CIO Work Package 1 Summary: Theoretical Concepts

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This is an updated version of the CIO Whitepaper summarizing the theoretical contributions of the project.

1 INTRODUCTION

The CIO project (https://cs.au.dk/research/pages/cio) was about exploring the role of theory for Human-Computer Interaction (HCI) and Computer Supported Cooperative Work (CSCW) and for design of technological artifacts based in such theory. Rogers [73] proposes that we consider HCI theories in terms of their formative and generative powers: To build overarching frameworks for HCI is to provide a set of concepts "from which to think about the design and use of interactive systems." The idea is to "stimulate new ideas, concepts, and solutions. In this sense, the theory can serve both formative and generative roles in design" [73, p. 121]. Beaudouin-Lafon [7] talked about interaction models and how they should be descriptive so as to incorporate both existing and new applications, comparative for comparing alternative designs and finally constructive/generative as to facilitate creation of new interaction techniques (see also [2, 8]).

In CIO, we have worked to develop theory for joint activities and common objects [39]. The theoretical basis unites a CSCW-based focus on common objects with the activity theoretical understanding of mediation and human activity as joint or cooperative and rooted in practice. Beyond this, the project is based on the assumption that both practice and objects are changing and, hence, it has a profound concern for how theory supports change and for understanding future technologies, for good and bad [2].

The main research objectives of CIO are to:

(1) develop the conception of common interactive objects so as to offer a new understanding of human-computer interaction, focusing on human control.
(2) develop a new perspective to support the building of user interfaces in a coherent and unified framework.
(3) make common interactive objects that will empower users to better understand and develop the technologies they use.
(4) carry out ground-breaking research regarding the technological basis of common interactive objects with focus on malleability, control and shareability over time.

The current report summarizes WP1 which is the work package set out to do theory exploration and development, so as to offer new understandings. WP1 has included studies of theories and frameworks for common interactive objects and object thinking coming out of HCI and related fields. By discussing, contrasting and distilling concepts that are then applied and re-iterated empirically, analytically and in design in specific cases in particular, this methodology has helped provide new concepts, bring concepts together and provide means for thinking about the wholeness and the unity of the framework.

The objectives of WP1 was to develop the conception of common interactive objects so as to offer a new understanding of human-computer interaction, focusing on human control (Objective 1). WP1 reviewed literature on common, interactive objects in order to develop a theoretical basis towards objects, interactivity, materiality, control, sharing, development, and time. The goal was,

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furthermore, to develop innovative empirical and design-oriented research methods to address common interactive objects.

WP1, as it was outlined in the grant proposal, had six parts:

- WP1.1 Literature survey and taxonomy regarding physical/virtual objects, common objects, boundary objects, runaway objects, objects and time, objects and history, object blends, participation with objects, tangible object interaction, augmented virtual objects, and etc.
- WP1.2 An international, high-profile workshop with approximately 15 invited participants.
- WP1.3 Common interactive objects and the new materiality. Enhancing our use-oriented understanding of computing as the materiality of human-computer interaction.
- WP1.4 Humans interacting through shared objects — reaching out to modern cognitive and motoric understandings.
- WP1.5 Mixing and blending. Moving towards an enhanced understanding of common interactive objects as they journey across human use and experience, activities, practices and (re-)appropriations.
- WP1.6 Control and common data. This WP took its starting point in "big data" and the IoT and the lack of understandability and control of the human users of such data. It was to explore and provide an alternative, object and control-oriented understanding.

We produced an early version of the CIO Whitepaper [39] in WP1.1 in order to present and discuss it in WP1.2 (the workshop). The research group debated whether to update the Whitepaper after the workshop, but decided that it would be more appropriate to wait Hence parts of the Whitepaper has been used and refined in various publications [e.g., 1, 2, 8, 23, 27, 54, 61, 62, 64]. The purpose of the current report is to bring these parts together and extend the discussion.

There has been issues of timing and manpower as regards WP1.4 and WP1.6. As regards WP1.4 it was originally planned in collaboration with colleagues who were not available once the research was scheduled. Hence we have hence moved back a bit from these possible collaboration and done work instead with associate professor Eve Hoggan [37].

As regards WP1.6 this was hindered by the pandemic and meanwhile the ideas have shifted somewhat theoretically, to focus more on multiple and complex data (an area where we have supervised a number of student projects) and to using Common Interactive Objects in a critique of AI. This focus is still under development but was presented by Bødker on several occasions e.g. in a talk at Sorbonne University in May 2023.

2 SUMMARY

Our goal in this work is to summarize a conceptual framework for describing and designing common interactive objects in order to maintain and extend human control over the technological environment, by human beings, both individually and together. We offer CIO as a way of addressing such human control over technology by tying together an understanding of use and of building user interfaces in a coherent conceptual framework, to be applied in Interaction Design and HCI research. We propose a coherent conceptual framework for interactivity that can afford a new focus on the relationship between technology and its use, as interactive, common objects that are mediators of collaborative human activity.

In our attempt to propose new understandings of interaction we conceptually re-frame the problem space [41, cf.] and offer alternative approaches for further research in HCI. This work is based on a number of strands of thinking that support the idea that the notion of Common Interactive Objects can bring together an understanding of use and building of user interfaces in a coherent and unified framework (language, methods and tools), to be applied generatively in interaction design and HCI research.

Below we summarize major empirical and theoretical contributions as they relate to WP1. CIO has published a large body of papers where many to some degree contribute to WP1 and the development of theory in CIO. The details regarding different concepts, elements and cases can be found in the referenced papers.

