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Infant Fingerprints: Enrolling Identities and Designing Biometric Future

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Infant Fingerprints: Enrolling Identities and Designing Biometric Future

A dissertation submitted in partial satisfaction of the requirements

for the degree Doctor of Philosophy

in

Anthropology

by

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2021

The dissertation of Mayya Azarova is approved, and it is acceptable in quality and form for publication on microfilm and electronically.

University of California San Diego

2021

DEDICATION

To my mother Sofya

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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Chapter 4, in part, has been submitted for publication of the material as it may appear in "Just slack it: A study of multidisciplinary teamwork based on ethnography and data from online collaborative software.". Azarova, Mayya, Michael Hazoglou, and Eliah Aronoff-Spencer. New Media & Society, 2020. The dissertation author was the primary investigator and author of this paper.

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FIELDS OF STUDY

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ABSTRACT OF THE DISSERTATION

Infant Fingerprints: Enrolling Identities and Designing Biometric Future

by

Mayya Azarova

Doctor of Philosophy in Anthropology

University of California San Diego, 2021

Professor Steven M. Parish, Chair

Professor Martha Lampland, Co-Chair

This dissertation examines the nuances of multidisciplinary teamwork on a biometric device to fingerprint newborns. Since 2015 a group of engineers, medical professionals, social scientists, and designers have worked on a non-contact scanner that would capture infant fingerprints and create a digital record of one's identity for vaccination purposes. My research

opens critical space for imagining alternatives for the two competing perspectives of either infant biometrics as the pure evil or the ultimate solution for all problems.

I analyze an online collaboration software called Slack, which the team used, as an additional lens in my ethnographic account of the team. I examine to what extent Slack mirrors offline team interactions and project progress. My research shows how to visualize the team's multidisciplinary collaboration throughout the project, the phases of biometric design by discipline, and what the limitations of such representations are.

I observe how the team wanted to go beyond just making a tool and redesign the whole healthcare delivery system to make it more equitable and accessible. Unable to solve all global health problems, after conducting multiple tests in the field, the project ends up centered on the technical side of making a device work. I also find how ethics is practiced from distinct disciplinary vantage points in the daily entanglements of limited resources and interpersonal relationships. At the team level, I demonstrate which concerns are voiced and draw attention to the role of the team leader in many key decisions. At the project level, the story of a particular biometric device is an invitation for a dialogue between those who make technologies of the future, and those who are rightfully skeptical and emphasize the unintended consequences of any biometrics.

Ultimately, I suggest an approach to the biometric device not as one static deliverable but as a boundary object that brings together all the different stakeholders. I demonstrate how human the making of future technologies is; and how from numerous daily interactions the final device is created, influenced by people who, at some point, participate in the project as employees, volunteers, and study participants.

Chapter I: Introduction

I wish you knew the kind of garbage heap
Wild verses grow on, paying shame no heed ...[1]

Prologue: One Weekly Meeting

It is a Wednesday morning, and we are in a conference room for a regular team meeting. Today's meeting starts with an unresolved problem. An electrical engineer, Co Ling ,[2] who is responsible for data processing and analysis, states that based on his latest results the contact device works better than the non-contact alternative. This contradicts previous findings. Co Ling explains that the non-contact roller is not matching well because it covers only a small area of the finger. Surprisingly, there is no immediate response, debate, or tension when the news is delivered, and the meeting goes on.

The technical lead, an optical systems' engineer, CJ See, starts sharing a document on the screen about the quality of the fingerprint images. Based on that longitudinal data, CJ See says: "I have a theory that images number seven, eight, and nine for all fingers are the best." He explains further: "at first the swirl is not there, then we move again, and by the third time it [image] is the best." CJ See is convinced that, "it's all about interaction." He adds that "it makes sense" why those images come out the best. First, there is some movement as biometricians look at the screen and adjust the infants' fingers while capturing fingerprints, by the 7th image the finger is stabilized in place. CJ See also suggests a technique to obtain the best images, showing the movement with

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[1] Akhmatova, Anna (trans. A.Z. Foreman) "I have no use for regimental odes." Poems in Translation. www.poemsintranslation.blogspot.com/2009/09/anna-akhmatova-i-have-no-use-for.html. Accessed February 10, 2021. Full poem in Appendix I.

[2] All team members' names are pseudonyms

his hand and saying: “we’d need to rotate outside, middle, then inside … maybe device rolling around and scanning the finger from three sides.”

Next, a mechanical engineer, Joe Niel, demonstrates three device tops.[3] Upon seeing them, the PI comments, “we are missing something with shape.” In his opinion, the device is “a mechanical engineering problem: it should hold it [the finger] but not stretch the finger.” The team debates about the device shapes. CJ See brings up the crucial choice between contact and non-contact devices by asking: “Throw out contact?” The PI promptly answers: “When Co Ling shows real data, then yes.”

Then, the PI changes the topic and refers to an “urgent matter” of making sure that while three software engineers are in the same room, they should synchronize data, pull out “patient-date-finger” information and “make sure we don’t lose anything.” The software subgroup’s response is that next Monday backup should be done, and it will be possible look at the data after each session using their software.

Ann Hughes, the Project Manager, mentions that one external advisor is missing from the meeting although she was expected to attend. The PI notes: “people are interlinked, one does not allow another one to move forward,” hinting that some team members do not fully contribute and occasionally hinder teamwork. The team finishes the meeting with a conversation about the “device top taxonomy,” and everyone agrees that they first need to schedule “a top test evaluation session” to create such taxonomy. The goal is set to identify which tops – with more movement or

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[3] In the team’s vocabulary, each device had a main fixed body called *module* and a number of interchangeable caps, which were called tops.

more fixed ones – prove to be better for the practitioners, processing, and what type of analysis should be done on the images that the devices capture.

The previous anecdote was intended to draw you into the complex everyday world of multidisciplinary work on a biometric device, which is the subject of this dissertation. How does anything get done in a team working on a project with multiple changing variables and a lot of uncertainty? The meeting did not follow a strict agenda and might have even seemed disjointed or chaotic to an outsider. There were abrupt stops and conversation deviations but that was how real meetings progressed. They made sense to the people who were fully involved with the project.

This dissertation tells a story about the development of a new fingerprinting device from a perspective of team interactions online and offline, their multidisciplinary collaboration during the device design and field testing, and the development of social practices around the device within the team. I looked at what traces were left behind and how one could reconstruct a multidisciplinary effort to understand the way potentially life-changing technologies are made today. The contribution of this dissertation project is to support a more inclusive dialogue between those who create new technologies and those who criticize and report on the unintended consequences, and the public. It is crucial to have multiple connecting points across social and technological perspectives on new systems and devices, especially in a rapidly developing field of infant biometrics and identification. The goal is to examine the social construction of infant fingerprinting as a technology placed in broader social and historical context of the 21st century. While 2020 became a year of global pandemic, the question of vaccination certifications, tracking, surveillance, and digital record keeping have all become even more important to tackle and present in our daily lives.

Multidisciplinarity in Collaboration Age

How do people manage to understand each other and work together despite their differences? That question of a common narrative or goal, gradual knowledge production, and work change through time, lies at the core of this dissertation project. Large companies like Google, invest considerable amounts of resources to investigate how people work together and what the perfect ingredients for productive or effective teams are.[4] Generations of scholars and practitioners across the globe have shared their observations and advice on the construction and maintaining of different hierarchies, bureaucracies and societal structures that allow people to collaborate and achieve their goals. Social scientists and anthropologists, in particular, have contributed to bringing attention to culturally distinct ways of seeing and experiencing the world, the importance of diversity, and the daily practices that might otherwise be forgotten, obscured or not acknowledged (Ortner 1984; Appadurai 1986). Multidisciplinary teamwork, no matter how long it has been studied, remains a challenge, especially when teams speak distinct disciplinary languages, come from different countries, and use new digital technologies to communicate.

Numerous multidisciplinary collaborations are created as a response to the rising complexity of societal problems such as the growth of urban population, global warming, health disparities and outbreaks of preventable diseases (Wuchty, Jones, and Uzzi 2007). There are natural disasters like wildfires and earthquakes, and certainly the most recent example that in some way affected everyone on the planet is the COVID-19 pandemic. This means that problems and their solutions cross national and cultural borders, affect more and more people and have an almost immediate long-term impact on the world.

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[4] Rozovsky, Julia. The five keys to a successful Google team. Nov 17, 2015. www.rework.withgoogle.com/blog/five-keys-to-a-successful-google-team/. Accessed Feb 17, 2021.

It has become obvious that such interdependence requires people from different disciplinary and institutional backgrounds to work together on researching and developing tools to measure and predict a variety of possible socioeconomic and political futures. Such initiatives are usually technology-driven, like contact tracing and vaccine delivery, and are not solo efforts, even if started by one highly motivated person or a small local group. They involve extensive data collection, analysis and dissemination, as technology becomes more and more advanced. Thus, stakeholders, often from diverse backgrounds, create shared knowledge whilst simultaneously dealing with growing concerns about data protection, usage, recycling, and exploitation for commercial purposes. All these questions are relevant in a broader discussion about the consequences of integrating infant biometric scanning at birth.

Since the 1960s, studies of the informal communication among scientists show that different communication needs exist even within the same discipline and specialty (Gaston 1970). The reason for that are the different types of problems those groups solve and the division of labor in highly specialized research fields (Gaston 1970, 39). What happens then in these new hybrid project-based multidisciplinary teams? Coming back to the meeting snapshot, I ask how such messy everyday interactions result in producing new technology like new biomedical devices and, more importantly, what lies beyond the mechanics of the device itself. How did team members explain results and justify decisions? What were their aspirations, and did they get reflected in the device design?

Theoretical Background

The question of how diverse individuals construct meaning and find ways to achieve certain goals has been addressed from several different viewpoints. It could be seen as an organizational study problem, a question of productivity and time management, or strategies to reduce stress. However, what is productivity for this particular team? Let's take one step further and start by questioning just what a team is.

Some scholars distinguished between teams and work groups by the degree of interdependence, where team members required each other to do their job and work groups were less interdependent (Kozlowski and Bell 2012). Team research traditionally focused on tasks and technology, while group research emphasized interpersonal relations and interactions (Goodman, Ravlin, and Schminke 1987; Bettenhausen 1991). There is an extensive body of literature in organizational psychology and organizational studies about the development, effectiveness, and organizational function of teams. However, as pointed out by Kozlowski and Bell (Kozslowski and Bell 2013), certain aspects about team knowledge production require further research attention, namely the diverse organizational contexts, multilevel nature and time aspect in team research and theory. Both a multilevel theory (Kozlowski and Klein 2000) and systems theory (De Greene 1973) approaches call for a more holistic perspective. This is where an ethnography is well equipped to provide a valuable account for temporal and contextual impacts on team function and process on both the individual and organizational levels. The value of ethnography is in long-term observation and participation in dynamic team processes on multiple levels over time.

In this dissertation, a team is defined following Cohen and Bailey (1997) as '… a collection of individuals who are interdependent in their tasks, who share responsibility for outcomes, who see themselves and who are seen by others as an intact social entity embedded in, one or more, larger social systems [. . .], and who manage their relationships across organizational boundaries" (S. G. Cohen and Bailey 1997, 241). I employ Bijker's definition to describe technology as a three-part phenomenon, which includes "artefacts and technical systems; the knowledge about these; and, finally, the practices of handling these artefacts and systems" (Bijker 2009, 64). It allows us to separate complex dynamic processes in the project into smaller components. If the design of technology reflects cultural and socio-economic preferences of its makers and users, in other words if technology is socially constructed, we can explore it on different levels from artefact to technological culture.

The presence and importance of technology as a historical texture of the project is somewhat echoing the idiom of "co-production," which presents scientific knowledge as "neither a simple reflection of the truth about nature nor an epiphenomenon of social and political interests" (Jasanoff 2004, 3). The co-production of knowledge could be reflected through bureaucracies, policies, technology, and new scientific knowledge but it is not deterministic (*ibid.* p.14). The main question of co-production is not so much what knowledge is produced but how particular states of knowledge come into being, are preserved, maintained, or rejected through time (*ibid.* 19). In my analysis, I paid attention to the backstage of work at Pediatric Technologies: how the team discussed device iterations, how each subgroup reflected upon the importance and relevance of the device, and what role they foresaw for their new device and consequences of the technological culture it would bring to the communities that would be using it.

To understand how heterogeneous actors cooperated on a project, created something tangible and constructed meaning, I chose a boundary object framework as my main lens of inquiry. At its core, the concept of a boundary object was motivated by a paradox of "cooperation without consensus" (Star 2010, 604) and allowed to look at boundary objects as "agents that organize distributed cognition" (Henderson 1991, 450). Such boundary objects have been often investigated within broader "boundary infrastructures" and marked an intersection of different social worlds, negotiated areas where different communities of practice collided and overlapped (Bowker and Star 2000). In other words, boundary objects are used when different groups understand and use the same material, concept, program, or physical object in a way that suit their purposes.

This framework has been widely used since its inception in the late 1980s to deconstruct the process of knowledge production and standardization of processes. For example, there is work on boundary objects in engineering and software development teams (Henderson 1991; Barrett and Oborn 2010), healthcare (Islind et al. 2019), and studies of new technology (Harvey and Chrisman 1998; Fox 2011; Bowker et al. 2016). The word "boundary" does not necessary mean marginal and is explained as a shared space, a representation, or a metaphor belonging to two or more social groups, which could "speak" to them (Star 2010, 603; Fox 2011, 72). At my field site, the boundary object was the biometric device that the team designed, iterated upon, shaped, negotiated functionality, and at the end reached a certain level of standardization.

Usually "engineered boundary objects" (Bowker and Star 2000, 305–6) are described in literature as artificially created monstrosities, which tend to lack the necessary ambiguity and flexibility. However, there are examples of feminist responses in a form of "boundary objects that learn" (Juhasz and Balsamo 2012), which successfully created distinct communities of practice. In my work, the boundary object is artificially engineered as it is a new man-made biometric device, yet I argue that it manages to remain responsive and ambiguous, not imposing its role yet, which could be partially explained by the fact that it has not reached the market.

Methods and Research Questions

This study contributes to the analysis of multidisciplinary teamwork, more specifically, the processual characteristics of knowledge and meaning production through human-centered interviews, in-person meeting observations and the lens of quantified data in Slack. My work was based on two modes of inquiry: in-person ethnography and a mixed methods approach to incorporate insights from the team's usage of the digital tools. The eighteen months ethnography of the team focused on work practices, membership, and the everyday process of creating new knowledge in a multidisciplinary team. I chose open-ended interviews as a way to "explore the presence or absence of certain thoughts and feelings and the ways in which were expressed (directly or indirectly), suppressed, denied, or hidden" (Hollan 2005, 461–64). Such immersion and day-to-day observations were necessary to probe what individuals and team valued, enjoyed, or argued about.

A long-term engagement with the team allowed me to observe a local example of the intellectual and social mobility in research, namely how different specialties coordinated their work in different phases of the project. I could see how in multidisciplinary hybrid teams the variety of specializations blurred through time as the group core congealed and transformed. It allowed social mobility and recognition within the team, represented by growing skills and responsibilities for individual members.

I was very lucky to be able to conduct my research from July 2017 until February 2019 in person before the start of the COVID-19 pandemic. The team started working together in the late 2015 and finished in the late 2020. Some former members have stayed in the project until spring 2021 and a couple of new students were hired to analyze the collected data. I observed the processes in which the team produced technological devices in both external reports and internal presentations, during team meetings, interactions in the lab, and during field sessions.

I studied the digital side of collaboration through the analysis of the emerging "virtual portrait" of the team. The virtual portrait is a term I used to describe how the team's online footprint was represented across digital media. I looked closely at the team infrastructure (Bowker and Star

2000, 35), defined by Bowker and Star as a number of characteristics, which are not always easy to parse, for example transparency, scope, membership, and embodiment of standards.

My observations focused on the team's core members, who were collocated in the US headquarters. Multidisciplinarity primarily reflected different disciplinary backgrounds in this dissertation. As mentioned before, the boundaries of multidisciplinarity have been in flux and negotiated within the team. During interviews, members distinguished more specializations, for example, among engineers, yet they were always referred to, during team meetings and everyday interactions, as one group, often juxtaposed to social scientists, called human factors subgroup. In my analysis, engineers were referred to as a single group because that was how they self-identified and were referred to by other team members.

I received Institutional Review Board (IRB) permission (Project #180660XX) for the study. I conducted fourteen in-depth semi-structured interviews with ten core team members. Some interviews had two parts or follow-ups as team members were open to share more insights about their daily routines and ideas about the project. I asked ten open-ended questions about disciplinary background, project timeline, main challenges, workspace, and, finally, technologies' the team members used. The answers were transcribed and analyzed in NVivo software, using a codebook developed with the open code method (Given 2020). I interviewed people who actively participated in the weekly team meetings and used a snowball sampling method to recruit interviewees, who were mentioned as team members by others. The interviews ranged from forty minutes to two hours. I also had informal conversations with team members throughout the study period, asking for clarifications and team members' opinions on different issues raised in meetings. All interviewees knew from the beginning that I was a social scientist, an ethnographer, and a "historian for the team," and that my study was not a report to their leadership but an attempt to understand better how new technology and knowledge were produced and reflected in the digital technologies.

I took detailed handwritten notes of sixty-one weekly meetings, which were digitized and analyzed in NVivo software, using a customized coding scheme adopted from previous studies of creative meetings (Olson et al. 1992). On average, team meetings lasted from one and a half to two hours, with shorter forty-five-minute meetings called “check-ins” toward the end of the study period. My goal was to capture the structure, key discussion points, and what the team deliberated upon. I collected the following information across all meetings: place and time; a number of participants; sitting arrangement; main tasks, core issues, milestones, and references to project and meeting coordination.

There were fifty-seven team “members” on Slack: fifty-five people, a duplicate account, and an “empty” account created automatically for synchronization with Google Drive. I joined the team’s Slack account on the first day of the study period on 6 July 2017. Since then, I observed and participated in conversations on Slack 24/7 having it on a smartphone, a laptop, and a tablet. The goal of those observations was to understand day-to-day online interactions, to capture small rituals like weekly team lunch updates, news from the device field sites, and to gain a general understanding of who posted what and where.

The advances in biomedical technologies have raised numerous questions in terms of design, implementations, and long-term societal consequences. This dissertation research aims to touch upon the following array of questions. How is a biometric device constructed, if described through the lens of boundary objects? What is the cost, or the trade-offs, of having a virtual portrait of a team? In other words, I question sustainability of digital archives as the team was forced to pay a proprietary company to maintain access to their archive. A quick change of technology affects record-keeping and the institutional memory of the project. Finally, I ask how biomedical technology creates a way to authenticate one's identity, both from a technical and a social point of view. The overarching question, central to this dissertation, however; is how a multidisciplinary team develops an infant biometric technology over time and what the everyday work of making future looks like.

Project Context

A number of studies have scrutinized modern infrastructure and standardization (Lampland and Star 2009) and power dynamics in the center (Hannerz 1989). Examples include ethnographic accounts about corporations (Cefkin 2010; Urban and Koh 2013) and organizations that have institutional power (Markowitz 2001) and money (Hart and Ortiz 2014) as opposed to socio-economic and political periphery. My work is following the rationale of "studying up" (Nader 1972) by focusing on the social power structures of the middle and upper-classes.

This dissertation is situated in the specific context of a multidisciplinary team composed of people in academia and industry as they work toward producing a viable prototype for a young infant biometric identification device. It is an engineering project at its core. The team received a grant from the Global Scale Foundation[5] to solve a practical problem of identifying infants under the age of one for vaccination purposes. It was not required to justify the need for such device. In the team internal documents I saw references to sources explaining how there is a large number of unvaccinated and under-vaccinated people, especially asylum-seeking young children, which creates global health risks and causes problems at national vaccination programs (Nakken et al. 2018). Scientists who have previously worked on infant biometrics argued that reliable

[5] All organization, personal, and team names are pseudonyms.

identification could reduce and eventually eliminate deaths from vaccine-preventable diseases, and malnutrition (Engelsma et al. 2019). Moreover, according to the UNICEF, reliable methods of birth registration are still challenging both in the global South and the global North (Unicef (org) 2020).

The team Pediatric Technologies (PT) received funding to create a non-invasive biometric identification (ID) system that could be used in any challenging conditions in the field. This meant the team needed to account for changing light, heat, intermittent internet connection and long lines of patients who might not trust new technology. Previous design efforts by computer scientists illustrated how a successfully developed prototype working in lab conditions did not always perform well in operational contexts such as hospitals and vaccine clinics. Scholars developed a number of recommendations specifically for infant biometrics and reported a longitudinal comparison of identification methods and benefits of infant fingerprint recognition systems (Lemes et al. 2011; Jain, Cao, and Arora 2014; Jain et al. 2016; Engelsma et al. 2020). The challenge for Pediatric Technologies was to make their own low-cost, ergonomic device that would work in the field and, and as the project developed, the team aspired to re-imagine the whole process of vaccination and healthcare delivery.

I am in agreement with Jasanoff, who noted that even during the time of rapid technoscientific change people more often experience continuous rhythms of everyday life, rather than abrupt disruptions (Jasanoff 2004, 16). I observed how most milestones or moments of important transitions were either realized in hindsight or announced by the leader of the group during the team meetings. Such office and lab context brought several interesting questions for a social scientist. While the team was producing knowledge, questions arose organically concerning the production of meaning, trust and confidence in technology, and positioning of different disciplines in the team. In this project my assumption is that members of any research group are not independent problem-solvers as they have a certain range of cognitive and technical standards (Mulkay 1970, 7). What is particularly important is that those norms and standards are currently developing in biomedical field, especially for newborns and children, as new biometric measurements become both more accessible and sophisticated.

As this dissertation project was situated among university affiliates, studying up had certain advantages because the researchers themselves were interested to learn more about their knowledge production, product development, design, and procedures. My ethnographic study period started at the pivotal point when the device was first introduced to the clinical setting in the United States in summer 2017. I assisted the social scientists and engineers by observing and evaluating testing sessions, device design, recording interpersonal interactions, and analyzing the overall program workflow. I participated in the field sessions, where team members tested prototypes of the new devices and attended informal social gatherings with the team members, including weekly team lunches, celebrations of project successes, happy hours, farewell, and graduation parties.

Starting in January 2018, the Mexico Team, supervised by the Mexico PI, joined the project and was responsible for local recruiting, device testing, and reporting back to the headquarters. The PT communicated mainly in English, with more discussions in both English and Spanish when field sites opened in Mexico. The team spoke eleven primary languages, which included English, Spanish, Hebrew, Mandarin, Tamil, Norwegian, Hindi, Farsi, Swiss-German, Ukrainian, and Russian.

As mentioned before, throughout the study period, the team used a popular workspace messaging tool called Slack to exchange messages and files among the team members. Slack was used both for communication (e.g., sharing updates) and collaboration (e.g., working together to make changes in documents). The PI created a Slack account for the team and made sure all new members were added there when they joined the team. Slack application can be accessed via a smartphone or a computer from anywhere in the world with an Internet connection. Slack not only shows all public messages when you are online but encourages users to read all missed posts. It highlights unread messages and sends notifications. The main dashboard in Slack is organized around chats that occur in separate online spaces called channels. Users can create, name, and describe the purpose of channels using a hashtag, for example, #literature or #surveys. Inside and across these channels, participants can send messages, mention each other, share documents, photos, GIFs, and reactions in a form of emojis. "Mentions" in Slack are explicit callouts when a user adds the "@" symbol before typing their colleague's name to bring attention to the message. Apart from facilitating quicker and easier messaging, Slack also promotes informal work communication, illustrated by channels named #tacos and #random for fun and team jokes.

The team paid for their Slack account in February 2018 to gain access to the complete digital archive from 2015. All the details about public channel creation and membership were available for team members to see and download. Default Slack Analytics also aggregated numbers of daily and weekly messages in public and private channels, direct messages, file uploads, "reactions" to posts, and active users. Team members used private channels only four times during the project. We excluded private channels and private direct messages from our analysis for privacy reasons. The PT had a total number of 68,695 messages shared in Slack by all members from 2015 to 2019. Only 14,146 of those messages, however, were public. Messages in public channels comprised roughly 20% of the total amount. There was also a consistent drop in weekly active members during holidays around December-January every year. The online activity of the team, measured in all messages sent in Slack, demonstrated how the nature of the discussions became more and more private over time. This meant that despite providing many data points, the team's digital footprint was just the tip of the iceberg, which required ethnographic contextualization, especially when the team expanded and started to transition into direct private messaging.

Digitally mediated encounters and challenges of digital or virtual ethnography, especially in the organizational setting, have been problematized before (Garcia et al. 2009; Hallett and Barber 2014; Kallinikos, Aaltonen, and Marton 2013; Murthy 2008; Pink 2015). Although the "informants' digital and physical interactions are not necessarily equivalent" (Akemu and Abdelnour 2020, 300), the online spaces are becoming more and more significant to fully understand different lived experiences. I engaged available digital archives where the team's documents have been stored, for example in Dropbox, Google Drive and on GitHub.

The nature of the project and the team, which was funded by a series of competitive grants, brought a number of issues often found in similar non-constant, dynamic research sites like NGO's (Markowitz 2001) and start-ups (Sontag 2018). This meant that team members had to wear different hats and learn as they go, and the interpersonal relationships played a significant role in the project's success. One specific feature of "soft money" funding is chronic personnel turnover as one would hire people for specific projects and might not afford to have them full time.

An Elephant (or Panda) in the Room: Another Surveillance Device

Many scholars have been writing about the increase in surveillance practices and pointing out potential harms specifically around biometric surveillance as a form of control and exclusion (Lyon 2003; Aas 2006; Marciano 2019). The term "the body as password" appeared back in 1997 in Ann Davis' article in a popular technology magazine and brought attention to "the age of the body-part password." Reading this article now, it is hard to believe that it was written twenty-four years ago as it still feels as relevant and contemporary as ever. It is fascinating how much of the technology existed back in 1995-1997 and how some of it became normalized, for example facial recognition or fingerprints to unlock certain consumer devices. Slowly but surely, biometric data is now required to cross borders and while there is no robust interoperable biometric database for the whole world, it is already operational in certain countries. However, the same fears and concerns are raised today around the security and usage of human bodies for law enforcement or marketing purposes by governments or medical providers. Mandatory biometric national ID cards have been described by non-profit organizations like The Electronic Frontier Foundation (EFF) as oppressive state mechanisms, way of policing, especially when the technology development and implementation was outsourced to private companies. The EFF also voiced a counterargument for biometric ID reliability, emphasizing that compromised biometric IDs cannot be reissued like signatures or passwords.

Fingerprints, therefore, as other biometrics not only became carriers of information about the person but also started to identify human bodies as information (Van der Ploeg 2003, 64). Van der Ploeg made a provocative argument, claiming that digitizing physical body in a machine-readable format, biometric technologies affect the ontology of the human body. In other words, one can expect transformation of embodiment, similar to the one, which happened when people started to use "modern, anatomical-physical body" (Van der Ploeg 2003, 70) in the in the late-eighteenth century. The new ontology also implies that by communicating directly with the body the biometric technology would provide objective information, bypass the mind, prioritize the physical body, and produce "mute individuals whose bodies speak for them" (Marciano 2019, 128). It was described in earlier literature in a well-known and often repeated quote: "what the subject thinks, does or believes … is simply meaningless for the technological device" (Lianos 2003, 423).

Many technology-driven solutions and categorizations go unnoticed until they break. For example, I never knew that after I taught a university course during summer and requested course reserves for my students, the library system registered me as "a professor" while maintaining my previous record as a student. The next time I tried to request a book the log-in page showed an error message that "the code is not unique" and required me to speak to a librarian. Thankfully, when I reached out to a human on the other end, she quickly fixed the problem by taking out a zero from the barcode associated with my record and explained why I had a duplicate in the system after teaching a course. Being cut off from my academic record and losing my identity for a moment felt quite uncomfortable. Such breaks in technology illustrate the paths and scenarios, which were not supported and therefore require a human intervention. That situation becomes much more complicated when instead of an access to a book from a library, one might be losing access to their identification, medical history, or essential services.

The new body ontology and growing surveillance concerns were not a type of conversations I ever heard at PT or during discussions at any other design or engineering projects at the university. I do not think such thoughts even crossed my mind either during fingerprinting or brainstorming sessions about the design of the devices. There were certainly questions and discussions about the local environment in different communities and the consequences of adding such technology into the hospitals, mainly from the perspective of adding extra labor and time to standard procedures and existent workflows. However, it has not been ever presented as a way to control populations or prioritizing body over mind.

The society decides how to define progress, use new advancements in technology, and the general public should know how, where, when, and by whom those technologies are developed. In this dissertation I look at the team, their membership and work as an example of multidisciplinary human-centered collaboration in times of uncertainty. Kelly Gates, describing advancement of facial recognition, emphasized societal circumstances, not just an inevitable result of progress in computer science. She wrote: "computerized facial recognition promised to facilitate the forms of mass individuation, social differentiation, and intensified security on which neoliberalism depended" (Gates 2011, 33). Many everyday activities play a formative role, but they are also overwritten and forgotten; individual contributions and team hesitation might not be as evident until you look back at all the documents and false starts, ideas and goals, challenges, and disagreements. To know who is doing the research and how the processes are organized brings us closer to estimating possible consequences of any new technology implementation. Oftentimes, the devil is in details, and I would add in daily routines, which in a hindsight might seem like intentional planning.

