Incompleteness and redundancy: Organizational components of a design-enabled infrastructure to support coordinated action of multiple stakeholders

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Abstract
This paper analyses an R&D project funded by the European Commission and aimed at studying, testing and implementing technological and gamification-based solutions for hearing impairment. In the course of the last three years, a variety of stakeholders with their different wants and needs, languages and agendas have interacted within the project. Particularly, this paper focuses on (1) how the project has built a design-enabled infrastructure to support the interplay of these stakeholders and (2) on how some specific organisational dimensions of this infrastructure - namely incompleteness, and redundancy - favoured coordinated action. Even though the concept of infrastructure has been thoroughly examined in design research, the organisational dimensions that allow to at least partially control divergences and convergences among the various stakeholders remain understudied. To address this gap, this paper intends to offer a contribution at the intersection of design research and organisational studies.

Keywords – design infrastructures, coordinated action, design for healthcare

1. Introduction

This paper examines some features of 3D Tune-In, a research and innovation project aimed at studying, testing and implementing software and video games that can be used by people with hearing aids to fine-tune their hearing devices, either directly on their own or with the help of an audiologist. 3D Tune-In engages a wide variety of stakeholders, including academic researchers, video game companies, healthcare professionals, hearing impaired and their families and relatives, through processes such as workshops and seminars, participatory design sessions and a software platform articulated into a set of interlinked open source components. All these elements are part of a design-enabled infrastructure to ignite and support collaboration among these stakeholders.

Within the broad design field, a good number of scholars and practitioners have framed design activities in terms of creating and maintaining 'infrastructures' for collaboration (Binder, Michelis, et al. 2011; Björgvinsson, Ehn, and Hillgren 2012a; Ehn, Nilsson, and Topgaard 2014; Karasti and Blomberg 2017; Le Dantec and DiSalvo 2013; Manzini 2015; Selloni 2017; Star and Bowker 2002). An infrastructure can be a physical space where various stakeholders (e.g., government officials, companies, citizens) are invited to participate to sessions where problems of common interest are defined and where solutions are imagined, tested and implemented. For example, a physical space containing equipment such as laser cutters, 3D printers, CNC milling machines and other fabrication tools (i.e., a FabLab, a makerspace, a living lab or other kinds of innovation spaces) can be considered an open infrastructure that can host people and organizations interested in developing and prototyping their ideas, concepts for new products or services and social and cultural interventions (Seravalli 2014; Seravalli and Simeone 2016). An infrastructure for collaboration does not necessarily need a physical space, though, and can be articulated through thematically-linked participatory sessions organized in multiple spaces (Binder, Brandt, et al. 2011) using the premises of the various organizations involved and/or through a series of participatory activities to be carried out via Internet.

Framing the design process as an infrastructure allows considering this process as open to multiple stakeholders who can contribute to participatory design sessions and workshops and who can also use this infrastructure to organize their own events or carry out activities in light of their needs and interests. Since stakeholders might have divergent (and potentially conflicting) needs and interests, these infrastructures can also harbor controversies or fuel conflicts (Björgvinsson, Ehn, and Hillgren 2012b; Simeone 2016; Simeone, Secundo, and Schiuma 2017).

Even though the concept of infrastructure has been quite thoroughly examined in design research (Karasti 2014), the specific organizational dimensions that allow to at least partially control divergences and convergences among the various stakeholders remain a terrain that can be further explored. In line with what the communication theorist, Eric M. Eisenberg, suggests (Eisenberg 2007), the paper will build on the idea that, in some cases, it is difficult to reach unanimous agreement among stakeholders, and the only way around is getting to sufficient understanding to permit coordinated action. Rather than seeking consensus and eliminating divergences, coordinated action accepts existing divergences while trying to favor minimal levels of convergence. This is a quite delicate process, which can be riddled with conflict and ambiguities (March and Olsen 1976; Eisenberg 1984; Davenport and Leitch 2005; Meyerson 1991; Denton 1997). This paper intends to investigate this process by closely looking at the organizational infrastructure of 3D Tune-In and by exploring if and how this infrastructure favored coordinated action among multiple stakeholders. In plain terms, the specific question that will be examined is, consequently: What specific organizational dimensions of a design-based infrastructure can favor coordinated action?