2.1 Empirical Studies of CIOs

CIO has combined its theory development with empirical research and technology development. We have explored the following examples with multiple collaborators. The cases illustrate how technologies can be common in a very concrete way, as an in-situ shared system, and something that evolves over time with a community and/or practice. Similarly, they show the kinds of collaborative and social context wherein the research is situated. CIO has been fortunate to have access to a number of empirical cases carried out before or on the side of the project, and also produced novel empirical insights through the case studies carried out in the project.

2.1.1 Pre-CIO empirical studies. We started the theory work by analyzing a handful of projects carried out prior to the project. Our postdocs and collaborators brought on board other cases that were used in comparative analyses and to illustrate theoretical concepts and principles. From the start we used previous studies of e.g. food communities and sticky-notes, and as new postdocs joined for example, Dearboard [50], a mobile keyboard that two users can customize and use together across their ecology of messaging apps, served as an example of a common interactive object for interpersonal communication. Dearboard offers two co-customizations (collaborative customizations): a toolbar of shortcuts to emojis and GIFs and a color theme. The empirical study with 18 pairs of friends, relatives and romantic partners provided a case for analyzing collaborative malleability as mediating (rather than communicative) material: participants appropriated the co-customizations to express internal jokes, shared interests and activities, and intimate knowledge of each other *in the interface itself*, rather than with verbal expressions in their chats. The malleability of the co-customizations enabled two interesting observations: First, since both users were free to customize the shortcuts and colors, different patterns of negotiation of co-ownership emerged (e.g., delegating the control of some shortcuts to one user, some to the other, and some kept by both). Second, these negotiations evolved over time, as participants daily contexts inspired new customizations and experimented with how Dearboard fit into their particular communication needs and habits.

Another case brought by postdocs is MirrorBlender [52], a video meeting platform where all members of the meeting can manipulate the position, size and transparency of each other's video feeds (i.e., their camera feeds and screen sharing feeds). The shared control over the malleability of the video feeds allowed both the co-located and the online participants of the video meetings to configure and dynamically adapt their meeting space according to what best fit their collaboration task or the group's preferred ways of working.

These cases inspired reflections about the interaction between different CIO concepts, e.g., between malleability and common objects, CIO principles such as material vs. communicative mediation, and also contributed to discussions about additional principles to explore in related work related to negotiation practices around common objects and artifact ecologies (see Section 6).

2.1.2 CIO cases. The three funded PhD projects by Mirzel Avdic, Ida Larsen-Ledet, and Marcel Borowski made their contributions in each their ways: Mirzel Avdic with [1–3] focused on objects in IoT settings leading to an understanding of traces in interactive objects without displays, Ida Larsen-Ledet [61–64] provided detailed focus on collaboration, artifact ecologies, traces and appropriation in shared writing environments, and Marcel Borowski did a specific contribution as regards malleability of collaborative software [24, 25, 27].

We have done detailed studies in collaborative work settings, such as collaborative writing [61–64], collaboration in virtual/remote meetings [51], leading to detailed theoretical conceptions such as traces [2] and transitions [64] within and across artifact ecologies in work around common objects that may be physical, virtual or combined (see also [51]).

Volunteer-based communities have been in focus in several empirical studies activated by CIO. Common Interactive Objects have been in focus when a local food community develop their shared tools [17, 18, 21, 66], and multiple, and even conflicting motives have been in play in both a food community [76] and a community working with registration of ecological data [81]. We have been fortunate to also be able to connect with the EU project Commonfare, and its theoretical considerations regarding commoning and participation [78, 83].

Studies of appropriation of games and of game masters have in various ways been important for CIO over the years. Thiel and Lyle [84] did a survey regarding people who modify games (game "modders"). The on-line game world is interesting because it is characterized by many different games that are played and modded in various communities. Thiel and Lyle [84] reviewed literature of non-professional game-modders, i.e. people who modify on-line games, an example of communities where flexibility and appropriation have important implications. They identified content-related and methodological issues and discuss types of modders and modding-relevant skills. They argued for further understanding of the dynamics within modding teams and their ways and techniques of collaborating. Tchernavskij et al. [82], in several studies, looked at game masters who plan and orchestrate tabletop role-playing games. The studies pointed out how game masters adapt everyday technologies and materials as support tools for improvisational and collaborative play. Game masters prepare and deploy readymade artifacts: analog and digital materials and tools that flexibly mediate recurring creative tasks.

2.2 Developing and Synthesizing Theory

The CIO project did literature and technology surveys regarding caring [76], platforms [19], artifact ecologies [66], patterns [17] in community settings.

It further used and developed conceptions of Common Interactive objects in the contexts of communities [81, 82], and developed the notion of caring in Rossitto et al. [76]. Drawing on two cases, Rossitto et al. [76] showed how interactive technologies overshadow communities' key concerns for care, and how attempts to design for community settings can result in anti-designs, that is socio-technical configurations that can disrupt collaboration and caring practices. Petersen et al. [68] made a very important contribution by putting order to definitions of the term "affordance" when it comes to shape-changing interaction as an additional theoretical discussions.

With work by Korsgaard et al. [60], CIO made a major contribution to shifting from a rather vague formulation of "communities" to the more precise conception of collectives in relation to artifact ecologies and common objects. The concept of collective artifact ecologies helped identify struggles of collective use computations artifacts and objects, delimiting collective artifact ecologies in order to study and explain how they develop and overlap. The concept illustrates how collectives face challenges in establishing, maintaining and negotiating their artifact ecologies. This paper, therefore, contributed a theoretical foundation for analyzing groups and communities as collectives, with a particular emphasis on the multiple tools and artifacts they use.