Organization of Dissertation

This dissertation consists of six chapters organized to reveal the rich cultural context of multidisciplinary teamwork on a new biometric device to fingerprint newborns. That device could be regarded as another method to measure bodies to control populations through collecting biometric data from birth until grave. Therefore, it is quite a contested space of meaning, intentions, and practical applications. In the introductory Chapter I, I talk about the relevance of the ethnographic research of the multidisciplinary teamwork, the complexity of the everyday interactions in diverse teams, my theoretical assumptions, research questions, and the methods I employed in my work. Chapter II provides context for the field of biometrics, its historical development, especially after forensic fingerprinting went beyond finding suspects by matching latent fingerprints from crime scenes to fingerprints stored in central databases. I also analyze a fingerprinting session at a hospital, illustrating the process of testing a new biometric device for the infants.

I chose to introduce the context, site, and the team before a discussion about the theoretical tools I implement in my dissertation in Chapter III. There I talk about the device as a boundary object, and how the making of it happened behind the scenes. That includes the location, vocabulary, and interpersonal relations of the project. In Chapter IV, published earlier with my co-authors as a separate article, I address the digital side of multidisciplinary work and show the limitations of any evaluation based solely on online activity. My final analytical Chapter V addresses the question of ethics, the biometric future, and focuses specifically on ethics in practice at Pediatric Technologies. Chapter VI is a conclusion, where I summarize my main argument about the importance and the role of everyday human practices in making decisions about and creating new biometric technologies and suggest directions for further research.

Chapter II. The Field of Infant Biometrics

PI: Do you like kids?
Maya: Hmm … yes, sure … why?
PI: Then everything is going to be alright. Let's go – there is a session now …

When we enter the room, it feels crowded. The session is in progress. There is an engineer at the computer looking at the images and manually saving them in specific folders; a biometrician with a device in one hand is seated by the caregiver who is holding an infant. There are two engineers observing the process, a behavioral scientist, and now the PI and I joining the group. Despite the large number of people, something about this small "lab office" feels cozy. There is a comfortable armchair for the caregiver, colorful toys, and mood lights to distract and comfort the infants. There is a slight smell of lavender. It is not scary. There are antibacterial wipes, tissues, and rubber gloves on a round table. There are several chairs by table and a big TV screen on the wall opposite the caregiver's armchair. On the walls, I can see the images of different prototypes and photos of the PI with infants testing previous devices. The behavioral scientist points at those pictures on the walls and tells me that photographs played a very important role for the PI and the rest of the team to recognize the details of the process they never noticed before.

The large TV serves as a display showing what images are taken. Suddenly a close-up of the infant fingerprint appears on screen. The image is grayscale, crisp and vivid. For a second all eyes are directed at the screen. The next picture comes up and it is blurry and caught in motion. The team needs to adjust the device to capture the best photos possible. The biometrician is baby-talking and chatting with the caregiver. The engineers exchange short comments about the image quality: the contrast, bad light, specifically "the spotlight" which is "ruining the image." They sometimes ask the biometrician to move the infant's finger, repeat the scan, or confirm which finger they are on. Everyone is very tuned to the infant's mood and comfort, and the moment she becomes fussy, the session stops. The biometrician continues the session if and when the infant calms down. She makes sure both the infant and the caregiver are not burdened by the process. The session feels homey and in no hurry – I wonder whether every session is like that. The biometrician compliments the quality of the infant's fingerprints. I look at the screen and wonder whether anyone ever has "bad fingerprints"[6].

In July 2017, when I joined the team Pediatric Technologies, I took a role of a biometrician's assistant in the team's social scientist subgroup, also called Human Factors. On my very first day at work, the principal investigator (PI) and I went to see the device testing session at the lab office. Until very recently the PI conducted all sessions himself, but since the team had been growing, a new member, a biometrician, had been hired to do that job. The biometrician, Bal Asana, made sure the consent forms were signed and all the necessary data was being collected. She was in charge of field tests, which were referred to as "sessions" or "kid sessions." The standard operations procedures (SOPs) for the sessions were still being developed, and a part of my role was to help with standardization through understanding better the workflow, the risks, and common errors, as well as timing and cooperation among the participants. In short, I was another pair of eyes to observe the process, record what I saw, discuss with practitioners how sessions went, and provide descriptions to accompany the collected data.

The social condition of infant biometric knowledge production, or the process of fingerprinting babies, struck me as an observer when I saw it for the first time. I imagined the bright electric light, white walls, government officials in uniforms, long lines and waiting time. A

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[6] That can happen, and in fact I will soon learn that my own fingerprints are not the best quality.

familiar picture for any international traveler who had to go through fingerprint scanners at the borders. There you must press fingers against the cold glass, often lift them up and re-try a couple of times, hoping the system works well and recognizes your fingerprints. You anxiously glance at the scanner and wait for all the lights above the screen to turn green, indicating that all fingerprints were successfully captured. You do not know whether they matched previously collected fingerprints; the border officers hold that knowledge. Such experience of the biometric collection and authentication process has been studied before as forms of governing and redefining the individual, "extracting information from the corporeal," especially in the context of airports (Kruger, Magnet, and Van Loon 2008, 105–11, 117). Such claims often build upon what Michel Foucault called "biopower," which allowed a new type of mechanism to regulate population:

> "…The disciplines of the body and the regulations of the population constituted the two poles around which the organization of power over life was deployed. The setting up, in the course of the classical age, of this great bipolar technology-anatomic and biological, individualizing and specifying, directed toward the performances of the body, with attention to the processes of life characterized a power whose highest function was perhaps no longer to kill, but to invest life through and through." (Michael Foucault 1978, 139).

Therefore, the field of biometrics is often presented as the expansion of the power to discipline, surveil and legitimize individual subjects in the modern state. However, the process of creating and testing of a new fingerprinting device that I observed in the office lab at Pediatric Technologies was very different from the airport setting. Infant biometrics at the research stage is not yet standardized, and it illustrates the difficulties, including uncooperative subjects, adapting the technology in a way it is accepted by caregivers and works well on newborns.

My dissertation project is answering a call to widen our understanding of the design of new biometric technologies at every level of their development (Gates 2011, 199). I structured this chapter to discuss the two major claims about the field of biometrics, as it applies in the context of fingerprinting infants. First, how it relates to building systems for monitoring individuals, and second, what role human-centered design plays in that process. I am going to share the background about the field of biometrics and biometric modalities, focusing on infant fingerprinting. I illustrate how the team Pediatric Technologies performed biometric recognition to understand how such technology was used in different ways under various social conditions. I describe the backstage of fingerprinting sessions, device building, and discuss some controversies that accompany them. I also focus on how the team applied and experimented with the Human-Centered Design (HCD) approach, which is often used in medical services and medical device design. Specifically, I point out the shifts in the division of labor after the team employed the HCD practices. I conclude with situating the team, Pediatric Technologies, within the current biometric research domain and consider the social consequences of using this technology in comparison to other forms of biometrics.

The Science of Fingerprinting

Biometrics, or biometric recognition, is defined as a science of or a set of methods for measurement and analysis of one or several intrinsic physical or behavioral characteristics in order to recognize individuals (Jain, Flynn, and Ross 2007, 1; Woodward 1997, 1481). "Biometric modalities" is a term used to describe the areas of the human body or characteristics chosen for unique identification, for example ears, face, fingers, feet, eyes, palms, or speech, gait, or even handwriting (Dargan and Kumar 2019). Although fingerprinting itself is a unimodal biometric system, the standard operation procedure, which Pediatric Technologies developed and refined, included the capture of photo data of the infants' hands, face, and ears, which made it a multimodal biometric system. Pediatric Technologies conducted multimodal data capture and enrollment but only unimodal analysis, authentication and matching of fingerprints. In other words, they also collected face, ears, and palm pictures but never used them for anything, although it was planned to integrate them in the analysis at the later stages.

If we count biometrics as a part of biomedicine, it opens an array of questions associated with the subject from an anthropological perspective. "Biomedicine" is a name associated with professional, Western medicine, with an emphasis on biology and a scientific approach, juxtaposed to the "non-medical," "homeopathic," or "folk" systems of health care systems in the non-western world (Ember and Ember 2003, 95). According to Hahn and Kleinman, the sociocultural status of biomedicine can be examined by looking at the division of labor, for example roles and practice of medical specializations, how and in what settings they are taught and reproduced (Hahn and Kleinman 1983, 311).

Another way of looking at biometrics is through the lens of Foucauldian biopolitics, where biometrical systems are a way of controlling the health and well-being of the population. They contribute to making an individual "a case" so that an individual can be "described, judged, measured, compared with others," in which Foucault sees the power of "pinning every individual in their particularity" (Michel Foucault 1977, 191–92). Building upon that, some types of biometrics, like facial recognition, have been described as systematic techniques and procedures for "mass individuation," which are supporting neoliberalization[7] (K. A. Gates 2011, 15, 33, 57).

Infant biometrics is a special case of biometrics as it is both more challenging technologically, trying to capture tiny fingers of the newborns, and also brings up even more ethical concerns. If we look at it from the perspective of biopower, it seems to be even more concerning than other types of biometrics because it is specifically, what some might call,

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[7] Aihwa Ong defines neoliberalism as "a new relationship between government and knowledge through which governing activities are recast as nonpolitical and nonideological problems that need technical solutions." Ong, Neoliberalism as Exception (Durham: Duke University Press, 2006): 3.

“targeting” infants. I do not discard the biopolitical potential of this technology; however, I want to underscore the processes how such new technology is being created, tested, and iterated upon without sliding into judgement and preconceived distrust.

A Brief History of Biometric Recognition

If you have a close look at your palms and fingertips, you will most probably see different patterns of ridges, swirls, wrinkles, and fine lines. These patterns might look similar at first glance, but they are never identical, and most people[8] are born with a set of unique fingerprints. As we grow up and age those patterns that we have remain the same (Galbally, Haraksim, and Beslay 2019). This made fingerprinting one of the earliest ways of identification, alongside photography and anthropometry (Cole 2009, 28, 32). Historically, biometric identification was developed for the police to track and identify criminals. For example, anthropometry, also known as the Bertillon system, was used from the 1880s until the first decade of the 20th century. Anthropometry is a measurement of the physical size and proportions of a human body. That method was later discontinued as it was neither easy nor cheap to implement and required special equipment, training and procedures (Fosdick 1915, 364).

The measurements of the Bertillon system were based on 120,000 subjects, where women were “less numerous,” accounting for only 20,000 cases and another 10,000 were minors under 21, who according to Bertillon, required a special classification (Bertillon and McClaughry 1896, 19). Later evaluations of the system described that as a known deficiency of inapplicability to

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[8] There is a rare genetic disorder called adermatoglyphia when individuals are born without fingerprints. In 2011 scientists identified the gene mutation that causes it. Immigration authorities were particularly interested in this disorder as it became a barrier for the affected individuals to enter countries as they could not provide fingerprints. To read more see: Burger, Bettina, Dana Fuchs, Eli Sprecher, and Peter Itin. "The immigration delay disease: Adermatoglyphia–inherited absence of epidermal ridges." Journal of the American Academy of Dermatology 64, no. 5 (2011): 974-980.

women and children, who were deemed “impossible to accurately measure” (Fosdick 1915, 364–65), quote:

> “… it [anthropometry] cannot successfully be applied to women or children, as it is based on the measurement of unvarying portions of the human frame, between adolescence and old age. Children before full physical maturity are obviously eliminated, while a woman's hair, to say nothing of recurring pathological disturbances, makes exact measurement almost impossible. Bertillon himself frankly admitted this gap in his system and later supplied the deficiency by a separate finger-print file for women and children …”

The science of fingerprinting, or dactyloscopy, started developing roughly at the same time in the late 19th century (Faulds 1880). The debates around that type of identification appeared in the works of Hershel (Herschel 1894) and Galton (Galton 1889), who presented fingerprinting as a robust system for criminal identification. It was soon adopted by police forces across Europe. It is curious that fingerprinting was deemed to be easier and gained popularity in the colonies as it “required less skill from the operator” (Cole 2009, 149). In other words, colonial authorities favored fingerprinting as they did not have to send out specialists to train local practitioners. Between the two systems – anthropometry and dactyloscopy – the latter was widely adopted as a standard for identification.

Although the elaborate eleven anthropometric measurements (Bertillon and McClaughry 1896) have been replaced by easier fingerprinting; however, the practice of measuring human body has been adopted in a wide range of disciplines. On the one hand, in pediatrics it led to special protocols for child development and malnutrition metrics (Phillips et al. 2019). On the other hand, the legacy of measuring physiological differences and human variation was exploited in forming ideas fueling scientific racism and eugenics (Mascie-Taylor, Yasukouchi, and Ulijaszek 2010, 185). Gould described biological determinism and how the racial discourse was created through the 20th century. He illustrated how “measured intelligence” became so prominent, how by measuring skulls, one tried to evaluate intelligence, mental ability, and even morals (Gould 2006, 28). He specifically pointed out what destroying effect those ideas had on social prejudice and stigmatization of certain groups. The topic remains relevant today because anthropometric measurements have been recently revisited with the advances of new biometric technologies. In combination with precision-medicine and new technology for better measurement of a human body for a wide variety of purposes, we now find preoccupation with precision and customization for anything from healthcare to tailoring clothes and vehicle designs (Wanberg, Caston, and Berthold 2019; Osborne et al. 2020; Yan, Wirta, and Kämäräinen 2020).

Now, a new era of biological measurements and quantification is gaining popularity (See Appendix). In the 20th century, fingerprinting has become normalized, standardized, and as some authors argue, even "taken for granted, and not contested" in comparison to other identification methods (Cole 2009, 4). For example, when in the 1990s a new term "DNA fingerprinting" (Lander 1989; Weir 1995) became known to wide audiences because of the O. J. Simpson trial[9], there were heated debates surrounding the validity of genetic evidence. We know that not only scientists produce and stabilize knowledge, yet an important role is always played by the actions of different social worlds, comprised of "many individuals with specific goals in disparate institutional contexts" (Derksen 2003, xxiii). The crucial aspect of any emerging technology is in public rejection or approval.

According to some scholars in medicine, engineering, finance and IT security, biometrics is coming to all dimensions of our lives, and we are at the cusp of the second generation of biometrics, which is more integrated, digital and autonomous (Mordini and Tzovaras 2012, 11:10).

[9] Britannica, The Editors of Encyclopedia. "O.J. Simpson trial". Encyclopedia Britannica, 17 Jan. 2021, https://www.britannica.com/event/O-J-Simpson-trial. Accessed 26 February 2021.

In healthcare, specifically, there is an argument for reliable biometrics to identify infants from the first day of life until they are about two years old in order to both fight human trafficking and improve vaccination delivery around the world (Tesini 2009). The social impact of biometric technology has been an interest not only for the criminal justice and finance applications, but also for policy changes and government decision-making.

Back in 2004-2005, the European Parliament carried out a study of the biometric technologies, specifically the biometric-based identification and its impact on society (Maghiros et al. 2005). Since then, there has been research done on the social, legal and cultural constraints of the issues related to biometric technology, its implementation scenarios, potential limitations and shortcomings (Thakur and Vyas 2019; Tanwar et al. 2019). However, most social scientists write about biometric technologies first and foremost as tools to make authoritative claims about truth, evidence, and identity. Biometric devices are understood as transforming social and cultural phenomena into "measurable objects of science … incorporated them into the domain of biopolitics" (K. Gates 2011, 183). This means that all claims and goals of human-centered computing and interactive design, empowerment of users come at a price of the new forms of systematic data collection and supporting certain human needs and behaviors. Kelly Gates voiced that concern in the following way: "… so-called human-centered approaches […] harness particular forms of human subjectivity, technical skill, and mental and emotional labor to the task of building systems that in turn can be used to monitor individuals with increasing ubiquity and precision" (Gates 2011, 184). My fieldwork experience did not completely support such perspective on the human-centered approach in infant biometrics. As I witnessed and documented the adoption of human-centered approach at PT, which did not quite look like a textbook example, a hidden mediation, a one-day design competition, or a hackathon. It was more like a slow almost invisible behavioral shift, noticeable in retrospect. The core of the team has been changing through time, as the engineers started to go into the field, and think more how the device was going to affect the communities of stakeholders.

My goal is not to idealize the discourse of Human-Computer Interaction (HCI), although I do not see as many unintended malicious consequences and links to repressive apparatus in the idea of technology that should adapt to people rather than vice versa. Any extreme claims, for example of universality and one-size fits all, can often become marginalizing and flattening the differences to control and structure the possible range of what being normal or human means. I understand that the broader issue social scientists refer to is the problem of fascination with computational logic and algorithms (Gates 2011, 188), which has been recently being very well covered in a series of talks by the STS scholars called the Just Infrastructures.[10]

Previous research on biometric verification, for instance voter registration and authentication in Ghana in 2012 (Dorpenyo 2019a), illustrated a technology break down when designers did not take into consideration the complex socio-cultural, economic and political conditions. However, the author identified linguistic, user-experience and subversive "localization" strategies and articulated best practices for international and intercultural communication and technology transfer (Dorpenyo 2019a, 17–21). He defined localization as "the adoption, adaptation and incorporation of technology to meet local exigence … when users reconfigure and subvert the intended use of technologies" (Dorpenyo 2019a, 8). Dorpenyo presented "localizations' as strategies to understand users, contextualize designs and bring flexibility needed for successful adoption (Dorpenyo 2019a, 202–3). What is particularly

[10] The Just Infrastructures Speaker Series. www.just-infras.illinois.edu. Video Archive of the speaker events available www.youtube.com/channel/UCPMHSRjNKAkWN1XK6T-9S6g/featured. Accessed on March 31, 2021.

interesting about that study, is the use of longitudinal empirical data for localization of biometric technology in the non-Western postcolonial context. The author described the processes of socialization of technology through the active participation of the community, errors on user level, and the social practice of biometrics. This was done by re-writing the user manual and introducing new laws making biometric identification required for voting (Dorpenyo 2019a, 207). The key take-away was that biometric technology should be considered beyond its physical and instrumental dimensions, as it was always interacting with the surrounding sociocultural context.

While in Ghana biometric failures led to rejected voters at the polling stations, the problem was resolved in some places by washing hands with locally manufactured detergent or by cleaning hands with Coca-Cola (Dorpenyo 2019a, 10). In the team Pediatric Technologies, there was a similar path, in the same breakdown scenarios, when no prints were captured, the practitioners experimented with cleaning infants' hands with alcohol swabs and saline wipes. While Dorpenyo argued for the developer and user levels of technology localization (*ibid.*), in Pediatric Technologies those two categories partially merged over time. In Ghana, Dorpenyo pointed out "the biometric ideology," defined as a "belief that the technology is neutral objective, accurate, and truthful" (Dorpenyo 2019a, 17). At PT, user localization and environmental factors have been acknowledged and discussed from the beginning of the project.

Investment and development of biometric technologies tells us something about the society and historical moment that produces them. There has been a lot of interest and publication on the topic of biometrics at The Institute of Electrical and Electronics Engineers (IEEE), particularly since the 2010s. There are a number of papers specifically evaluating different approaches for newborn and infant identification (Lemes et al. 2011; Tiwari, Singh, and Singh 2012; Balameenakshi and Sumathi 2013; Tiwari and Singh 2014; Best-Rowden, Hoole, and Jain 2016).

There is also a large number of edited volumes published, describing the fundamentals and recent advancements in biometric computing and recognition (Arya and Bhadoria 2019), usually focusing on the technological side of the process. Literature on identification from the position of policing and surveillance (Walsh 2019) gets published by other disciplines, not always in conversation with those who created the technology at the first place. The only time they have an opportunity to have a dialogue is in the discussions of ethics and new technology, which often happen after a number of unpleasant incidents already took place (Swierstra and Rip 2007; Kranzberg 2019). This is a disturbing gap that I intend to address by providing an account of how one of such technologies is being designed and created.

Infant Biometrics in Practice: Data Capture and Enrollment

The most common adult biometrics, such as face recognition, contact fingerprinting and iris scans, are not always feasible and do not perform well for newborns (Kumar and Singh 2019; Saggese et al. 2019). There are different modes of biometric authentication, yet they all must perform common operations, which include 1) data capture; 2) enrollment; 3) authentication, and 4) matching. All those steps are necessary for a successful biometric scan. The process goes from capturing an image, analyzing it by a set of processing procedures, creating a template in most cases, and comparing it to other previously record templates, by matching them to provide authentication. Biometric authentication also has to adhere to the developing governmental standards (Romine 2013).

In the U.S. in 2001 INCITS/M1 Biometrics Technical Committee was established by the Executive Board of the InterNational Committee for Information Technology Standards (INCITS) to work on rapid development and approval of national and international biometric standards[11]. Newborns present a particularly challenging case, as their fingers are so small and soft, also they do not always cooperate during the process. Those constraints are addressed by multi-modal biometrics and non-contact fingerprinting solutions (Saggese et al. 2019). The team Pediatric Technologies has been one of several groups who worked on non-contact infant fingerprinting solution.

Kinship, family relations, and specifically childbirth as a biosocial and cross-cultural phenomenon has been studied by anthropologists for a long time (Morgan 1871; Jordan 1992). The clash of medical, high technology and non-medical forms of knowledge around childbirth in particular has been discussed in the context of creating authoritative knowledge on which decisions are made (Davis-Floyd and Sargent 1997, 61). Introducing a fingerprinting device, which is used right after birth, seemingly, adds up another technologically mediated component to childbirth. This, in turn, could increase the hierarchical distribution of knowledge and medicalize the process even further. There is a strong body of literature that brings evidence of the unintended consequences of bringing new technology in the context of developmental projects and their effect on reproductive health and women's rights (Smith-Oka 2009). The disconnect between planning, implementation and the unintended local consequences often includes an increasing pressure on mothers. What is particularly interesting is the coerciveness does not always mean direct physical threat or forced medical procedures. As Smith-Oka noted, oftentimes the "authoritative knowledge of doctors and nurses" (Smith-Oka 2009, 2074) devalued and discredited the local knowledge of the women who would come to hospitals and clinics.

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[11] M1-Biometrics. www.incits.org/committees/m1. Accessed on March 31, 2021.

Having in mind those previous findings, I was interested to look for any overt tensions during data capture and enrollment in hospital and office settings, where the devices were tested. I observed that the creators of the device, mechanical engineers, and computer scientists, parsing the collected data back in the lab, had the authoritative knowledge about the device and infant fingerprints. At first, one of the engineers would accompany a biometrician,[12] oversee the process, and as a technical expert, record and interpret fingerprints, provide legitimization and authentication. What was particularly important and unusual in the case of Pediatric Technologies was that that hierarchy changed through time. Engineers started to go to the field to quickly test new devices, then worked in pairs with biometricians and at the end often substituted or accompanied biometricians in hospitals and during office sessions.

Those changes in the team roles affected the design of the system, including the decision to allow switching hands and fingers during the session without fixed order; automatically finding and attaching the name of the device to the recorded data; experimenting with infant and caregiver's positions and adjusting the light in the room. A lot of those principles of prioritizing the users' needs and creating solutions in order to change technology and not the people, corresponded with the Human-Centered Design (HCD) approach: "Human-centered design (HCD) is the process of ensuring that people's needs are met, that the resulting product is understandable and usable, that it accomplishes the desired tasks, and that the experience of use is positive and enjoyable" (Norman 2013, 219).

The choice of the HCD approach was intentional and top-down as it was introduced by the team leadership. That was also supported by the fact that the team had designers and behavioral

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[12] Note that the person handling the device and directly interacting with the infant had a number of names in the team, which I will be using interchangeably throughout the text: practitioner, biometrician, and "the baby wrangler."

scientists early in the project. The daily practice of HCD was harder than it seemed in terms of explaining and getting everyone on board, as some team members saw HCD activities as a waste of time and resources. Based on my observations and interviews, I believe that the real focus on human's needs started to be integrated only when the disciplinary boundaries blurred and the team members from the engineering sub-group started to participate in the testing sessions in summer 2017. For example, the choice of light was a contested question for a long time. Bright light around the infant was not soothing but worked better for the device. The whole team agreed that a mood lamp would be worth investing in for the office sessions. That created a more comfortable environment for both the caregiver and the infant, while also working better with the new device modification.

In the hospital setting, there were more external limitations, like "touch time," regulating when one could interact with infants. The "office visits" in the lab felt less formal, involved a lot of experimentation, testing new devices and constant feedback from the caregivers. From the field observations and interviews, I noticed that in the US, in the lab testing and the proof-of-concept stage of the project, the human focus was on the infant and caregiver, even at the expense of the practitioner. Occasionally a biometrician would stand on her knees, lean over, and adjust her position to reach out to the infant. She was never forced to do it but had to experiment and find out how to perform the task as the device was new and the procedures were not yet written out and standardized. The U.S. and international hospital field sites were much more standardized and medicalized from the very beginning: sessions were quicker (max. 30 min), and the practitioner would stand by the crib and lean over to reach the infant or stand by the caregiver. While medical space was expected to be more formal and regulated, the level of engagement with stakeholders seemed much higher at the early stages of the project during the lab visits.

The hierarchy during the field sessions moved back from more horizontal, “research mode” into a vertical medical procedure, where biometricians had the legitimate knowledge about the device and its usage. The notion of the “research mode” will be discussed in more detail in Chapter III as it appeared to be quite an interesting phenomenon, which played a significant role in the future of team’s work. The “breaks” when the device would not start or “freeze,” accumulated as points of tension and discontent, which were later expressed in both private conversations and during the team meetings. While the engineering sub-group saw those errors as inevitable, necessary steps in the development, for the human factors group in the team, the same problems of lost data and not saved images meant wasted time and even days of work in the hospital and a devaluation of their efforts. I observed how opinions on errors in the process were gradually transformed and merged with interpersonal tensions, where one party would blame their colleagues for failing the testing session and excused others, who they were more friendly with. That dynamic played most clearly during the team lunches, where some people never showed up and ended up being scapegoats for the project’s difficulties.

I believe that the more engineers participated in the field sessions and got relevant feedback from biometricians, nurses, and caregivers, the more horizontal the power structure became. The devices and their performance were tightly associated with the team members responsible for the given functionality. For instance, when a practitioner dropped the device and it cracked, it was recognized as the failure of the hardware design, which was not resistant to falls. When the software was glitching and interrupting data capture, the blame was falling on the person who wrote the code. The relative influence or importance of each subgroup transformed during the project, and I will be talking more about the changing ‘core’ of the team in Chapters III and IV.

Field Sites and Testing

After testing at local hospitals, Pediatric Technologies had to make important decisions planning different field sites and deliberating upon terms and conditions for such sensible research across one of the busiest border regions in the world, between the U.S. and Mexico.[13] In the team meeting, members shared their perspectives on the possible logistics, and it was an iterative process. Participant incentive models, specifically, were revised twice during the study and demonstrated "behind the scenes" nuances and an acknowledgment of the socio-economic inequity between the U.S. and Mexico. Should the U.S. caregivers get the same amount of monetary compensation as their Mexican counterparts? Such questions were discussed in collaboration with Mexican partners and addressed during the planning stage of the study.

The first step involved getting an IRB approved for the cross-border study, securing all the necessary documents, including a list of vaccines for the personnel, medical history records, an export license, and deciding upon pay ratio and incentives. The team sought out help and advice of their collaborators to decide upon the pay levels, safety protocols for the team members, data transfers, management, and storage. They chose a customized approach and raised the incentives higher after realizing what compensation would encourage more participation, especially for the follow-up sessions. The crucial aspect of infant biometrics is that there are small changes every day: children grow quickly, develop reflexes, and during the first month there is natural peeling of skin, which affects the quality of captured images. It was very difficult to motivate and predict how many people would come for the second visit, which is very important for the authentication

[13] Resource allocation and how work differed at field site, is beyond the scope of this dissertation and could be a separate comparative study.

purposes. By capturing the same fingers from the same infants at birth and two weeks after that, the team could enhance the chances of successful recognition in the future.

Manuals, presentations, websites, and all promotional materials for biometric technologies were the spaces where the team negotiated the meaning of the device, provided a language for how to think about it, and attempted to establish its legitimacy. It has been described that forensic videos for the face recognition technology were often "not simply technical processes, but, instead, require human perceptual labor and decision-making " (Gates 2013, 250). Likewise, for Pediatric Technologies, the development of device software and hardware required human interpretation and a choice which direction to take, which constantly came up during the weekly meetings. A peculiar example showing how computer scientists influenced the finger counting convention by using number from zero to four instead of counting fingers from one to five.

The workflow of cross-cultural infant biometrics was not explicitly different, although the practitioners seemed to notice that it was easier to work in a medical setting in Mexico. The process was more standardized, quicker, and the local recruitment and incentive strategies worked at times much better than in the US, and yet there were some unexpected constraints. For example, caregivers, mostly mothers, would schedule a second visit a month ahead and would not show up, promise to come but because of strikes in local schools or bad weather would not be able to make it. Further research, beyond the scope of this dissertation, should have a closer look at the scaling of infant biometric technology across international borders.

Fingerprinting Session at the Hospital

Below I describe in more detail the context for local U.S. hospital visits and the everyday constraints when team members would go out in the field for what they called fingerprinting sessions. Conducting studies in any hospital requires proper institutional authorization, which for

Pediatric Technologies included mandatory immunization, successful completion of an online ethical and privacy training modules, identification badges and coordination with hospital stuff. As several infants were in the Neonatal Intense Care Unit (NICU),[14] there were further restrictions. The so-called touch times limited the infants' availability to the researchers to only three short sessions during a day – at 9:00 am, around noon and at 3:00 pm. The team would usually come early in the morning as suggested by the stuff because the hospital was busier in the late afternoon. If the infant at NICU was not calm, for example crying, and described by nurses as "fussy," Registered Nurses (RNs) recommended researchers to "try their luck next time" and come during the next "touch time." Therefore, the team could come to a hospital and miss a chance to collect any images of fingerprints from any infants, if babies were sleeping, crying, or moved to another location, or taken home from the NICU.

