criticism is connected with lack of reflection on the fac-
tors, such as values, that lie beneath innovators' decisions [15, 34].
Technology innovators could be more explicit and mindful also with
regard to the trends influencing their future-oriented thinking [45].
Neglecting such factors leads to problems, in that reflection on alter-
native futures has often remained a 'non-issue' in HCI practice [46].
In consequence, technologists tend to over-emphasise the influence
of technological progress and underestimate societal and structural
constraints. In the case of technological foreclosure in sub-Saharan
Africa, technologists failed to anticipate that new technologies'
dissemination might end up limited to large corporate players and
therefore not lead to wider access [16].

Advocates of speculative approaches and critical design have
vocally chastised such ignoring of alternative futures [18] and em-
ployed such means as participatory workshops to generate alterna-
tive visions of the future [e.g., 23, 51]. Processes of this nature have
helped to challenge the dominant frames of thinking and prevailing
images of the future while remaining situated and contextual [58].
Known as design fiction, another form of speculative design for HCI

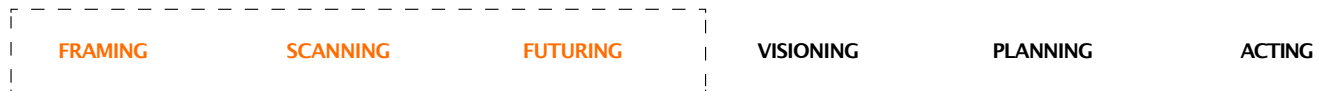| FRAMING | SCANNING | FUTURING | VISIONING | PLANNING | ACTING |

Figure 2: Strategic foresight as a six-stage endeavour [28]. The first three stages, highlighted here, hold particular potential for integration into design [20].

achieves the desired pluralistic outcome by constructing pictures from *concrete* futuristic technologies and their impacts [40].

While the HCI field's speculative approaches do not miss criticality, the work rarely promotes foresight approaches that apply holistic and non-linear thinking about the futures' complex systems in aims of managing uncertainty. Studies often focus on a single scenario, taking it as a starting point for critical reflection about prevailing assumptions in design practice. This omits analysis of many elements and of complex interrelations in larger, connected systems with a synthesising mindset [9].

However, newer methods whereby reflective practice gets integrated with speculation and design fiction have taken steps toward more systematically considering alternative possible futures. Lindley et al. [34] have suggested that the development of design-fiction narratives should transcend the 'hype zone' to enter a 'reflective zone' wherein technologies are appropriated and their use may follow several (not yet certain) patterns. A CHI workshop run by Sturdee et al. [54], in turn, examined speculation on unintended consequences in the peer-review process. Other scholars have proposed methods for assessing ethics aspects of emerging technologies [3, 58] and developed means of exploring fairness, privacy and security, reliability, inclusion, transparency, accountability, and user control. Among these are such mechanisms as game-like tools (e.g., Judgment Call [3]) for value-sensitive design and design fiction and also adaptations of the above-mentioned Futures Wheel (e.g., Timelines [58]) for world-building and anticipation of consequences in everyday situations (on micro scale) and broader societal impact (at macro scale).

With the work presented in this paper, we sought to develop such approaches further by embracing non-linear thinking about the futures' complex and uncertain systems.

2.2 Foresight Processes

One of the most fundamental tenets of futures studies is that the future is not predetermined and that we face a multiplicity of alternative futures [38]. Also, futures cannot be straightforwardly forecast with any great certainty. While the state of the present world and known processes influence the future, human choice, innovation, and chance too play crucial roles. Ideas and images of the future influence our decisions and actions today, and values underpin our visions of tomorrow. In addition, humanity does not make choices collectively, so people are motivated by a plurality of values, aspirations, and projects.

Referring to awareness of such premises for futures thinking, the notions of *futures literacy* and *anticipatory capacities* are umbrella concepts applied in the foresight literature for a mindset that acknowledges openness to possible futures and sensitivity to possibilities, as opposed to seeking accurate probability-oriented prediction. Whereas attempts at prediction easily lead to simplistic

thinking, anticipation of change enables people and organisations to make strategic choices. As such, futures literacy is a reflexive and constructive capability to "use-the-future" [37]. De Boer and colleagues [17] have listed several important capacities on which futures literacy depends: critical thinking, open-mindedness, self-efficacy, creativity, and low personal need for structure. These anticipatory capacities together enable embracing complexity, which futurists must do if wishing to understand futures from a non-linear, holistic perspective. For this, they must, furthermore, make sense of the future by contrasting open (i.e., exploratory/novel) futures against closed (i.e., predictable) ones. Developing these anticipatory capacities demands learning via processes of futuring consistent with context-specific goals [37]. Because similar capacities are valued in design too, innovation teams are positioned well to develop their futures literacy.

Foresight processes have been developed to nurture futures literacy and then put it to use. Voros's generic foresight approach, which has widespread currency in the foresight community [57], follows a four-step model wherein inputs feed foresight work, whose outputs then get applied in a strategy process. Voros described ways of implementing each step by means of several distinct methods. Input generation often includes scanning activities: e.g., discovery of weak signals that can lead to diverse future outcomes, trend identification, and a Delphi process. The foresight work analyses the inputs and interprets possible future paths and prospects. Its outputs, typically taking the form of narrative scenarios, explain the prospects. Finally, the fruits of these reports can be turned into actions in the strategy process.

The Association of Professional Futurists has proposed a similar process [20, 28], with six diverging and converging phases: framing, scanning, futuring, visioning, planning, and acting. We find designers likely to benefit particularly from integrating the first three of these stages [20] (see Figure 2) into their innovation practice. This would aid in stepping beyond attending to the end user, produce better understanding of the present and a more critical view of the expected future, and support considering alternative plausible futures.