The paper is organized as follows: Section 2 reviews the literature and introduces the nexus between designing infrastructures and coordinated action. Section 3 describes the research approach and the research context. Section 4 presents the findings of the study. Section 5 discusses the results. Finally, the last section concludes the paper underlying the practical as well as the theoretical implications.

2. Literature review

Approaches such as participatory design or co-design have long supported the idea that the design process should be open to multiple stakeholders, including final users (Robertson and Simonsen 2012; Binder, Brandt, et al. 2011). Researchers focused on the challenges of tuning the potentially conflicting agendas, needs, and interests of different participants (Björgvinsson, Ehn, and Hillgren 2010; Hellström Reimer et al. 2012; Löwgren and Reimer 2013; Winschiers-Theophilus, Bidwell, and Blake 2012) but also on how to carry out a design process that proposes a direction where the efforts of the stakeholders should somewhat converge and, at the same time, remains open for unanticipated uses (Allen 2009; Binder, Michelis, et al. 2011).

One way to keep designerly approaches open to variation is to ensure that they can harbor tensions and controversies. Rather than expect consensus among participants, participatory approaches should facilitate discrepancies and acknowledge asymmetries (Keshavarz and Maze 2013). Framing design interventions as infrastructures goes in this direction. While describing the creation and maintenance of an infrastructure articulated into various living labs in the Southern part of Sweden, Björgvinsson and colleagues argued that this infrastructure could be seen as "arenas consisting of heterogeneous participants, legitimizing those marginalized, maintaining network constellations, and leaving behind repertoires of how to organize socio-materially when conducting transformative innovation" (Björgvinsson, Ehn, and Hillgren 2012a, 143). When Björgvinsson and colleagues talk about bringing together heterogeneous participants and legitimizing marginal participants, they refer to an approach that values divergences among the participants rather than tries to minimize these divergences. Within design research, projects based upon infrastructures have been extensively carried out and analysed (Karasti 2014; Star and Bowker 2002; Star and Ruhleder 1996; Le Dantec and DiSalvo 2013; Hillgren, Seravalli, and Emilson 2011; Hillgren, Linde, and Peterson 2013; Lukens 2013).

Within the more specific context of healthcare, a stream of research has analysed multistakeholder interaction, even though not often using the notion of infrastructure as a core analytical concept. Høiseth and Keitsch used phenomenological hermeneutics to gain understanding of stakeholders in healthcare contexts (Høiseth and Keitsch 2015). Donetto and colleagues presented the Experience-based Co-design as a participatory research approach that builds upon design tools and ways of thinking to bring healthcare staff and patients together to improve the quality of care (Donetto et al. 2015). Lee examined the design of ambulatory healthcare from a service design perspective, thus with an eye to the interplay of various service actors and to the quality of communication between patients and staff (Lee 2011). Along similar lines, some other authors focused on how a multistakeholder service design perspective or an attention toward co-creation methods can be instrumental in developing social connectedness in healthcare (Ballegaard, Hansen, and Kyng 2008; Wildevuur and Dijk 2011).

In organizational studies, Eisenberg used the concept of coordinated action to describe situations such as those represented by some of the above-mentioned authors, where multiple stakeholders work together while maintaining their divergences. He claimed that "coordinated action can occur under conditions of limited agreement and shared understanding. People can understand, appreciate, and respect one another's experiences and worldviews without seeking agreement" (Eisenberg 2007, 135). Various authors studied coordinated action in different contexts, from large technology companies (Vuori 2011) to multiteam systems (Davison et al. 2012) as well as to online gaming (Williams and Kirschner 2012). Generally, coordinated action is seen as an "orchestrated sequencing and timing of interdependent actions" (Davison et al. 2012, 810) and as something that can be analyzed and bettered in order to improve collaboration performances.

The contribution of this paper goes in the direction of further exploring this concept of coordinated action within the context of a design-enabled infrastructure for multistakeholder collaboration. More specifically, the focus of the paper is in exploring some organizational dimensions of such infrastructure and in examining if and how these dimensions can support coordinated action.