In July 2017 the boundaries between the engineer and non-engineer coordinating the technology and the visit logistics were still quite pronounced and easy to distinguish. Bal Asana (BA) was a global health graduate in charge of handling infants and the flow of the session, she was the team's first biometrician, who later coordinated international field operations. Craig Dallon (CD), an undergraduate mechanical engineer, was responsible for the technical side of the process. The goal of hospital visits was to scan fingerprints from the infants, whose caregivers previously consented to participate in the study.

Bal Asana commented that it was "tricky" to get access to infants during that limited "touch time" and to have no guarantee that anyone would be available. For example, one day only two

[14] A neonatal intensive care unit specializes in the care of ill or premature newborn infants.

out four consented infants could be approached to conduct a fingerprinting session and they were relocated to another pavilion*,* where less acute cases stayed longer while recovering.

Doors in the hospital were card activated and both Bal Asana and Craig Dallon had those special three-part ID badges to operate the doors.[15] All entrances had no-touch hand sanitizers, which were used every time you go into and out of the rooms. The receptionist in the pavilion met the researchers and told the bed number for the infant they were looking for. BA went alone at first to check whether the infant was still there. It happened before that the infant was unavailable if she was sleeping or already taken home. CD was waiting in the reception area with the equipment, which included a foldable computer stand, a briefcase with a fingerprinting device, and necessary supplies like alcohol wipes and extra gloves. The room with newborns looked like an open plan office with multiple cubicles, in which cubicle walls are separating cribs with babies. The computer on an adjustable stand with wheels usually took a lot of space by the crib and the passages between cubicles tended to be quite narrow.

When the infant availability was confirmed, three of us moved towards the numbered crib to start the session. The crib was conveniently located by the exit door and the window, so we did not stand in anyone's way in the narrow passage between cubicles and had more room. During a field trip, even finding and getting access to an infant required some luck. The fingerprinting sessions in hospitals would usually take under thirty minutes, often end early if needed. The nurses would often be curious to see the process and help by holding the pacifier to soothe the baby.

At NICUs it was quite noisy, constant sound was coming from either beeping equipment, buzzing medical refrigerators, or crying babies. Such contrast with the empty, quiet, and long hospital hallways surprised me. For somebody like me, who was not used to hospital environment,

[15] As an observer, I had a different "visitor" badge.

the sounds felt too intense, distracting, and even distressing at first. Nurses, however, seemed to be serious and nonchalant even when there were two infants crying non-stop and waking up the others. How could one keep professional and seemingly undisturbed when they heard those sounds of distress? I later asked the team members who participated in the field sessions about their research at the NICU. Most reflected back that one gets used to the noise and crying quickly. However, they also reported that visiting hospitals, specifically the NICUs, was very difficult and had a high emotional toll. It was two completely different experiences to conduct fingerprinting sessions with healthy infants and their happy caregivers either in or outside the hospital and to visit intense care units where infants had serious health conditions. While certainly important for the research purposes, there was a sense of relief among the team members involved in the hospital visits when the NICU sessions were completed.

The hospital setting included necessary bureaucratic seriousness, formality, and a very distinct smell of disinfectants. There was an air of solemnness in hospital NICUs where the stuff was often overworked, patients were very young and slowly recovering under close supervision. As the team was only visiting to conduct fingerprinting sessions, not shadowing doctors, and not seeing the whole shifts, there was a limited exposure to the hospital culture. I could see hospital whiteboards with strict schedules and noticed that a lot of work happened under the time pressure, like the "touch time" at the NICU. During fingerprinting sessions nurses might be present and helpful, yet it was not always like that; there could be caregivers there too, and there was that background noise of crying babies and buzzing equipment. I also noticed that like at the casino, there were no clocks on the hospital walls anywhere in the patient areas, which we visited, so I could check the time on my phone only in between sessions in hallways.

As mentioned above the team were coming to hospitals with all necessary equipment. They brought a computer, a folding stand for it, a backpack with sanitation products like alcohol wipes, surface disinfectants and saline wipes, and the briefcase with their device. There was also a GoPro camera to take videos of the process and a digital Linux camera for pictures. CD noted from the very beginning of a fingerprinting session that the resolution was not good enough. In summer 2017, the process of the fingerprinting session was just being developed and tested out in a hospital setting. Before each session the device and the practitioners' hands were sanitized. They both wore hospital white coats. BA who served as a biometrician was also wearing single-use gloves. The standard operations procedures were the following, based on instructions:

1) Take pictures of palms, ears, and face of the infant before the start of a session with a digital camera.

2) Clean the fingers, palms with alcohol pads (there was often glue/lint/sweat/saliva on baby's palms).

3) Launch the device (CD started it earlier, yet CD had to announce that the device was ready to be used).

4) Begin Print Capturing: "Reapply (x3) - Break". There was no one set order for fingers to be scanned. That would be later discussed in team meetings and the reason why it stayed like this was the practitioners' explicit request to be able to scan in any order depending on the infant's orientation i.e., opportunistic capturing of what is available.

However, that order was an ideal plan of action, which rarely went smoothly and uninterrupted. First, it took time to start the device, which froze and stopped responding. Then the infant could get disturbed so the operation was stopped to see whether she could be calmed down with a pacifier. It was obvious to anyone who ever had interactions with newborns and infants under the age of one that it was unrealistic to expect compliance and a straightforward uninterrupted process.

Overall, if the infant was quiet and calm, her hands were relaxed and easy to manipulate, according to BA. During successful sessions BA would say: “Her hands are perfect.” If infant’s palms were clean of lint and other debris, BA would not use additional alcohol pad. At some point BA, CD, and I discussed an idea about having a GoPro camera on their heads or chests to see what they were seeing as it seemed that those fingerprinting sessions contained so much information and detail: who said what, who moved where, how team members reacted to the baby, and how they communicated with each other. Team members were quite interested in the way their own work happened, probably because their interest was inspired by a senior social scientist in the team, and my presence was also explained to the team in terms of learning about team’s work and operational procedures. It was an important factor for any ethnographic endeavor to have a buy-in within the community and the instances of self-reflection and discussion about the session procedures made me believe that at least some team members were quite interested to learn about themselves and their work processes.

Once the team was fingerprinting a newborn who had a serious heart surgery. BA got ready, taking pictures, sanitizing infant’s hands. CD said that the computer was frozen again, but thankfully the technology came back to life quickly and they could start. Meanwhile, the baby was sleeping and gradually waking up, making those soft breathing crying sounds that were truly heart-breaking. There was a tube that helps her breathe; it went inside her nostrils, and her head was supposed to stay in a certain position to be able to breathe. While fingerprints were taken, she tried to move and grasped on the tube. The process had to be stopped to get her hand under the blanket, not to allow her to touch the tube. She had a big scar on their chest, and sensors attached to her feet. We could see the readings from all the sensors on the screen by the crib. CD asked the nurse what the resting heart rate for babies of that age was. The nurse said it is about 110-135 and at 140 they were usually getting agitated, disturbed, or crying. So, the team started to glance at the big monitor to see whether baby was still calm, slightly pausing when the heartbeat was elevating.

As there was no software yet, all enrollments, including the initial paperwork and putting the collected fingerprint images in different folders, were all done manually. There was often a "mess up situation" - a confusion on which finger/palm was already scanned, with which device, and which specific top was used. Thus, the process had to be stopped to figure that out. Overall, it was a successful capture of all data that was required because the nurse allowed the team to stay as long as needed, and the baby was calm. BA said it was not always the case, unfortunately. When the sessions were finished for the day, BA and CD exchanged opinions about the day. BA thought the first nurse was "a bit rough on the baby," meaning the nurse was moving and holding the infant very firm, not very gentle. BA and CD also discussed a couple of disruptions that happened - most interruptions of the process were caused by the baby movement, overall mood, yet there were also tech freezes, which happened twice, and so that BA had to ask pretty frequently (1-2 times a hand) questions like – "which finger/palm is it?" and make sure that they were on the same page.

The difficulty of those sessions was that one person was taking images, another one was simultaneously sorting them by hand, and the biometricians did not see the computer screen with images and folders that were being created. It was also hard to tell whether the picture quality was good or bad just by looking at it. Thus, biometricians had to reapply the finger three times then to raise the finger ("break") to try to secure at least one good picture.

A field session brings out several complex team negotiations: from preliminary preparation and arranging an access to hospital and infants, to the scanning sessions themselves. Alongside

IRB submission, renewal, modifications, and the consent process, all those invisible steps provided the necessary infrastructure to conduct fingerprinting sessions to collect data to test the device.

Authentication and Matching

What happens when the data is collected? A schematic process flow of biometric matching at PT is shown below in Figure 1. Grey areas mark the parts of the process that happened inside a proprietary software, and dotted lines show the manual parts of the process, which happened only at certain occasions during the device demos. The device the team was developing was both an identification and authentication system, which could enroll new users and verify their identity. In technical literature, identity often does not equal an individual, because one person could have multiple identities, for example demographic data separate from ten different fingers as separate identities (Nanavati, Thieme, and Nanavati 2002, 11). At PT, each enrolled infant received one identity, which included metadata and fingerprints.

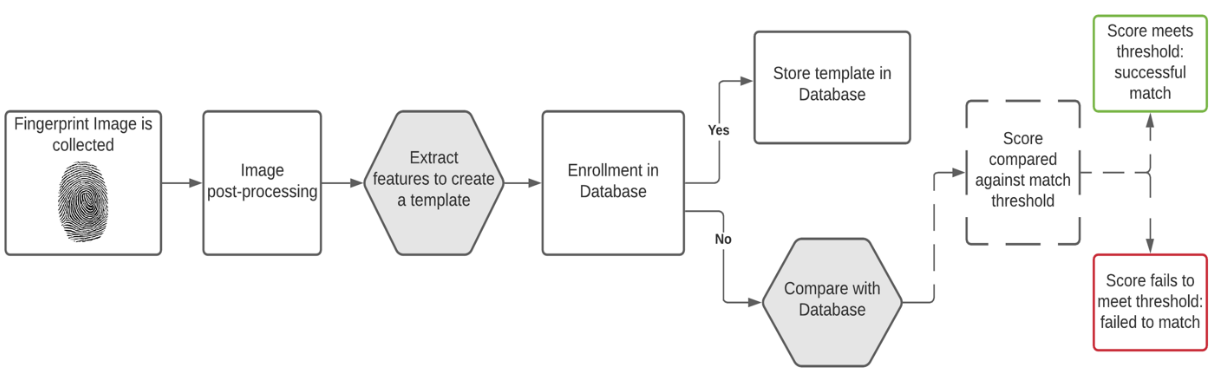

Figure 1. Biometric matching process flow at PT

In April 2018, the team conducted an experiment, asking team members to rate the quality of one hundred images just by looking at them and compared the results from human raters to the score from an algorithm. It was proposed as a fun thing to do in a meeting. Technology was set up to automate aspects of what Charles Goodwin (1994) called ‘‘professional vision,’’ or ‘‘socially organized ways of seeing and understanding events that are answerable to the distinctive interests of a particular social group’’ (Goodwin 1994, 606) long before biometric scanners. Not surprisingly, the "best eye" belonged to the person who worked most closely with images, pre-processing, and sorting them.

Early on, the team tried to use video to cut out significant evidence, yet it was not good enough, so they decided to work frame by frame taking multiple images per second instead of a video and parsing it afterwards. The raw photos of fingerprints, like raw surveillance footage, had little or no evidentiary value until evidence was "produced," or at Pediatric Technologies it was called "processed." The team followed seven steps to post-processing images, then uploaded them to the off the shelf matching software to get a score. The usage of a 3rd party feature extraction and matching algorithm called MegaMatcher[16] was a painful tension point among the team members. Some were concerned about having to be dependent on an external vendor. That solution was planned as a temporal fix but, as many temporary things, it became permanent. The issue was that when an algorithm was not an open source, nobody fully understood how exactly it worked and how it measured fingerprints. I will return to the discussion of the propriety software and what it meant to the team in Chapter V.

Conclusion

This chapter introduced the field of biometrics and described the particularities of the process as performed by the team Pediatric Technologies. In my work, I want to make a sense of the multidisciplinary team effort of building new biometric devices and to understand the social

[16] MegaMatcher fingerprint template extraction and matching engine. www.neurotechnology.com/megamatcher.html#fingerprint-engine. Accessed on March 31, 2021.

forces that are shaping such technologies. Therefore, in the next chapter I cover what stories surround the fingerprinting device itself and what those narratives could tell us about a society in which it is embedded. Following Kelly Gates, I see technologies as "thoroughly cultural forms from the outset, embodying the hopes, dreams, desires, and especially the power relations and ideological conflicts of the societies that produce them" (Gates 2011, 4). My fieldwork illustrates the amount of ambiguity and error that new and modification of the old technologies entail, and the lengthy time spent in development. While many social scientists are justifiably critical of both the technology and the reasons for its implementation, especially when the latter "promised to bind identities to bodies over networks and facilitate the securitization of identity," (Gates 2011, 44) I could not find evidence to those claims in my fieldwork. I see technology development as a much more ambiguous space, where individuals in the team had to defend themselves and the project, constantly explaining and thinking what they do and why.

Finally, a curious detail from the history of fingerprinting is that fingerprints per se were never associated with types, traits or features of the owner. However, palm prints, on the contrary, are connected to various cultural traditions, such as the Chinese palmistry, which allowed specialists to read personality, future and fortune based on the shape of the lines on one's palm. PT also experimented with matching palm-prints for a short period of time. They even joked about opening a psychic center to offer palm readings as biometricians became so adept to looking at fingers and palms. In the next chapter, I will turn to the making of the device, as a boundary object situated across different disciplines.

Chapter III. Making the Device

"Any information systems design that neglects use, and user semantics is bound for trouble down the line-it will become either oppressive or irrelevant"[17]

This chapter sets out the conceptual framework for this dissertation, namely the role of boundary objects in the practice of multidisciplinary teamwork. The approach I follow is influenced by the studies of knowledge-making in the sciences, which takes practice as a site of contingency and change with both human and non-human active participants (Knorr Cetina 1999). With the rapid development of different recognition and authentication technologies, it is crucial to address the epistemic culture of biometrics in the 21st century. As described in a previous chapter, in this work I want to formulate principles that inform thinking and creating infant biometrics on a level of a multidisciplinary team developing and testing such technology.

I also draw upon the example of laboratory studies and grounded theory "to elucidate the key forms of action undertaken by participants in a particular situation" (Clarke and Friese 2007, 363). I look at the making of meaning not on the level of one individual or society but a social world of one multidisciplinary team. I suggest that we can discover different social worlds that influence the creation and implementation of infant biometrics through the boundary objects, which act as arenas, where "various issues are debated, negotiated, fought out, forced and manipulated" (Strauss 1978, 124). The boundary object in Pediatric Technologies (PT) is the fingerprinting device the team has been building since 2015.

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[17] Bowker, Geoffrey and Susan Leigh Star. Sorting things out: Classification and its consequences. MIT press, 2000. P.7

I address a set of questions drawn from practice-oriented studies of science and technology, by asking what kinds of objects and subjects do the team's practices make, and how do those practices produce them? In this chapter, I first discuss the biometric device as a boundary object, describing what theories of practice, social worlds and boundary objects can tell us about technology development, particularly in the context of infant biometrics. I explore the dimensions of social worlds that help us account for multidisciplinary teamwork in a public university project based on the hand-drawn conceptual maps I made during my fieldwork.

A simplified digital version of one such map is shown below (Figure 2). Groups in green and blue interact directly with the biometric device that is being made, while several other stakeholders are shown in orange. Although the map shows all engineering subgroups as one unit and human factors and practitioners are labelled as biometricians, it is nonetheless useful to indicate the overlap and interconnectedness of the team. At the implementation and field-testing stages of the project, the core of the team interacting with the device are the engineers, biometricians, team leadership, and the caregivers.

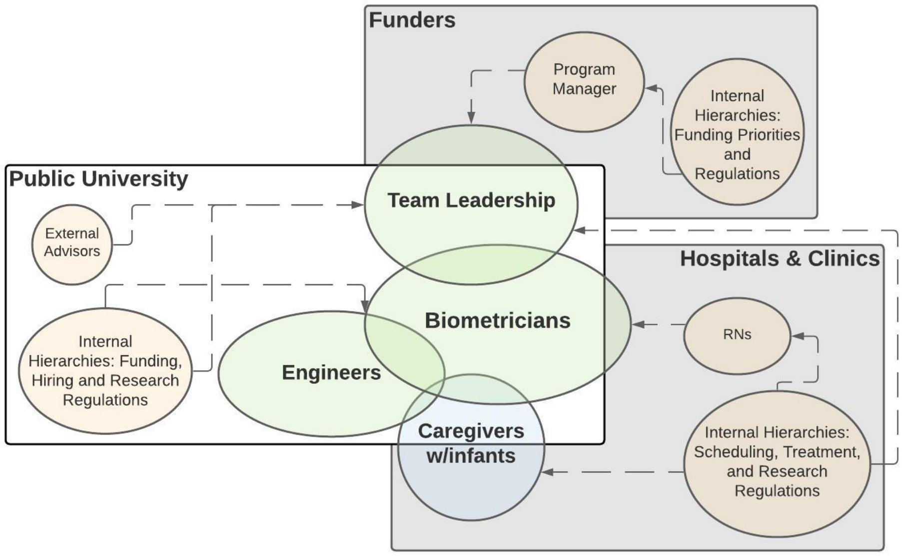


Figure 2. A simplified conceptual map of the social worlds, labelling the organizations and key groups connected through the biometric device

My contention in this chapter is that team members, the funders, and users of the device come together and negotiate their space in interactions around the device. As a boundary object, the device therefore was created and refashioned based on the tensions among several social worlds it occupied. The team was organized around that biometric device, which changed through time and served as a boundary object in each of its various iterations. The same way the design of any physical infrastructure, like a bridge or a new road, requires not only civil engineers and construction workers but also the public response to the proposals, infant biometrics will be accepted only with very clear explanations of what it does and why it is needed. In a case of biometrics, the population should not only be told how the system works, what information is stored and where, but also see how it is being created and deployed. I end this chapter with a discussion of how the relationships around the device change the closer it comes to the market.

Fingerprinting Device as a Boundary Object

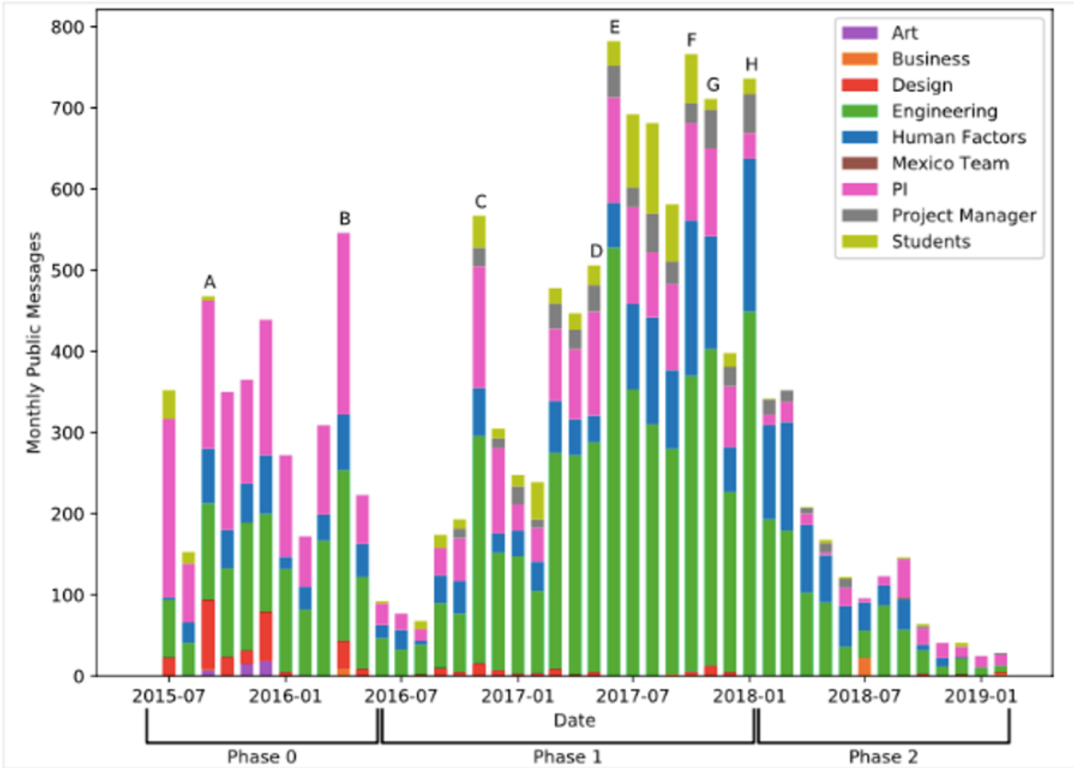
The importance of the boundary object framework is in the analysis of cooperation in the absence of consensus. The original definition of a boundary object includes three main components: "interpretive flexibility, the structure of informatic and work process needs and arrangements, and, finally, the dynamic between ill-structured and more tailored uses of the objects" (Star and Griesemer 1989; Star 2010, 601). The first aspect of interpretive flexibility implies difference in use and interpretation of the same object by different groups. The canonical example of that would be a campground that could be experienced by tourists as a recreation area and as a data collection site for scientists looking for specimens there. Second, boundary objects have "organic infrastructures … a sort of arrangement that allows different groups to work together without consensus", also called by Star "information and work requirements" (Star 2010, 602). Finally, the questions of scale and localization are quite important as boundary objects are changing in time and are subject to local tailoring. The dimensions of boundary objects are based on specific forms of action and cooperation and are not meant to be exclusive. I use the notion of a boundary object to explain the usage and place of the fingerprinting device in the team. Careful observation of how infant biometric devices are made and change over time helps answer the question "what goes into making things work like magic" and demonstrates "a lot of hard labor in effortless ease" (Bowker and Star 2000, 9). The future of healthcare design and desired technological progress fits very well with Bowker and Star's description of the routine work of creating classification[18] systems and producing standards"[19] (Bowker and Star 2000, 10).

The overlapping boundaries, which the device occupied, depended on the central "core" members of the team, who changed only slightly through the lifetime of the project. Both the

[18] "A classification is a spatial, temporal, or spatiotemporal segmentation of the world. A "classification system" is a set of boxes (metaphorical or literal) into which things can be put to then do some kind of work-bureaucratic or knowledge production" (Bowker and Star 2000, 10–11).

[19] "A 'standard' is any set of agreed-upon rules for the production of (textual or material) objects. A standard spans more than one community of practice (or site of activity). It has temporal reach as well in that it persists over time" (Bowker and Star 2000, 13–14).

intended use of the device, its physical design and functionality, changed depending on the disciplinary affiliation of the team's core. Those changes were interconnected with team membership, which could be traced back based on the group's online participation in Slack (Figure 3), discussed in more detail in Chapter IV. What is important to note here is that at the very beginning of the project, in Phase 0, the team had public discussions with designers, artists, students, engineers and the PI. At the later phases, the primary role of engineers and human factors had grown in the project while activity in design channels almost disappeared. One could assume the topic became irrelevant for the group to address but based on observations of the daily work, design-thinking integrated in the forms of cooperation and action during field testing. Thus, the complexities of teamwork and their knowledge production can be effectively analyzed by using the notion of boundary object to talk about the device, which heterogeneous groups in a team have been working on.



A	Sep-2015	First IRB, Funding Meeting (Call)
B	Apr-2016	Funding Meeting II (In Person)
C	Nov-2016	IRB training
D	May-2017	Funding Meeting III (In Person)
E	Jun-2017	Start Fieldwork US Hospital
F	Oct-2017	Funding Meeting IV (Call)
G	Nov-2017	Funding Visit to UCSD
H	Jan-2018	Start Fieldwork Mexico Hospital

Figure 3. The Pediatric Technologies Project Timeline and Milestones

The Social World of PT

While analyzing my fieldnotes, I created "social world maps" (A. Clarke, Friese, and Washburn 2015, 18) which helped me illustrate the entanglement of the biometric device in the social contexts of the lab, office, clinics and hospitals. I collected photographs and videos of the testing sessions and team meetings, which are not simple evidence of actions, as Sarah Pink notes - "images and words contextualize each other, forming not a complete record of the research but a set of different representations and strands of it" (Pink 2006, 120). For example, hardware engineers discussed device models based on technical qualities, such as optics, while the biometricians using the same devices differentiated them by the shape of the outside "shell" or form.

The database of collected fingerprints with accompanying metadata about the participants represents the record of what was selected as important data points. This was a negotiation and during team meetings there were moments of disagreement about what to record, what to do with corrupted data, why the number of records does not match and what additional information might be useful. For instance, the biometrician would argue for a freedom of choosing any finger on any hand to scan, while other members of the team, working on the workflow standardization and software interface, would prefer a set procedure and a predetermined order of the fingers allowing examiners to switch babies' hands only when one is completed. As I noted before, the biometricians won that battle and finger enrollment did not have a strict order so one did not have to start for example with a pinky on the infant's right hand.

At Pediatric Technologies, the engineers, biometricians, and study participants did not have to agree on the greater role of infant biometrics for the device to work. A lot of time was spent translating between the worlds of administrative requirements of the public university, hospitals, clinics, languages, and scientific to non-scientific concerns. The lack of attention to the backstage of any new technology development could be problematic in the future if the uses of the technology are set by the unknown groups of actors. In the case of PT, the device design has been reiterated by several groups in the team, under a supervision of institutions and other stakeholders. However, the decision-making would often be done by those who stay in the team the longest time. I call them the "core" of the team, those members who joined the team and became central to the project:

at PT those members were mostly male mechanical and electrical engineers, a systems designer, and a medical doctor.

Behind the Scenes of Effortless Magic: Methods Standardization

In the past three decades, there has been a steady interest in anthropological studies of work contexts and organizations (Bate 1997). At the same time, there has been also a growing interest in the concept of boundary objects, which range from a state of California (Star and Griesemer 1989) to sketches (Henderson 1991), virtual prototypes (D'Adderio 2001), project management tools (Sapsed and Salter 2004), timelines (Yakura 2002), drawings and schedules (Carlile 2002, 449). Several authors successfully bring those two topics together. For example, a study about marketing professionals demonstrates how marketers construct "tellable stories," which identify "boundaries, relations, agency and identities for entities" and create "the tales that the organization can tell about itself, about the markets it is trying to shape and the constituencies required" (Simakova and Neyland 2008, 96). In other words, in teams that have reached or entering the market, there is a need to tell stories for various audiences within and beyond one's organization. At PT, the storytelling process and boundaries have just been forming among different disciplines and we could observe what factors influenced the narratives about the device and how fingerprinting was discussed.

Printed forms and models were widely used during the early prototype testing stage at PT. Team members wanted to measure the sizes of infant hands and record natural interactions. Numerous sketches and photos circulated in the team, and one particularly important step to understanding the process was a close-up recording of testing sessions. This allowed the practitioner to see what he or she was doing and then compare what they had reported on and what had gone unnoticed. Yet often the names for the devices and testing results were managed by one person at first and thus did not require standardization until there were more people involved.

Decisions in PT took place in a variety of spaces — from the office, lab, hospital, to a local coffee stand. To observe decision-making in progress during many types of team interactions, I used several activities, including:

1) Observation of team meetings, which included design discussions, concept reviews, and clarifications.
2) Attendance at team meals or coffee breaks.
3) Semi-structured biographical interviews about team members' careers to locate self-identified sites of decision-making and disciplinary affiliation.
4) Visual analysis of intermediate design products – from silicon molds to printed and machined fingerprinting devices.

One of the most challenging tasks was to follow the trajectories of multiple decisions, including the project artifacts, resources, and people. The day-to-day questions I asked study participants and tried to observe included: How are decisions made? Who makes them? How are they justified — and how do justifications change? My choice of using both a moving hand-held and a fixed camera to record testing sessions is based on a theoretical debate over these two approaches (Pink 2006, 123; 2015). On the one hand, a fixed position provides reliable evidence, yet arguably the complete objective visual documentation might never be possible, so a selective hand-held camera shows participation in the process. It's interesting to see where the two coincide and on some footage, I can see myself taking additional photos and videos of the newborns interacting with the device (Figure 4). It became clear early on that important way the team was exchanging information, asking each other for help and clarifications also happened online in a desktop and phone application called Slack. In Chapter IV, I specifically address the online team space and compare it to the offline interactions.