For any high-quality foresight process, it is crucial to generate several scenarios of futures instead of only one. This is because foresight's purpose in strategy and policy processes is to create awareness of possibilities, not predict the most likely future. Therefore, several methods have been developed to map out scenarios that are plausible yet cover the space by differing from each other. We can avoid one-sidedness by remembering to attend to the many relevant forces, such as ethics factors [3, 58]. These are commonly captured via the acronym 'STEEPLE', encompassing social, technological, economic, environmental, political, legal, and ethics aspects [e.g., 50]. Also, futures can be generated reflectively along several dimensions; for instance, one may deliberately consider

extreme futures along two dimensions, thus creating a 2D 'cone' of possible futures [22].

Problematically, all of these foresight frameworks assume processes that are allowed to continue for weeks or months. While such timelines are feasible in strategic management or policy research, HCI and similar innovation-oriented design efforts require faster processes. Individual rapid methods do exist, however, and they serve as valuable starting points for HCI-adapted foresight methods. We review them in the next section.

2.3 Rapid Futuring Methods

While there exist myriads of methods in the foresight toolset [28, 42, 57], most represent disjoint activities intended for application within larger foresight processes. In contrast, the two presented below – the futures workshop [29, 30] and Futures Wheel [19] – are, as closed rapid processes, better suited to innovation teams' straightforward adaptation and adoption.

2.3.1 Collaborative Futuring with Futures Workshops. The futures workshop has been developed for broad-based stakeholder groups' engagement in collaborative, creative futuring [39]. Its stages encompass preparations, observation and critique connected with current issues, imagining future ideas and solutions, and implementation of actions. This method has found application particularly for participatory design [11, 21, 30] and sustainable HCI [e.g., 26]. To cater to stakeholders of all stripes, the workshop focuses on practical problems and is 'characterised by visuality, playfulness and multiple modes of communication' [1]. Embracing the same goal, HCI scholars have developed several further approaches encouraging participation [33, 43].

Such a practical, down-to-earth approach may hinder teams' musing on multiple, alternative futures [25]. This issue was critical in our project, since the goal was to find ways to increase innovation teams' anticipatory capacities. One solution developed to address this problem entails using the STEEPLE framing introduced above, scanning of the horizon for weak signals, and the Futures Wheel to generate imaginary and creative ideas aligned with pre-selected themes [25, 32]. Horizon-scanning is a family of methods for systematically identifying potential threats and opportunities that remain poorly recognised [55]. When attuned to weak signals, the search uncovers factors in the present world that, while not yet prominent drivers of change, may gain that role in the future [e.g., 27]. The Futures Wheel is a rapid method for mapping consequences and has been used in futures workshops. It suits our purposes well and we examine it next in more detail.

2.3.2 Mapping Consequences with the Futures Wheel. The Futures Wheel is a visual brainstorming method that identifies consequences of weak signals, trends, or changes as they unfold in the future [19]. For the analysis of consequences, a wheel form is created that has the factor of interest at its centre. The consequences identified for that factor are visualised as concentric rings around the centre. By providing for a 'smart group process, graphic structure, and non-linear thinking' [7], the Futures Wheel can facilitate collaborative, creative, and critical thinking. Glenn [19] identified its potential also as 'an easy means of diagnosing any group's collective thinking about the future', though it does require skilled guidance and

facilitation so that the consequences generated do not become too speculative or what he termed 'messy intellectual spaghetti'.

Recently, the Futures Wheel method has found favour among design practitioners [5, 53]. For speculative design, Wong and Nguyen [58] adapted brainstorming of implications with a futures cone to generate linear timelines of fictional news articles. The technique's use by non-experts is not free of challenges, though. In a study involving real-estate experts and students, the latter, as participants with less expertise, expressed lack of confidence in their contributions [56]. A report on another study notes, in a similar vein, that the outcomes may be 'limited by knowledge and perceptions of participants' and that 'information overload, complex and time-consuming data analysis, varying in consistency, and speculative nature of data' too can impair the outcomes from a Futures Wheel workshop [6].

Awareness of these issues informed our efforts to adapt the method to our needs, as detailed in the following section.

3 DEVELOPING AN AGILE FORESIGHT METHOD VIA REFLECTIVE PRACTICE

The motivation for our work arose from a larger research project aimed at developing methods that enable futures thinking in technologies' development and evaluation processes. As prior method-development work has [e.g., 30], we approached the evident lack of rapid foresight methods suitable for innovation teams via experimentation. Accordingly, our study followed a practice-based research approach, creating knowledge through creative practices and their outcomes [14]. Practice-based research stresses the role of systematic reflection emerging over the course of the process, both within the practice (reflection-in-action) to inform the action as it unfolds and after the fact (reflection-on-action) to evaluate and analyse said action [49]. The aim of such a research process inherently undergoes continuous reinterpretation and reframing so is subject to subsequent adjustment.

Our reflective research approach involved developing a new method through which innovation teams, including designers and technologists, can devise scenarios of alternative futures so as to advance their anticipatory capacities. For our case, we conducted four workshops in an iterative fashion, interleaved with reflection taking place after each one. All authors reflected on their experiences both privately and by sharing written reflective notes. In addition, we collected external participants' reflections via an online form and one semi-structured interview (with a group leader in the fourth iteration).

We made use of the reflections in several stages of the method-development process. Firstly, we analysed the reflective notes after each workshop to obtain insight and inform the design of the coming workshop, which incorporated adaptations accordingly. The process is detailed in this section and the next.

Secondly, after the last workshop, we analysed all the reflective notes in a bottom-up manner to identify overarching themes emerging from the data gathered throughout the process [12]. Section 6 outlines the resulting understanding.