3. Research approach

This paper uses a case study approach (Eisenhardt and Graebner 2007; Yin 2009; Eisenhardt 1989) which allows analyzing the phenomenon with a certain degree of depth and which is suited to the exploratory nature of this research (Dell'era 2010). Case studies allow identifying key insights over time (Paré 2004) and through a number of examples; they work especially in situations where 'how' or 'why' questions are being posed and when the focus is on a contemporary phenomenon within real-life contexts (Yin 2009; Pettigrew 1990) that are investigated using multiple sources of evidence (Robson 2002). Case studies have been steadily used in organizational studies in the past decades (Berg 1968) and more recently (Breslin and Buchanan 2008; Buchanan 2012), and scholars analyzed the relevance and the limitations of this approach (Dasgupta 2015). Consistently with Yin's view (2009), a case study approach allows to gather useful and intermittent feedback; to adapt to the availability of different types of evidence and data; to assess outcomes and test theories and rival theories; and to develop key learning points in relation to the major themes within a field.

The author was part of the 3D Tune-In consortium and had the chance to gather data during more than three years, through ethnographically-inspired methods such as participant observation and semi-structured conversations with key project stakeholders. The role of the author in the project was to contribute to the interaction design phases and to explore exploitation possibilities for 3D Tune-In. Research material was collected and generated through archival research, direct observation, the author's experience as participant and various conversations with key members involved in the investigated case study across 2015 and 2018. Ethnographic methods such as participant observation and conversations are a common element of recent studies on organizations (Czarniawska 2012). Official communication tools, like the websites and other social network accounts connected to 3D Tune-In, have also been used. The research was enriched by a dozen semi-structured conversations with key informants (Kumar, Stern, and Anderson 1993), including representatives of 3D Tune-In and external stakeholders. These conversations were based on semi-structured schemas that allowed gathering the informants' perspectives on specific issues. Conversations were also a way of checking whether the informants could confirm insights and information (Myers 2013). Multiple data production and collection methods were used to exploit the synergistic effects of triangulation, i.e., the integration of different investigative techniques to reduce the bias of a single observation (Tarrow 1995).

4. Key findings

An overview of the 3D Tune-In project

3D Tune-In is an R&D project funded by the European Commission and started in 2015. The specific goal of 3D Tune-In is to study whether various new technological engines (i.e., binaural spatialization algorithm, hearing loss simulator, hearing aid simulator) and gamification mechanisms can be used by people with hearing aids to fine-tune their hearing devices, either directly on their own or with the help of an audiologist (Levtov et al. 2016).

According to the World Health Organization[1], over 5% of the world's population – 360 million people – has disabling hearing loss (328 million adults and 32 million children). Approximately one-third of people over 65 years of age have disabling hearing loss. Hearing impairment can lead to frustration, low esteem, withdrawal and social exclusion (Wilson et al. 1999; Yoshinaga-Itano 2003).

Hearing aid technologies have significantly advanced in the last 25 years, but people's perception and use of these devices have changed very little. Hearing aids now incorporate several functions that go beyond the simple amplification and equalization operations performed by the traditional analog devices. Current devices offer a variety of functions that can be highly personalized in relation to both the specific audiological profile of the people with hearing impairment and to the real acoustic ecologies, i.e., the specificities of the context of use

[1] http://www.who.int/mediacentre/factsheets/fs300/en/

(Pichora-Fuller and Singh 2006). However, these technological advances are not always accessible or generally accessed by the hearing-impaired population. The calibration of a digital hearing device is a complex process (Hickson and Meyer 2014) and the end-users are rarely able to fine-tune their hearing device on their own. The full potential that these devices could offer in terms of improving the hearing quality is not reached and this has an impact to the psycho-social factors tied to hearing loss (Knudsen et al. 2010): individuals with hearing impairment might experience difficulties in accepting and coping with hearing loss (Jerram and Purdy 2001) or they can minimize or deny the problem, also because of the stigma they perceive as associated with hearing impairment (Meister et al. 2008).

3D Tune-In relies on the idea that newly developed software engines and gamification mechanisms can help individuals suffering from hearing impairment to test hearing aids and to calibrate them in simulated digital environments that recall real-world situations (e.g., at a concert, in a restaurant, on a street, at a train station, in a classroom). In addition, the three most important software components developed in 3D Tune-In (binaural spatialization algorithm, hearing loss simulator, hearing aid simulator) are released as open source and can be used by third-party organizations to create video games and other software applications for hearing impaired. Figure 1 shows an early sketch of a video game where users can play some simple games (e.g., 'Guess the right word') and simultaneously tune sound parameters such as directivity, tones, compression. Through this video game, individuals with hearing impairment and their families can directly experiment with various acoustic parameters and form their own conceptual model of how these parameters influence hearing.