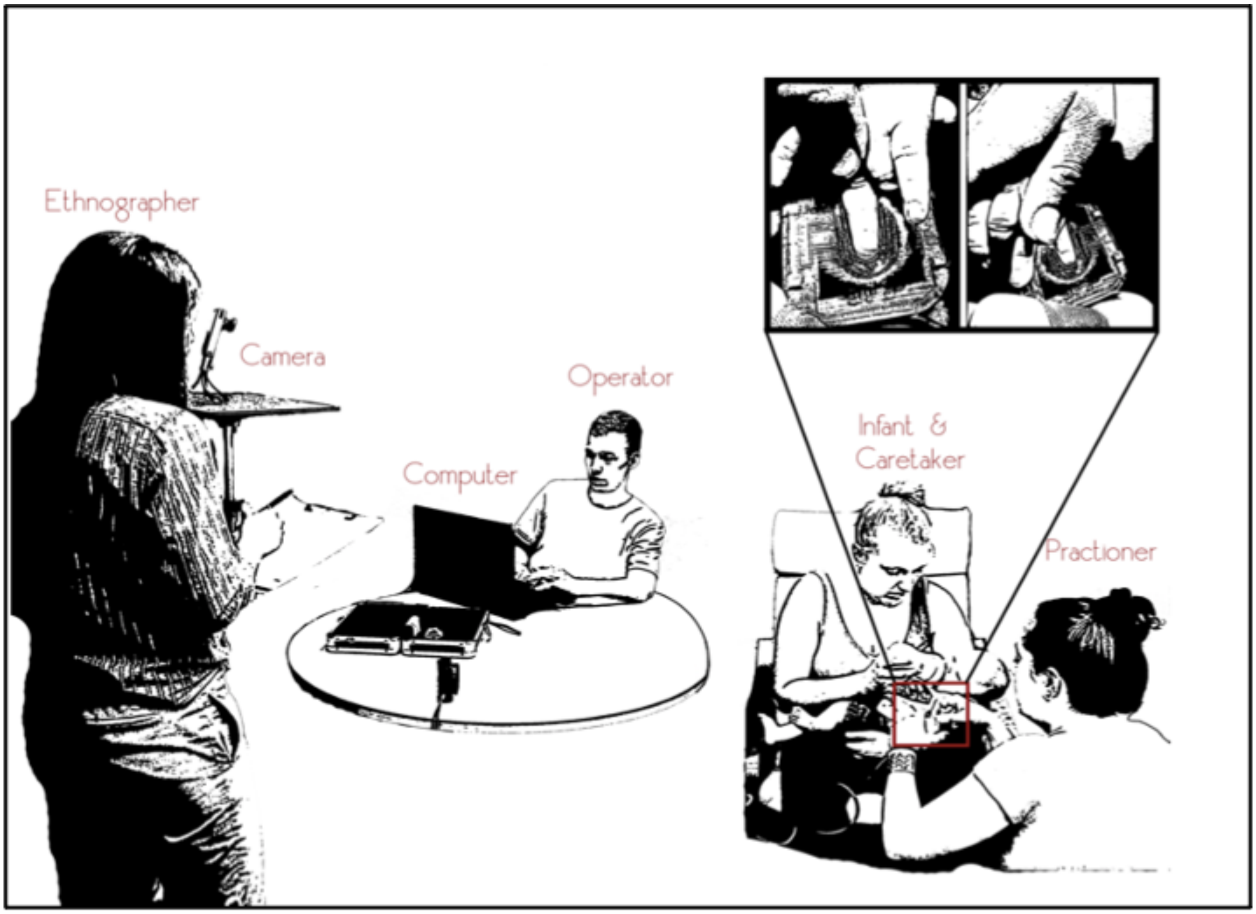


Figure 4. Observations of a device testing session (courtesy of PT)

Boundaries between professional sub-groups were drawn in a form of roadmaps and color-coded timelines, yet they were used only at the beginning of the project. As one team member noted in an interview - “somebody has to keep it up” and eventually the project manager herself saw that such standardized approach did not work within PT. It was never quite clear why but primarily because the PI wanted to coordinate the meetings and workflows himself. As the project grew that caused some team members to notice that the PI had some “blind spots” because one person could not be at once in all places, expert at everything, and aware of all issues, testing modifications, and new techniques. Eventually, he delegated some standardization efforts to the human factors team, and I, myself, was helping the behavioral scientist and the field coordinator with those. One goal was to create a fishbone graph with all possible failure modes, starting with a device itself and situations with infants and caregivers. Then there was a discussion about the post-session survey for biometricians to record any issues, which happened during the visit. It has been an iterative process to come up with a universal language and terms that describe technical issues, fingers, or even caregivers' and infant mood. All that work was based on infant visits and direct observations, video recordings and numerous photographs of the process. That standardization effort was instrumental for a later training manual development.

It has been observed in various workspace contexts that often "people do not do the ideal job, but the doable job" (Bowker and Star 2000, 24). This means that any work process is not quite straightforward and at PT, for instance, it's not easy to distinguish when the most work happened. Even the milestones I have identified are still approximations of important passages of time and points of transition for the team. It was not always clear to me as an ethnographer how to distinguish team responsibilities and juxtapose online and offline interactions. In the interviews, participants mentioned that they had calls with the PI to discuss urgent matters or exchanged messages outside Slack. An example of such urgent matters could have been anything from interpersonal conflicts and tensions around certain task delivery dates among engineers, a phone call from human factors focused on IRB renewals, relationships with hospital staff or questions about international collaborators and their responsibilities in the team.

The practical politics of the device come up in "visibility issues," described by Bowker and Star as situations where "one decides where to make cuts in the system, for example, down to what level of detail one specifies a description of work, of an illness, of a setting" (Bowker and Star

2000, 44). An infant fingerprinting scanner had to be set up to be safe to use, accommodate different finger sizes, and skin colors as well as the hand size of biometricians or nurses who would be using the device. In practice that looked like trying to prototype and iterate a couple of times until the device did not feel too bulky in a woman's hand,[20] testing from three to five most common finger sizes for newborns and adjusting the camera.

Another important factor in the discussion of the device making is the acknowledgement of multiple voices with their own interpretations of what happened in the past. What online space adds in this case is the reference point and markers of the participation in the past and work done by members who might have left the project a long time ago. When we look at the finished product and the final iteration by the current core of the team, we look at the collaborative effort of many students, research scientists, designers, social scientists, and biometricians who might not be a part of the team anymore. We have the records of post-visit questionnaires and notes from biometricians who recorded issues with hardware, software and left their suggestions on how to make the process easier in the local circumstances of a city hospital or a lab visit.

Finally, a crucial record of continuous work of different team members in creating, using, describing, and naming or referring to the device, is in a way a process of standardization. When I joined the team in summer 2017, there still were two devices being constantly tested to determine whether contact or non-contact modification works better with infant fingerprints. The tensions grew as the team broke into two camps of those who believed that there is not enough data to prove non-contact is better and those who thought that there was sufficient evidence, and it was time to retire one of the devices in favor of focusing all efforts on the non-contact model.

[20] In most cases, all practitioners in the field were female, although the engineers, who were predominantly male, occasionally visited the field to test new prototypes and to fix errors with technology.

Membership and Belonging

While the team started with as few as three to five members in 2015, it expanded up to thirty-four people by 2018. Over time, the team had 55 different members who were engineers, physicians, nurses, social scientists, designers, undergraduate, and graduate students. Most team members were co-located in one city in the United States, had a shared laboratory space, an office, and met in person for the weekly team meetings.

The types of team interactions included weekly face-to-face meetings, one-on-one ad-hoc discussions, small-group meetings focused on the issues brought up during a general team meeting or concerning barriers in the workflow, or urgent matters. There has also been online communication on the application called Slack. It is a cloud-based platform, where teams create "workspaces" with public and private channels to exchange files and messages throughout the day, for example posting updates or sharing presentation slides for everyone to see in the "general" channel. However, as I will be discussing in the next chapter, the public online space became less and less representative as time went by and it was easier for team members to discuss concerns in private both online and offline.

In a conversation about challenges in the project, one team member identified the lack of highly skilled experts in infant biometrics as a core problem and the main challenge for the team. However, while nobody started as an expert in infant biometrics, arguably, after years of experience, the team members became experts. Those team members who went out into the field to test their new devices not only learnt about human-centered design, but they had to learn how to work around medical personnel, infants, caregivers, and their needs. That was step one and the necessary second step was to have someone analyze the data collected and give feedback on the device's performance.

Upon joining Pediatric Technologies in July 2017, I acted as a team member myself, taking a project-related role as other students of technology development did in the past (Simakova 2010, 551) in order to observe and participate in work. For example, I would be recording and taking notes during field tests, sharing observations in team meetings, and assisting biometricians with paperwork and attending team meetings. In the interviews, some team members referred to a horizontal hierarchy with blurred boundaries among members; however, there was a Principal Investigator (PI), Project Manager, and then all the other team members. A senior systems design engineer eventually took responsibility over the device's technical side, coordinating the efforts of student engineers and external experts. There were also a few senior advisors, who were never visible during the daily work but had conversations with the PI, attended meetings with funders, and were supportive of certain aspects of the project like optical advice, data safety and security, additional funding, and university bureaucracy.

Formally, team membership was negotiated before the presentations to the funders when I saw for the first time several advising members who were never present during weekly team meetings and barely mentioned. Some of those people would describe themselves as the "founding fathers" and advisors for the project. Informally, I noted that there was a "core" of the team, which fluctuated but consisted of the people who were getting paid by the project, did the everyday work, design, built the device, and recruited participants to test it. There were often seasonal student volunteers who were affiliated with certain faculty members or resident nurses working with specific doctors. During the interviews, I learnt that several team members, including the senior software engineer, some hardware engineers, Project Manager, and even the PI had additional percentage of time attributed to other projects so that Pediatric Technologies would be their part-time job.

It is important to acknowledge that there was some tacit tension early in the project between the solo behavioral scientist and the PI in terms of power of decision making and inclusion. Denny Oster pointed out several times in her journal how she wanted to be included on certain calls or join meetings, and even explicitly mentioned power dynamics during team meetings: “Ven is saying exactly what I said 3 minutes ago – and the PI listening to him a lot more.” This could be interpreted as either rejection based on gender or social science expertise, or both. Looking at other interactions and an overall strong interpersonal relationship among the PI and Denny Oster at later stages of the project, it seemed to be more rooted in professional side. Attending team meetings in person, I never noticed any gender skewed judgement, for example between male and female biometricians, but most of the time would be always dedicated to hardware and software group members, who were all males.

Confidentiality and Privacy

Capturing one’s identity, fingerprinting babies, surveillance state, taking personal data from newborns – all those notions might come to mind when the team’s project is discussed with outsiders and even team members admit that they often must “defend” the project to their friends and family by explaining why it is being done. In open-ended interviews, when asked about the goals of the project and how they explain their work to relatives and friends, the majority recited the official description of making a device for vaccination purposes. However, during follow-ups people reflected that, quote, “of course you have to explain” and “any technology might be evil.”

Unlike design consultancies or other research labs, I didn’t have to sign any formal non-disclosure agreements (NDA). The observations I made during the lab visits I uploaded to the shared project Google Drive. The team had to trust me personally as a member of the campus community enrolled in a graduate program in the same university. However, the lack of strict boundaries marking information that can travel from "inside" to "outside" of the team like observed in other contexts (Simakova 2010) reflected the hybrid nature of the project. For example, it was obvious that names of participants (caregivers and infants) were private; however, the overall number of participants and the location of the upcoming trials were announced and published. It was not a secret in the research building where the PT team had lab space and what they were doing but it was never emphasized explicitly who was on the team, apart from the PI and the Project manager.

The project had to go through a long IRB-approval process before they could start recruiting participants. Several measures were taken including password protection and locked physical storage spaces to keep participant data secure, and team members who had access to it were all listed in the IRB and went through special training to handle personal data properly. Privacy of the research subjects has been the utmost priority of the project from the very beginning.

I noticed that in everyday insider conversations diminutive names for infants as "Annie" or "Teddy"[21] would slip through sometimes as team members will be getting ready to scan fingerprints from the infants who visited the laboratory more than twice. The members would be reminded by the PI to refer to the upcoming infants in Slack and among themselves by their encoded numbers and not use their first names. At the same time the caregivers would expect biometricians to remember their names and certainly would be shocked to hear numbers instead of their infant's name. I saw that small detail as a marker of certain connections between the team members participating in the fingerprinting and caregivers. Testing early prototypes takes time and team members witnessed how infants were growing over repeat visits, and it was only human to build relationships with both parents and infants by calling them by their first name during the

[21] All names are pseudonyms.

visit. This was particularly prominent in the lab setting where many early participants were also part of the university, and being scientists themselves, wanted to participate in the study. The project had social capital and was trusted by colleagues who volunteered to be in the study as first participants because they believed in the mission and trusted the people doing the study.

In hospitals in the US, such long-term personal connections would not be as pronounced as infants normally do not stay for a long time in the hospital unless there are health complications. Therefore, second visits in the hospital happened only in the NICU (Neonatal Intensive Care Unit), one of the most intense and psychologically difficult places to work for the majority of team members, constantly witnessing human suffering and the seriousness of surgical operations the newborns had to go through. In a public hospital in Mexico, mothers would go home only several hours after giving birth, yet they would come back for revisits to the hospital and clinic to get the necessary vaccines for the newborns. The shortage of vaccines was an unexpected challenge that occupied team discussions for several months as nobody could have predicted such situation. Eventually, the vaccines were back in stock, but the delays caused a lot of stress among caregivers and hospital personnel.

The process of fingerprinting did not put infants at risk, so caregivers did not mind stopping by the lab while running errands to get their infants' fingers scanned and receive a gift card as a compensation for their time. Internally, team members would even call certain caregivers "professional moms," who would bring their infants more than four times in a row, without much time in between. While longitudinal data was necessary, the team had to collect a wider sample size of more people coming twice rather than the same ones returning repeatedly. The team discussed those nuances during the team meetings. It was not always clear what one should do if one person keeps coming back all the time, while the study needed a follow-up from other participants. The solution was to limit the number of visits per infant and clearly set up those expectations with the participants from the very beginning.

The reason behind getting at least two visits for each infant was to make sure the created system recognized the same person during their second visit after several days, weeks, and even months. At first, there was no standard time in between visits apart from a requirement for a follow-up. However, it became clear very quickly that smooth field operations required a schedule to coordinate the time and number of visits. That meant standardizing visits per infant and scheduling visits two to three weeks apart from birth.

Nurses and biometricians from international locations did not usually attend the weekly team meetings but they would take notes with concerns and suggestions which would be crucial for the team's success. For example, one biometrician pointed out that a new device modification did not work particularly well in the busy health clinic:

> "Both kits now have palm pad top. This does add a significant amount of time to the process. Some of the mothers expressed concern during the process with how long it was taking. In some situations, to cut time we will take the minimum number of photos of each finger (10) I hope this is not sacrificing quality for quantity? We're trying our best."

Beyond reporting the device malfunction, describing specific issues and questions which came up during training and device use, international collaborators also contributed immensely by explaining what types of compensation would be the most appropriate in the local context. Only the local providers had on site knowledge, including unexpected circumstances that hindered the project such as the vaccine shortages:

> "Vaccine Shortage. In all of […] there is a shortage of vaccines for older babies […] the nurse had to turn babies away that were older than newborns! Not sure if they were completely out, but the vaccine nurse makes a judgement call and will stop vaccinating kids when she is running low."

The device for biometricians in the field was a combination of hardware and software, one piece of equipment which might cause a lot of irritation and even anxiety, when it would “freeze” or lose the collected data. For the engineers in the lab, such situations would be just another “bug” in the system, inevitable with testing or any upgrades. However, it is very hard to see any malfunction as an unavoidable glitch when you arrive at 7 am to the hospital for an opportunity to have a session with an infant, who might be fussy and non-compliant, only to find out that your whole workday was erased, and you have to try to reschedule again and collect the data once again.

Such interdependence of the biometricians’ success and the engineers in the lab, caused some tensions in the team. While it never occurred as an open heated argument during any team meeting, there was certainly an unspoken concern that the device was not quite ready on time and biometricians had to wait or explain to their international collaborators, as well as hospital staff, why the technology did not work. I witnessed how the responsibility for being the primary contact and hence the group’s public face fell disproportionately on biometricians who did not have as much agency in terms of changing or fixing the device themselves. Biometricians could only report on certain issues and ask for help, yet they had to meet and talk to caregivers, nurses, and represent the team in the hospital and clinics.

When data storing and device problems arose, for the engineers in the lab who were in the “research mode,” work on the device inevitably meant a process of trial and error. Meanwhile for the biometricians in the field those hiccups and problems with the device were a source of stress and discontent as their success was measured by the number of correctly enrolled and scanned infants. This dynamic illustrated the divergent responsibilities and viewpoints on the boundary object from the perspective of team subgroups.

Disciplinary Boundaries

By the time I joined the project in July 2017, the team had just expanded and entered a new phase. The design consulting company Crossing Design[22] joined the team in October 2016 alongside a design advisor Matt Mayor, who worked at the same public university. The design company offered to have one of their employees, a graphic designer, come weekly to the team meetings. They created flow charts on paper, which they put on whiteboards, illustrating chunks of work to be done and people involved. They also produced flyer layout for the study, needed for the recruitment. During the team meetings the lead designer from Crossing Design mostly operated on the whiteboard to illustrate his ideas.

Since November 2016, the team focused on rethinking the contact fingerprinting and the form of the device in relation and interactions with infants' hands and fingers. They tried out several shapes from rollers to cylinders. However, already by December 2016, there were some internal concerns about whether to continue working with Crossing Design agency. The PI believed that the design company was "not giving us what we need" and asked Tom Moseley, a mechanical engineer serving as a project advisor, if any of his students could help. Denny Oster remarked in her journal that it was important not to outsource the system architecture because even "hiring out design doesn't work." In the meantime, PI closed the year with planning in January 2017 an interactive design workshop, or charette, bringing together the Crossing Design lead, Matt Mayor, and Denny Oster. As I was looking through the team archives and interviewing members, there was no excitement or engagement with that charette among the core of the team.

Matt Mayor warned the PI against going down rabbit holes and insisted on choosing either to do a sprint first or an exploration of new technology. The PI insisted that he was exploring "on

[22] A pseudonym.

the side," but his main strategy was sprints. In practice, that would entail additional tasks devolved to certain team members, who would be less focused on the sprint. The method of sprints is quite popular in design, yet it has a set of rules and order to it. Sprints usually include a four to five-day process for answering critical business questions through specific exercises, prototyping, and testing ideas with customers. The PI often mentioned sprints in team meetings, by which he meant intense short work periods, which took about two weeks to a month to complete and produce desired outcomes. According to the interview data, at PT, despite the dissimilar goals and incentives of independent participants, team members often pushed themselves above and beyond their normal effort level to accomplish the challenging tasks during those sprints. It was hard to find any evidence at the time and distinguish whether a new exploration was indeed a rabbit hole and distracted from the main goals of the project. In personal interview, the PI later admitted that he made some mistakes and at times led his team in the wrong directions, but he was glad the team could recover.

Much later, when I built closer relationships with team members, I learnt that there was a sort of misunderstanding between the team and the external designers. The tensions were mentioned in passing during individual interviews. Some team members noted that during earlier phases of the project interpersonal tensions had happened between the current team members, the PI, and the outside experts from the design agency. There were no direct accusations, yet team members hinted that the deliverables were subpar, and designers did not build relationships outside their design agency with the existent team but instead worked almost exclusively with the PI. I came across their design work results when I was helping clean the lab space and found prototypes stuck in the corner of the top shelf in the lab. I never saw them being used or discussed so I asked about them and the team members told me those were not that useful; there was no accompanying description or paperwork easily available at hand describing those early prototypes. The lead designer from the agency continued to be in the advisory role but stopped coming to the meetings and eventually their consulting services were terminated. When I was looking at the photos of the past lab device tests, one of the members also mentioned that those designers "never even cared to show up to the actual testing with real infants," emphasizing how the outside experts did not participate in the daily work and did not seem to care enough to understand the project.

Despite the skepticism towards the external designers, team members applied the human-centered design by changing their work practices, especially during the device tests in the field. In other words, the work practices around the boundary object, the device they were making, included "negotiation among actors working in organizational contexts" (Fujimura 1988, 261). One undergraduate student involved with a project even presented a poster and gave a talk about the human-centered design approach in the project at a design conference. I believe that the team members tried out and rejected the performative design activities, but they put into practice the value system of iteration, the input of the stakeholders and the importance of the human factor to adopting the device. In other words, the advice from the behavioral scientist on the team, who was closely connected to the biometricians in the field, was taken while abstract concepts of design thinking stages, design charrettes and other similar design exercises were rejected. The main reason was that they came from those who were not familiar with the project's everyday routines.

After all, PT was originally at its core an engineering team, yet their work culture transformed over time by adopting the core value of putting humans at the center of their device development. The adoption of that core value was cultivated both by the social scientists and designers in the team, who filmed the testing sessions, developed a training manual, and maintained relationships with the hospitals and clinics. When the field testing had finished, the group focused once again on the technical characteristics of the device rather than the end users' experience.

PT was not an interaction design studio; however, certain aspects of creative co-creation and design are present in the team's daily work. It was a fast-paced, multidisciplinary, and project-based environment and interaction design was crucial to deliver prototypes of a device. Goodman described performance practices in design, defined as "episodes of storytelling and narrative that take place before an audience of witnesses" as very important for interaction design work (Goodman 2013, 195, 208). Such "performances" of the project, according to Goodman "produce and sustain alignment" for both the designers, their clients, and teams (Goodman 2013, 196). Also, professional design practitioners often work more with user-representations rather than humans directly (Goodman 2013, 96). Considering those differences, we could better understand the tensions between the external designers from the agency and the internal team members.

A mismatch between the performative culture of interaction designers and engineers led to certain critiques of design principles and practitioners in general (Table 1). That tension was directly expressed by PI in the team meeting, where he said that "we don't need designers; we are designers ourselves." During the team meetings, the PI often openly rejected the value of design charrettes as "time wasting rabbit holes," which did not move the team forward. His intentional avoidance of design charrettes throughout the project signaled that formal design process was not getting the team anywhere. The core issue was between "doing" the engineering work and "showing" design by planning, creating digital representations of the device, not rooted in the field testing, and based on designers' previous experience, not widely shared with the entire team. One time, PI would even say "let's not call it a charrette, let's call it work!"

Table 1. The disconnect between the external design practice and the internal team effort of making the device

Internal Team Effort	**Outside Design Team**	**Resulting Tension**
Physical Device Prototypes	Digital Device Prototypes	The outside design team had vast previous experience and developed several digital prototype ideas based on that. The internal team developed physical prototypes based on the observations in the field.
In-person testing with infants	User journeys and wireframes based on the design standard procedures	While the designers continued with the standard design process, the internal team relied on trial-and-error during in person testing.
Testing and iterating as they go	Planning and writing out the necessary tasks and steps	The contrast of planning and doing escalated further as the designers attended the testing session only once and relied on the photos and video recordings as well as their own vision of the problem.
Scheduling infant sessions	Scheduling brainstorming sessions	The engineering and human factors sub-groups of the team did not communicate much directly with the external designers.
Connecting the backend of the system	Developing esthetically pleasing "visuals" (presentations and futuristic device vision)	The software subgroup could not effectively implement the advanced designs suggested by the designers and worked with a temporary simplified version. The external designers created sophisticated presentations for external funders and potential shapes and interface for the device.

Nonetheless, the team acted upon the core tenet of what is called in the design literature as "user localization" (Dorpenyo 2019b, 15) by linking the device design to use. That meant discussing and accommodating themselves to the context of local weather, politics, logics, and needs. Local specificity of the field site was central in preparation and during the pilot in Mexico in January 2018. The exact term "user localization" was never used, instead, the team discussed the idea as a necessary feature of user-centered design, which included conversations about the nature of use and attention to user knowledge. I also noticed that team members collected feedback from the local biometricians and tried to incorporate that situated knowledge in device updates and modifications. For example, biometricians asked to limit the number of device names in a drop-down menu in the software to make it less confusing; to allow file deletion and the ability to retake pictures, and to limit the number of detachable separate parts of the device, such as different-sized tops, which could be lost or mixed up, especially for the new users. The more feedback that was taken into consideration, the fewer issues with software and hardware that appeared in the post-session feedback forms. The device modifications illustrated the iterations and feedback implementation from the early prototypes and explanations (A-D) for each design (Figure 5).

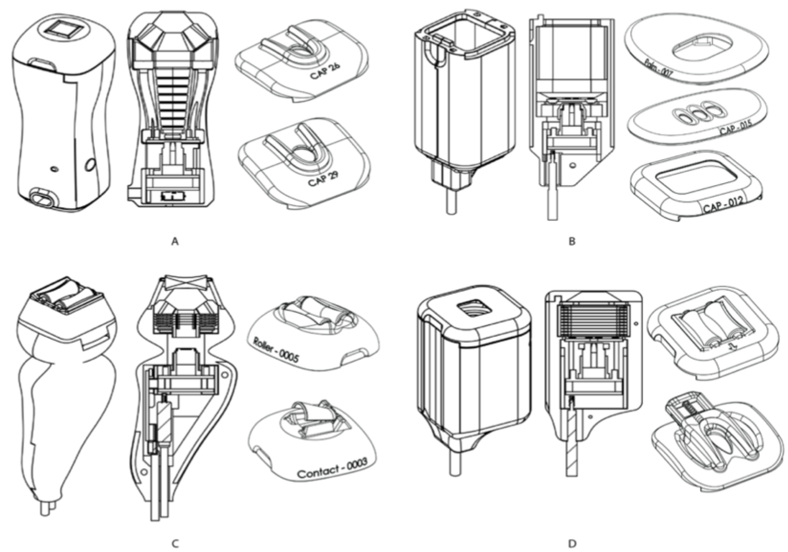


Figure 7: Device Matrix. (A) early prototype contact & non-contact

A. Early prototype – contact and non-contact caps. The device includes fiber optics designed to be closer to the camera – and to absorb stray light – by providing angled illumination, and adding a diffuser.
B. Design for non-contact capture of an infant's palm – includes large field of view but low resolution and direct lighting.
C. Razor handle, shaped for both contact and noncontact capture. The device form intended for better ergonomics for the practitioner. It includes a polarizer / analyzer – the use of a variable lens made it possible to do both contact and noncontact with the same device. It featured angled light illumination (like in A.)
D. Noncontact only with direct light – larger field of view with high resolution – fixed focal length – not a lot of flexibility but effective in noncontact capture Tops – include rollers, spring mechanism to accommodate for varying sizes.

Figure 5. Device matrix shared in the team's poster presentation (image courtesy of Pediatric Technologies)

Feedback forms from the field sessions were quite interesting artifacts in themselves. Social scientists and designers in the team insisted that each session should finish with a short feedback form so that there was always some metadata, accompanying the prints and pointing out any difficulties or special conditions. There was skepticism in the team in terms of usability of those surveys in the future. Who was going to look through them? How much time would be spent filling out additional forms? All those questions were raised and discussed in the team meetings. Eventually, feedback got incorporated into the workflow and retrieved when things did not go as planned. That happened when, for example, all scans were corrupted, or the number of enrolled patients was quite low. Over time, feedback forms became more formulaic as practitioners got used to them and got more efficient reporting. The team collaboratively iterated over different post-session feedback form templates, which eventually contained the most common types of issues. However, no systematic work was done on those feedback forms, dispersed through personal Google Drive folders, which were not necessarily always accessible.

The Vocabulary of the Project: Prototypes and Naming Conventions

The vocabulary of the project evolved together with the device, and it was not always shared equally across all groups in the team. Attention to the naming conventions and words used to describe the fingerprinting process was something a social scientist on a team specifically asked me to help develop, record, and observe how it might be changing. The team members were aware of the multidisciplinary vocabulary, yet each meeting members used jargon irrelevant and unclear to others. At times team members would ask for clarifications but, in the interviews, they admitted that often they felt like it was not their job and "above their pay grade" to know about all those "tech things." Most technical terms were used in relation to device settings (aperture, light, etc.) and were understood by most people in the room as at any given time >50% had an engineering background.

The team vocabulary for the failure modes was something I directly contributed to and discussed with all team members. The PI really wanted to have a "checklist for failure modes" that would be available to the practitioners during and after the field sessions. Those "codes for issues" included some localized jargon created to discuss certain conditions and things that could go wrong during the testing field sessions. For example, when an infant finger would not be properly aligned with the camera, it could "dip," "curl," and "yaw[23]." Device names like roller, cone, Blue Mixing Palm, Neon 10, Norelco, and others, also caused several difficulties with the database, overall user experience, and turned out to be quite a contested space. When the team decided to merge old and new data in the cloud storage, those questions became top priority as they had to standardize the language for active devices, agreeing to use a formula "device X with top Y."

Device classification and chronology required a standardized language that could be used across testing settings and workspaces like the lab and the office. The main issue was the lack of transparency as there were no guidelines at first for new naming and labels. Engineers would come up with idiosyncratic device names, which they would share among themselves and start using during team meetings. The PI also invented device names based on their appearance, like ice-cream cone, corn, and others. One example of how such labels were adopted was the name "Norelco" for the contact device. Norelco was chosen because the device reminded some members in the group a Norelco shaver (Figure 6), which was not a clear association for everyone. During one team meeting the PI admitted that probably a male shaver is not a universal comparison; however, the name stayed until the device was retired.

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[23] As a non-native English speaker, I insisted that the term "yaw" is not a very wide-spread term to describe twisting and, eventually, the team decided to drop it from the checklist.

Figure 6. Philips Norelco Shaver 2500[24]

Device names were not necessarily learnt as a part of the membership as the new members would not have access only to the current devices and only a few people would remember how and why certain names came to be. That had to change and started to cause breaks in a workflow when the system became automatized, and the team grew so not all practitioners would not know the names of the devices or the top sizes. As a temporary fix the team would add identifiers to the device tops, for example a star or a circle sticker on the device itself. However, it was clear that to avoid human error, the computer should recognize the device serial number and automatically pick the right one. The device names had to be multifunctional and comparable with both the database for record-keeping and easy for biometricians to remember.