Table 1: The four workshop iterations

	1st iteration	2nd iteration	3rd iteration	4th iteration
Duration	3 workshop days	2 workshop days	1 day of homework + workshop	1 day of homework + workshop
Goal	2–3 futures and sketches of potential user studies	Holistic futures concretised in everyday life situations	Futures that afford defining possible research-through-design projects	Futures that aid in ideation for possible research-project proposals
Facilitators	Authors 3 and 5	Authors 2 and 3	Authors 1 and 2	Authors 2 and 3
Participants	All authors	Authors 2–5 and two external designers	Authors 1–4	Author 4 and three material scientists
Scanning	Horizon-scanning and data cards	Prepared data cards	Horizon-scanning (asynchronous)	Horizon-scanning (asynchronous)
Framing	Prioritisation	Prioritisation	Discussion of scope and the pebble	Discussion of scope and the pebble
Mapping	Multiple Futures Wheels	Multiple Futures Wheels	Creating ripples	Creating ripples
Follow-up	Seed scenarios + scenario development	Future news + a 'day in the life' story	Desirability analysis + ideation of next steps	(Splashes and) desirability analysis

3.1 Participants

The team of authors comprised two mid-career researchers, one with a cognitive-science and HCI background (A3) and one with a background in engineering, design, and sustainability science (A5). The other authors were three early-career researchers with a design background, who were specialists in HCI (A1), interaction design (A2), and textiles and fabrics (A4). For the second workshop, the authors were joined by two mid-career design researchers (one focusing on service design, the other on industrial design). For the fourth, in which our team acted as facilitators (with the exception of A4, who took part directly for reason of an existing research-collaboration relationship), the participants consisted of a material-science research team.

3.2 Workshop Iterations

We developed the Future Ripples method through the four workshops' iteration (see Table 1). Our original idea was to develop a three-day sprint-like process (akin to a Google Design Sprint [31]). While the first two workshops, in line with that goal, were oriented toward developing a more comprehensive process (both involving future scenarios and sketching plans to study them), the final two focused solely on the Futures Wheel and pursued a method that could yield engaging future scenarios without also taking them as starting points for research projects or proposals.

Even before the first workshop iteration was complete, we recognised the Futures Wheel's potential, so we focused our efforts increasingly on adapting it for our purposes. While the method helped us cultivate ideas that we found deeply insightful, it proved challenging for some participants. The technique, in its original form, requires an open mind and speculation about future outcomes while at the same time demanding that these outcomes be direct consequences of outcomes identified earlier. This felt difficult for those of us whose creation process usually proceeds from a problem that

needs a solution. Because of this difficulty, we wanted to render the Futures Wheel's use more convenient for everyone.

We conducted all workshops remotely, using the remote-collaboration tool Miro, which provides online-whiteboard functionality, as the canvas for the creative process. In the process through which the Futures Wheel developed into the Future Ripples method, we paid special attention to two elements: Firstly, we experimented with several framings – how the futures of interest should be expressed at the beginning of the workshop to imbue the team with the right mindset for the work lying ahead. Secondly, we sought the best form of content to position as the wheel's starting point.

With regard to the core work with Futures Wheels – thinking about consequences – we varied the canvas on which the notes would be posted. The first workshop was free of any guiding material. Recognising that this made it too easy to forget the STEEPLE categories [22], consider only technologically inspired futures, and compromise the holistic thinking we were seeking, in the second setting we divided the wheel into separate STEEPLE sectors (similarly to the version suggested by Glenn [19]). This breakdown ended up pushing workshop 2's thinking into fixed, isolated categories that hampered brainstorming, however, so we returned to the basic wheel for workshops 3 and 4. Our new solution was to guide the participants to tag every note with related STEEPLE categories. The tags, which Miro can display with dots of corresponding colours upon zooming out, helped us apply efficient visual scanning to identify those ideas that holistically synthesised several STEEPLE categories vs. those that did not.

In addition, we experimented with post-processing of the wheel's outcomes. While the first two workshops included attempts to develop sketches of research plans for futures that excited us, such activities protracted the workshops dramatically. Therefore, we decided to evaluate the impacts of the wheels' consequences by using a more lightweight closing activity. This entailed grouping
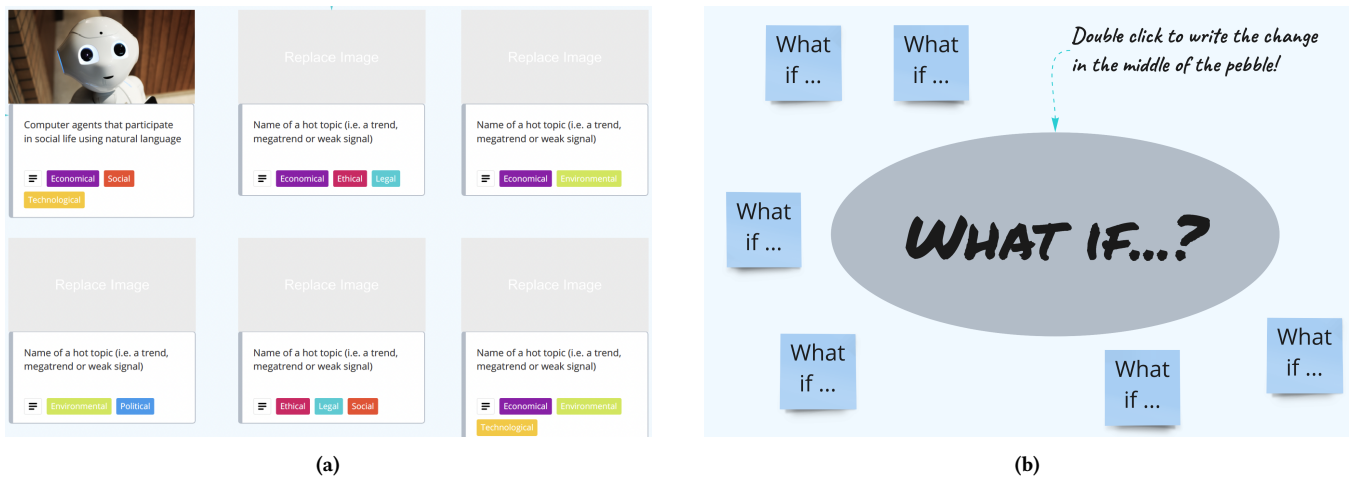
Figure 3: Portions of the Miro template. At left, a data-card template (photo by Alex Knight on Unsplash). Participants are asked to fill in the cards with weak signals or trends and tag them with STEEPLE categories. At right, a pebble template. Participants formulate a 'what if' scenario as a starting point for ripples' creation.

the most promising ideas into positive or negative futures and placing each on a two-dimensional grid whose axes denote the profoundness of the impact and its plausibility.