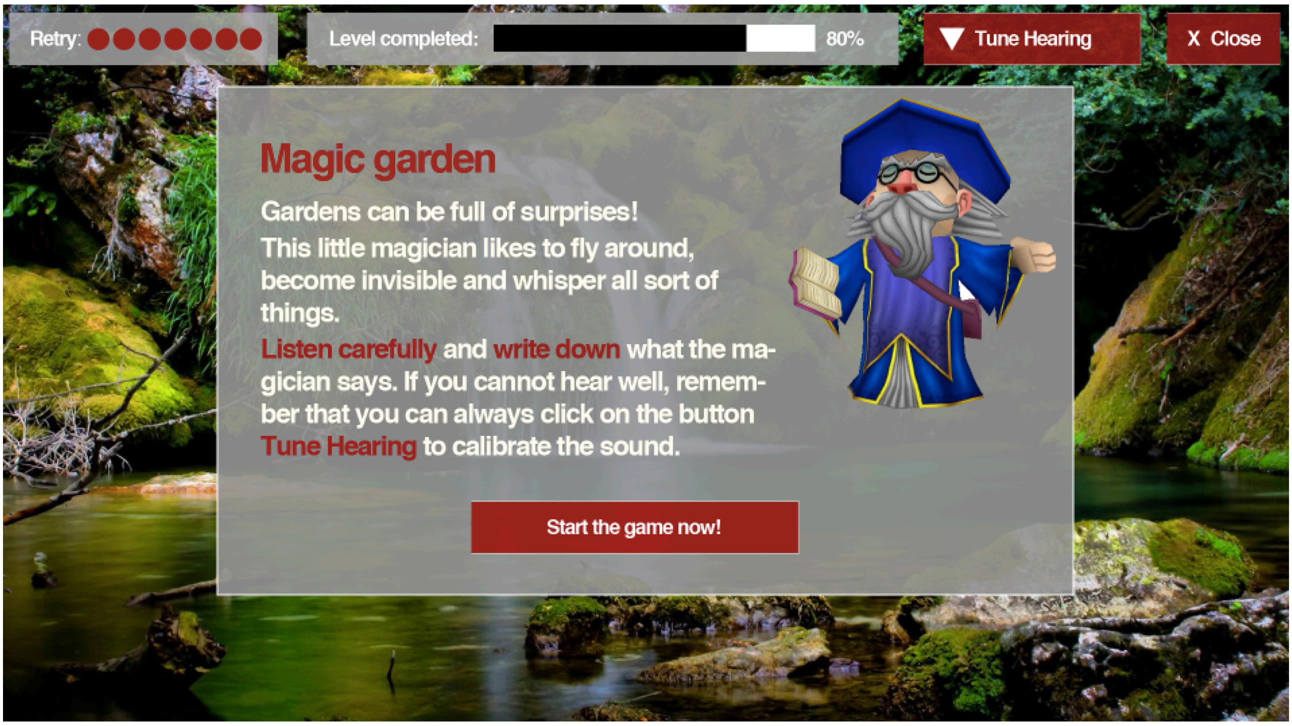

Figure 1 An early sketch representing a videogame showcasing potential features of 3D Tune-In technologies

Internal and external stakeholders involved in 3D Tune-In and their differences

3D Tune-In originated from a consortium composed of nine members: video gaming industries, research centers, a large European hearing aid manufacturer and hearing communities. In this paper, these members of the consortium will be referred to as *internal stakeholders*.

External stakeholders such as end-users, healthcare professionals (e.g., audiologists) and third-party software developers contributed to the project by regularly participating to seminars, workshops and sessions to envision, discuss and test functional requirements and technological features of the 3D Tune-In open source software components.