The construction of any intervention classification implies "a drive to abstract away from the local," which means language standardization and comparability (Bowker and Star 2000, 240–41). I observed that process when the team discussed and decided upon the name of their final

[24] USA Phillips website. www.usa.philips.com/c-p/S1311_82/norelco-shaver-2500-dry-electric-shaver-series. Accessed April 16, 2021.

device version. Its name also came up from the device's appearance. One day, Cliff Sky printed a colorful kid-friendly black and white device with zoomorphic features, taking inspiration from toys for infants. It was black and white, and the naming options that started as a joke, included a penguin and a polar bear, but the team agreed that the "cutest" device was Panda (Figure 7).

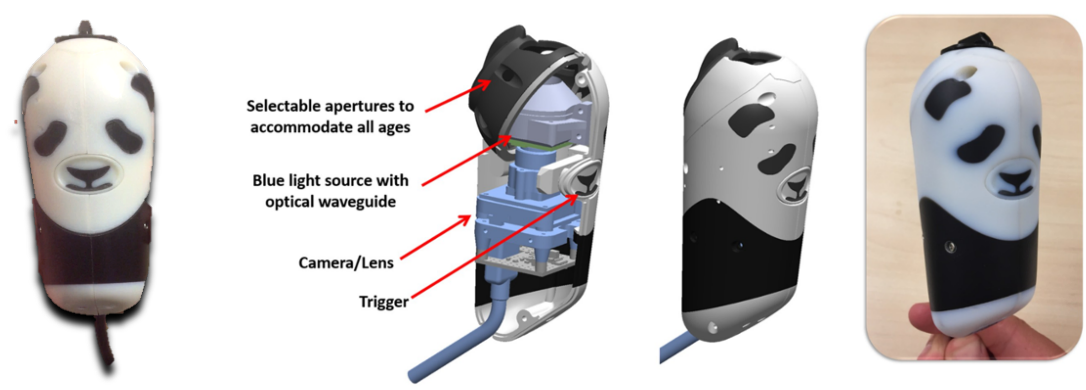

Figure 7. The device called Panda used in clinical setting by Pediatric Technologies (PT) (images courtesy of PT)

Beyond naming conventions, the disciplinary boundaries related to the project language stood out the most during the following distinct episodes. One happened during a team meeting presentation by a junior electrical engineer, who said, "that big" and indicated the size with his hands. That gesture resulted in an outburst of criticism from one project advisor, who demanded precision and said, "you are an engineer after all, not some sort of social science major." That was quite a telling example of how important it was for the trainee to learn the cultural rules of the disciplines and use them accordingly. It also caused an awkward silence in the room as social scientists felt degraded, but the issue did not escalate further, and the following week the same student came in with precise measurements in his presentation. Later, while asking for clarifications, one core member of the team, an optics specialist, joked that "I'm not a MAE person" teasing the external expert and referring to the mechanical and aerospace engineering (MAE) program.

Another significant differentiation among the team members happened when one software engineer wanted to show a biometrician how a dataset worked to teach her to use the backend of a new program. However, the biometrician declined, saying that she never understood technology and had neither time nor desire to learn it. One could interpret that as a clear disinterest in the job or lack of dedication to the project; however, as I observed that interaction, I could tell that it was a more nuanced issue. That biometrician did not feel comfortable around that software engineer because she never felt heard when she submitted comments or suggestions. Thus, ignoring all prior concerns and offering to teach a new skill was perceived more as an attempt to outsource even more work to the biometrician.

Interesting enough, the software and human factors subgroups often had confrontations, which made the learning even less desirable. I interpreted that failed attempt to share knowledge across disciplines as a lost opportunity and volunteered to learn more about the dataset as I was assisting the biometrician and had more time. Eventually, I found possible bugs in the system, which caused problems with recording fingerprint data. I noticed that the names of the devices were sometimes too long so they would not be recorded, and the system would block the whole process. Those small observations changed the software engineering lead's attitude toward me as someone who sincerely cared about their part of the device. It opened a door to me not only to better understand what software engineers struggled with, but also what they thought was important and why there were often misunderstandings with the hardware and human factors sub-groups.

Apart from disciplinary jargon, which consisted mostly of technical terms familiar to mechanical and electrical engineers, certain phrases used by one group and not another stood out during my fieldwork. For example, as I attended weekly meetings and joined the team's daily activities, I noticed how some team members often mentioned “the research mode.” They explained the lack or presence of features, the way the work was done and the amount of research by saying that “we are in the research mode” and I wondered what that meant. That sounded very close to what Star described as “the gap between formal representations, including publications, and unreported “backstage work” (Star 2010, 606–7), which I found quite captivating. Moreover, there was a sense of juxtaposition of their research mode to a commercialization or start-up mode, which was not universally shared across all team members.

Right at the end of my fieldwork, the PI decided to transform the project by registering it as a company. That transition was briefly mentioned in one team meeting but discussed individually with team members involved, and some of them decided to leave the project and continue their careers in other spaces as they did not want to be a part of the “start-up” world. During interviews, those members who left said that they believed that starting a company would take something very important away from the project because they would transition from the academic “research mode” into the market and production.

Another example of the local parlance, and one of my personal favorites, was “good and bad prints.” That description was used in a very different ways by those who worked with processing the prints for computer evaluation and the biometricians who would tell parents that their infants had very good prints. In the first context, a good print was an image of a fingerprint that had certain parameters, like contrast and alignment, which would get a high score in a matching software. When biometricians told parents or nurses that the infant had good fingerprints, they usually meant the images looked good to the naked eye and they assumed the numerical value would also be high. The team ran an experiment comparing what seemed like a “good print” to humans and to the machines and those values would not necessarily agree. Even after those results, the biometricians, who directly interacted with caregivers and collected the fingerprints, kept using the term "good and bad prints" during the sessions anyway. Also, as I mentioned before, the person whose judgment of a "good fingerprint" was most accurate and close to the machine evaluation, was the professional vision of one team member who spent every day looking through the prints and doing image post-processing.

The issues with naming devices were not only related to the software glitches. There was never a clear, precise, and complete list of all devices with each of the specifications. Device naming happened organically, or chaotically, from 2015 and started to get standardized around the time I joined the project in 2017. Some team members mentioned in interviews that better book-keeping was something that they should have spent more time on. When one entered the laboratory space, it was clear why it was hard to reconstruct the device history. Multiple physical models printed using 3-D modelling software, sketches of caregivers' and infant hands, silicon casts of shrunk human hands, plastic baby dolls bought on Amazon – all those items had one thing in common. Those were building blocks for the early prototypes and reflected the ideation process on the form and function of the device, linked to the external design work and contributions from the team members, who left the project.

The prototype ideas were sketched on white-boards and then erased, sometimes team members would take pictures of the board and maybe even post them on Slack but that was not a regular practice. As mentioned before, all devices had household names like ice-cream cone, corn, Norelco, and others. All those names meant nothing to a newcomer like me and often confused biometricians as each module had a separate cap with unique names and numbers. Later, the team agreed that such diverse unstructured lists only bred errors and there either should be limited options with clear understandable names or a machine-generated names that the system would automatically recognize. Most early prototypes were featured both in presentations to the funders and weekly updates to the team members, preserving the collective memory, which was a tacit knowledge in the heads of several core team members who were with the project from early on and still remembered how it all started. Therefore, a performative practice of designers was used to present the device prototype to the funder's representative. It also played the role of record keeping which allowed the team to publicly announce the changing approaches to the problem of infant identification for vaccination purposes. Oftentimes, when the team members could not remember something about the past devices, they would go back to those presentations and ask new members to look through them to get acquainted with the problem space and experiments.

The PT published only one white paper, describing the advantages of contact infant fingerprinting. That relatively short publication summed up a major debate solved only in 2018, which was brought up almost every team meeting about the comparison between contact and non-contact devices for infants. The core issue was inconclusive data as all infants were different and every day they grew and changed; moreover, babies' behavior was not static, and they could develop skin conditions. Peeling skin after birth, for instance, is normal but does not allow good fingerprints to be taken.

Despite all difficulties, the PT cultivated an ecology of the workspace, comfortable for the hardware sub-group who had the freedom to iterate on designs, run multiple tests, and experiment with different device shapes and settings. Oftentimes, only the person who made the device knew exactly what the specifications were. They would test several things, scribble some lines in their notebook and return to the lab to rework and modify features more. That style of work was not sustainable as the team grew bigger and more people needed to know the details so that knowledge could be shared and passed to new team members. There was a gap between the "unreported backstage work" (Star 2010, 607) manifested in the device, which was created using the tacit knowledge of individual team members hidden behind final reports to the funders. For example, device naming, post-processing the images, saving feedback, fixing enrollment errors, accessing all collected data, and showing weekly result in one chart – all those activities were usually performed by specific individuals who knew how to do that without a written protocol. When one computer scientist had to leave, he would teach another electrical engineer or computer scientist how to perform those activities. Moreover, the choice of software to use and the steps to take would be often modified based on the individual preferences, which would make it even harder to pass the knowledge quickly in one session or one day.

Standardization of Infant Fingers

Is there such a thing as a "good" fingerprint and what could possibly make it bad? Biometric identification through fingerprinting produces an image and requires one to define parameters of what is going to be recognized as valid input, in this case an infant fingerprint. As the team wanted to develop a process of automatically capturing and identifying the images, they spent a considerable amount of time discussing and trying out different ways of doing that. Although the idea was clear from the beginning, it was somehow very hard to bring it to life.

The off-the-shelf matching algorithm that the team was using, called MegaMatcher,[25] was the de facto way that images were scored and defined as good or not. As it was a proprietary software, it was not quite clear what parameters were being used. The PT spent a considerable amount of time to develop a pipeline of image modifications, called pre-processing, and rules about how to distinguish a good fingerprint. Those good prints were centered, in focus, clean, had

[25] MegaMatcher Automated Biometric Identification System (ABIS). www.megamatcher.online. Accessed on Feb 24, 2021.

visible ridges and valleys, and were not motion blurred. As the device prototypes were tested by the team members on themselves too, I learned my fingerprints were not that good; some fine lines and defects made them difficult to compare. To be honest, I felt a little disappointed by that, and it is hard to explain why, but a scary thought passed my mind, that one day the quality of one's fingerprints would be another beauty standard and a way to compare our bodies.

The fingerprint quality is a known concern because it might discriminate against people who have rougher hands, play musical instruments, or simply do more manual work. Those characteristics of adult hands would not be present in newborns; however, some infants might have special conditions or excessive skin peeling, which was identified during the field tests. Biometricians made notes of congenial hand disorders, skin peeling, blood stains from birth, lint and other debris on the surface of the palms and fingers. The team tried to develop solutions for the "edge cases" and came up with a few recommendations on how to capture prints. They concluded that the best way in such situations was to have a back-up plan for identification to make sure all infants were included.

Social Capital of the Team Leadership

> "Is leadership simply innovation— cultural or political? Is it essentially inspiration? Mobilization of followers? Goal setting? Goal fulfillment? Is a leader a definer of values? Satisfier of needs? If leaders require followers, who leads whom from where to where, and why?"[26]

The device meant different things to the team leadership: it was one of the invested technologies for the funders, one of the projects for the PI, core site of interest to engineers, and a part of the new infrastructure for the hospital. The PI and the project itself had a certain social

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[26] Burns, James M. G. *Leadership*. New York: Harper & Row, 1978. Print. P.1-2

capital, when people would work extra hours and volunteer their time, and one of the possible explanations to that is the direct personal connection to the PI. Based on the interviews, I noticed that for many team members interpersonal connections with the PI mattered more than anything else. When those ties broke or weakened, people no longer participated in the project. In the individual interviews that special connection between the team members and the PI was often present in the discussion of motivation and explanation why people participate in the project in the first place. This observation is similar to what James MacGregor Burns (1978) called transformational leadership, which implied a component of mentorship, an interaction, and an attempt to elevate followers so that later they become leaders themselves.

In PT, those "followers" would be team members, who achieved more by publishing, graduating, presenting at conferences, and even finding better paying jobs in the industry. That type of leadership is often juxtaposed to transactional leadership, which is beneficial to both sides yet is not long term, could be manipulative and not ethical. I do not think it is very important to get into the debate around the definition and practice of transformational leadership (Khanin 2007), yet there is a pattern of personal interconnectedness among team members with the PI, which was important in Pediatric Technologies.

The leadership of PT consists of the principal investigator, supported by the project manager, and a wider changing circle of senior advisors. The latter did not participate in the weekly team meetings on a regular basis yet when they did, they were mostly in conversation with the PI. I observed the following instances of encouraging collaboration and guidance by the PI, which happened during the team meetings:

- Presentation skills and expertise setting by more senior team members to teach newer team members.

- Acknowledgment of the importance of field session observations by those working in the lab.
- Decision to analyze data on-site, not outsourcing the analysis completely to the third party.
- Practice of looking and comparing which images "work," which don't and building up explanations why. This task of defining "a good image" took much longer than expected as at its core that's the main challenge for the device they were building.

Due to the context-based nature of leadership, no model can be equally applicable to all cultures and organizations (Burns 1978). There is a temptation of universality in the transactional-transformational leadership paradigm (Bass 1997), which is rooted in studies of military training. It showed the importance of idealized influence, inspirational motivation, intellectual stimulation, and individualized consideration (Stewart 2006). However, transactional-transformational leadership appears to be most applicable to situations in which leaders transfer ready-made knowledge to passive followers in organizations with distinct hierarchies and high uncertainty avoidance (Khanin 2007, 19–20, 23). Meanwhile the emphasis on leader-follower collaboration, a mutual quest for shared meanings, appears to be more relevant for political leadership and innovative management in creative organizations. Project work within Pediatric Technologies falls within the latter conception of transforming leadership with an emphasis on the leader-follower collaboration as the defining aspect of leadership.

With such strong centralized role of the team leader, the device itself has not been fully defined by the PI and its boundary role developed through the day-to-day interactions and during field sessions. The boundary work could not happen solely by one group or person installing their vision on others, yet they could certainly influence other groups and control what narrative about the device was shared with funders and other stakeholders.

When and Where Work Happens

Personal involvement in the project made me ask whether one would find online a reflection of extra time and effort people invested in the project on weekends and after hours. I asked team members to fill out a survey about their vacation times. I wanted to survey those patterns to compare the online patterns of their activity during those vacation periods to see whether people still engaged in work during their time off. It turned out to be hard to get responses even from such a small group. The main complication was the problem of recall, it was hard to remember past events from summer 2017 in June - July 2019. I didn't manage to learn much from the account of given vacation times about the teamwork cycles, yet I did get a glimpse into personal preferences of the team members.

For example, CJ See, a senior hardware engineer, who joined the project in April 2017, meticulously wrote out nine periods of time off work, specifying dates, months, and years, adding a description of project-related trips and time spent in the beginning working on other consulting jobs. A senior software engineer under pseudonym John Yossarian joined the project in January 2017. He mentioned traditional holidays in the U.S.—Christmas, New Year and Thanksgiving breaks—and noted days "here and there," which were hard to recall. Tim Yun, a younger engineer, who joined back in January 2015 and received a master's degree during the time of the project, regularly took two weeks off either in June-July or in February. Cliff Sky, another engineer, who joined in September 2015 and similarly graduated during the project, was also taking a couple of weeks off every summer to visit family and once went away in winter. There was a certain regularity when each person preferred to take a break, yet the overall team online activity showed seasonal fluctuations during Christmas and New Year break while many people continued to work through their holidays and kept in touch with the team during the "off" time. I observed that those who stayed in the project for the longest time had more regular time off. This pattern of underreporting work, especially the translation work across disciplines and the backstage of device making is something that would be interesting to trace back through time in the digital space, which inherently records even the smallest online transactions.

From June 2017, there were two major roadblocks: the payment for the software had to be a wire transfer and there was some legal language in the contract that the University could not accept. The Project Manager had to deal with those issues via the Contracts department and the resolution was achieved only in August. However, the download link would be sent only when the University completed the payment, which it could not issue until University tax analysts received a copy of W-8BEN-E for federal reporting and withholding that could apply to that payment. That was not the end of the bureaucratic hell. As SFinGe software was being downloaded onto computers that belong to the University, there were additional regulations and paperwork. Finally, five months later, the team received access to that synthetic fingerprint generator in November. By that time, Francisco García had left the team and other team members had to use that software. The first update produced by an engineer, Co Ling with a help of undergraduate interns, was shared in February 2018. The update identified that "although the quantity was promising … fingerprint quality was inconsistent," therefore the team had to select candidate images manually before they had a workable database. It also suggested approaches to tacking two main problems: fingerprint image enhancement and fingerprint identification. An external machine learning advisor, Henri Bernard, commented that it was a good approach to try Siamese Network for matching, and suggested more relevant papers. It seemed like a promising start. In May 2018, John Yossarian's undergraduate student Naveen Patel developed and trained the first neural network. Initial results demonstrated that although testing on smaller datasets worked well and the network was able to find some patterns, with an increase of the training set, the network lost confidence in its predictions and was probably overfitting. Iteration and tweaking the code is a standard practice of machine learning practice, yet when this student moved on, nobody was designated to develop the code. The conversation on Slack stopped abruptly and by July 2018 Co Ling shared Fingerprint Image Quality Assessment Using Convolutional Neural Networks Proposal, which was put on a backburner and never acted upon.

Conclusion

This chapter described the sociality of technology and knowledge that Pediatric Technologies created during the numerous interactions over the device. I presented the instances of slight revisions in the attitude towards the device, roles played in the team, and a gradual process of standardization over time. The most important takeaway is that making of the device happened at the boundaries between different disciplines and oftentimes illustrated the gaps between approaches. For instance, I showed the difference in approach between the external designers and the internal team, the explicit manual and feedback in the field and the tacit knowledge in the lab. I also emphasized issues of membership and belonging, confidentiality and privacy, the vocabulary as well as naming of the devices and processes. All these scenarios surrounding the making and usage of the device are the mechanics of everyday work, which were rarely discussed or remembered.

However, even with a strong influence of the team leader, the minutiae of the everyday practices had a foundational role to reduce uncertainty and create a common team narrative around the device. For example, the most advanced device prototype had zoomorphic black and white pattern, and it served as a boundary object between the software, hardware, social scientists, health workers, caregivers, and infants. An engineer iterating on the device design suggested to name it

Panda, to make it more kid friendly and less intimidating. Taking inspiration from toys for infants, such an approach illustrates a mindset of human-centered design, building for and with future users, hearing their concerns and taking into consideration their preferences.

In this chapter, I discussed the notion of the "research mode" which seemed to work as a shield used by team members to advocate for more experimental, often less standardized processes. That research mode also collided with the design worldview of showing and performative practices, which valued iteration and testing more than talking about the results and settling on one standard solution. I foresee how more standardization is essential to this device to reach the marketplace and at the same time become a mode of control. Operation procedures become prescriptive as soon as the device leaves the laboratory and is not used by the people who made it. Although the discussion of marketplace and governmentality is beyond the scope of this dissertation project, I will talk more about the ethics of technology and consequences of device standardization and implementation in Chapter V.

Witnessing how healthcare workers, engineers, and designers created a device demonstrated that it had potential to be widely adopted on the opt-in basis. The team collected numerous testimonials from hospitals workers who could see the potential benefits of such device in a clinical setting. However, implementation and wider acceptance depends on a greater scale than several pilots, when the device gets manufactured and used by other biometricians, who are no longer linked to the "core" team in Pediatric Technologies. As shown at the beginning of this chapter, the device has been created between the social worlds of engineers, biometricians, team leadership, and the caregivers. It did not directly interact with any market players, policy makers, technology sceptics and advocate groups, which means that the device prototypes potentially lack their perspectives. This brings me to the main takeaway about the making of the device and the boundary work of biometric technology: the everyday work, which changes through time, defines the boundaries of ethical and possible work so the human factor in such project is utmost important. If the device is seen solely as an engineering problem, the result will be an engineering solution to a predefined problem. While technology becomes more advanced and teams rely on automation, even more weight is put on everyday practices of people making devices as decision-makers with their personal preferences, diverse backgrounds, and interpersonal connections.

This case of infant biometric device development is a part of a larger process of contemporary technology design. There are no clear societal regulations on how one is supposed to make such devices, and the rule of doing no harm is quite open-ended. There are certainly standards and technical specifications of the amount of light, pixel numbers and image quality but, I believe, that they are not enough for device comparison. The boundaries of what is possible and ethical, therefore, are created by the groups involved in the technology development, and not only at the beginning but throughout the project during the everyday work. This is why it is crucial to record the work processes in such initiatives before it is too late, and we face new tools and devices propagating algorithmic discrimination (Noble 2018) and inequality (Eubanks 2018). In the next chapter, I employ a lens of technology and automation to look at the team interactions and making of the device as seen through their online interactions.

Chapter IV. "Just Slack it" - a mixed methods approach to visualizing and understanding multidisciplinary teamwork

"... the way in which something is said or done really is the most important message"[27]

Waiting by the locked door of the conference room, where the team meetings usually took place, Terry Better, who was an external graphic designer, and I were wondering whether the meeting was cancelled, and whether we'd missed any announcements. It turned out that we did; there was a brief memo on Slack saying the meeting was postponed by thirty minutes. Clarifications and reminders about weekly team meetings often appeared in a general Slack channel. By saying that meetings were "often" discussed, I mean such announcements appeared 928 times in Slack at the time of my fieldwork finished. Such precision and ability to quantify every small mundane interaction online counting specific words, phrases, or types of emojis seemed both fascinating and terrifying to me, mostly because that information is widely harvested by data miners and used in analytics.

A good example is Slack itself, a communication platform, which now allows its users to track several different parameters of one's team, including the overall number of messages sent, read, and received, activity over the last thirty days, and so on. Slack has been adding new features and ways to evaluate teams' activity online as a part of their workspace administration suit through

[27] Hollan, Douglas. "Setting a new standard: The person-centered interviewing and observation of Robert I. Levy." *Ethos* 33.4 (2005): 466.

analytics dashboard and a number of settings[28]. Considering that the owner of the group could download all chats, including private messages, and all members can any time see all public messages and search through the old ones, one gets a perfect Panoptikon. Slack was not only capable of constant supervision but an ability, like Panoptikon, to "judge them continuously, alter their behavior, impose upon them the methods he thinks best" (Foucault 2008, 8). However, collaborative software like Slack is also convenient and quite useful to quickly communicate with others on the team. It is also advertised as a safe space, where "people get work done, together"[29]. There are several humorous articles in popular press about the new culture of Slack, for example types of typical workers on Slack such as workaholics who are always online or perfectionists constantly editing their messages[30]. Whether one loves them or hates them, work group-chats are becoming more and more prevalent means of communications in teams and that is why it is important to include Slack as an additional lens to explore device development and multidisciplinary collaboration.

In this chapter, I employ mixed methods approach to gather insight on team's online activity patterns, observed online and correlated to meetings and relationships in real life. From that data comparison, I ask the following research questions: (1) What are the trends in online multidisciplinary messaging team behavior over time? (2) Does the digital footprint of the team in the online collaborative software (OCS) reflect real-life interactions? (3) What aspects of the teamwork are underrepresented in online data? Those questions are significant to foster collaboration, creative work, and boundary work in multidisciplinary teams situated in "blended

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[28] Slack Help Center. Workspace administration. Learn how to manage your Slack workspace or Enterprise Grid org. Accessed March 4, 2021. www.slack.com/help/articles/218407447-View-your-Slack-analytics-dashboard
[29] One platform for your team and your work. Slack features. Accessed March 4, 2021. www.slack.com/features.
[30] Allgood, Evan and Kempa, Sarah. The Eight People You Meet on Slack. Daily Shouts. Posted February 26, 2021. Accessed March 4, 2021. www.newyorker.com/humor/daily-shouts/the-eight-people-you-meet-on-slack

realities" (Grimshaw 2014, 598) between the physical and the virtual worlds. With the start of COVID-19 pandemic, stay-at-home orders, and a transition to remote work from home, a critical discussion about measuring online productivity and representativeness of the digital avatars is even more relevant than it was before March 2020. This chapter was published as a separate article in New Media & Society journal (Azarova, Hazoglou, and Aronoff-Spencer 2020), and here I present an expanded version of ethnographic observations and fewer technical details, which can be accessed in the article.

Slack: A Workspace Collaboration Tool

Workspace collaboration tools have been widely studied and evaluated for their impact on team efficiency (Ferreira and Antunes 2006) and engagement (Bassanino, Fernando, and Wu 2014). There is a large corpus of computer-supported cooperative work (CSCW) literature on group chats as well as linguistic research on conversation analysis and dialogues, including online chats and forums (Goodwin and Heritage 1990; Freiermuth 2011; Meredith and Potter 2014). With the rise of new media and research on virtual-physical spaces, the structure of social networks can be discovered online and studied based on large data sets from social media networks and websites (Lindlof and Shatzer 1998; Dunbar et al. 2015). However, less attention has been paid to the detailed analysis of the information stored in such repositories, the practical use of that information for people who generate it, and how all the digital traces correspond to ethnographic observations in the context of multidisciplinary teams.

Scholars have studied social interaction patterns through different media, for example, by analyzing videos (Rawls 2008) and sensor data from interpersonal social interactions (Y. Zhang et al. 2018). However, in teams working on a new technology, it is not always feasible to videotape meetings due to privacy concerns and sensitivity to the topics discussed. Neither is it always possible to attach a piece of equipment for continuous monitoring to all team members. With a rise in the popularity of organizational engineering to enhance human collaboration by using sensors to measure human behavior (Waber et al. 2007), it is time to make sure long-term human observations stay in the loop and our data-driven metrics are connected to the work on the ground.

Previous empirical research examined the impact of Slack on team formation, collaboration, workplace processes, and professional culture in virtual newsrooms and civic challenges. Slack has been used as a research site of an international journalistic collaboration, which reported on humanitarian issues, enabling both a new kind of digital "space" for creative solutions and global journalism but also opportunities for stronger managerial control and pressure (Bunce, Wright, and Scott 2018). The use of Slack in a civic design competition (McInnis, Xu, and Dow 2018) showed spikes of public discussion around important competition events, yet an overall decrease through time, as teams formed and people moved to private messaging (McInnis, Xu, and Dow 2018, 120:12). It was also noted that there were missed opportunities to connect discussions across channels (McInnis, Xu, and Dow 2018, 120:15). The issue of usability and keeping track of Slack discussions was further addressed in several recent articles, which introduced channel summaries created by collaborative tagging (A. Zhang and Cranshaw 2018) or machine-learning algorithms (Wang et al. 2019).

My work is different from previous studies incorporating information from Slack because it is centered around a longitudinal ethnographic study of a multidisciplinary team, working both online and offline for multiple years on a specific project. Ethnographic approach revealed additional facets to the theoretical concept of virtuality (Deleuze 1991, 97) and multidisciplinarity (Brettell 2014). By studying virtuality as "human activity mediated through digital technologies" (Nardi 2015, 16), the empirical findings juxtapose the mutual shaping of everyday reality in a team across digital (Slack) and physical (interviews, team meetings) realms, bringing attention to the sorts of shared data that is produced.

Questions about the Internet and cyberspace in relation to the material world and offline interactions have been actively investigated by many scholars. The dual life of technology as both "the object of the everyday lifeworld," and "embodiment of social relations" was shown in the context of domestic non-professional Internet users (Bakardjieva 2005, 7). Some authors suggested reframing the concept of "virtuality" to understand the online articulation of gender, sexuality, and embodiment in different web cultures (Van Doorn 2011, 532). The notion of "virtuality in teams" has been used previously to add value by complementing face-to-face interactions for virtual teams (Dixon and Panteli 2010, 1178).

I approach virtuality not as "discontinuities of time and place" or "continuities of technology" (Dixon and Panteli 2010, 1180) but as a site, developing "a society of control," where technology plays a central role, which can end up in "Deleuze's control society" (Galič, Timan, and Koops 2017, 19–20). Through Slack one can illustrate multidisciplinary engagement around important milestones and growing private messaging trends during a four-year Slack use within the team. My observations of weekly team meetings and in-depth interviews provided the necessary context for our exploration of Slack. Although the team also used other digital platforms, yet Slack was the team's major online communication tool. Below I briefly describe how we parsed the team's Slack data to compare the team's "the virtual portrait" with the real-life project progress and participation.

In this chapter, the team's success, progress, and innovation output is defined the way the team perceived them. PT linked success, and progress with innovation output, which included a physical device with custom software designed specifically for infants. The team was tasked not only to build a good fingerprint scanner, or obtain the best image of a fingerprint, but to identify infants, measured by matching rate—an ability to identify and confirm one's identity. Therefore, project success and the output of their collaboration were represented not only numerically, by the sheer amount of collected fingerprints, or the number of participants, but by the matching rate. Collaboration is defined as "the coming together of diverse interests and people to achieve a common purpose via interactions, information sharing, and coordination of activities" (Jassawalla and Sashittal 1998, 239)

I downloaded and worked with the team's default Slack data, which included Comma Separated Values (CSV) files with the member, channel, and enterprise analytics. I obtained the raw data, namely all public channel messages as JavaScript Object Notation (JSON) files from the PI and the Project Manager, the only ones who had access to them. My collaborator, Dr. Michael Hazoglou and I used Python, an open-source programming language, to visualize and analyze data. We looked at the vocabulary of each channel individually to distinguish topics and compare different channels. To analyze the text corpus of all public messages in Slack, we applied the term frequency-inverse document frequency (TFIDF) vectorization of each message to find how important a word was to a document in a corpus. We performed a two-dimensional embedding of TFIDF, using a machine-learning algorithm called T-distributed stochastic neighbor embedding (t-SNE). This was done to flatten multidimensional data to visualize it on a two-dimensional plane, preserving nearest neighbors.