Beaudouin-Lafon et al. [8] introduced Generative Theories of Interaction to define specific concepts and actionable principles, to be used as guidelines for analyzing, critiquing, and constructing new technological artifacts. The paper suggested detailed concepts and principles for analyzing, critiquing and constructing Common Interactive Objects.

Borowski et al. [25] synthesized eight tensions between the principled design of computational (i.e., shared, malleable) media and its implementation pragmatics based on the development history

of Webstrates [58], Codestrates [77] and Codestrates v2 [26]. Through the lens of these tensions, the analysis of users' experiences with Codestrates v2 advanced the understanding of collaborative IDEs as mediating artifacts and common objects, e.g., based on how users negotiated collaborative development practices over time, and on how users' broader ecology of artifacts (e.g., their usual IDEs) played a dialectic role in facilitating and hindering the understanding of computational media as material for developing software.

CIO has also done theory development in close contact with empirical (analytical and constructive) cases e.g. studies of collaborative writing among university students or researchers, with a focus on the multiplicity of tools co-authors use [64]. The work consisted of two empirical studies: A mixed methods study [62, 63] and a co-design study [61] building on the mixed methods study. The authors studied researchers, Ph.D. students, and master's students undertaking projects involving collaborative writing in a university setting. The studies focused on co-authors' habits of switching between writing tools, such as drafting in a separate application from the one in which the shared writing was taking place. It addressed participants' motivations and strategies for choosing when and how to use which technology.

These cases at various levels show the challenges of addressing interaction as it unfolds over time and in collaboration between people, and it is the specific contribution of CIO to address Human-Computer Interaction *not* as a simple relation between human beings and computers but as unfolding and becoming [85] in the multiplicity of people, activities, devices and software, in which Common Interactive Objects get used and developed.

3 GENERATIVITY AS A METHOD

In work by Beaudouin-Lafon et al. [8], it was discussed how theories of interaction and interactive technologies can be developed to work generatively, i.e. analytically, critically and constructively. This work was inspired by Rogers [73] and embraced the work of Gergen [48].

Gergen [48] argued that the role of generative theory is to "foster reconsideration of that which is 'taken for granted,' and thereby to furnish new alternatives for social action." Theory that aspires to be generative then is not merely about developing new set of ideas and concepts but more fundamentally about generating alternative framings for current social issues. Generative research must "provoke debate, transform social reality, and ultimately serve to reorder social conduct."

The analyses of Beaudouin-Lafon et al. [8] talked to the need for theory to help innovate interaction. This is in line also with e.g. Bødker and Christiansen [14] who discussed design and change processes in the space between experience and expectation, and Engeström's cycle of expansive development [44]. Innovating interaction comes at three levels of processes: (Research-based) new interaction concepts, (extrinsic [55]) design projects that target particular use situations and organizations/user communities, and the ongoing (intrinsic) development in use.

CIO has engaged all these levels, mainly analytically and constructively [2]. This is done on the one hand as analytical frames or contexts, from which to build understandings. On the other, we have been aiming for a multi-layered perspective to synthesize new artifacts and drive emergent phenomena, from the ground up. In this sense, the production of artifacts can be understood as a context engineering of the socio-technical fabric of society, where an understanding of development movements can help an emancipatory agenda [74], in line with CIO's roots in Participatory Design [36]. As it happens, much of the critical engagement with theory has been presented rather implicitly because criticism has been embedded in the analyses, as e.g. in [2, 63, 81]. In applying the method, however, it is important to have an explicit focus of analysis, criticism and construction.

The analytical, critical and constructive approaches provide three successive lenses that help to both understand current technology and point to possible alternatives or futures: an analytical lens

provides a factual description of current use and practice; a critical lens assesses both the positive and negative aspects of a system, given different needs and contexts of use; a constructive lens inspires new solutions relative to the critique, expressed in the generative theory's constructs. We do not see these lenses as research approaches for providing ideal solutions as such, but rather for exploring possible alternatives [13, 54] as we return to below.

Accordingly, the perspective is analytically addressing how interaction is based on concepts and practices from users' past, how interaction contains the germs of future development (exemplified by, e.g., Bryant et al. [30]), is multiple and supports patterns and transitions across objects and tools, for the individual user as well as for the community.

Below we return to how the concepts of CIO have been developed and can be deployed in these three forms.

3.1 Prototyping

Korsgaard et al. [59] discussed prototypes as computational alternatives in research. They discussed how prototypes are generative and point ahead: When a prototype serves as a computational alternative it raises questions, and makes us see what is in a new light. Wartofsky, and with him Bertelsen [9], refers to such artifacts as "tertiary" artifacts; artifacts that shed light on alternatives. In representing possible futures to participants and researchers, computational alternatives serve as Engeström's springboards [44]. Springboards do not come about smoothly or automatically, and they are not as such solutions to a problem that one is facing.

In CIO Kannabiran and Bødker [54] discussed prototypes in research and pointed out that prototypes can be used as research instruments to introduce a shared structured procedure for making observations and claiming inferences. Prototypes are offered as objects of desire. Desires are different from needs and requirements and point in the same directions as Bødker and Christiansen's [14, 35] expectations. Since prototypes point to practices and uses that do not yet exist, they can be seen as epistemic objects that provide the direction, motivation and meaning for the activity [67]. Prototypes are emergent, fragmented, and constantly expanding. They are instruments of translation (boundary objects) and sources of attraction (epistemic objects), and triggers of contradictions and negotiation. Nicolini et al. [67] summarize epistemic objects to foreground the power of material objects (and not only visions and ideas) (see further in [54]).