4 THE FUTURE RIPPLES METHOD

A distinct futuring process emerged from the iterative process presented above. Here, we present our adaptation, which we dubbed the Future Ripples method, in a manner that allows for its replication at various points in a design or development project. For instance, it can inform understanding of futures in the field of interest (e.g., a prospective research area), to assist in ideation and envisioning or, equally, enable creating a more comprehensive picture of possible futures involving an existing product or design (such as a novel interface), to steer the development and evaluation processes accordingly.

The entire workshop process is built on a metaphor of ripples in a sea of possibilities. We find this metaphor more accurate and fruitful than the original wheel analogy, which, for example, communicates the idea of multiple interconnected circles of consequences less well. In fact, we consider the sea an ideal metaphor for visioning. Figure 1 attests to this by presenting the metaphor's main elements. In the figure, the land functions as an analogue for our knowledge, the ground on which we stand. The sea, in contrast, is volatile like the future and appears endless until reaching the horizon. It is vast, unattainable, and full of uncertainty[1]. While we cannot know every feature of the land, we can nevertheless scan the shore for existing knowledge. What is beneath the surface of the water stays hidden. By throwing a pebble into the water, we can create ripples that might help us understand a bit more about the depth and dynamics of the sea. Still, the sea is turbulent, and the ripples merely give a glimpse of its depths.

Created with small teams in mind, the method builds on active use of group discussion. We found groups of 4–6 optimal for

avoiding a heavy moderation burden, but the technique still can accommodate larger groups, by separating them into smaller subgroups. The process begins with the team defining the workshop's goal. This should enumerate the areas of interest and the outcomes expected of the workshop. We recommend formulating the goal with the whole group of participants, to align their thinking – e.g., 'We want to brainstorm the consequences of the novel conversational user interface we are developing.'

After setting of the initial goal, the process follows four phases: scanning the shore, choosing a pebble, creating the ripples, and follow-up. The first two phases pave the way for the main activity, in which consequences are mapped out. These three steps, respectively, correspond to the scanning, framing, and mapping/futuring in a traditional foresight process, such as the Association of Professional Futurists one [20], diagrammed in Figure 2. After these, the follow-up step concludes the workshop with steering toward implementable activities. For the full workshop, we found 3–4 hours to be a feasible length.

4.1 Scanning the Shore: Data Cards

While this is not mandatory for mapping of consequences, we advise starting Future Ripples with a scanning activity (see Figure 3(a)). In foresight work, scanning (e.g., Horizon Scanning [55]) hunts for observable signs of change in the present. These changes may appear as trends, megatrends, or even weak signals. Weak signals hold a particularly important role in connection with long-term futures, in that they point to possible radical changes not yet perceived as actual trends. While such signals are volatile in nature, they aid in grasping alternative futures beyond trend projections.

While the facilitator may choose from among numerous scanning techniques, we present a version that helps to balance effort against outcome. Each participant is asked to reflect on three (or more) weak signals or trends independently before the group workshop. The facilitator shares detailed instructions for this in advance of the workshop. These include examples of how scanning may

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[1] Michael Lapp. 2015. 'The sea – the ideal metaphor for a vision'. Retrieved 30 January 2022 from https://www.memecon.info/?p=1027.
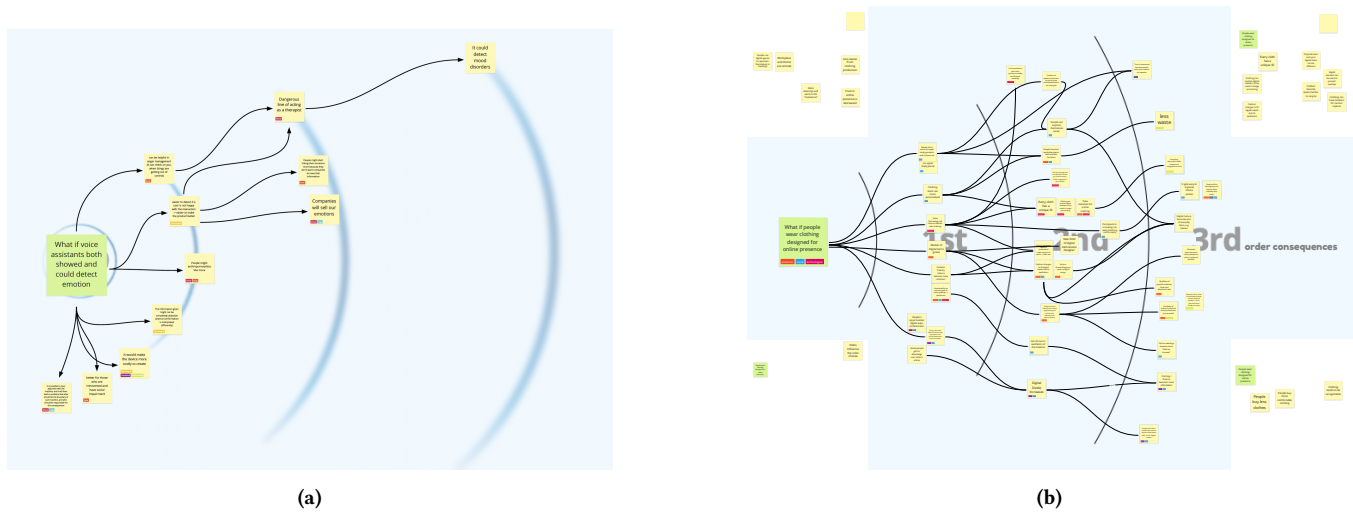
Figure 4: Creation of ripples as concentric waves spreading from the pebble (the green notes). On the left (in pane a), an early diagram shows the first chains of consequences. At right (in pane b), a later-stage diagram shows a more complex web of consequences, with participants' brainstorming areas in the corners, where contents can be privately prepared until ready for sharing.

be performed, featuring useful search-term patterns (e.g., 'Future of [topic]') etc. Participants can then draw on their personal or professional expertise to identify relevant topics. In our workshops, one participant shared a weak signal pinpointed via discussions with a teenaged son about intentions not to have children due to eco-anxiety.