Python functions were used to sort messages by channels, dates, and each person. To recognize the multidisciplinary interconnectedness in the team, I suggested counting mentions during different phases of the project and grouping them by occupation. In research collaboration literature (Rupika and Singh 2016), there are several inter-group collaboration measurements from psychometric assessments (Gedney 1994) to paper co-authorship (Kahn 2018), and they all have limitations. Without an ethnographic context, message frequencies do not necessarily mean collaboration among the occupational clusters. I believe that Slack; however, provides a close alignment between "the research object and the medium" (Venturini et al. 2018, 4201), therefore it is possible to use 'mentions' as proxies for the development of multidisciplinary collaboration based on the public interactions between members from different occupational clusters.

Mentions in Slack are like direct questions or comments during team meetings, when everyone could see and hear you. At PT, mentions were mostly used to call for action, express urgency, and assign responsibility, made intentionally visible for the whole team. The main difficulty with Slack mentions was that people often used nicknames, and there were members with the same name in the team. That never confused team members themselves but caused errors while automatically parsing text. By creating a matrix of mentions we found online ties between team members, located central "hubs," or groups of people who exchanged the largest number of public messages. We calculated all mentions by occupational groups and manually double-checked messages for the members with potential name clashes. We constructed a directed graph based on mentions, real names, and nicknames in Slack public channels, where each member was a node and mentions were edges. To calculate the degree centrality, or the importance of members and groups, measured by the number of connections, we counted the edges from each node. The degree of centrality online allowed us to compare meeting attendance in real life to an online presence in Slack.

Team Meetings In-Person

Team weekly meetings served as a space for clarifying coordination, assigning tasks, making announcements, and discussing a wide range of external and internal issues. For example, a potential field trial abroad was planned for months, yet ended up being canceled due to the political instability and water shortages in the region. The sitting arrangement in meetings reflected the team hierarchy with the PI at the head of the table, the senior engineer on the right side, and the Project Manager on the left. Engineers who were all male always sat together, usually opposite the social scientists, who were predominantly female and situated by the door, next to the Project Manager. While there were no explicit rules, people who worked together in occupational groups tended to sit side by side and hang out together.

I paid particular attention to overlapping conversations or "mistakes" in turn-taking, which are extremely important moments to show complexity of human interactions (Moerman 2010, 19–20). Normally such disruptions happened when subgroups would start talking across to each other while in the same room. Those side conversations included both the trivial watercooler talk and concerns over the main work topic. Such informal interactions constituted the social life and interconnectedness of PT members, made collaboration possible, and showed who worked with whom and therefore would not mind digressing at an opportune moment. People working well together would often tease each other in a friendly manner. However, when more than one person was talking in a meeting, there was a chance that other people would get distracted checking emails, browsing the internet, or writing code. The PI would usually call out that behavior and attempt to get everyone's attention by asking people to stop side conversations and pay attention. However, miscommunication still happened, for example when the PI asked a certain part of work to be done and did not specify who was responsible for it. Later, when no progress was made, one team member claimed that he had no idea that it was "his job to do." The team debriefed the incident during a team meeting and such misunderstanding never happened again, although side conversations still popped up organically at times.

I also observed the changing structure of the meetings and checked across informants' interpretations of what was happening. The changes from structured presentations to more informal check-ins corresponded with more work offline and closer ties between the team members. In the early prototype phase of the project, there were fewer members, labor was less specialized, and meetings were held at a coffee shop. The more members joined, the more specialization was observed, with more tasks delegated and discussed in public channels. Closer to the end of the clinical study period, the team grew smaller again, met in the lab instead of conference rooms, and had less structured presentations. Members often understood each other without explicit explanations, and there were both more informal updates and direct messaging. Such behavioral development has been previously observed by scholars studying group cohesion and knowledge sharing (Wojciechowska-Dzięcielak 2020). My observations confirmed that daily work side by side with a relatively small number of participants created a close-knit offline social core of the team with strong interpersonal relationships.

Daily work happened on different floors in the building with an engineering "lab" physically separated from the "office," where training and recruitment happened. While engineers would often come down to the office for testing sessions, social scientists would not normally go and stay for a long time in the lab upstairs. Talking about their workspaces, team members reflected that there was an unspoken spatial division and some lamented that the lab and the office were physically separated due to the university bureaucrats and the lack of available space. Others saw an opportunity in it: they explicitly said that being on different floors brought a necessary pressure to deliver a more finished prototype because "you can't simply go and fix it on the fly . . . you don't have all your equipment next door." Overall, the atmosphere was friendly and inclusive, but most "non-core" members of the team did not participate in social activities, while the "core" would get together for weekly team lunches, which resulted in closer interpersonal ties both during work meetings and in Slack.

The "core" of the team consisted of those who regularly attended team meetings, participated in informal team gatherings, and did the actual day-to-day work. We observed how the team roles and expertise domain changed through time. For instance, starting as students, some engineers graduated during the project and became permanent members of the team. They obtained new skills from designers and social scientists, which allowed them to take over the responsibilities of biometricians in the field testing and influenced design decisions. One of those significant decisions was to iterate on the device top caps, switching from a large set of detached tops to a more user-friendly rotating one. They also understood through practice why certain image capture errors occurred as they worked with infants, who were not always compliant research subjects.

Slack was often mentioned during team meetings as a means of quick access to updates, for example: "post it on Slack," "share it with me on Slack," and "is it on Slack yet?" The most popular meeting phrase was "just slack it," used as a shortcut for sharing information, scheduling, and sending reminders. A concern about procrastination on Slack was never discussed in meetings, although it was mentioned in interviews and the turned-off notifications were implicitly indicating that members did not want to be distracted by activity across different channels.

It seemed to me, as an ethnographer, that attending a meeting in person played an important role of being present in the project. The core of the team went to those weekly meetings to keep conversations going and to share barriers they faced, which might have been affecting others as well. When somebody was missing at the meeting, the concerns or questions were left unanswered, pending, or required a formal, written follow-up on Slack, or over an email. The PI himself observed and noted that team members built stronger interpersonal connections when they met in person and shared lunches after the team meetings. They would often continue discussing some work topics, or plan what to do next in the informal setting. Overall, the bonding effect of sharing food worked well for the group but, at the same time, it emphasized the gap with those who were missing the meetings or did not have time to participate in lunches. Although everyone was invited, in practice it was the PI, the Project Manager, the engineering core from the lab and the human-factors from the office, who would usually attend. When the office visits stopped and the field coordinator and others would often work from home, calling in for the weekly meetings, the lunches would not be consistent and would not happen if the PI was busy.

In-Person Interviews

In the interviews, I asked who was in the team, what they did, and how members described their educational backgrounds and contributions to the team. I also created occupational clusters (Table 2) based on members' self-identification in the project and confirmed by their colleagues and leadership. Engineers in the team constituted the predominant cluster. As mentioned before, even though software and hardware engineers distinguished each other's specialties in the interviews, in the everyday interactions and team meetings, "engineers" were referred to as one group.

Members with social science backgrounds were colloquially called "Human Factors" in the team, although none of them received formal Human Factors and ergonomics training. They participated in a wide range of activities from field testing and training, paperwork, and ideation, to ensuring the comfort and safety of human subjects and caregivers. That sub-group helped interaction designers, especially during the pilot, thinking about "the people side" of the project, how the project was perceived, communicated, and adjusted to the local environment. Interestingly, the "Design" cluster eventually got dissolved in "Human Factors" and

“Engineering.” “Students” cluster included undergraduate engineers working part-time for short periods on specific tasks under the supervision of their senior mentors.

Table 2. Occupational clusters and membership

Occupation Cluster	Number of People	Role/Domain
Admin Support	2	Coordination, university logistics
Art	1	Drawing, sketching, observations
Business	2	Funding, development strategy
Design	6	Prototyping, ideation, presentations
Engineering	19	Hardware, software, prototyping
Human Factors	5	Recruitment, field operations, training
Physician	1	U.S. hospital support
Mexico Team	3	Recruitment, field operations, hospital support in Mexico
PI	1	Responsible for the project, physician
Patent	2	Legal rights, regulations
Project Manager	1	Organizing, scheduling, strategy
Students	11	Temporary worker (mainly engineers)
Mexico-PI	1	Mexico collaboration effort, physician

Asking about the temporal division of the project was a challenging question for many members who joined at different times and often did not know when exactly which phases started. However, everyone gave an approximate timeline roughly divided into three parts with a further separation by work at different field sites. I documented successful trials and each phase showed a 5–10% improvement in performance measured by the matching rate. Another source of information for periodization were official presentations and reports to the funding agency.

The project went through the preliminary one-year long pilot, followed by two years of work, divided into "sprints." During a sprint or a shorter period of intense work before a certain deadline, the team developed and tested the technology, obtained subsequent study renewals, and expanded the testing to larger populations. Phase 0 (27 May 2015 to 1 June 2016), or the pilot, was devoted to "the proof of concept" and funded by a separate grant. Phase I (1 June 2016 to 16 December 2018) was the longest and the most important period. It featured the growth of the team from 2016 until spring 2017, preliminary work, and getting paperwork ready for the first testing in a US hospital in summer 2017 and the first stage in Mexico in January 2018 until June 2018. It involved regular border crossings, a period of local training, multiple issues with the software, hardware, and device design changes. The second stage in Mexico, from June 2018 until December 2018, was more locally independent and required fewer visits in person from the US headquarters. The device and software became stable, local biometricians and recruiters were more experienced and managed community relations very well. Phase II of the project (15 January 2018 to 14 February 2019) involved data analysis, writing up the results, and wrapping up before the next funding was available.

At the beginning of the project, often during the discovery phase, people tended to post more in public channels. The closer relations between team members corresponded with more private messages. Answering a question about the use of Slack, most team members stated that they preferred direct messaging to deal with the more specific details, discussed one-on-one or in smaller groups, posting only the final versions to public channels in Slack. Such team behavior was very similar to the observations described in the virtual newsrooms (Bunce, Wright, and Scott 2018, 3389), where more preliminary work or initial critique was discussed and edited in smaller private spaces.

Team members mentioned in the interviews that the division of Slack channels was not always clear as many channels crossed over several topics. Therefore, individuals sometimes did not know where to post an update or could not remember where something was shared. The latter issue was solved by the Slack search feature, which made information retrieval much quicker and easier. However, the question remained where to post, for instance, about a planned device. It could be shared in the "general," a site, or a topic-specific channel. There were thirteen channels with no description explaining the purpose of the channel. Some of them were self-explanatory and popular like #software, but others like #roadmap and #inspiration were rather ambiguous and rarely used. This led us to further investigate the content of Slack channels.

Describing Slack, team members saw the benefits for collaboration: "it is used to keep in touch because a lot of us worked remotely or not in the same office. So, it was good for there to be one place where everyone could see what was going on." My collaborator and I did not find a pattern showing the effects of physical proximity on the public message frequency exchange. There were as many messages from the people in the same office, who happened to work remotely 1–2 days a week, as those who communicated only via Slack. The message frequency was probably dependent on whether individuals were the "core" members of the team or not. When asked about the amount of digital communication happening off Slack, members estimated about 10%. For instance, the logistics questions with non-team members happened in emails; the bigger financial project expenses and external negotiations were not reflected on Slack either. In general, team members said that Slack added efficiency and allowed them to be more focused by checking only their topic-specific channels and channels where other people talked. One member summarized the team use of Slack the following way: "I think what is cool about this project [is] that everybody is on Slack . . . Slack is at its best when everyone uses it and a conversation is going, while in some teams it dies off and then Slack loses its purpose."

Slack Versus Real-Life Observations

Slack was consistently used for clarifications from team members and expressions of support to celebrate successes by "likes" and positive emojis to the messages with field test results. As I looked closely at the types of interactions on Slack, especially at the later stages of the project, most concerns and criticisms were discussed in sub-groups and "taken offline" when possible. Slack channels were important markers of questions, which the team wanted to dis- cuss in separate spaces, and could be divided into the following broad categories:

1. *Logistics.* Updates and announcements for the whole team, meeting agenda and time, purchases, project results, and milestones.
2. *Topic-specific.* Channels to publish specific tasks, issues, questions, or comments about particular aspects of the project, for example, about software, hardware, or design.
3. *Site coordination.* Separate channels for field sites, including directions, scheduling, problem-solving, and sharing reports and results.
4. *Miscellaneous*. A #tacos channel for a structured reporting and analysis system for the best tacos in Mexico, a #random channel captured everything else that was not directly work-related but fun.

Software personnel changes, within engineering, and multiple updates were among the main concerns for the team. "Software" as a task, presentation, or a point of discussion appeared in 93.44% (53 of 61) of weekly team meetings. Not surprisingly, the channel with most messages was topic-specific and called #software, accounting for 3527 public messages. In other words, 25% of all public messages were in one channel out of 52 that ever existed, and we saw that the topic of software appeared across other channels as well. We also recorded an increase in the software discussions specifically in July-August 2018 during the weekly meetings. That period was marked by a rise in activity in the tools, which software engineers used to discuss and share their results, namely Slack, GitHub, and BitBucket. My collaborator and I calculated a running total of GitHub and BitBucket commits through time and found that after July 2017 there was significant growth. Therefore, the Slack trend reflected correctly what happened in the project and across other platforms.

The number of members who never posted any public messages on Slack was 15. We wanted to know who those members were to find plausible explanations of why some individuals never participated in public discussions. Four of them were part of the forming Mexico Team, who started participating later; five were senior advisors, who only used direct messaging, and the other six "silent" members were administrators and temporary workers, who communicated only through private messages. They certainly played an important role in the project, yet for automatic analysis of online public activity, those people were empty data points and non-existent entities. At the same time, none of them belonged to the "core" of the team. When we recorded a decline in Slack membership, which did not affect the average of people posting messages, we asked team members in interviews about deleted accounts. Nobody felt the difference, as they did not have social relations with the absent members. That observation made us interested in the changing core of the team and public discussions in Slack throughout the project.

As we grouped all members by occupation, we counted all public messages shared by each group by month to see how different occupational clusters participated in Slack discussions during different phases of the project (Figure 3). Each vertical bar reflects how the team composition shifted through time, for example, starting with just five clusters: Engineering (green), PI (pink), Students (yellow), Design (red), and a tiny thin line representing input from Human Factors (blue). The amount of public messaging from the PI stayed relatively high but started to decrease after the pilot. While the Engineering cluster consistently played an important role, we saw how the designers and Human Factors participated in public discussions early on during the pilot phase and were not just added at the end. This was consistent with the stated team goal of Human-Centered Design for the success of the project. Milestones were chosen based on team observations and interviews. They reflected IRB training, major presentations to funders, and work at new field sites.

While formally being a part of the team, the lack of active communication on Slack usually meant distance from the "core" active members of the project. That observation of digital traces of "daily 'real' lives" supports the virtual as a site of "generative potentiality that is delineated through actualizations in daily life" (Van Doorn 2011, 533). The active core of the team was much smaller than the overall Slack membership at any given point. During my study period, there were on average only eleven people attending weekly team meetings, and those members closely resembled numbers and composition to active members of the team online in Slack public discussions. Figure 8 shows how the higher degree centrality online corresponded to higher observed participation in team meetings. I was the only exception, an anthropologist in Human Factors, who was present at all meetings; therefore, I had a high meeting attendance rate, yet did not participate as much in public channels on Slack.

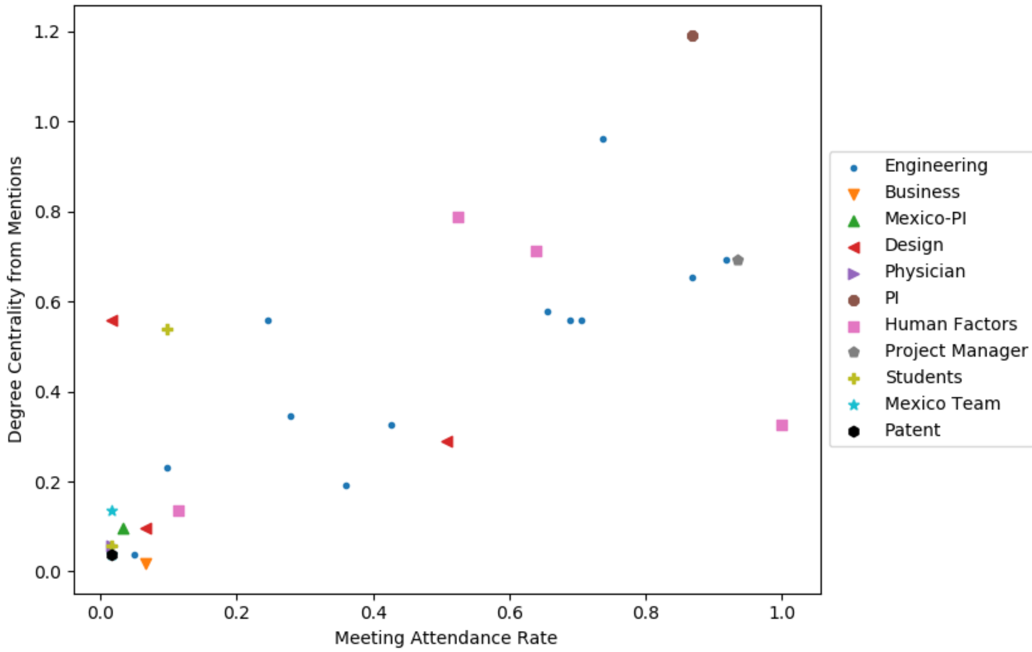

Figure 8. Relationship between the meeting attendance rate and the degree of centrality in public discussions online

As expected from the ethnographic observations, the PI and the Project Manager were both quite central figures within the team. They were present most of the time at the meetings and active in online public discussions. The cluster of students, on the other hand, usually participated online and rarely attended meetings in person. Both the Physician and Business cluster rarely attended meetings in person and rarely posted anything in public channels. Mexico PI and Mexico Team came to visit the US team twice and did not regularly attend meetings in the United States. The Mexico Team started to exchange public messages only at the end of our study period, thus their degree of centrality was still low. Those members who did not attend meetings in person and did not share public messages of Slack appear to overlap at "0" as one point, so they were left out in Figure 8.

The team members' intuition about Slack channels, which they shared during individual interviews, was supported by the online data. We found that there were many channels with multiple topics with a great deal of overlap (Figure 9). The text analysis of public channels confirmed that there were fewer topics than channels, which meant that certain channels had similar discussion topics. For instance, the "software" channel in dark blue was among the dominant topics, yet it split in half with the "tijuana_fieldwork" channel in pink. This made sense as a considerable part of discussions in the "tijuana_fieldwork" included questions about the software used in the field. I observed overlapping channels, "design," and "events," which were both sparsely used and involved scheduling meetings in person. Therefore, the team's confusion on where to post messages was supported by the quantitative analysis of the channels.

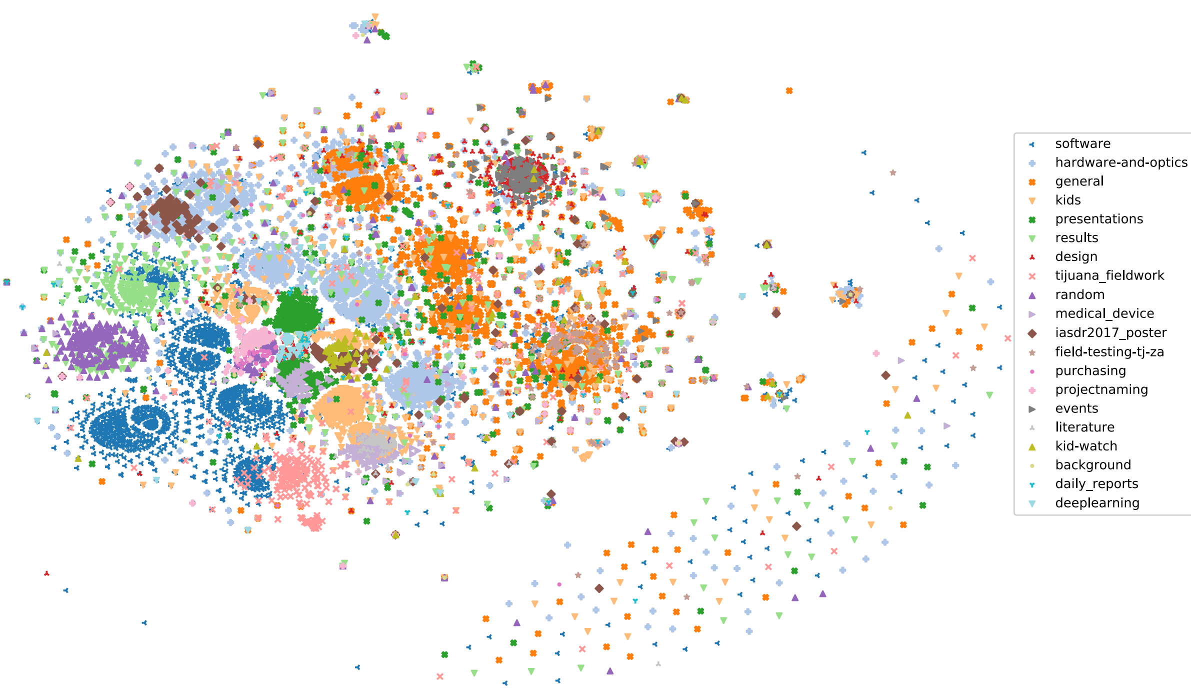

Figure 9. Visualization of the overlapping topics in channels

After visualizing the team's multidisciplinary collaboration online over the time during different phases of the project (Figure 10), we found the strongest multidisciplinary collaboration among engineers themselves and between the "Engineering" and "Human Factors" clusters, which intensified during Phases I and II of the project. There was also a rise in engagement of students during Phase I. That trend was expected as the project expanded at that time, had the largest team membership number, and happened during the school year. One could also see the message exchange between designers and engineers, and how the collaboration happened in the ideation part of the project during Phase 0. During Phase I, we noticed how the Mexico Team started to participate as fieldwork was unfolding. The heat map brought attention to those who had never or rarely been explicitly mentioned. Note how the Artist communicated mainly with the Human Factors, PI, and Design, leaving at the beginning of Phase I. The Project Manager, on the contrary, was hired only in Phase I and started interacting with all active clusters in the team.

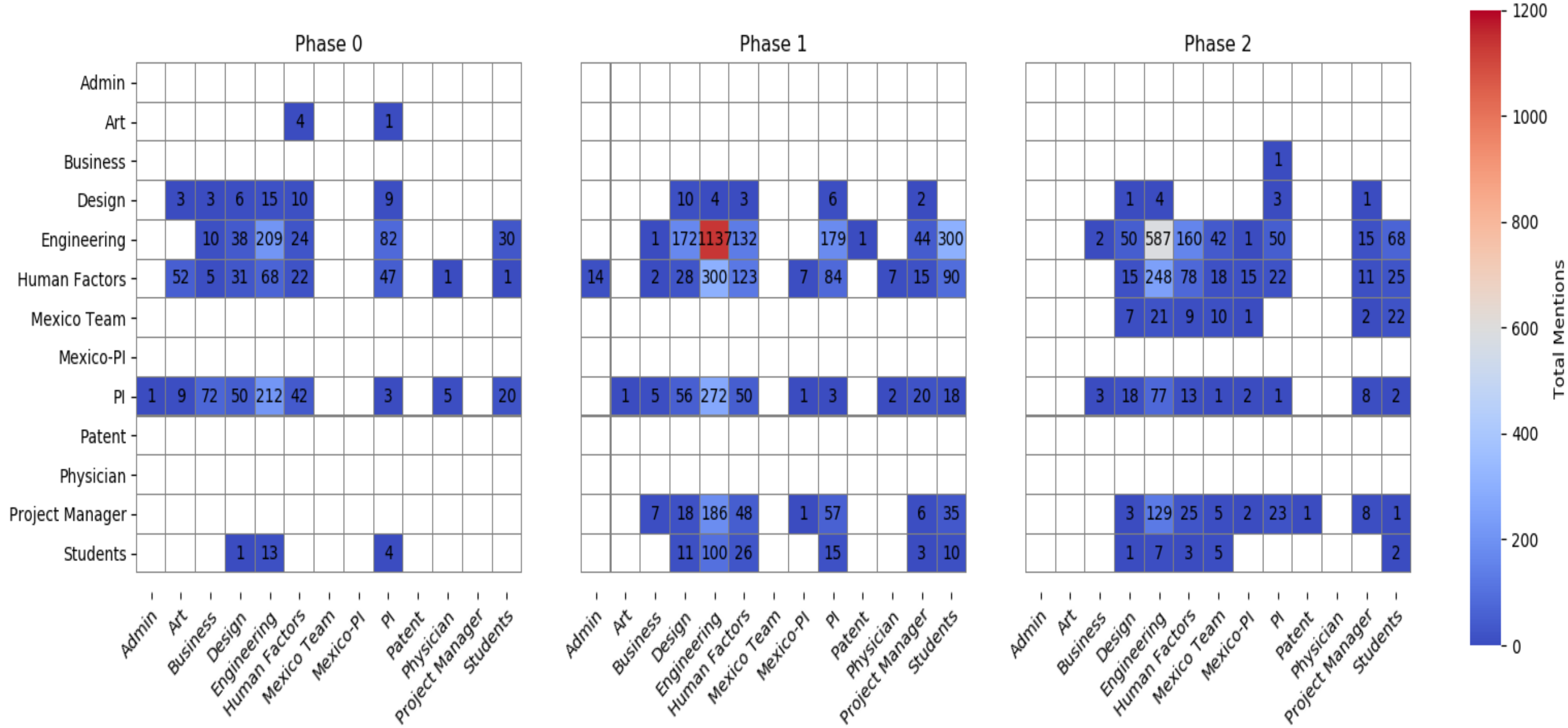

Figure 10. Visualizing the team multidisciplinarity. A heat map of the developing explicit mentions in public channels clustered by disciplinary occupations

The directed graph of Slack mentions was based on the heat map (Figure 10) and served a useful approximation of real-life connections among team clusters (Figure 11). We provided the numerical measurements of connections among occupational nodes in Table 3. In terms of strength, or the number of mentions, the engineers had the most, but this was due to them working in a larger group with many internal mentions. Per capita, the PI had the most mentions and connected different groups that would otherwise be isolated. That indicated the centralized nature of the team, where the primary investigator played a key binding role. We can also observe that many groups played a peripheral role and had little interaction with other disciplines. For example, Art, Business, Physician, and Patent clusters advised the team on separate questions and were instrumental only during certain phases of the project. Looking at the degree of centrality for all clusters, we identified the PI, Human Factors, and Engineering together with the Project Manager as the strongest hubs and active core members of the team.

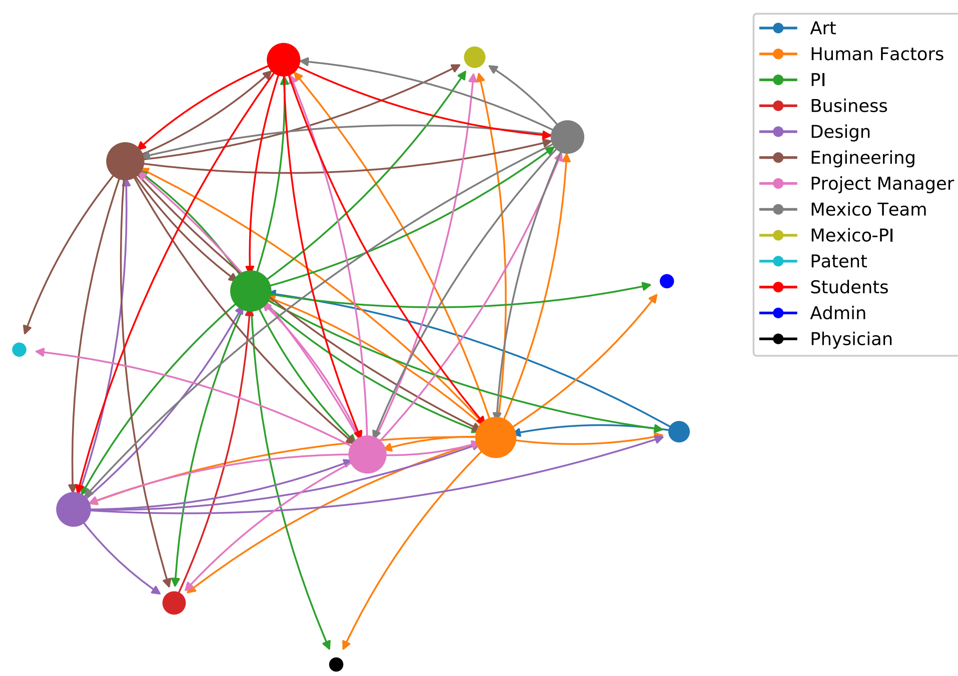

Figure 11. A directed graph showing mentions between occupational groups made in public channels. The node size reflects the edge centrality of the node

Table 3. Centrality measures and connection strength for each occupational node

Occupation	Number of members	Degree	Betweenness	Closeness	Strength
Admin	2	0.17	0.00	0.42	16
Art	1	0.42	0.00	0.41	80
Business	2	0.50	0.00	0.48	113
Design	6	1.17	0.02	0.53	561
Engineering	19	1.42	0.04	0.53	3669
Human Factors	5	1.67	0.11	0.59	786
Mexico Team	3	1.08	0.00	0.48	98
Mexico-PI	1	0.42	0.00	0.52	30
Patent	2	0.17	0.00	0.38	2
Physician	1	0.17	0.00	0.42	16
PI	1	1.67	0.17	0.59	597
Project Manager	1	1.42	0.04	0.53	171
Students	11	1.08	0.00	0.48	629

To summarize, Slack mirrored real-life interactions by identifying central clusters and the active core of participants in Slack and weekly meetings. It allowed us to visualize multidisciplinarity and understand better which types of work were important at different phases of the project, based on the most engaged occupational group. Slack in the later phases of the project, when many discussions moved to private messages, did not make much sense on its own. I found human errors in Slack membership records, with "empty" integration accounts, inactive and duplicate accounts. All public messages reflected only twenty per cent of all messages sent in Slack, which means members adapted its use for private discussions with their colleagues and overall found it quite useful. The knowledge about present and past members allowed us to notice that two accounts belonged to the same person under different names and email addresses. Those were minor miscalculations on a small scale of one team, but for an organization with thousands of employees, it could become more problematic.