The paper by Kannabiran and Bødker [54] identified five roles for prototypes as objects of desire for research and articulated four seeding dynamics to govern exploration of future use:

(1) Despite being epistemic and not-yet-known, prototypes jointly manifest shared visions.
(2) Prototypes are manifestations through which multiple visions may be juxtaposed, contrasted and explored, hence enabling critical reflection.
(3) Prototypes allow for a dynamic reiteration of visions on the background of other visions.
(4) Prototypes can become icons as material evidence set standards for what is desirable.
(5) Prototypes can provide disruptive justification and question existing norms.

3.2 Hackathons and Theory Make or Break Work Workshops

Hackathons have, according to Falk et al. [46] been used to empower a broad and diverse audience through participation in various phases of designing technology. Hackathons are often framed as a way of democratising the development of technology through participation. In our use in CIO we have however mainly applied the fast-paced format [45] in which we spent a few hours among members of the research group to systematically do a design based on one of the CIO cases and a theoretical concept or constructs. For instance we explored the concepts of "We-awareness" and "Transitions" and in several instances this lead to continued research/design processes.

Similarly we used Theory Make or Break Work workshops, to systematically explore and ponder the theoretical principles of the project (see below). Researchers worked with the principles of CIO in a form that picked up on the intensive hackathon format.

The researchers e.g., worked with material and communicative mediation (see later) and chose an example of use. They concluded that the dialectics between material and communicative should be more prevalent and suggested to keep the definition concise by referring less to their connection to design and focusing on dialectics themselves.

Following on to this they also confronted their findings with some of the other principles of CIO. With an earlier list of the principles of CIO, one of the suggested concepts failed and another was significantly re-iterated through the workshop, where researchers in groups were focusing on one concept.

3.3 Critical Alternatives

As pointed out by Korsgaard et al. [59], technological alternatives have always been an important part of the research tradition out of which CIO was born. They are an important way for Participatory Design to focus on both process and technological outcome.

Korsgaard et al. [59] suggested to do research into technological artifacts and see prototypes (see also above) as computational alternatives in research practice: "When a prototype serves as a computational alternative it raises questions, and makes us see what is in a new light. A computational alternative is not designed to showcase a new technical solution to a well- known problem, but to elucidate problems in the otherwise taken for granted."

They proposed that computational alternatives elucidate problems otherwise taken for granted. This is done through concrete technical development, as CIO has done in WP3. Computational alternatives are manifestations of research and design ideas and demonstrations of possibilities. "They are functional in particular microcosms, at the same time as they support the investigation of more general alternative futures. They provide backtalk and punctuation, and not least are they the simplest means of filtering and manifesting alternatives of a specific use setting."

This perspective also situated the research in WP3 [33] and explains what has mainly driven the technological research in CIO.

The step from computational alternatives to critical alternatives lies mostly in CIO's focus on being both analytical, constructive and critical, i.e. in the above mentioned focus on manifestations through which multiple visions may be juxtaposed, contrasted and explored enabling critical reflection.

3.4 Summary — Method

Generative research processes, from the CIO perspective, always balance: (1) empirical and participatory research with communities of human users, looking back, analytically and critically, at their past and current use activities, and looking ahead, constructively exploring and seeding possible change; (2) theoretical research to seed appropriate interim concepts and principles into the empirical process and to reflect critically and constructively upon the empirical findings; and (3) seeding of technological possibilities and alternatives through prototypes to bridge theory and empirical research.

4 CONCEPTS

In order to develop the idea of Common Interactive Objects, we have critically revisited object thinking from a number of perspectives [39]. It is fundamental that human activity is constantly changing, and that objects and artifacts in use, hence, change with, and as a result of this process. Hence the theory is pointing towards addressing both future technologies and re-understanding of

the past (as discussed above). Design leads to objects that influence users' activity (whether intended or not). These designed objects are appropriated and developed further in use (see also [55]). In other words, Common Interactive Objects must be understood as always changing, and existing in a field between the well-known and how they seed the future, the epistemic.

Beaudouin-Lafon [7] pointed to the dynamic relationships between objects and instruments/artifacts and presented a multi-layered understanding of objects to support analysis and design of human-computer interaction. In Computer Supported Cooperative Work (CSCW), boundary objects [80] are used to address and understand sharing and cooperation within communities and across time and place.

Robinson [72], using a hotel keyrack as example, pointed out that having and holding in common means to have access to and use, without using specifically together all the time and for the same purpose. He introduced the idea of the common artifact to help understand what it means to share artifacts or objects.

4.1 Mediation and Objects

In addition to this focus on dynamics and sharing, CIO stands on a foundation of related work in activity theory, distributed cognition, and situated interaction which all, with some differences, have been used in HCI to point to the situated and mediated nature of human-computer interaction. Fundamentally, activity theoretical HCI [10, 31] led to extending HCI to focus on analysis and design for a particular work practice with concern for qualifications, work environment, division of work, etc. Activity theoretical HCI focuses on the appropriateness of certain tools for certain practices and on the interactive objects that human beings shape and appropriate as tools.

Beaudouin-Lafon [7] used the term instrument to embrace both the physical/material means of interacting with objects and the logical/virtual ones fundamentally pointing out that materiality is an element of all computer mediation, whether the objects are in the mediator or not, i.e whether the object itself has a material manifestation outside the computer or not.