As an asynchronous activity carried out beforehand, scanning permits greater extent and depth than the workshop setting alone does. To guide their collection of a broad set of topics, participants are encouraged to find topics in different STEEPLE categories or that transcend category boundaries. The participants enter their findings in data-card templates that ask for a title; the related categories; the nature, relevance, and impact of the topic; and sources of additional details. This paper's supplementary material contains more in-depth instructions and points to further resources.

The results of the scanning activity constitute the starting point for the workshop. As their first joint task, the team must align and cross-pollinate their thinking. We suggest that participants present their data cards in rotating order, discussing each card's relevance with respect to other aspects of the project at hand. In addition, using data cards that the participants have created themselves increases their sense of ownership and engagement in the workshop's later steps.

4.2 Choosing a Pebble: A Starting Point

The next step in the process consists of selecting the pebble (see Figure 3(b)): the starting point for mapping the consequences. The choice of the pebble is critical for the whole ripples process. It must be specified narrowly enough to support easily thinking of direct consequences yet sufficiently broadly to leave room for wider implications. Whilst a small pebble might create only small ripples, a heavy one is harder to handle. We suggest formulating a pebble as a 'What if …' scenario consistent with the workshop's scope

and the goal of the team. It might express a concrete idea (e.g., 'What if textiles had self-repair capability?'), entail more general exploration (e.g., 'What if clothing were based on living organisms in 10 years?'), or stem from a weak signal identified in the shore-scanning step. Pebble selection should follow the principle of developing plausible futures. Accordingly, it should not be counterfactual, i.e. deviate from what is assumed to be possible in light of present knowledge [57]. In addition, to stimulate better creation of ripples, the facilitators should make sure that all participants see some relevance in the pebble.

4.3 Creating Ripples: Brainstorming of Consequences and Impacts

The creation of ripples forms the cornerstone of our method (see both panes in Figure 4). It applies an adapted version of the Futures Wheel, tailored for novice futurists and innovation teams. The goal is to brainstorm consequences and impacts of the pebble in the form of concentric rings. The first ripple represents direct future consequences of the 'what if' prompt from the pebble, and every further ripple describes consequences of the preceding one's contents. Further on, we present diagrams produced by workshop participants in this activity.

To encourage a good flow for the brainstorming process, we propose alternating individual-level brainstorming and group discussion: At first, individuals work on their own to generate consequences for an earlier consequence of their choice. For this, a facilitator could ask 'what happens if this consequence occurs?'. Every participant jots down ideas for about 10 minutes without adding them to the ripples diagram yet. This individual process should be facilitated by giving each participant a dedicated area (e.g. see the white the corners in Figure 4(b)). After this, all participants, in turn, present two or three of their ideas, those they deem

most significant, and place them on the board. Lines are drawn to connect the ideas with the corresponding earlier consequence. As the participants articulate more and more ideas in this process, the new ripple forms.

Some care must be exercised in the generation of consequences. They should be plausible, referring to 'theoretically occurrable' trajectories of events while also representing processes that experts and stakeholders have jointly fleshed out and agreed on [47, p. 20] (for discussion of the term's etymological history, see Ramírez and Selin [44]). To this end, we adapt a variant of Futures Wheel that applies a 'rule of unanimity' [19]. Participants discuss each consequence and its relation to those already placed on the board. Because initial interpretations of what constitutes a 'direct' consequence may differ, situating the consequence may entail finding a suitable place in a ripple other than the one the participant originally had in mind. For example, expressing a sequential relationship between consequences identified by two individuals might demand placing them in separate ripples and, thereby, creating a chain of consequences. Only after reaching consensus can the group move on to placing the next consequence.

In this stage, one of jointly discussing individual-generated notes and placing them on the wall together, the internal coherence of the ripples is more important than the quantity of consequences. The group's goal should be to map out the ripples of a change and the possible consequences' relations to each other. In pane a of Figure 4 we can see how this creates chains already after only one cycle of brainstorming. Additionally, each note should be tagged with its corresponding STEEPLE categories (in Miro, we used tags of distinctive colours for this). Once all participants' most insightful ideas have a place, the group must assess which categories are over- or under-represented. At this point, participants can also consider any left-over notes from their brainstorming that they deem valuable additions to the diagram.

Then, the individual- and group-work steps described above are followed again, to fill the next ripple. In the later iterations of ripple creation, the facilitator encourages participants to think about consequences that tie in with under-represented STEEPLE factors. Because some consequences may involve longer chains than others, the process grows more dynamic. Therefore, consequences can always be moved around to improve the ripples. Ripples' creation can involve three cycles or even more, to saturate the map of consequences.

The ripple-generation process is speculative, and the ripples' details depend on the scope and the team's expertise. Consequently, the results are never final, so the facilitator judges whether saturation is adequate or decides to stop after a fixed number of iterations.

4.4 Follow-up

While the ripples themselves display a map, innovation teams need practical outcomes. The Future Ripples diagram from the previous step serves for orientation and inspiration but does not directly meet that practical need. Therefore, any Future Ripples workshop needs a follow-up activity to create actionable steps or concrete scenarios. We advise selecting consequence chains or particular consequences that the team judge significant (e.g., by voting) for

further development. The chains and their most far-reaching implications can be transformed into fully fledged scenarios (for instance, we experimented with turning them into news articles for the fictitious newspaper *Future News*; see Table 1). One follow-up activity we recommend is a desirability analysis and brainstorming of the next steps. In this activity, participants vote for the consequences that they feel represent the most positive and negative impacts. The consequences with the most votes then are placed on a crosshairs 2D graph whose axes express perceived likelihood and the positive/negative impact's extent. Once the consequences' positions have been plotted, the team brainstorm actionable steps to mitigate the negative consequences or exploit the opportunities. It is important to bear in mind that how the Future Ripples method is applied depends on the group, since all teams should adapt it to their specific needs. If this entails relaxing the method's structures, leaning more extensively on facilitation is unavoidable. To help facilitators assess the method's utility and decide whether to adapt it to their project's needs, the following section evaluates the outcomes of our process and the factors that are critical for successfully implementing a Future Ripples workshop.