One of the main challenges of the project was how to catalyse the attention and coordinate the efforts of all these internal and external stakeholders that had different needs, interests and agendas and came from different backgrounds: computer sciences, acoustics, audiology, human factors, video game studies, hardware development. Some stakeholders (mostly, the research centers and the hearing communities) strongly advocated for open source and open access, while some other ones (mostly, the commercial partners) would tend to leverage a less open and stricter approach toward intellectual property as their core element of market differentiation. Companies that were part of the consortium were strongly interested in quickly bringing results to the market and were pushing to advertise the progress of the project early and widely. Conversely, a fast time-to-market was not necessarily the prime concern for academics who needed proper time to further their analyses and to go through the various iterations of the scientific publishing cycles before publicly releasing information about the project.

Another challenging area of the project was that the internal stakeholders were bound to some specific and predefined milestones, deliverables and timelines – also formally agreed with the European Commission. A certain level of ownership and control was needed to steer the project and to respect this formal agreement. At the same time, these internal stakeholders believed in the need to engage external stakeholders (i.e., individuals with hearing impairment, healthcare professionals and open source software developers) and to let them have a say in how the software applications should be implemented and could be used, configured and further adapted (e.g., in terms of functionality and user experience).

The challenge, then, was not only how to balance divergences and convergences among the stakeholders, but also how to open the project for bottom-up participation and, simultaneously, to maintain a top-down control over formal scientific outcomes to be delivered according to a predetermined timing. It is in this spirit that the internal stakeholders embraced the idea of designing an infrastructure that would foster collaboration with external stakeholders.

A design-enabled infrastructure for collaboration

The 3D Tune-In infrastructure for collaboration relied on a significant design component: (1) a series of workshops and seminars with participatory design sessions organized in various countries (Italy, UK and Spain) and online, (2) a software platform consisting of interlinked open source components that can be configured, re-designed, extended, deployed by internal and external stakeholders, and (3) a research, communication and exploitation strategy relying upon infographics, data visualizations, videos and other design artefacts (including documentation on how to use the software platform).

All these elements were tied together by an overarching and coherent guiding policy, i.e., an approach that aims to put individuals with hearing impairment in the condition of better controlling and guiding the process of calibrating their hearing device. This guiding policy – formally codified in the project as a set of predetermined actions, milestones and deliverables - is what allowed to see the local activities carried out in different geographic areas as a coherent cross-country infrastructure for collaboration (Figure 2).