In the perspective of CIO, Common Interactive Objects are developed in collaborative human activity and they are used in (other) collaborative human activity, with a purpose, by people, as designers or users (who are working with them as artifacts on other objects of activity). In order to situate the potential Common Interactive Object in context of communities of practice, other artifacts and objects and places of use, it is important to address users and designers as participants, as well as the contexts in which design and use happens.

Human activity is the analytic starting point. Human beings undertake actions and operations together, mediated by objects used as artifacts. Operations from earlier generations of activity are crystallized, or reified into next generation artifacts. In addition, artifacts are representations of certain modes of acting in the activity [31].

People collaborate and this collaboration is mediated through technology; more generally human activity is mediated by artifacts. Human beings are embedded in praxis, in routines and activities that they learn, do, and change, together and through their interaction with material objects and artifacts [31]. Technological mediation of human activity is hence the primary principle and focus of this perspective.

Bærentsen and Trettvik [4] pointed out that activity theoretical HCI bridges conceptually between understanding and doing, between individual and shared practices and between history and change. They presented the activity theoretical description of human activity as three-leveled, consisting of activity, described in terms of meaning and purposes, or the question *Why?*, action described in terms of possible and critical goals, asking *What?* and operation, described in terms of routines and specific conditions, hence asking *How?*.

We see technological objects as artifacts that mediate human relationships. They have the attention of human users in breakdown situations [10, 31, 32, 70] or in more deliberate design and building situations [32]. Objects are outcomes of building processes but they are also mediating artifacts, helping users act on other objects in ways they could not without using the mediator [7, 31].

Bødker and Klokmose [38], in developing the argumentation for mediation as a key principle, emphasized dialectical thinking as a way to understand things concretely in all their movement, change and interconnection, in unity with their opposite and contradictory sides. Since movement and change are essential parts of dialectical thinking, this approach focuses on development of use. Bødker and Klokmose addressed the development of artifact ecologies beyond singular artifacts in use by communities. This perspective is further developed by Bødker et al. [16, 20].

In other words, common objects must be understood as always changing, and existing in a field between the well-known and the epistemic, i.e., how they seed the future. Accordingly it is important to always understand and address practices and technological objects *historically*, by looking back as well as looking towards the future and what they *may become*, i.e., how technological objects may change human practice. Addressing technological objects in use means focusing on *breakdowns* that happen in use [31, 70], when the common object stops supporting the activity. It is equally important to understand and address the seeds of future use embedded in the objects, which is really the core of a generative theory. These *epistemic objects* embody what is not yet known, and provide motivation for the creation of new knowledge [67].

Bødker [31] talked about objects in relation to mediation, in particular [31] distinguished between objects that are handled in the mediating artifacts and objects that are handled through, and with multiplicity this is not an either or, but rather some mediation happens through, and some in, the mediating artifact, with spreadsheets being a good example.

The CIO whitepaper [39] discussed the roles of automation and control in human partnerships mediated by interactive objects. Karpatschof [56] talked about artifacts or tools as either actively or passively externalized. As pointed out above, use is dynamic and happens at various levels. Raeithel and Velichkovsky [71] talked about how development happens at all three levels of activity: actions develop for users, deliberately and habitually in and by the individual as part of the relevant community of practice, activity develops historically, socioculturally, and microsocially, whereas common operations are learned by imitation as a, barely ever, conscious habits.

Bødker and Christiansen [15] defined appropriation as "the way that users evaluate and adopt, adapt and integrate a technology into their everyday practices" (following [40]). According to Bødker and Christiansen [15], appropriation happens in the social context first, and only later at an individual level. All of these analyses further illustrate a fundamental tension between the change/appropriation process on the one hand and the artefacts on the other. This change process is both technical and social.

4.2 Common Objects

Objects in general are in focus, and critically examined in CSCW [e.g., 53]. In Participatory Design, studies revealed objects in participation and engagement [12, 59] be these based in mock-ups, prototypes or more classical design representations. Discussing e.g. a case of open-source, Engeström [42] talks about software that has been modified by many, while being under the control of nobody as run-away objects.

Bødker and Klokmose [38] focused on the plurality of objects and artifacts and talked about *artifact ecologies*. With a starting point in the concept of boundary objects ([65, 79]), Nicolini et al. [67] proposed to understand objects as performing at least three types of work: Objects motivate and allow collaboration and point towards the future as epistemic objects; they allow participants to work across different types of boundaries, even in cases of conflict and contradiction; and they

constitute the fundamental infrastructure of the activity. They are multiple and plays different roles for a local activity and on activity and community boundaries, they are hence heterogeneous and potentially conflictual. Nicolini et al. [67] state that: "Objects allow us both to act at a distance and to make our interaction endure beyond the present. What makes human sociality distinctive, then, is that practices are not merely constellations of intersubjectivity, they are also constellations of "interobjectivity."

Bardram [5] as well as Bødker and Lyle [20] and Larsen-Ledet [61, 63] have characterized cooperation as happening through interactive objects, as coordination around the object and co-construction of future use with the object. Nicolini et al. [67] offer, in addition, that they have a role at three levels: as secondary (artifacts) of doing, as secondary (artifacts) of organizing and boundary objects and tertiary in negotiating across communities and establishing new forms of collaboration.

4.3 Community

It is fundamental to the activity theoretical concepts that human activity is embedded in praxis, meaning that communities have shared practices, tools, language/concepts and means of dividing work between the members. This includes also routines and tools/means for teaching/learning and for, e.g., documenting and otherwise articulating work within the community.