5 DIVERSE FUTURES OF WEARABLES AND SMART MATERIALS

To illustrate how the method can be fruitful for innovation teams, this section presents some of the outcomes from our Future Ripples workshops and how they sparked futures thinking. Our focus here is on the workshops' direct outcomes; in Section 6, we offer our reflections. As noted in our description of the method's development, the mappings and future scenarios developed in the first and second workshop were more experimental than those in the final two. The former aided in stimulating futures thinking and finding core activities for the method, while the third and fourth iteration were more refined and focused on fine-tuning the Future Ripples process's details.

The authors share an interest in futures of smart textiles, particularly with regard to clothing and wearables, under the changing conditions of the climate crisis. We used the outcomes of the first three workshops as guidance toward possible prototype-based research-through-design studies in a more extensive project aimed at developing future-oriented methods for HCI. Our fourth workshop brought in an external set of participants: people interested in radically creative ideas for textiles, fabrics, and materials. The ideas and results from that workshop informed identifying a new topic for a research proposal.

5.1 Climate Wearables and Multi-Sensory Communication

While we changed the framing in line with each workshop iteration's goal, our areas of expertise created a common element within and among them all: interest in wearables and designing interactive systems. Although the first workshop did not establish a good flow, it showed potential, generating scenarios that surprised us. We were inspired by the understanding that can result from thinking more holistically about future impacts related to a given technology and were impressed by the magnitude of changes that we came to consider thereby. Our Futures Wheel had this starting

point: 'What if people experience increased mobility and capacities from wearables?' We ended up considering highly disparate futures. One scenario featured medical personnel rebelling against being replaced by data-driven health-care providers. In another scenario, fatal accidents and serious injury become more commonplace as exoskeletons and other cybernetic aids distort people's physical self-awareness.

Workshop 3 offers another example of our framing. It asked us to consider smart-garment-enabled multi-sensory interpersonal communication in 10 years. Our pebble for the ripples was 'What if people wear clothing designed for online presence?' (Figure 4b provides an overview of the process). Our ripple creation identified potential for people to express themselves more freely. This led to an avalanche of further consequences, such as digital augmentations allowing clothing to become more personalised and changes emerging in some existing meanings of garments. For example, through higher-volume interaction wrought via videoconferencing, digitally augmented garments may obtain increased relevance because they allow for new kinds of digital presence while at the same time being physically worn objects. Via these phenomena, our practices in the digital space could start to influence our physical appearance: we might wear particular clothes because of their digital rather than physical appearance. However, in another consequence we detected the possibility of this leading also to digitally afforded distinctions, thereby widening the digital divide: consumers could end up with different levels of access to those technologies and capabilities of using them. Moreover, such changes would require more electronics incorporated into clothing, thus rendering recycling more difficult and bringing on a new negative environmental impact from the fashion industry.

When reflecting on our own research project in light of the workshop results, we noticed that we had become better aware of the benefits of adopting non-technological starting points for our innovation and more comfortable with working from such starting points.

5.2 Novel Smart Materials

The group for workshop 4 consisted of a team of material scientists. Apart from the author with dual affiliation, they were not familiar with the Futures Wheel or any similar foresight methods. The group's intention was to generate ideas for an interdisciplinary funding proposal. In the preparations for the workshop, we helped the participants formulate the following framing: 'Our goal is to develop futures that help us define a research proposal that is radically creative. The topic for the proposal would be textiles that could be considered to be alive, reactive, and symbiotic in the far future.'

The participants prepared themselves for the workshop by creating a small deck of data cards. After presenting them near the start of the workshop, they chose this pebble: 'What happens if textile materials can deform, change their tactile and visual properties, and adapt to different environmental stimuli?'

Among this workshop's outcomes were scenarios involving computational materials that have a long-term memory (see Figure 5). Considering a circular-economy scenario that entails passing cloth

material on to new users, the team recognised a possibility of accidental leakage of private information in conjunction with smart clothes' recycling. While situations exist in which conveying information about past owners can serve positive ends (e.g., passing the item down through the generations as an heirloom that people of many shapes and sizes can use), this scenario also aroused a feeling of uneasiness within the team. That sense developed into broader questions pertaining to a future involving human-to-human tactile information transfer through context-aware computational fabrics.

While this was just one idea and not aligned so well with most other ripples found, the group leader stressed the importance of the team thinking about 'the bigger picture', generated through creating all the ripples, in the preparation of the research proposal. As the prospective research consortium was interdisciplinary, the outcomes helped the team present their ideas to collaborators by letting the listeners position their own research in a space populated by more holistic concepts. As the group leader described it, 'the background helped a ton because [...] everything converges at the very abstract level'.

5.3 Qualities of the Futures Generated

One benefit of the Future Ripples method is that it creates a causal chain of consequences. Any outcome from the process can be traced back along a causal chain to the pebble and to the weak signal that indicates the start for it. Identifying the chain of consequences leads to generation of futures with greater plausibility. The benefits emerge when the futures extend beyond near-term windows (5–10 years): participants are able to maintain a connection to practical developments in the present state of affairs and also consolidate those developments' unexpected, surprising future consequences. This possibility of linking near and far futures together, via the structure of the ripples, aided the material scientists in planning their research proposal focused on memory textiles.

Furthermore, the futures exhibited more variety. Participants noted that the inspiration from scanning led to unexpected ideas of impacts and consequences – e.g., 'We got a different Starting Point because of [the] Data cards. [...] It worked well.' In the same vein, multiple participants also described the STEEPLE categories as useful and inspirational (e.g., the tags had a 'broadening function in that we normally don't think about legal at all'). The approach likewise enhanced communication of the futures, by rendering them more holistic and, therefore, comprehensible to different stakeholders, across the consortium's disciplines. Resulting futures were 'relatively complex, dynamic, potentially surprising' [13]. These findings imply that the future-scenario work benefited from a process of framing, scanning, and mapping. In fact, participants cited the scanning and discussion of the pebble as crucial for their understanding of the consequences and as inspiration. One material scientist characterised the 'network between ripples and how new paths arise and intertwine' as remarkable.