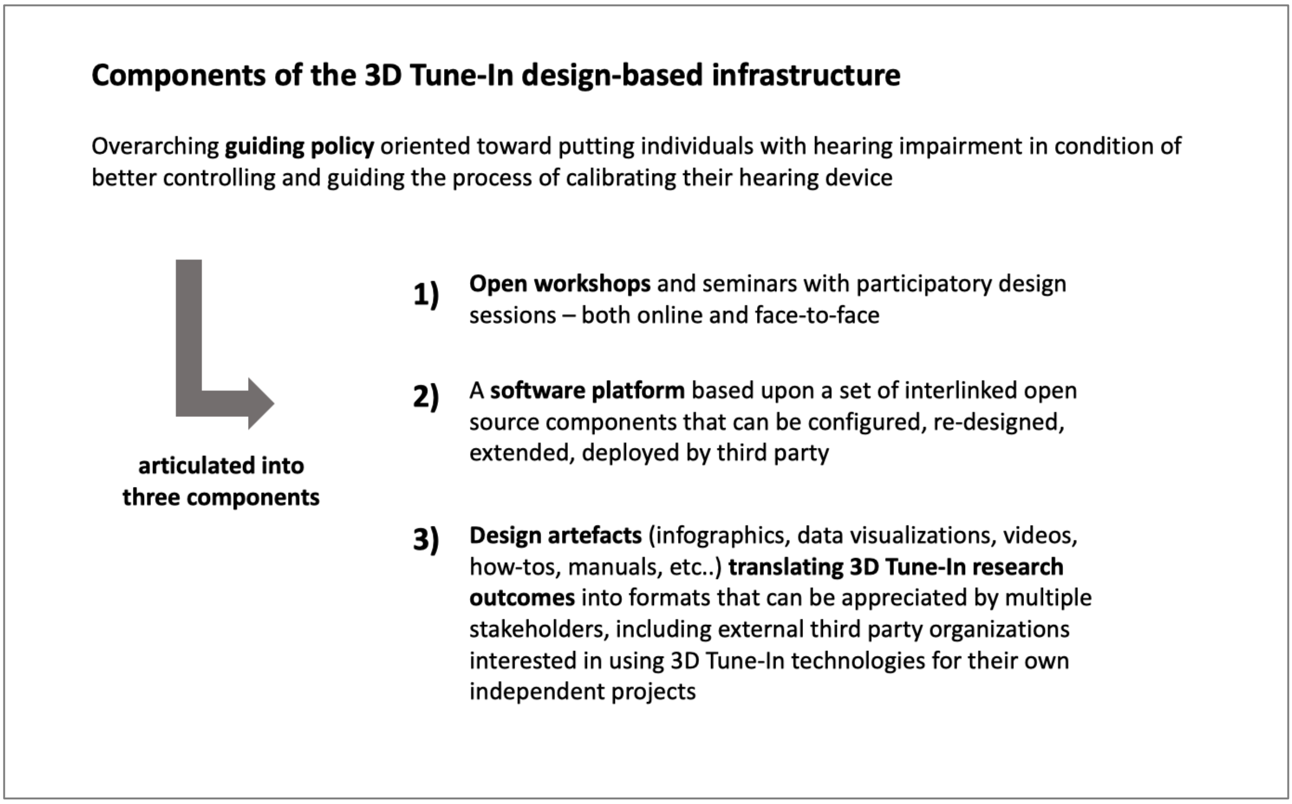

Figure 2 Components of the design-based 3D Tune-In infrastructure for collaboration

These articulated components can be considered an infrastructure as (a) they aim at going beyond the scope and the duration of a single project (in this case, beyond the three-year funding provided by the European Commission), and (b) as they implement a modular framework where stakeholders cannot only participate to design sessions and workshops but can also use this infrastructure in light of their needs and interests. In other terms, this modular infrastructure was not only aimed at hearing-impaired end-users who would use it to tune their own hearing devices, but it was also open to any third-party organization (e.g., software companies, hospitals, audiological centers), which could utilize and modify some of the modules of the infrastructure, branch out and develop their own new projects, technological engines or healthcare services. While the internal stakeholders were mostly concerned with activities such as preliminary design, development and deployment of the key software components of 3D Tune-In, the external stakeholders would build on such components and carry out activities of testing, adaptation, re-appropriation, re-design and future maintenance. During the project, about 340 external stakeholders had the chance to directly contribute to participatory design processes in Spain, UK and Italy. In parallel, about 600 people autonomously downloaded and tinkered with the software outcomes of 3D Tune-In.

Features and tensions of the infrastructure

The whole infrastructure was envisaged and initially set up by the internal stakeholders, who established the guiding policy and some key features of the infrastructure that would allow external third-party to collaborate.

The first feature was an approach supporting modularity. Instead of focusing on a single, unified technological outcome, the project worked on a set of software components that could be used by a third party either simultaneously or independently (high-level code, multiple wrappers for several development frameworks, various simulators for hearing aids, hearing loss and HRTF, hearing testing application, etc.). For example, rather than having a single set of functions for the preliminary fitting of the virtual hearing aid, the 3D Tune-In software components foster three parallel systems with various scales to measure hearing loss. Each end-user or developer or stakeholder can choose which of the functions or components to activate for this preliminary fitting. This modularity was a key element of the participatory design sessions (e.g., design jams and hackathons), which were organized by the internal stakeholders and where external third-party organizations could quickly tinker with these software modules, provide feedback and, possibly, continue their development independently.

Additional features of the infrastructure suggested specific ways of using such modules. On the one hand, the open sources components were released according to technological standards (i.e., types of files, compatibility, interoperability) that would make these components easy to use for third-party organizations and ready to be plugged into external existing applications. On the other, a quite nuanced intellectual property strategy defined an organizational protocol to govern the relationships among the stakeholders that (1) would provide to the internal stakeholders a certain level of control by limiting the possibility of creating commercial applications by external stakeholders and (2) would grant external stakeholders a certain level of freedom in implementing their own solutions (i.e., non-commercial applications that could, at later stage, be brought to the market but only in agreement with the partners of the 3D Tune-In consortium).