In CIO we have studied work communities and communities that are brought together in more ad-hoc manners, sometimes due to a shared technology or platform [19, 66]. We have also been critical to the widespread understanding of communities and introduced instead the more specific notion of collective, that allows for discussing how communities are held together through shared motives, desires and visions.

As discussed in [60], Engeström [42] analyzed amoeba-like collective activities that do not pursue short-term goals. He introduces the notion of "knotworking" [43, p.194] to refer to "rapidly pulsating, distributed, and partially improvised orchestration of collaborative performance between otherwise loosely connected actors and activity systems." Through this notion, Engeström studied more temporary collectives that come and go and talked about a mycorrhizae-like formation that does not have strictly defined criteria of membership.

Korsgaard et al. [60] used Petrovsky's distinction between the collective and other types of group: "the collective is a group in which interpersonal relations are mediated by the socially valuable and personally significant content of joint activity" [69, p.78]. At the core of collectives is the understanding of the identity and values of a collective, their shared activity, how these two aspects mediate interpersonal relations, and how it all develops over time.

When considering who is who in the collective, Petrovsky talked about how members look to their group as a source of orientation in the surrounding reality. He understood these connections as *referentiality*, where any given member of the collective can mediate the subject-object relationship of another, towards the shared goal, essentially as "a form of special subject-subject-object relations" [69, p.115]. The notion of referentiality provides a way to identify and articulate the roles that members develop and take on in order to do something with regard to the collective's joint activity.

4.4 Artifact Ecology

Objects and artifacts exist together, and people rarely only engage with one at the time, hence Bødker and Klokmose [38] talked about artifact ecologies. Bødker and Bøgh Andersen [34] exemplified how multiple mediators for specific activities may be connected across the material and communicative mediation and developed detailed analytical accounts of how material and communicative mediation are constantly at play and supplement or substitute one another. By pointing out that mediation

is multiple, heterogeneous, dynamic, and consists of webs of mediators [34, p. 374], Bødker and Klokmose proposed that development of instrumental skills goes hand in hand with the formation of successive concept formation (see also [16]). Bødker and Klokmose's work on conceptual blends [16] also points towards the ways in which the conceptual background of objects point ahead. These ways of thinking have been picked up and developed further in CIO.

Larsen-Ledet and Borowski [62] developed the concept of artifact ecologies to examine the multiple interactive artifacts in use throughout a collaborative process. The paper highlights the multiplicity and dynamics of computer-mediated collaborative writing, including the interplay between the personal and the shared, that shape the ecology and its use. Artifacts typically originate within a personal artifact ecology defined as the collection of artifacts a person owns, has access to, and uses. Familiarity is key and artifacts are understood in relation to common uses and complement other artifacts within the ecology. A personal artifact ecology is dynamic and changes as new needs and desires arise and/or when people learn from, or collaborate with, others.

In collaborative writing, the potential artifact ecology is the sum of co-writers' personal artifact ecologies, from which they negotiate an aligned artifact ecology consisting of the tools and applications to be used in the work. Rossitto and Eklundh [75] used the term orchestration to describe the (meta-) activity of aligning the group's work ecology and describe how alignment of the ecology happens both at the onset of the group's formation and in relation to different contextual, temporal, and task-specific constraints throughout the work.

Community artifact ecology as a concept is introduced in [21] to focus on how artifact ecologies are shaped in community settings by personal and community relationships. Theoretically, dynamics in artifact ecologies are shaped by the social interactions taking place, around technological artifacts, in everyday situations. Based on the above understanding of collectives, Korsgaard et al. [60] developed the notion of collective artifact ecologies . This concept enables the identification of struggles of collective use of computational devices today, delimiting collective artifact ecologies as a theoretical foundation for analyzing groups and communities as collectives, with a particular emphasis on the multiple tools and artifacts they use.

Analyses of artifact ecologies have recently been applied to understand collaboration in informal educational settings [28] and in hybrid work settings [11], as well as communication via messaging apps. For example, Griggio et al. [49] documented how an update to WhatsApp's privacy policy pushed its users into a massive attempt to switch to other apps, re-configuring their personal artifact ecologies for messaging and consequently, their contacts. However, the study showed that most users were unable to switch their communication to other apps as much as they wanted. Participants failed to switch apps primarily because of disagreements with their contacts about which apps they should move to, but also because of differences in the functionality between apps that interfere with their existing communication practices. These results support CIO's goal of rethinking the design of software as mediating artifacts that are embedded within personal artifact ecologies: messaging apps should shift from being rigid, "walled garden" apps to malleable, common objects that let users adapt them to the communication habits they transfer from other artifacts, and thus, granting them more control over how to communicate with whom.

4.5 Summary — Concepts

The theoretical framing of CIO follows a long line of thinking in HCI and CSCW addressing mediating artifacts, development, common objects, communities and artifact ecologies. With CIO this thinking has developed to focus specifically on multi-mediation, collectives and multiple overlapping artifact ecologies.

5 PRINCIPLES

Following the above development of concepts and the work in Beaudouin-Lafon et al. [8] and Avdic et al. [3], CIO works with the following principles. In both papers the principles were also presented as a series of questions to be asked analytically, (critically) and constructively. We refer to the papers for these.

5.1 CIO Principles

5.1.1 Principle of Mediation and Common Objects. This principle has its roots in how human activity is collaborative and mediated. Artifacts mediate human relationships with technological objects, and artifacts are themselves such objects. Objects draw attention of human users in breakdown situations [10, 31, 32] or when designed or build [32]. Objects are outcomes of building processes but they are also mediators that help users act on other objects, in ways they could not without them [7, 31].