6 FACILITATING ANTICIPATORY CAPACITIES

Having described the practical merits of our workshops' outcomes, we now turn to the central themes from our reflection on developing and facilitating Future Ripples.

6.1 Self-Efficacy and Embracing Complexity

One critical success factor we pinpointed for this format of futuring is the participants' self-efficacy. Everyone involved in the workshops had to find a balance between personally perceived competence/incompetence, or the self-efficacy stemming from the relevant personal professional competence, and the feelings of uncertainty arising from learning the unfamiliar futures-thinking approach. The author with the least exposure to futures thinking and its methods made particular mention of the struggle to contribute to the very first workshop. For that author, the workshop brought a sense of low self-esteem and hesitancy surrounding completion of the tasks. While self-efficacy is undoubtedly an important factor in all collaborative work, we see it as a particularly pressing issue in scoping of a futuring method intended for an innovation team. The added difficulty in the case of Future Ripples seems to stem from learning a new cognitive capability: futures literacy and consequential thinking.

As described in Subsection 2.2, futures literacy encompasses many, disparate realms of cognitive capabilities. Our reflections elucidated that Future Ripples demands all of them. To begin with, mapping out consequences is a central aspect of making sense of futures. This activity requires critical and causally oriented thinking to reconcile closed futures grounded in current trends with open futures based on speculation. Both types of futures get represented in the Future Ripples process: the trends revealed through the scanning exercise and the pebble that grounds the full ripples in the present can be seen as closed futures, while the speculation in creation of the ripples and addressing the STEEPLE categories forces participants to open themselves to exploratory or novel futures. Most participants were able to apply critical thinking in our workshops. In this case, using scanning activities and group discussions that include personal perspectives helped everyone keep an open mind.

In addition, futures literacy requires embracing complexity, for dealing with inherent ambiguity and novelty [17]. This entails general self-efficacy, creativity, and low personal need for structure. While creativity should be an innate ability of any innovation team, those participants with a natural-sciences background seemed to struggle especially with it. While applying analytical thinking and reducing complexity, so as to make knowledge reproducible and model closed systems, is a key component of scientific work, in the futures and foresight domain it is crucial to make sense of large complex systems and their interrelated parts. This demands an approach of synthesis rather than analysis. The cognitive challenge of switching between analytical thinking and synthesis becomes crucial for the performance of Future Ripples. It demands good facilitation, which has to instil a suitable mindset in the participants and support their self-efficacy.

An external participant in workshop 2, held before we had developed the ripples metaphor, put it thus: 'It would be good to understand what is the [expected outcome]. At the same time, the outcome may be "understanding" or "knowledge", so perhaps that is impossible.' This too highlights the need for facilitation to guide participants through such a demanding process.

6.2 Instructions and Facilitation: Metaphors and Conceptual Mapping

Throughout the project – from our first experience with Futures Wheel through to the final workshop, with external participants – we saw that brainstorming a coherent map of consequences requires ample guidance. Participants repeatedly requested ever more precise instructions for this unfamiliar approach. Not just the process but even the foresight terminology posed a challenge to us as novice futurists. Therefore, as we facilitated the workshops, we soon understood the need for easy-to-comprehend metaphors that could steer the participants' creative imagination. Most importantly, the wheel metaphor from the original Futures Wheel method proved difficult for us. Although the process is intended to be carried out in a radial manner whereby concentric circles of consequences are generated before the next circle is formed, the wheel metaphor rendered it urgent to complete the circles for the sake of doing so, rather than map highly interconnected chains of consequences. This is why we sought a better metaphor. Choosing the 'ripple effect' that occurs in Futures Wheels, as described by Glenn [19], as a central analogy, we opted for a cone-like layout that affords a clearer overview of the chains. From this visualisation, the image of throwing a pebble into the water emerged. The new metaphor immediately grew into a mental image encapsulating the whole and eventually gave us the name for our method.

The metaphor of ripples grew into an analogy of throwing a pebble of change into the sea of possibilities. This proved itself a useful tool for guiding us and the other participants through a complete process. Since the four workshops presented in this paper, we have continued exploring the method's possibilities. In a university course on novel voice-based user interfaces (VUIs), we facilitated a Future Ripples workshop for computer-science, design, and engineering students' brainstorming of VUIs' direct and indirect consequences, in pursuit of developing potential research projects. The intuitive metaphor, coupled with clear instructions in a template we have created[2], allowed the students to choose a pebble and generate ripples within a brief, one-hour seminar.

6.3 Openness vs. Output-oriented Thinking

Throughout the workshops, we witnessed how participants abandoned their usual lines of thought. For example, seeing how some of them chose very different and even personal topics for the data cards widened others' perspectives. Furthermore, the discussion of where to position a consequence generated critical reflection and further relational understanding.

However, this openness seemed at odds with the output-oriented thinking of several participants. Especially for teams with a scientific or specialist background, the urge to produce results runs counter to engaging in deeper, more open discussion. After all, their everyday work requires **reducing** complexity, as noted above and highlighted by a group leader's remark that "as a scientist I tend to think that I should have a systematic justification". Likewise, Mankoff et al. [36] characterised the process of research as able to hinder long-term thinking.

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[2]See the supplementary material or https://miro.com/miroverse/future-ripples-method/.

We saw such a tendency in ourselves when a facilitator of workshop 4 perceived the material-scientist group as having become stuck after "finishing" the third order of consequences. Feeling an urge to intervene, the facilitator tried to assist by adding a large cluster of related notes in rapid succession (see the isolated branches of notes in Figure 5). This process deviated from creating ripples to build a bigger picture, though. Each cluster manifests just one link to the ripples. Hence, the result is closer to MindMapping (creating separate linear chains) than Futures Wheel work [19].

We interpret this as the outcome-oriented innovation team's reaction to the alien mindset represented by the systematic, open-ended thinking demanded by the the ripples' creation.