Conclusion

The virtual interactions mediated in online collaborative software have become the everyday practice in many organizations and educational contexts. Findings even based on a single Slack team, should be useful for all scholars of the "hybrid world" (Jordan 2009) and the notion of virtuality (Deleuze 1991; Akemu and Abdelnour 2020) researching the relationship between the boundaries of virtual and physical environments. I explicitly asked whether Slack helped to build new friendships or solidarity among team members in interviews and closely observed day-to-day interactions, looking for markers of team identity in online spaces. In contrast to previous research, Slack as a separate space, did not shape new relationships, probably since it was not an entirely virtual team. This matches an expectation that in case studies "variables may create a unique experience of Slack" (Bunce, Wright, and Scott 2018, 3396). Nonetheless, the #random and #tacos channels did prosper in the team, so there was the reflection of jokes and relations from the "real" world. From team observations, it seemed that physical objects related to inside jokes and team rituals, for example, a toy panda, a giant gong, silly hats, and a whining/late jar with 1-dollar fees for those, who come in late and/or complains during the meetings, served that bonding role much better.

Slack facilitated collaboration across state borders and different geographic locations. Team members could work from home and send reports from different field sites. The early engagement of designers and Human Factors in the process was well reflected in Slack. However, early inclusion of discussions about infants, caregivers, and providers during the team meetings, was critical to the team's success, was not directly mirrored in Slack as they were not mentioned in online public discussions. We found that most explicit mentions happened across Engineering, and Engineering to Human Factors clusters, which could be seen as proof of their multidisciplinary nature of communication. At the same time, it could be interpreted as initial higher barriers between groups, which later connected and moved to direct messaging. The closer the team members got, the less they were inclined to mention colleagues using "@" and posted messages publicly. This made the digital team portrait less representative.

All members could contribute to conversations on Slack, yet certain topic-specific channels were visibly used by those who worked in a specific domain. Nonetheless, from the interviews, we learned that members read discussions across multiple channels. A virtual portrait of the team provided a timeline of the project, yet it misrepresented the activity of "silent" users and often showed lower public activity before big milestones at the later stages. This would be important for any further analysis of teamwork interactions online and drawing conclusions on individual contribution and performance. My collaborators and I did not succeed in calculating a robust predictable success cycle of public activity based on the peaks and troughs of Slack activity and observed real-life milestones. This remains an interesting avenue for further research.

The visualization of a team interaction network with central hubs was quite representative of the core actors in the team. At the same time, we found that training algorithms to predict productivity based on the sheer number of messages in channels were misleading because work was discussed in private, and there were human errors in channel use, especially over time (i.e., people did not always follow rules, what to post where, etc.). Different digital platforms like GitHub, GitLab, and BitBucket can be used to add complexity to the activity analysis. We tracked the output by the time-stamped commits by different team members and saw when the team became big enough to collaborate on different tasks and required additional platforms for storage and analysis. The bigger the team, the more decentralized the work became, with team members completing smaller tasks outside the main platform, working individually on drafts and presentations, only sharing the final products of their work with the larger group. Therefore, analyzing file uploads in Slack did not always mark the process of work over them. There is a need for a more nuanced definition of an active user and how a choice of measuring tools for activity levels changes one's perception of the team.

It should be noted that my study is limited in its generalizability and the specifics of this account will not apply to all groups of different professions working together. For example, the PI might have influenced the team members to post more in public channels than they might in other contexts; work in the same region and time zones of team members might have also affected their usage of the platform. However, the analysis highlighted several important threads that retain value beyond one specific Slack team, namely the question of representation and virtual portrait of a multidisciplinary team effort through the lens of the online collaborative technology. It showed the steps to visualize multidisciplinary effort through time and an acknowledgment of the diverse collaborators who helped develop the project throughout its timeline.

The main takeaway for those who manage and work with Slack is not only to assure that all channels have clear purpose descriptions, which are discussed with team members, but also to educate team members about the use of their activity data in Slack. Overreliance on online social networks and tracking human behavior leads to overreliance on any OCS to make decisions on members' productivity, impact, and contribution to the project. My observations illustrate how team members forgot to post, often asked somebody else to create folders and upload documents. Thus, any productivity metrics put in place using Slack should be evaluated against the real-life context of any given team. The analysis of the team confirmed that multidisciplinary teams followed the trend of less public messages over time, switching to sub-groups and doubling direct messaging during the most intense periods of development. The visualized multidisciplinary collaboration over time based on public interactions on Slack and provided a framework for other researchers to compare data across different teams.

With an expansion of the cloud-based tools, like Slack, and their omnipresence in teams, both in the academia and industry, it is crucial to evaluate how the online image of the team mirrors the work and interactions in real life. It matters for furthering the theoretical understanding of virtuality not as an opposition to what is “real” but what is being reflected in the new digital technology and has a practical significance for the communities that use Slack in the organizational settings.

The online and ethnographic data collected about PT pointed toward several interesting observations: the overlap between public online discussions on Slack and participation in the weekly meetings; the representativeness of key players in the online messaging networks; and the powerful visualization of key disciplinary groups active in the project at different time periods. I brought attention to the limitations of technological platforms to represent team relationships without ethnographic context, especially at the later stages of the project when members tended to communicate privately.

The example of PT departed from the studies of social networks and virtual worlds in online games by focusing on a research team “portrait” that a longitudinal study made possible. The goal was to critically assess a large number of unused and not necessarily well-understood data points coming from Slack, a popular collaborative software.

Multidisciplinary teams leave a significant trace online in Slack, which can reflect some real-life interactions and be used to support the performance evaluation of a multidisciplinary team. A priori, we knew that human communication reflected online was partial. However, we observed that overall public online discussions on Slack mirrored the dynamics of participation in the weekly meetings. The top five people who participated in meetings were the same top five who messaged the most in Slack. Online messaging networks recognized key players and their interconnectedness, even based only on their public messaging habits. The key outcome was that continuous data from collaborative software allowed us to visualize main active groups of the project, when different disciplinary groups mixed, interacted the most, and how those patterns changed through time.

The ethnographic context was particularly important at the later stages of the project when members tended to migrate into private messages and did not post as much in public channels. At that point, usually, during the highest intensity of the project, a lack of activity on Slack in public channels reflected the periods of active offline work by the team members and an increase in private messaging.

One positive side-effect of such omnipresent tracking is that digital technologies preserve the project memory in a form of the digital footprints left by changing team members, which makes past contributors more visible. Before the introduction of Slack and other digital platforms, individual contributions and additional work done digitally and recorded as "commits" by students, or other temporary workers, was often invisible. Now, we have an opportunity to obtain a more detailed and inclusive story of the knowledge production in multidisciplinary teams, often involving many people doing small tasks at certain periods of time.

Available quantifiable categories to analyze Slack, such as adjacency, centrality, and overall number of messages by occupation, which we used in the article are by no means exclusive. New updates in software and further empirical studies would uncover more categories for analysis. From both the interview data, meeting, and online observations, it was evident that too much activity in Slack could be distracting and happened more at the exploration stages of the project.

Later project stages are often focused more on implementation and tend to be less “chatty” but should never be completely silent if they want to keep members engaged. There is a possibility that the amount of team activity can be quantified by scholars in the future, yet the most important takeaway, for now, is that team members themselves should realize why and what data are being collected, and how it is analyzed.

Overall, Slack as a collaborative media should be investigated by other teams to help them make use of their Slack archive. The amount of team activity in online application Slack has important implications from a managerial and leadership perspective and requires a nuanced ethnographically grounded evaluation. On the one hand, team members should be aware of the digital traces they leave behind and how that digital activity could affect them if the analytics from online spaces is drawn to make decisions on raises, cuts, and promotions. The second reason is to see what OCS analytics can tell us about team processes, and what kind of caveats there are.

In this chapter, I summarized our findings from the article where together with my co-authors I discussed the activity online and offline in the team (Azarova, Hazoglou, and Aronoff-Spencer 2020). What exact amount of Slack activity is optimal for multidisciplinary teams to cohere but not get too distracted is still an open question. Most probably that ratio must be industry dependent. On an anecdotal level, we know that there is a need for a critical mass of participants and a constant rate of updates to keep Slack going. A promising avenue for further research could be in identifying common traits across a wide range of “dead” Slack workplaces, explicitly discussing online activity metrics and what it means to be an active member of a team in Slack.

Chapter 4, in part, has been submitted for publication of the material as it may appear in "Just slack it: A study of multidisciplinary teamwork based on ethnography and data from online collaborative software.". Azarova, Mayya, Michael Hazoglou, and Eliah Aronoff-Spencer. New

Media & Society, 2020. The dissertation author was the primary investigator and author of this paper.

Chapter V. Ethics of the Biometric Future

"Just because we can, should we?"[31]

It was a warm afternoon in southern California in November 2018, PT's electrical engineer Tim Yun and I were sitting in the sun at the outdoor patio during a lunch break. As I was asking him about the project, he described the project timeline and the main goal of "building a matcher" to identify infant fingerprints. I followed up with questions about the aspirations for the project and the challenges the team faced. He responded in a following way, voicing a concern about the use of proprietary technology:

> "My hope is that eventually we can get it get off this MegaMatcher... if possible ... Because there is a thing about engineering you don't really want to rely on other people's stuff you want to run your own stuff even though your own stuff is not as good… but you don't want to be dependent because what if they change their policy … So, you want to have your own … I think right now the challenge is how to get the data preprocess well. It's not easy. We have eighty thousand images just for phase one …"

The problem of dependence on a proprietary software was never explicitly brought up during team meetings when I joined the team. However, during the pilot stage of the project one team member was trying to develop a matching algorithm. When he left, the team bought MegaMatcher, which was deemed to be the best software for matching available on the market at that time. Matching was a crucial part of the device functionality; however, like other temporary fixes, it stayed long-term and was never changed. When asked why the team chose that specific software, most team members just referred to the team's leadership decision. Therefore, the matching of the images happened in a black box; nobody knew exactly how it worked. One way

[31] "Just because we can, should we?" Biometrics Institute launches ethical campaign. Biometric Technology Today Volume 2019, Issue 4, April 2019, P. 1-2.

the team addressed that issue was by uploading images at different steps of image processing to see the difference in results. This meant that they could only modify the input and hope for a better output. The team had to spend quite a lot of time changing image processing techniques to make images accepted by the MegaMatcher software and to get high scores. Eventually, PT got assistance from an external expert, who worked closely with the team's technical lead to optimize and standardize image processing.

Mechanical engineers tried out new shapes of the physical device and did not always get timely feedback on the image quality from the software. Therefore, they relied on the comments about usability from the biometricians and subjective evaluation from those who worked on data processing. The team collected the images, uploaded them to an external software, received the score, and saved it. Then, they collected new images of fingerprints from the same people and ran the new fingerprints again through the MegaMatcher and compared them against all previously collected images again using an external software. That meant that the work on a matching device did not necessarily mean making decisions about the algorithmic matching at PT. Due to practical reasons, mainly driven by the lack of resources, the question of actual matching was postponed, and the top priority was to collect raw data, and to perfect the physical device.

This chapter is about the practical trade-offs and challenges the team faced while devising a biometric tool and a broader discussion of potential problems and challenges such device could bring. Drawing upon the examples from my fieldwork at PT, I illustrate how the notion of boundary object might be used to explore ethical dilemmas that team members faced and the mechanics of ethics in research. I expand my main dissertation argument that practices of a multidisciplinary team developing new technology inform our understanding of emerging devices and technologies to include ethical considerations. Ethics here is defined as a system of moral values and principles, which guide individuals in decision making and telling right from wrong. While most professional disciplines have ethical guidelines, I am more interested in exploring how morality was understood while developing new devices and advancing technology. I also challenge the point of view of "biometrics as a mode of thought" (Grinnell 2020, 2), demonstrating how one could be making a biometric device without experiencing that ontological turn. At the same time, I discuss the unintended consequences infant biometrics might produce down the line, including tracking people by hostile governments or historical example of restricted travel.

I observed how the team's knowledge practices and device design followed the predominant optimistic narrative of technology in healthcare. That point of view implies that new technology can solve existent problems in healthcare through new algorithms, robotics, precision medicine, or new sensors. As discussed in Chapter II, the critical literature in humanities and social sciences usually emphasizes the contrary view and amplifies the unintended consequences during the implementation of many new devices and technologies. The goal of this chapter is to provide empirical data to support a conversation between technologists, ethicists, and those interested to communicate across technical specifications and broader societal implications of infant biometrics. I do that by bringing up the unresolved dilemmas created by the project, which demonstrate the tensions between the two competing ideologies of technological healthcare solutions.

Biopolitics and "Tiny Brothers"

The public perception of surveillance and privacy standards is highly dependent on normalized everyday activities. For example, remember going to a store to print photographs, letting complete strangers know where you went on vacation and what your family members look like? Even though photo printers became much more affordable, many of us would still send our images to companies, often using their mobile applications. We trust that our photos are not going to be misused and not found in the next commercial or stock photo library. By choosing to provide our information to companies, we agree to the terms of use to be able to get their services. An interesting ethnographic study about health and wellness data has found that there are up to six social "data valences," which define sets of values and expectations about such data in terms of its collection, use, privacy, reuse, and performance (Fiore-Gartland and Neff 2015, 1470). There are different social settings, where health and wellness communities welcome, question, and connect over the collected self-tracking and monitoring data that goes beyond photographs. Even though a comparison of vacation photos with biometric data might seem bizarre today, I think we are coming to are moment when our daily routines might normalize sharing biometrics to access certain services or platforms.

Some authors call this societal trend "a culture of surveillance" and draw attention to "tiny brothers," or the mundane practices of social control and surveillance not done by the central government but by private and public organizations and institutions (Staples 2013, 2). Those activities are almost invisible and have been integrated into our daily lives, for example the comfort we feel now using credit cards, cell phones, free wireless internet, location-sharing for parking, social media geotagging, and police streetlight cameras, among many other smart city[32] solutions. Specifically biometric recognition projects, most notably Aadhaar, have been criticized for being "privacy hazards" in terms of data security, mining of personal information, and, as such systems become compulsory, raising questions of constitutional rights and democracy (Khera 2019a, 6). In that context, those are not tiny brothers anymore and scholars bring up Orwell's "Big Brother"

[32] For example, see Smart Cities. www.sandiego.gov/sustainability/smart-city. Accessed April 5, 2021.

metaphor, where the government creates mass surveillance infrastructure, which facilitates tracking, profiling population, and self-censorship (Magnet 2011; Khera 2019b).

Most discussions about surveillance earlier or later end up mentioning Michael Foucault's work on disciplinary power, prisons and systems of punishment, and panopticon as a symbol of modern surveillance, where one's behavior is controlled and might be constantly visible (M Foucault 1980; Lianos 2003). Does fingerprinting infants equal being observed and inspected from birth? There is no single right answer for that. Some authors argue that biometric technologies strive to uncover "an incontestable, permanent IDentity," linked directly to the physical body and not the person herself who has "a negotiable, changeable personal identity that emerges out of social life" (Grünenberg et al. 2020, 4–5). In the next section, I show the mechanics of ethics during device development at PT by different disciplinary subgroups. I start with a premise that ethics in technology development is not one established "thing," but a conglomerate of processes composed through interactions and context, dependent on social infrastructure. I build upon the idea that the capacity of a tool, in this case a biometric device, depends on "how the tool is taken up or put to use" (Ahmed 2006, 46), and add that it is still being imagined at the early testing and design stages.

Building an Ethical Technology

There are institutional mechanisms which serve as a foundation of ethical research standards and guidelines.[33] At universities, those regulations are enforced by Human Research Protections Programs (HRPP), which advocate for the welfare of the participants by reviewing proposals that involve human subjects. The goal of the HRPP office is to assist researchers and

[33] The Belmont Report. www.hhs.gov/ohrp/regulations-and-policy/belmont-report/index.html

make sure their work complies with federal, state and University policies. However, previous studies have problematized the adequacy of relying solely on the extrinsic research ethics through institutional review boards (IRB), informed consent, and IRB protocols (Koro-Ljungberg et al. 2007, 1077). All of those necessary documents and review procedures have become contested, especially in the digital spaces (Vitak, Shilton, and Ashktorab 2016; Nebeker et al. 2017; Huh-Yoo and Rader 2020) and across the world (Parker et al. 2019; Salhia and Olaiya 2020; Ye et al. 2020).

Looking through the team's archive, I found the earliest notes from October 2016 about the initial set-up, which included obtaining IRB approval as well as necessary CITI training, flu shots and TB vaccines for the team members who would go into the hospital and interact with infants. At first, PT created a survey to learn more about both the current and possible future locations for vaccination sites including hospitals, permanent and mobile clinics, schools, and other public spaces like airports and train stations, theaters and sports arenas, refugee camps and border crossings. They looked at the existent non-profits, programs and initiatives that dealt with routine immunizations around the world (e.g., BID Initiative,[34] Global Health Delivery Online,[35] eHealth Africa[36]). The survey was designed to get a general understanding where vaccinations take place already, and probe where they might integrate infant fingerprinting in the future.

Another factor in the discussion of ethics is the funding source and research goals. According to the formal presentations and documentation, PT has been working on a fingerprinting device for infants to identify and record necessary vaccinations. Their funding information has been openly available online, announcing that the team received $3,078,430 funding in September

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[34] The BID Initiative. www.bidinitiative.org/history/. Accessed April 5, 2021.
[35] Global Health Delivery Online (GHDOnline). www.ghdonline.org. Accessed April 5, 2021.
[36] eHealth Africa: www.ehealthafrica.org/vaxtrac. Accessed April 5, 2021.

2016 from the Global Scale Foundation.[37] The purpose of that grant stated the goal “to develop a point of care biometric device” to improve global health. Scanning infant fingerprints, therefore, would create digital identities for development, solving the problem of vaccine records and delivery, which aligned with the funder’s global health mission. Nowhere in the research description was there a section about the potential hazard of creating and reinforcing social differences, advancing “social sorting” (Lyon 2003) of people who were or were not vaccinated. Such unintended consequences were never explicitly brought up at the team meetings either as something so obvious that they escaped mention at all. Nonetheless, scholars have problematized before that “unbiometrifiable bodies,” which are not recognized by the new technology, eventually get excluded and restricted in terms of getting benefits, working, and travel (Magnet 2011, 5). Previously, certain demographic groups, specifically the “elderly, construction workers/artisans, and those of Pacific Rim/Asian descent” were identified in technical briefs as “more prone to FTE than control groups” (Nanavati, Thieme, and Nanavati 2002, 36). FTE stands for failure-to-enroll (FTE) and represents a probability that a given person will be unable to enroll in a biometric system (Nanavati, Thieme, and Nanavati 2002, 33).

Case studies of biometric use in prisons, welfare system, and U.S.-Canada border make some authors like Shoshana Magnet rightfully skeptical about the narratives of development, innovation, and welfare. She investigates when biometric fails and claims that “breaking the body down into its component parts, from retina to fingerprint, biometric technologies purport to make individual bodies endlessly replicable, segmentable, and transmissible in the transnational spaces of global capital” (Magnet 2011, 8). Another significant point to note is the pervasive spread of

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[37] All personal and organization names of the funding organization are pseudonyms.

biometric national identification systems used for development specifically in low-middle income countries (Gelb and Clark 2013, 2).

Recording human identities in machine-readable digital data has become a point of contestation among different disciplines and societal groups (Masiero and Bailur 2021). Fingerprinting not only has a stigma of criminality, which I discussed in Chapter II, but it is also prominent in the debates about body measurement. The main concerns are usually around who is doing it, what is being measured, and why? In healthcare, mobile health (mHealth) technologies, such as wearable digital devices, routinely collect data on one's bodily functions and everyday activities. Several scholars problematize self-tracking practices and numerous health-related applications, which can record and monitor blood pressure and glucose, breathing rates, body weight, heart rate, sleep patterns, and other parameters (Lupton 2013, 394). One important caveat is that mHealth usually involves voluntary self-tracking to improve one's health. At PT, the team is tasked to develop a device to identify newborns, thus creating a digital record for humans just entering the world. This, no doubt, makes some people uncomfortable and brings up the question of whether it should be done at all.

Previous studies emphasized the importance of asking the questions about the cost of technology, mechanism of its work, and whether it worked all together (Magnet 2011, 10). Those concerns were weekly discussed at PT and had to be solved before the device could reach the market. The question "should we make this technology," on the other hand, was not often explicitly discussed as most team members truly believed that the problem was to make the device and then it would help in hospitals and clinics to identify who had which vaccines. For instance, the project manager, Ann Hughes, would come to the early prototype testing sessions with her daughter and participate in the device trials. The team would make silicon casts of her daughter's hand to have it as a visual clue to remind who they were building the device for. Early on, team members would first test prototypes on their own hands and record their own fingerprints. Some would go one step further, like one mechanical engineer, who took his early device home to iterate on the design after hours and to test it with his own newborn baby. However, such dedication and belief in the technology was not universal. Once during a team meeting, one of the team's technical advisors stated that he would not want his child fingerprinted when the PI asked if he wanted to try the device himself. That brought an awkward pause and a question why he would work on something that he would not want to use himself or on his own child. He shrugged and reflected that he saw his contribution solely as technical advice to an engineering problem. The participation of that advisor in the future was very limited, mostly interacting directly with some junior engineers and the PI.

Another dilemma, beyond accepting the device as a useful and harmless technology, emerged during the selection of the testing sites, collaborators, and future funding. Most discussions of this sort happened in private among team leaders; however, some team meetings had digressions into the funding perspectives and debates about whether the team should participate in certain wider ID-initiatives and who they should partner with. Once PI started the meeting by saying that he had an ethical question: they were invited to present in South Africa and needed to plan how to talk about their work. Although quite mundane, the questions "do we go where the money is?" and "what's the low-hanging fruit," were very important for the future implementation of the device. Oftentimes, the main factors for decision making on the future of the device use were interpersonal relations of the PI with program directors and organizations that had experience working in the region.

One specific difficulty for the team was that their biometric device was seen just as a tool, which was an add-on to other trials. During a team meeting in January 2019, the PI formulated his vision in the following way: "…biometrics [is seen] as a tool … we get stuck with other people's project, but we need to be in the lead [with] ... the whole baby biometric birth certificate." That led to a discussion among the different team members about the overall goal of such biometric birth certificates from a perspective of the graphic design, engineering, and behavioral science. Team members talked about the existent elements of birth registration and how biometric ID could fit that workflow. Everyone started suggesting different names for that system, and the main question was "how do we talk about it?" A variety of suggested names included words like "certification," "birth," "smart," "link," "safe ID" among others. One common thread was that they were all positive terms, trying to emphasize that this would be a safe and smart digital biometric birth certificates. The PI repeated that he wanted everyone "on the same page" and emphasized once again that he wanted the team to "own a problem … we need not to be a tool but people solving a real problem." Therefore, he envisioned going beyond just developing a tool to identify infants for vaccination purposes, and really hoped they would not be making just a device but rather redesigning a whole system of delivery, birth registration, and vaccine administration. Creating such an imaginary for the device echoes Heidegger's "toward which" usability of the tool, and assigning who is going to use it and where (Heidegger 1962, 99–100).

Beyond lofty goals and official programs, there was always a messy reality of ethical dilemmas during technology development, which the team members faced every day throughout the project. For instance, while researchers wanted to provide equal benefit for all participants, should participants in different countries be paid the same way or not? The team decided to discuss that question with their local site collaborators and realized that U.S. gift cards would not work very well in the given context. PT ended up switching compensation to smaller cash incentive in local currency accompanied by a pack of diapers and a free consultation in the health clinic. Then, they revised monetary compensation once again when their collaborators noted that participants would probably be more willing to come back if there was higher monetary compensation so that they could cover public transportation costs. How to equate those different contexts and compensations had to be solved on the fly. Those small details are often taken-for-granted, and team members had to experiment and use their own judgement. The lived experience of ethical research, therefore, started with official regulations but often resided in local micro-interactions and decisions based on what felt appropriate at that time.

To understand how the group addressed ethics, technology, and surveillance, I looked backed at all meeting notes and through my interview transcripts. I must report that in the everyday work, ethics has not been often discussed as a separate topic. It was "known" but never explicit until new members joined, asked questions, or suggested solutions or brought up new ideas. For example, when biometricians crossed international borders, should they stay overnight at the site or that would be too dangerous? How important was efficiency and personal safety? Who would be mentioned in a patent, and how to question one's collaborators' results politely without open conflict or accusations? The biometric device as a boundary object played an important role of establishing such dialogue between different stakeholders, allowing for a more ethical technology, where knowledge was represented, learned, and transformed. Below I illustrate what "ethics" meant practically for each subgroup in the team.

Ethics in Practice

The infants' safety had always been a core priority for the team. The device itself was a high-definition camera and the process of scanning fingers did not pose any risk to either the newborn or caregivers. The team asked a neonatal specialist about the infant development and skin peeling that they noticed. The neonatologist confirmed that skin peeling, and flaking is normal and happens during the first couple of weeks of life. There was no way to prevent skin shedding so the team had to work around that challenge and hope that infants signed up for the scan have passed the peeling stage, otherwise fingerprints were hard to record and compare. Biometricians also asked whether it was safe to clean the infant fingers and got a recommendation to use either alcohol or saline wipes. Later, the practitioners would try to use mostly the saline wipes not to dry the skin further with alcohol.

In terms of ethical considerations, for the software group ethics was about the proper storage and file privacy. Ned Claxton, a senior engineer, once said: “we can hack and cheat” and reminded the PI about a past competition where his team lost “for being too honest.” The PI responded: "this is the exact conversation we had and failed … let's be the honest team and it was a mistake." The “cheating” that they refer to means “flashing” more features that they currently have and take “fake it till you make it” approach. That meant imitating confidence and competence while they were working on perfecting the system. Such an approach was quite similar to the way a lot of practical knowledge is acquired in the tech world, where people did not necessarily know all programs and learn as they go, searched for answers online and did not often admit that they had no idea how to make something work. That way of thinking sometimes backfired as certain skills took time to acquire and that hindered the team’s progress.

For mechanical engineers, ethical usually meant safe, which translated into personal safety while using the device. It was brought up informally in comments like “don’t burn biometricians’ hands with overheating device” or “check all the sharp edges,” “make it shatterproof and easy to clean.” However, the tricky aspect of making a new technology was that not all challenges and consequences were known upfront. Oftentimes consequences emerged as the device development evolved, and definition of what was ethical developed together with the device functionality.

While for the hardware folks, ethical practice was about ergonomics and safety for caregivers, infants, and practitioners, the biometricians had a holistic responsibility for everything from recruiting and scheduling, consent forms and personal safety, compensation and training, data collection and storage. That was a long list of responsibilities, which was managed by the human factors group. The voices of the practitioners were augmented and dominant in the team conversations during the field testing. However, overall, PT was an engineering-centered team, especially at very early and later stages, when human factors subgroup and designers got sidelined and often ignored due to the central focus on technical issues, which did not allow the project to make progress. I showed the visualization of that pattern of engagement of different disciplines at certain phases of the project in Chapter IV.

Traditional design engineering work involves making a prototype, testing it, discussing it in a group and writing specifications ("Specs"), then making new iterations to pass those "Specs." For the purposes of device testing, mechanical engineering advisor Tom Moseley said they needed an expert on skin to know the material they were working with. He identified success with proper material science. For social scientists, the key to success was in immersion in the field to bring good ideas forward. Most conversations about the context of device use, necessary IRB approval, changes in the IRB, local culture, and traditions of provided healthcare - all fell on the Human Factors group. Bel Asana, who was the main biometrician and later the field coordinator, almost single-handedly had to do the initial logistics of scheduling and preparing for the clinical study. She had support from the behavioral scientist, Denny Oster and later from Roxanne González, an assistant who was a fluent Spanish speaker who helped with the testing, paperwork, and the training manual. With the start of international operations, the local team in Mexico oversaw the recruitment and enrollment. However, all data processing was moved across the border back to the lab. Personal safety of the practitioners inside and especially outside the hospital who had to frequently cross the border has been discussed at the team meetings. PT agreed on a set of rules, which included, for instance, always travelling in pairs and having a backup of a back-up on micro-USBs, in case they were robbed and lost the computers with all the encrypted data.