Initially, the internal stakeholders thought that the use of such standards, licensing strategies and protocols for collaboration and exploitation would allow a balanced relation between maintaining some control of the project and offering some levels of freedom for external stakeholders. In general, this approach worked well to create interest around the project and ignite collaboration, but was also riddled with unbalanced and, at times, conflictual power dynamics. Firstly, it emerged that only some of the internal stakeholders strongly aimed at project outcomes that were open-ended and configurable. Some other internal stakeholders, in principle, supported this open-endedness, but in practice were more interested in commercialization opportunities and wanted to limit such open-endedness and to control as much intellectual property as possible. This created continuous tensions within the consortium, with different stakeholders trying to steer the project in different directions. Secondly, most of the internal stakeholders were convinced that they could initially deploy the infrastructure and then external stakeholders would use it and autonomously maintain it over time. The problem was that while the 3D Tune-In consortium was directly supported by the European Commission and had some funding to work on the project, external stakeholders had to invest their own financial resources. This created, obviously, an unbalanced distribution in relation to the sheer time and resources that the various stakeholders could dedicate to the project and the result is that most of the technical work on the software components of the infrastructure was carried out by the internal stakeholders. At present, dozens of external organizations from the Czech Republic, Israel, Austria, France, US, UK and Italy are currently further developing the 3D Tune-In software components applying it to domains such as musical composition, neurobiology research and video art, but, ultimately, it is unclear whether these projects will continue or succeed. It may as well be that when the European Commission stops directly funding the internal stakeholders, the 3D Tune-In infrastructure will not be able to secure enough interest of external stakeholders and to survive.

5. Discussion

So far, three years into the project, not all the stakeholders are entirely satisfied with what has been achieved, but most of the internal and external stakeholders are satisfied enough. Stakeholders have ideas on how they can keep exploiting (jointly or on their own) the technological components of 3D Tune-In and they are now trying to secure resources to implement or finalize these ideas. The 3D Tune-In infrastructure helped to support collaboration among these different stakeholders despite tensions and frictions.

Two interlinked organizational dimensions of the infrastructure were particularly important. First, the various design artifacts circulated among the stakeholders (not only the software components, but also sketches, mock-ups and prototypes) were often articulated as incomplete, early, preliminary and, as such, could be interpreted and adapted by the project stakeholders in light of their own wants and needs. For example, over time, some items – e.g., a wrapper to integrate 3D Tune-In technologies into the popular video game development framework Unity3D (https://unity3d.com/) – were purposefully kept incomplete. This incompleteness was the way to leave some room for multiple interpretations and for processes of re-adaptation and re-appropriation from various stakeholders. The term ‘incomplete’ is here deliberately used rather than ‘undetermined’ (Selloni 2017), as incompleteness seems to suggest that additional efforts are needed to complete the task, the artifact or the process. In some other cases, conversely, the internal stakeholders felt the urge to get to some sort of finalization in occasion of formal checkpoints of the project (i.e., milestones, due dates for the deliverables, etc.). In these occasions, design artifacts were brought to a higher level of completion and, as such, were more strictly specified and offered little margin for divergent interpretations, like in the case of when, after a few months of research, quite final prototypes for the video games were thoroughly tested with individuals with hearing impairment.

Secondly, the design activities of the project were purposefully oriented toward modularity and redundancy. Rather than just focusing on a single technological outcome, 3D Tune-In worked on a set of hardware and software components that could be used either simultaneously or independently (high-level code components, wrappers for several development frameworks, various simulators for hearing aids and HRTF, etc.). Rather than having a single software application that could only work when all its components were operating as an interlocked and unified system, 3D Tune-In focused on a variety of interlinked but also partially autonomous components, providing additional or duplicate functionalities that could function in case some other components or parts of the system would fail or would not be appreciated or deemed interesting by external stakeholders.

Together with the strategic use of incompleteness and redundancy, choices in relation to technical standards and to quite nuanced intellectual property rights further contributed to simultaneously fostering and limiting open-endedness by partially steering the way in which stakeholders could operate and tinker with the modules of the infrastructure.