While Future Ripples aims mainly at widening the scope of thinking about the change in question, an innovation team's process converges toward a concrete outcome. A team might exhaust its capacity to embrace the complexity associated with one pebble and then need to move on to the follow-up activities. Though the recommended three-iteration brainstorming of consequences provides valuable structure, we conclude that steering a team to the next activity still requires facilitation.

7 DISCUSSION

In our work, we strove to address the lack of critical long-term reflection in technology innovation within the HCI field. We aimed to broaden anticipation capacities, as technologically optimistic short-term design decisions can spawn unforeseen, far-reaching consequences, some of them negative. By adapting the commonly used Futures Wheel tool, we developed a strategic foresight method that shows potential to help cultivate futures literacy and enhance design/innovation teams' anticipation work. Importantly, it also yields practical output, rapidly. The fruit of our development process – Future Ripples – forms the heart of a complete futures workshop.

Tailored to innovation teams, Future Ripples constitutes a step toward strategic futures thinking in technology-innovation practices.
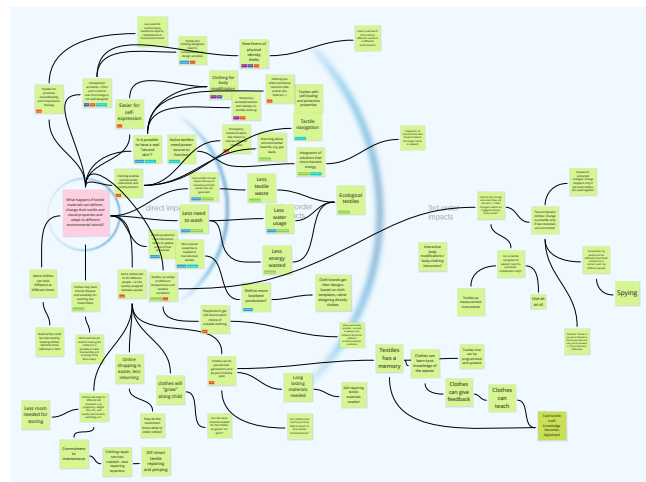

Figure 5: Workshop 4 outcome, with two clusters of notes isolated from the ripples.

Our work aligns with the design-fiction and speculative-design approaches, which have recently embraced more comprehensive reflection on long-term futures and on technologies' ethics implications [3, 58]. Our continuing aim with Future Ripples is to build upon speculation and foresight to incorporate long-term thinking and collective sense-making into the development processes. Similarly to our work, Wong and Nguyen's *Timelines* method [58] applies foresight methods (i.e., the Futures Wheel) and related thinking to envision and discuss ethics concerns and technologies' unintended impact. Future Ripples, however, adds an alternative rendition that adapts the key steps of a foresight process through framing, scanning, and futuring/mapping (see Figure 2). Where Wong and Nguyen's work used storytelling and creation of news headlines about everyday situations to create a familiar-feeling lightweight activity, we eased the cognitive burden of consequential thinking via the metaphor of water and ripples. Our approach purposefully discards linear timelines in favour of ripples, to focus on interconnected alternative scenarios. Future Ripples holds promise for discussing and speculating on ethics concerns in general, and, more importantly, it encourages exploring innovation opportunities in HCI practice specifically.

Lastly, we wish to address the positioning of our work. Throughout the project presented here, we played two roles. In our iterative method-development process, we both designed the workshop-based method and used it as workshop participants ourselves. Likewise, our critical evaluation of the workshop results and the method's overall utility – assessed between the workshops and also in the course of preparing this paper – was rooted in our experiences as developers and participants both. Our shared motivation for developing the method has been driven by our desire to generate visions of possible futures that are suited to research-through-design case studies, prototypes, and field trials later in our larger research project. Hence, our motives are aligned with self-interest.

8 LIMITATIONS AND FUTURE WORK

Although one aim behind developing Future Ripples has been to decrease technology-centredness in HCI innovation teams' futuring (by such mechanisms as explicitly reminding the teams to consider additional STEEPLE factors), technological development still plays a prominent role in the method. This is because we have developed the method with innovation teams in mind. Their main interest lies in contributing to the unfolding of futures through primarily technological interventions. Further work may be needed for devising supplemental methods to ensure the other STEEPLE factors' proper representation in the Future Ripples futuring process.

Also deserving of further attention is the participation of relevant stakeholders in the process. When one compares Future Ripples to various other implementations of futures workshops [4, 21, 25, 30, 32], it becomes apparent that our method's development thus far has arisen largely through internal workshops. More settings resembling the fourth workshop are needed, for evaluation of the technique's usefulness. Also, external stakeholders should be among the participants. This necessitates finding ways to onboard them naturally, so as to address the perceived-incompetence-related stumbling blocks that we recognised in our reflections. Finally, the method needs testing with teams who have no experience of any

of this paper's authors as a member or facilitator. Its use must be studied with people other than us. We are already in the process of exploring it in precisely such contexts.

It is crucial to remember that a Future Ripples workshop is not intended to replace a more traditional dedicated strategic foresight process. Just as Futures Wheel, the scenarios from Future Ripples are still mostly speculative in nature. However, as a rapid process, the new technique offers a means of integrating futures thinking into innovation teams' project work, helping them consider long-term consequences and impacts of their projects.

While we found the method valuable for our own practice and see it as promising for scholars and practitioners in technology innovation, demonstrating its worth for a wide range of design tasks and team compositions calls for further evaluations and development.

Hence, we invite scholars and practitioners to apply Future Ripples in their product-innovation processes, reflect on its success, and report on their experiences. To support collegial uptake, we have provided a template in the collaborative online whiteboard system Miro[3]. Our immediate next steps entail conducting further Future Ripples workshops in our ongoing research-through-design work. We plan to consider, with diverse external stakeholders, the consequences of smart garments that can collect, contain, and exchange information. The output from this consideration will form the foundations for future scenarios involving smart garments, which should inform prototyping and evaluation.

ACKNOWLEDGMENTS

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