Objects motivate and allow collaboration Nicolini et al. [67]; they allow participants to work across different types of boundaries; and they constitute the fundamental infrastructure of the activity.

Shared overview is a matter of mediation and how users may, together, be able to jointly overview the activity, the materials and mediators [3].

Common objects may be stable (versus negotiated) to participants. They may be used to communicate and collaborate with objects that are stable or in flux [37]. This connects to differences in whether and how participants are part of an activity only through the actions on the objects or beyond that with an internalized, joint motive of the activity.

5.1.2 Principle of Material Versus Communicative Mediation. Common objects and mediators are *material*, *social* and *communicative*, because they stand between people and mediate their joint activities. Hence, the principle allows for the analysis of materials, material objects and outcomes on the one hand, and of mediated collaboration and communication on the other.

A particular focus is the language and concepts related to cooperation and transfer of experiences across a community. Bødker and Klokmose [16] pointed towards the use of conceptual blends to constructively focus on this aspect, and in particular to consider what metaphors are or may be applied based on how users communicate in and about their activity. The paper used Fauconnier and Turner's [47] work where conceptual blends are important in scaffolding particular understandings by projecting structure from metaphors back to the people who are using them.

Pointing towards the inclusion of both communicative and material or instrumental mediation, Bardram [5] (see also [22]) distinguished between communicative, instrumental, and scripted collaboration.

5.1.3 Principle of Development and Malleability. Interaction needs to be understood as it *develops over time* and in the collaborative activities between people using technological artifacts and objects. The unfolding over time is a matter of development of community practice, individual learning and routines, as well as of technology in use with respect to the past, the present and the possible and desired future [67]. Objects/mediators can be collaboratively tailored and appropriated in use [6], and hence are changeable and malleable over time, all the while they resist this development, cause breakdowns and cannot be turned into anything users may wish for.

Appropriation happens in the social context first, and only later at an individual level. This change process is both technical and social, i.e. both a matter of how malleable technologies are and how possible it is to shape and change the use practices around them.

Malleability as a principle describes that users of software are able to change and shape their software to their idiosyncratic needs. It is, among other things, inspired by the visions personal dynamic media by Kay and Goldberg [57] and the shareable dynamic media by Klokmose et al. [58]. In CIO, Borowski [24] described various ways in which malleability can be achieved in software: Extensibility (adding an extension in a web browser), configurability (toggling options in the settings window), and reprogrammability (changing the source code of software or scripting).

These three ways have different levels of "power" in what they empower to user to modify, e.g., while extensions only allow to add pre-packaged pieces of software other users created, reprogramming allows to change every aspect of how software functions. These, however, come also with different skill requirements for the user, e.g., adding an extension is easy and reprogramming can quickly get very difficult, and at a cost for the programmer, e.g., creating a settings menu and ensuring that the options in it work or creating an API and documentation to allow for extensions to be created. These three dimensions, (1) the power of possible modifications, (2) the skill required by the user, and (3) the cost for the programmer, need to be balanced to create a meaningful framework for malleable software.

5.1.4 Principle of Multiplicity and Artifact Ecologies. Human use of particular artifacts and objects happen across activities and configurations of people, applications and devices and it is important for the interaction to embrace transitions and substitutions [38] across and in these multiplicities. Hence it is important to consider *multiplicity* and *artifact ecologies* as they are discussed above. This means to always consider one mediator, object or activity in the context of others and to scrutinize them together as a whole as well as each in their own right.

Concepts of personal, shared, community of collective artifact ecologies are useful for analysing and constructing multiplicities of artifacts in particular uses.

Addressing technological artifacts, Borowski [24] talks about distributability and shareability to discuss how objects such as documents in collaborative writing are distributed across devices (laptop, desktop, tablet, phone), applications, activities, and spaces (office, home, laboratory, conferences).

5.2 Summary and Possible Additions — Principles

The principles have been summarized several times during CIO and the above reflects their current crystallization. As part of the Theory-make-or-break-sessions held midway in the CIO project we concluded that it is important to focus on the tensions and dynamics across

- past, present versus future/epistemic common objects,
- the roles of common objects in specific (local) communities and activities versus the roles when shared across,
- objects and artifacts as they are taken for granted and routinized versus the ways in which they are negotiated [37],
- generally, the tensions between the principles, and
- the tensions between the analytic, critical, and constructive.

Towards the end of the project, the principles were revisited and the discussion led to some new tentative principles that we return to below.

6 DISCUSSION AND LIMITATIONS

The following section presents the more tentative ideas of CIO, it discusses the current state and the potentials and limitations of WP1.

6.1 Additional Principles?

The following principles were the focus of Theory-make-or-break workshops at the end of the project, where members of the CIO team brought their theoretical background and empirical cases to the table. These workshops allowed for a tentative description of two further principles that need further work in continuation of CIO.

6.1.1 Principle of Negotiation versus Taken-for-Granted. In wrapping up the theoretical work in CIO, we have returned to a concern and tension that has been mentioned several times, namely the notion of *negotiating* artifact ecologies in a collective or community, the set-up for a collaborative writing project, the common communication apps between a user and their contacts, etc. The artifact ecology as such may be stable or in flux and similarly the object and purpose of the activity may be negotiated or taken for granted [37]. From everyday experience post COVID we know how, e.g., Zoom or Teams cannot be jointly set up to, e.g., make visible a certain joint order of speakers, or to persist a certain set-up of the room from one meeting to the next in a series of meetings with the same purpose and participants.