Incompleteness left space for multiple interpretations and for re-adaptation of technologies and meaning by different stakeholders. Redundancy further supported these processes of re-adaptation by offering a multiplicity of possibilities to the stakeholders that could choose which project components were more suitable for them. In other words, redundancy helped the processes of local adaptation of the 3D Tune-In technologies in contexts where – even if not all the hardware or software components were perfectly suitable or in line with the local needs and wants – some other components could still be helpful and re-configured according to the local specificities (e.g., the hearing aid simulator could even be used as an isolated component to mod pre-existing video games).

Redundancy and incompleteness of the various software components helped the commercial companies in thinking that they could branch out and start building on top of the 3D Tune-In software platform before it was actually considered as completely finalized by the academic partners working on it. Conversely, the academic partners could keep working at their own pace and take their time in advancing their research agenda and not being too constrained by time issues.

In a broader organizational perspective, incompleteness and redundancy were also helpful because they allowed maintaining a strong, overarching and coherent guiding policy. The guiding policy was quite broad (putting the hearing impaired in the condition of better controlling and guiding the process of calibrating their hearing device), but its codification into coherent actions, milestones and deliverables was much stricter and more bounding. Still, the stakeholders were happy to adhere to this strict guiding policy knowing that incompleteness and redundancy would give them some margins of freedom and individual action. In other words, incompleteness and redundancy left space for some discretionality: the stakeholders in charge of coordinating or participating to some specific activities could, to a certain extent, orient the activities in a way that was compatible with their needs and interests.

The guiding policy and its formal codification (e.g., into formal milestones, deliverables, etc.) suggested a common directionality to the stakeholders and pushed to have some convergence among them. At the same time, incompleteness and redundancy helped the stakeholders in valorizing and even building on top of their divergences in languages, needs and interests. Within the infrastructure, it was precisely the interplay between a strong, overarching and coherent guiding policy and the incompleteness and redundancy emerging from the software platform, the translational elements (e.g., visual documentation, manuals, etc.) and the open workshops that helped in tuning and aligning convergent and divergent needs and interests of various stakeholders and in leaving margins for individual action (but within a shared and common framework).

Incompleteness and redundancy tied divergent stakeholders in coordinated action (Eisenberg 2007) also in situations where the full alignment of the agendas of these stakeholders was not possible.

Indeed, this coordinated action between internal and external stakeholders was riddled with tensions and frictions. Through the current infrastructure, internal stakeholders are still trying to achieve a balance between the levels of control that they want to retain and a certain open-endedness that grants the freedom to external stakeholders to exploit the infrastructure on their own terms. It is unclear whether a perfect balance will be achieved. It is, therefore, important to keep some critical distance in relation to the potential and the limitations of such infrastructures and the coordinated action they favor. Rather than just looking at the 3D Tune-In infrastructure in relation to the open-ended collaborative processes that it supported, it is important to see how such infrastructure was also a way for some of the internal stakeholders to further their power positions while tuning and re-balancing the project as to make it simultaneously relevant for other stakeholders.

6. Conclusions

Coordinated action potentially answers to a form of context-dependent, physically-situated and divergent collaboration which does not need the full alignment of agendas, needs, and interests and does not require getting to consensus or shared meaning. Orchestrating, sequencing and timing interdependent actions can also happen in conditions of divergences and disagreements. An infrastructure such as the one analyzed in the previous pages provides the opportunity to work beyond the scale of isolated projects and try to ignite and sustain long-term collaborative activities among different stakeholders.

Implications for theory and practice

Even if our considerations are based on a single case study, this paper provides insights on how design-enabled infrastructures can be used in complex, multistakeholder projects to support coordinated action. Scholars can use this study to further their considerations on the role that incompleteness and redundancy play in collaborative projects and how they can help to balance the convergences and divergences of the stakeholders. This study may also provide suggestions to organizations and individuals involved in managing and coordinating these kinds of multistakeholder projects.

Limitations and future research

The author acknowledges that the use of a single case study can constrain the generalizability of the research implications. This study calls for further investigations to more solidly contribute to theory building and empirical testing. Some areas appear particularly promising in terms of future research. Particularly, the specific features of the different design artifacts involved in such processes and how these features can be oriented toward incompleteness and redundancy deserve more attention and need to be more closely scrutinized as various modes of using design-enabled infrastructures. In addition, new studies can benefit from adopting further analytical concepts that other scholars within design research used to examine infrastructures.

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