Brodersen and Kristensen [29] carried out an early analysis of the limitations of considering AI as negotiation between a human and a computer and point to the concept of negotiation in CSCW. The paper defined negotiation as "the mutual mediation and translation process, taking place in specific HCI situations, taking into account the strengths of the computer as a computer and the human as a human. Hence negotiation is referring to the mediating process relating the human users and the technological possibilities in a given situation."

The starting point of any joint activity is that the participants draw on routines from previous participation in the activity and from other joint activity. Even though we may not have written a document together with a particular group of collaborators before, we draw on other experiences from, e.g., joint meetings, and from writing, alone or with others. Negotiation hence rarely means starting from scratch. It starts from taken-for-granted routines and to some extend from breakdowns of these, or anticipation of how the past routines will not work in the new setting (with new people, new tools, etc.). Stepping out of taken-for-granted routines has an important role to play for learning, yet up-front negotiation may at times shift the activity away from actually "getting-the-job-done" in manners that are unnecessary and disruptive ([31] talks about the problem of repeating breakdowns).

In Bardram's [5] characterization of different kinds of activity it is discussed how coordinated activity entails negotiation of mediators, whereas co-constructive activity also entails negotiation of the common object, and a re-conceptualization and negotiation of the mediators as a result hereof. Coordinated activity largely allows members to participate with their routines and mediators without much concern for negotiating mediators and objects with other participants.

This principle connects to concerns regarding malleability when it comes to how mediators can be negotiated, and it tentatively gives raise to questions, *analytically* such as: When do participants take the shared object and routines/mediators for collaboration for granted? When do they negotiate them? To what extend is negotiation happening up front, as a part of setting up the activity? To what extend is negotiation happening in the activity as a result of a breakdown where taken-for-granted routines get exposed?

Critically, questions need to be asked regarding both how objects and mediators can (and cannot) be negotiated and how this may disrupt the taken-for-granted activity in various ways?

Constructively, questions address how and when technologically (through mediators and common objects) negotiation can happen? How may, e.g., the setup of an artifact ecology be negotiated, based on participant experiences? and how may the transitions between negotiated settings and routines (and vice versa) be supported?

6.1.2 Principle of Negotiation and Sustainability in Malleability. Whereas the concept of negotiation seems to persist, another version of this principle emerged where Sustainability is in focus rather than Taken-for-Grantedness. This takes its starting point in different examples of how malleability manifests itself in our personal software use. While discussing the different levels at which malleability can happen, for example, extensibility vs. reprogrammability, we also discussed the differences between who can perform a change vs. who can influence the change vs. who is affected by the the change when collaborating with malleable software.

This comes down to how changes in malleable software are negotiated. First, there is a decision to make whether software allows for mediating the negotiation. For example, in Slack the customization of emojis is not mediated, because every user can add or remove custom emojis from a workspace. There is no mechanism to prevent a user from adding emojis, even though the added emojis affect all users in the workspace. On the other hand, if negotiation is mediated by the software, this can be realized in different ways. One way is using a "democratic" approach, where a certain number of users have to agree on a change before it is affecting users. Another way is using a hierarchical approach, where only certain groups of users, e.g., moderators in a online forum, can perform the changes.

Negotiation, however, can also happen outside of software — either entirely or in addition to the mediation of the software. For example, in Reddit, moderators can create "flairs" (tags) that can be attached to posts to categorize them. While the creation of the flairs is hierarchically negotiated and mediated by the software, the use of these flairs is negotiated outside of software: Reddit does not check or force users to use them but instead relies on moderators to check and ensure their correct use.

Besides the negotiation of changes in malleable software we also discussed their sustainability. For instance, changes done to a piece of software can deprecate over time if the structure of the underlying software changes, e.g., the DOM structure of web applications or APIs. This can introduce bugs to modifications or make them completely non-functional. As "customization work" is still work, it has to be done by someone. A challenge that often resides within this is the difficulty to estimate when a the customization work amortizes and actually saves time for the user. This uncertainty — especially coupled with the risk of deprecation in future updates of software — might lead users to not perform a customization in the first place.

These two versions of principles in some ways are parallel and in some ways point in somewhat different directions, mainly because their starting points are somewhat different. They are tentative both of them and it is quite possible that future work may present them in some form as one.

6.2 Discussion and Limitations

We are explicitly interested in designing for change, as also indicated by the discussion of tensions. We propose a generative theory that is both a generative process for sparking/inspiring new design ideas and how interaction needs to be changeable over time. In this sense we aim for a synthesis of constructs/patterns that can spawn and support new design dialogues centered on a critical perspective on CIOs in structuring new fabrics of society, but also in a renewed commitment to empower new forms of participation in driving social technologies.

These perspectives have been activated in CIO also through some of the work brought into the project which we have been fortunate enough to have access to. However, since long-term cases in CIO have, unfortunately, been somewhat hindered by the COVID-19 pandemic it seems that it is also the development of the critical dimension of generativity that is lacking behind. Why there is this connection between critics and longitudinality may be somewhat opaque, but it is possible that this dimension requires more time and reflection. Very recently it also seems, however, that

the CIO concepts and principles have a role to play in the discussion of big language models and AI as discussed in Bødker's recent talks.

7 CONCLUSION

Without repeating details CIO has provided ways and means of addressing use as common and this has made us focus on elements that often seems ignored in HCI: The communicative and collaborative side of interaction; appropriation and development as joint, connected with shared praxis and across uses, artifacts and tasks (rather than one of these at a time). The focus on collectives also has provided new ways of addressing what holds groups of users and their technologies together. This further points to the importance of engaging with users together, suggesting that classical user centered design is not enough.

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