PT had digital repositories, such as device computer assisted design (CAD) files for 3D printable device arts and fingerprint database with anonymized information about enrolled infants, which was stored in the cloud. Although such repositories should function as a shared resource, most files there required specific software to even open and a large amount of space to save and share. In practice, only few people in the team fully understood how to use all those resources and when they had to leave the team, there was always an acute problem of knowledge transfer.

Team members responsible for the software component of the device would oftentimes focus only on making changes to the computer and necessary image capturing and saving processes. For biometricians in a hospital, the device was both the hardware and software package, where the form and function were equally important. Thus, when either the physical device or the accompanying software was not in sync, this meant the workflow collapsed, since biometricians were not fully aware how to fix the system. At first, during the tests in the lab, all engineers were stopping by to check the process and help troubleshooting on the spot, yet in the hospitals there would usually be only one mechanical engineer, who might not always know how to fix the software issues. The fact that the software group never fully participated in the field testing meant that over time those using the device were increasingly alienated. Eventually, hardware engineers and human factors groups would become allies in trying to negotiate with the software sub-group.

This never ended up in hostile arguments during team meetings or in an open confrontation but, in general, there would be less friendly banter and more formal interactions, complaints, and problem mitigation through the PI and Project Manager.

The most standardized methods, which were mutually understood, related to the actual fingerprinting sessions as more team members participated and witnessed the actual testing and Bel Asana together with other members of the Human Factors subgroup created a manual, which explained the procedures and terminology. The technical side of the project was never fully circulated as it was not deemed necessary for everyone to know the details. As the PI would often say "let's take it offline" in the weekly team meetings, trying not to overburden everyone with technical details as he saw them as a waste of everyone's time. Although there were public Slack channels specifically dedicated to hardware and software, they were not quite recording all important documents and details consistently. In January 2019, the project manager created a public channel called "publications" specifically for the latest versions of reports, presentations, and both internal and external documents, none of which have been fully implemented.

All big picture changes and processes were best explained in the presentations and updates to the funding organization. More detailed technical specifications have not yet been published by the end of my fieldwork. Overall, the team produced an open letter, a report in open access journal by the Global Scale Foundation, who funded them and one undergraduate design poster. However, to date, there has not been a formal peer-reviewed technical publication at the end of the project. The concerns with publishing were on the priority list for the team and were often brought up during team meetings. In April 2019, a lively discussion took place on Slack and during team meetings as the work began on editing an article draft. The PI wanted Cliff Sky to try high-impact journals like Lancet and PNAS, Scientific Reports, or even open access journals like PLOS One.

That effort did not come to fruition but eventually that article draft came out as a report in their funders' journal.

Ethics Knowledge Production

To consider the production of new technology, it is crucial to address the question of ethics and how it was negotiated through device design. As shown in the previous section, different subgroups had a slightly distinct understanding of ethics and how it was present in their everyday practice. Likewise, the knowledge about the device, as a boundary object, was simultaneously produced by different subgroups in the team and their collaborators both the makers in the lab, practitioners in the field both in the US and abroad. The success of PT was to merge those groups and allow cross-pollination, which led to deeper understanding of the issues at hand. However, that collaboration was developed over time and at first there was a gap between those who wrote the code, designed the device on the computer, 3-D printed the necessary parts and then assembled them together, and the biometricians who had to use the "finished" product in the field. The one trend that persisted was the device was never completely finalized or ready. It was still in the testing, or research mode when I finished my fieldwork.

There were a lot of unknowns, so the PI repeated during team meetings "I want to make sure we are moving in the right direction" and a social scientist explicitly asked, "Do we know where we are?" The team had two and a half years of collected data, but the main issue was that there had been a rapid change of devices and no formal evaluation of different modules and tops.

At first, the PI oversaw field testing and handling the infants, while the Project manager and a social scientist had to handle all the paperwork. The first anonymized test data was not standardized, simply saved by hand on a local machine and then moved to the Google Drive folder. As I mentioned before, I joined the team when they received their main funding and expanded the team. This meant that there were more people who could focus on automating the uploads and create standard operations procedures both for testing and data management. The big change and a conversation about the ethical data storage and privacy came up during two important moments in the project. The first one was when the data was moved to the cloud and when the biometrician in charge of field operations, Bel Asana, had to create a user manual and training in preparation for the first international testing in Mexico. The more people joined the team, the more standardization was required in terms of vocabulary, naming conventions, and the overall compelling device story, which explained the need for a safe, digital vaccination record for everyone.

The human factors group, which consisted of one to maximum four people in the team, was responsible for developing formal testing protocol for hospital visits, follow-ups, and lab visits. Interestingly, the team originally planned to save grants, budgets, and papers on DropBox, and to use Google Drive for collaborative docs. Record keeping, however, was always problematic mainly because of rotation of personnel and rapid changes in the device. The human factors subgroup, nonetheless, tried the most to organize and document all changes by keeping journals, slide decks, and memos.

At PT the engineers' voices seemed more prevalent because there were more engineers in the project during all stages of the project. Also, the PI saw the device as an engineering challenge, and without a working device one could not go to the field. A lot of insight was already gathered at the early stages of the project, yet it was not technically feasible. In retrospect, this was the biggest challenge for the whole team as it is hard to continue work as usual when you know what needs to be done but it's not being done. It became clear soon that a bulky computer and cords attached to the device were not ideal for the hospital setting, where biometricians had to handle infants. The team brainstormed a solution and managed to get a small portable table on wheels to carry around for the equipment. For easier use for the practitioners, the device had to go wireless. However, it was easier said than done and although the insight was there from 2016-2017, by 2019-2020, it had not yet been implemented.

During test sessions, biometricians required an identifier to know where the captured print of the right quality was stored. The basic human-centered design rule is to let the user know about the progress and marking of successful entry. It was also known from early on but still not implemented. The gap being knowing what is right and implementing it resulted in predictable tensions of one group not seeing their recommendations being acted upon and the other group feeling the pressure of underperformance. Usually, it was easier said than done and, in the interviews, some team members associated roadblocks with the lack of the right people to solve the problems.

That critical realization of absent necessary expertise was summarized by one team member in the following way: “let's say you want to fly a plane, and the pilot is missing, you know, our pilot keeps missing and you hire a truck driver to fly a plane …” That disconnect between the lack of training and necessary skills was one of the “glaring problems” in PT. The team relied heavily on university students as temporary workers and software specialists who would come and go every couple of months. Students not only needed training and supervision, but also had very limited time for work outside school duties. The professional expertise and the change of personnel not only affected the time required to make changes but also made it harder for the core team to coalesce, share responsibilities, and discuss ethical concerns collaboratively.

On the technology side, the team deliberated on whether to use feature extraction or machine learning for fingerprint matching and recognition. However, a senior computer scientist advisor emphasized that the number of examples was so small that the latter option was impossible. The PI insisted on doing more research about machine learning with sparse datasets and created a separate public channel for the deep learning discussion in May 2017. Some attempts of further investigation were made by temporarily hiring a data visualization specialist, Francisco García. He wrote in the Slack public channel: "Once I have SfinGe [Synthetic Fingerprint Generator] then it'll be straightforward to train a NN [neural network] since I can 'input' several variations of the same fingerprint and train the NN to extract the minutia which SFinGe also provide (ground truth). Then I'll move to train with [PT] database." The challenge was that the team could not get access to SfinGe software and that hindered the whole process. That proprietary software was created by the researchers at the University of Bologna, and just as with the matching software of MegaMatcher, PT did not have enough resources to hire somebody to design their own system. When the temporary machine learning expert left, nobody in the team could and frankly wanted to learn how to engage with yet another proprietary software.

In August 2017 team meetings were attended by 12-16 people and at the center of the discussion were the choice between the contact and non-contact devices, different tops, and preparations for fieldwork in Mexico. The first two decisions meant ensuring ethical scientific research and finding evidence to make a transition one type of the device and to prove that a certain configuration was the best. The latter topic required solving the question of secure data collection and storage across borders. The team decided to use the cloud and back up data on password protected USB-sticks. The choice of a particular provider was decided in the following interaction between the Project Manager asking the software lead in a team meeting on Aug 23, 2017 about the reasoning behind a specific cloud service:

Q: "So … Atlantic[38] web services … why use them?"
A: "If they go down, we all go down"

Nobody commented or questioned that decision. Later, however, some team members reflected in individual interviews that there was always personal preference about which systems, providers, software, hardware the team bought and chose to use. Clearly that meant that as people changed in the team, so did the programming languages, computers, and information architecture, which required a new cycle of retraining and expenses. The most noticeable space for a constant change was software and it required constant re-training and re-adjusting. The issue was that there was no standard for equipment and providers for infant biometrics research so the team would try different solutions and buy the new equipment and licenses requested.

As I have mentioned before, the disciplinary boundaries at PT have been blurred and fluid. The relationship within the team was often built on a strong connection with the PI and informal interpersonal relationships. Previous studies of office spaces showed that experience of "family-like workspaces" often relied on "expectations of continuity," and social rituals of trust and support which would "promise continuity" (Letkemann 2002, 264). At PT, on the one hand, there was no formal guarantee for continuity because nobody knew whether there would be any continuous funding. On the other hand, the PI assured the core of the team informally that they would stay on board and be employed. Temporary funding led to disruptions in the workflow as team members who could find a more secure position would switch to more permanent jobs.

In the interviews, both the PI and other team members mentioned that they were "losing team members to better jobs," which provided more financial security and long-term employment. However, the PI emphasized that there were no hard feelings around people leaving the group.

[38] Pseudonym

Nonetheless, slowly but surely, as bonds with the PI weakened, more team members chose to find more stable jobs elsewhere to support themselves and their families. The feeling that some people would come and go led to more repeated work interruptions as new members had to catch up but at the same time required some level of formalization when core members had to transfer their knowledge. How much the logistics and motivation would be explained and shared? How much practice would be lost? There is no clear answer to those questions; however, we know that in terms of the team's priority on the mechanical device there would be a necessary transition. In terms of the human interaction with device and biometricians' observations, those were documented and shared in a form of a training manual. However, data processing, matching, and publishing stayed as an open question.

What happens if the fingerprinting device does not recognize a newborn and no fingerprints could be recorded? The team had discussions about that possible scenario. In September 2017, the PI requested to buy a card printer and was excited to steer the team's efforts in a new direction of designing vaccine cards. He gave a task to the industrial designer, Terry Better, to develop several layouts and asked the whole team for input. He envisioned the card with a little barcode on the corner, so a caregiver could check the information on the card by scanning the barcode with the device. It would open a file for that kid with their vaccine history. Thus, one could either identify an infant by scanning a card or fingers, and if it was the first visit, provide a card upon enrollment. The Human factors sub-group created a slide deck to keep a record of the research on creating those vaccine cards, which were named Global Vaccine ID Cards. They first showed the existent printed vaccine schedules used at their fields sites, recommended by the World Health Organization (WHO) and across different countries. For example, an initiative by South African

National Department of Health called MomConnect[39] aimed to support maternal health through text messages by connecting pregnant women and new mothers to services and information. That initiative was truncated by the funders who asked the team to focus on their primary goal of making a reliable fingerprinting device and not spend time fiddling with card designs.

Even though external justification was never discussed explicitly, biometricians collected testimonials from the hospitals and shared them with the team. Those were usually quite positive and optimistic stories, which showed how their device could be helpful. A particularly powerful testimonial included a story about a woman, who came into the vaccine clinic saying she was robbed and lost all her papers. She wanted to know how to get a new vaccine record card for her baby. She was very upset because she didn't remember all the vaccines her baby had gotten. The nurses did not keep records for each individual child they vaccinated. They had a paper log for each day where they listed the infants that came in and what vaccines they received. However, the nurses were saying it would be impossible to go through all their paper records from each day to find this baby's vaccines. Eventually the nurses sent the woman off to the Registration to get a new card.

The team never addressed the vaccine card application or infant biometrics outside of the healthcare application, yet one biometrician shared a story how other people reacted to the proposal. She wrote in a public Slack channel: "… US border patrol officer was excited about the idea of infant biometrics. He was saying the only way they can tell if the baby belongs to the parents is to keep them for a while and observes the baby's behaviors and how they react to the parents. I couldn't really tell if he was actually that excited about biometrics, or if he was just flirting... either way, we have PT supporters at the border." That story was met with enthusiasm in

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[39] Praekelt.org. MomConnect – Maternal Health Program. www.praekelt.org/momconnect. Accessed Jan 26, 2021.

the team, although team members expressed that it was “not so good for the people affected.” The team would not be collaborating with law enforcement, yet they followed and reposted in their Slack channel the news reports, which had anything to do with fingerprinting children, borders, and government regulations.

In person-centered interviews, all team members referred to the machine learning stint as well as physical vaccination cards designs, palm scanning, and ear photos as false starts and failed attempts. However, machine learning was used by their competitors and required more time, strict data collection protocols and a designated group to take responsibility for that aspect of development. The funders did not support further research into palm scanning, ear photo recognition and vaccination cards as they wanted PT to focus on fingerprinting newborns. Nonetheless, the vaccine card project from October 2017 seems even more relevant in 2020-2021 during the global pandemic, when different governments discuss the possibility of COVID-19 immunity passports and vaccination certificates (Phelan 2020, 1595). It also demonstrates that the team had certain concerns and wanted to include both more biometric markers, automatize the process, and have more ways to identify an individual.

Lessons Learnt and Lessons Published

In an open-access paper for the funders in 2019-2020, PT concluded that a non-contact imaging method worked the best for newborns and toddlers. Overall, they reported a comparison of two contact-based (frustrated total internal reflection (FTIR) and non-FTIR direct imaging) and one non-contact imaging approaches. That paper focused on design strategies, failure modes, and shared insight for future development of infant-centric biometrics. Therefore, that document was particularly interesting to include and look for the ethical discussions and considerations suggested by the team. PT emphasized that they used human-centered design approach, citing the IDEO toolkit, a guide from a design company, which advocates for early stakeholder engagement, co-design, problem reframing, iteration and prototyping (IDEO 2015).

Several major concerns in summer 2018 centered around inter-operator consistency, when the team provided instructions to the local biometricians and at first the performance dropped as different people started using the devices. While the PI lamented about being “under-resourced,” he suggested running micro-experiments in the field to compare device modifications. However, biometricians had concerns as there was no guarantee that infants would be calm and cooperating. A miscommunication about Subject IDs caused problems with the data base. The major difficulty happened because of the personnel transition, both in terms of the core team members leaving and explaining to somebody who had to take over their work. The Project Manager, Ann Hughes, and the lead systems engineer, CJ See, were both concerned about the knowledge transition. CJ See noted that as Co Ling was leaving, his part of work and automation had to be discussed and understood by the other engineers: "once it [process of data analysis] goes behind the scenes, people don't know it … I want Cliff Sky and Ned Claxton [to] understand that the bulk of work is going to shift." This episode illustrates how, even at the early stages of biometric development, many crucial processes become invisible for the majority team members and depended on certain individuals.

How should one use technology responsibly? What are the consequences of enrolling infants at birth? Those topics were not a part of the official agenda and not discussed as a group directly; however, among the team leadership there were some side comments of collaboration with healthcare projects and applying for development grants but not working with the law enforcement. As mentioned above, this topic was never fully discussed as a team but touched upon in one-on-one conversations among team members, which I learnt about during individual interviews. It felt that one had to defend the project legitimacy and benign intentions to the outsiders but inside the project it was presupposed and not frequently challenged.

One important part of the engineering world is technology demonstration, known as a demo. Tech demos are prototypes, incomplete versions of future systems, put together as proof of concept to show the possible applications, performance, and feasibility of designed technology. Demos could be challenging team ethics as well. After the proof-of-concept stage, the team got the funding for their work, and in November 2017 they had to present their early results. PT faced a moral dilemma of choosing either form or function as they did not have time to complete the fully functional system, so they just demonstrated what it would be able to do when finished. They used “The Wizard of Oz” tactic known from the 1980s, which has been widely used in Experimental Psychology, Human Factors, Ergonomics and Usability Engineering (Kelley 2018, 119). The distinct feature of this method is that an experimenter, who is the "Wizard," simulates the behavior of a computer program or application. Thus, the person who is testing the device gets the whole experience of capturing fingerprints, enrollment, and identification, yet it is all done manually behind the scenes by a computer scientist.

In August 2018, the number of enrolled infants reached 324 and the cap was set to 500 by November. How did the team decide on the number? It was based on available resources to pay the participants and one team member joked that five hundred was a nice round number. There was still misalignment on who was going to the field to join the local recruiters and biometricians. While Bal Asana and Roxanne González were working on the manual, Denny Oster was talking about writing a paper about that process. Neither the goal of writing a paper about the manual nor the process of infant fingerprinting ever came to fruition.

Why Was It Called a "Success Story?"

Despite all difficulties and unresolved questions discussed above, in several design and research meetings and formal presentations at their home university, PT and their device prototype were referred to as a "success story." The group neither extensively published, nor gained fame among the broader public or scientific community. They did not formally reach the market, so why would that be a success story? They managed to achieve tangible results and conduct field studies despite changing personnel, relatively limited funding, and socio-economic difficulties and shortages of vaccines at their testing sites. However, the main achievement that they were praised for and actively cultivated themselves was the idea that the core team members developed empathy by immersive experiences in the field. Thus, engineers engaged with practitioners and acquired skills to be more human centered by watching other people work and then participating in the process. Only then did it become clear how losing a day of work because of new feature failure was quite a painful experience. It also became evident why the device should be resistant to environmental pressures and easy to train and to use in a clinical setting. As one social scientist noted in an interview that participating in the field sessions brought all the great ideas and solutions, which were grounded in everyday practices.

Conclusion

In this chapter I described practical ethical considerations in a developing field of infant biometrics by looking how the process of device creation and implementation unfolded over time. I revisited the analytical concept of boundary object, which included looking at the device formation from different disciplinary understandings of ethics, which together contribute to conceptualizing possible biometric futures. A closer look at those discipline-specific understanding revealed how each sub-group acted within their "ethical boundaries," yet they had to be merged in one device, which had to be both physically safe but also socially integrated into hospital workflows. The team planned but never fully published all their findings, mostly because there were other project priorities. The high rate of employee turnover, mentioned in the previous chapters, made the knowledge transfer quite difficult and dispersed the responsibility for the database management, collected images, the procedures, and the device hardware. Despite the shortcuts and limited funding, the project always had a healthcare focus and several committed core members. In a hindsight, it was a miracle that any work was done and so many fingerprints were collected, despite external difficulties like vaccine shortages, political and environmental instability at potential field sites, among other factors.

Chapter VI. Conclusion

"Technology is neither good nor bad; nor is it neutral."[40]

Epilogue

Pediatric Technologies "evacuated" the lab on March 21, 2020, as they themselves recalled during one of the online weekly meetings. The team kept on working remote, as they received some new funding in winter 2020 just before the global pandemic started. They recruited four new members to add to the team's core of five people. New members included one mechanical engineer, who previously worked in the same building called Matt Freeman. He was a jokester, the one who would often say out loud the uncomfortable truths. Then came an intern Sol Silvestri, an undergraduate student who volunteered to do UX design and gain hands on experience with a real-life project. She had to advocate for the design work and collaborate with the newly hired back-end engineer Zhang Smith**.** The latter did not end up having strong interpersonal connections with anyone in the team. He was paid certain hours, never really engaged with the team but fulfilled his contact work, which was later criticized. There were several instances both during the online meetings and on Slack where team members wanted to find the results of his work or access the latest versions, which were still far from the team's expectations. Somehow Pediatric Technologies had no luck with software experts and Zhang Smith soon left the project. On the other hand, Vihaan Parker, who was an applied mathematician and a friend of the PI, quickly became a core member and stayed with PT, mostly due to the direct close personal connection to the PI.

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[40] Kranzberg, Melvin. "Technology and History:" Kranzberg's Laws"." Technology and culture 27.3 (1986): 545

While this dissertation was being written, the world and the nature of individual and collaborative work changed dramatically. Many argued it would never be the same. The pandemic of a novel coronavirus COVID-19 announced by the World Health Organization changed everyone's lives across the globe. A new respiratory disease spread from the Wuhan province in China and became the center of attention when hundreds of people got infected in Italy after a fashion show. It suddenly became a significant topic across different media as Europe started to close borders and struggled to have enough respirators and hospital beds for everyone. Nobody really knew how to treat the disease apart from isolating individuals and advising them to rest. The spread of the virus to the USA meant each state had to decide on restriction measures. That was a very interesting time to be living and experiencing such an event, especially when future vaccination programs and treatment solutions had to scale up globally.

While being lucky not to be fired, team members struggled through a period of adjustment to the new work environment. I kept in touch with the PT and followed up on everyone's well-being and organized virtual happy hours events to chat with everyone. CJ See was staying at home and he mentioned that his family was "saving on gas and eating out," while he was doing more focused and productive work without being interrupted; however, he was missing people and team sports. For others, like Cliff Sky, it was harder to tolerate restrictions as most of his hobbies involved outdoor group activities, which were prohibited.

At the start of the pandemic my flight from Moscow back to the U.S. after a spring break got cancelled. While I was examining multidisciplinary teamwork at PT, the news about ID 2020 initiative to use biometric identification reached Russia and was linked to all kinds of conspiracy theories. A well-known Russian movie director recorded a TV show episode linking biometric technologies with Bill Gates and his demonic plot to insert microchips into humans while offering them treatment for COVID-19.[41] That hoax became a media sensation, especially when the episode was postponed, which prompted the above-mentioned media personality to complain loudly on social media. He argued that his point of view was censored and encouraged his online followers to spread the word about the injustice and the threat of "Gates' microchips." Similar conspiracy theories emerged simultaneously in the English-speaking media as well. As the world was paralyzed because of COVID-19 and the lockdown, there was even more urgency on the educational fronts as many people lacked internet literacy. Depending on their social media activity, members of the public could get an enormous number of non-scientific publications and click-bait articles poured into their news feed.

Later, amid the pandemic in summer 2020, I managed to return to the US but there were no tests available for asymptomatic patients. However, by the Fall quarter, the university campus provided access to wider testing and designed very convenient self-testing facilities for university students and employees. That allowed some researchers to return to the lab, reserving spots in advance by adding their names to a waitlist for lab visits. In such circumstances, personal visits or device testing in hospitals were out of question, but PT had a lot of data to parse from the past field seasons. Starting winter quarter 2021, vaccines became widely available and there was a promise that soon everyone could return to their workspaces and start meeting in person again. Many core members of the team had moved on with their careers and by Spring 2021 the original Pediatric

[41] Билл Гейтс заявил, что хочет имплантировать микрочипы в каждого человека, чтобы бороться с болезнями. www.zen.yandex.ru/media/mir_chudes/bill-geits-zaiavil-chto-hochet-implantirovat-mikrochipy-v-kajdogo-cheloveka-chtoby-borotsia-s-bolezniami-5e81f0601a056b3af3dad9c9. Yandex Zen. Accessed April 5, 2021. Published March 30, 2020.

Technologies team ceased to exist; however, their work will probably be continued in the upcoming years.

Chapters Summary

In the Introduction, I state the central research question of this dissertation, which is concerned with the everyday work of creating biometric technologies. I describe my research methods, project background, its multidisciplinary nature, and my role in the project. Following that, in Chapter II, I lay out the background for the field of infant biometrics, its historical precursors, and the development of biometric recognition in general. I describe a hospital field site, testing environment, and current fingerprinting procedures. I identify the concern about algorithmic matching, which is often brought up as a root cause for unintended negative consequences of biometric systems (Wickins 2007; Magnet 2011). At PT, both the feature extraction and verification get outsourced to the 3rd party provider and later are problematized by the team members themselves.

In Chapter III, I focus on the concept of boundary objects and explain why it is useful in making the biometric device. For example, the boundaries between formal membership, discipline-specific vocabulary, and technology barriers, all got reflected in and centered around the physical device. In tracing the backstage of the everyday work on an infant biometric device as a boundary object, I focused on parsing the social meaning of the device for different subgroups who worked together on that technology. For the engineers, for instance, the device meant certain materials, specs, and a constant work on light, shape, and proper coordination with the software. For those in charge of image processing, the device itself was a conduit that enables them to do the analysis, a tool that would capture the necessary data. For the human factors group, the device allowed them to be successful at their job of recruitment, field operations, and build a relationship with caregivers. It did not really matter which device modification was used if it worked properly. I also discussed the role of the leader, echoing some observations from the research on leadership in innovative projects, which often have a default state of uncertainty. Personal social networks seemed to have played a key role in Pediatric Technologies as every active team member had a personal link to the PI and if that relationship was broken, people did not stay in the project for a long time. Bringing people in the project equated with personal connections, centered around the group leader who had a very particular sense of humor and ability to engage people in such project.

Chapter IV, which, as mentioned before, was published earlier as a separate article (Azarova, Hazoglou, and Aronoff-Spencer 2020), turns to the digital footprint of the team itself to compare the team's online and offline interactions. When one has an ethnographic context, it is possible to find how certain behaviors and trends get reflected online, for example the centrality of the PI for the team and the difficulty to choose which Slack channels to post in. The biggest limitation of the virtual portrait was that with time, the closer the team members worked together, the less time they spent explaining and discussing issues in public channels on Slack. Moreover, the emphasis on improving efficiency based on data, often backfire, as shown in some recent studies of the biometric identification system implementation where online activity tracking through online dashboards, set-up for transparency, actually contributed to "audit regime" and produced "performance of management" (Solanki 2019).

In Chapter V, I analyze the potential biometric future through the critical lens of biopolitics, showing the ethics of knowledge production at PT, and reflect upon the unintended consequences of infant biometrics. From previous studies, we know about the potential implications of system flaws in regards to privacy and surveillance, which currently arise from the government-led initiatives of incorporating biometric systems in South Africa (Breckenridge 2005; Gelb and Clark

2013), India (Jacobsen 2015), Kenya (Weitzberg 2020), Estonia (Martens 2010), Turkey (Bozbeyoglu 2011), China (Zhai and Renzong 2010), and other places. The concluding Chapter VI reiterates my main argument about the backstage of multidisciplinary collaboration, the significance of everyday interactions, and the uncertainty of technology development stage. It suggests some contributions of this research and opens a broader discussion about avenues for future studies.

Beyond the "Good" Prints

My longitudinal fieldwork with Pediatric Technologies allowed me to record a gradual change in the team and to show how the principles of human-centered design approach slowly formed multidisciplinary collaboration within the team. I witnessed the early development and formation of principles surrounding a new biometric technology and, similar to a much larger biometric identification project in India (Cohen 2019, 482), the central role in the process that was played by engineers. However, at PT, the biggest internal change happened when the engineers started to spend more time in the field with the practitioners. At first, some mechanical engineers occasionally helped with sessions and attended just to troubleshoot on the go if the device stopped working. Later they got IRB approvals to conduct sessions by themselves to test new devices. That was the key change in the everyday work that distinguished Pediatric Technologies and, arguably, allowed them to successfully finish field testing in the US and abroad.

This dissertation draws upon and contributes to continuing discussions in three literatures: Anthropology, Science Technology and Society (STS), and design studies. In contemporary multidisciplinary teams, especially the smaller ones, the borders between disciplines and specializations are blurred before all processes are standardized and optimized. People are often expected to learn as they go. At Pediatric Technologies, team members hired as engineers became biometricians and worked with infants and caretakers. In such hybrid situations, there was no traditional transition as observed in previous ethnographies, for instance between the civilian and military, academic and non-academic, hospital and non-hospital contexts (Bourdieu 1988; Hutchins 1995; Van der Geest and Finkler 2004). Such fusion plays a significant role in nurturing hybrid disciplines, methods, and a need for ethnographic research, especially in the field of technology development.

How could one ensure learning the value of other roles, especially when not all work was visible? Is it realistic to teach and make explicit the value of different fields? While expressing gratitude to collaborators is a regular practice, it is often rare to hear in teams that members would thank each other or emphasize the expertise of the other subgroup. At PT, both the team leadership and individual members made such effort, which solidified the relationship among the core members. Based on day-to-day team interactions online in Slack, we could even illustrate how the multidisciplinarity developed during different project phases.

In a context of using the machine learning to match fingerprints, the PI asked: "Is this the right direction? Other ideas on approach?" The team answer was that "we need to close this before starting something new." The PI often posed such questions about the goals and overall direction of the project. Most steps were an unknown terrain, and nobody had participated in such projects before. After all, the research agenda of "fingerprinting babies" sounds scary, alarming, and discomforting to most people when they hear about it for the first time. Nonetheless, the team members who joined and stayed with the project believed that they were working on a good cause and an interesting challenge. Some explicitly mentioned in the interviews when describing the project that they only agreed to participate because the PI asked them personally, and that they believed in the high ethical standards of their colleagues and the PI himself. That demonstrated how certain high-stake multidisciplinary projects, often funded through networks of collaborators, often depend on the personal traits and leadership style of the principal investigator.

The use of the boundary object framework, which came from STS studies, raised a question of the kind of worlds the device occupied. For PT, the device belonged strictly to the world of biomedicine and technology, hospitals, and trained practitioners. I examined how different subgroups in a multidisciplinary team saw the device, from their disciplinary ethics and a set of requirements. A natural next step for future research would be to record the role of the device in the lives people outside hospitals and clinics. There are other interesting questions, beyond the scope of this dissertation, which I did not address. For example, the reasons why people wanted and agreed to participate, possible domestic use for similar devices, like the scales and thermometers many parents would have at home. If, and when, this or similar infant biometric devices reaches the market, one should trace the limitations of the version that got selected, and what trade-offs were chosen during the design process. An excellent example of work on existent national biometric programs is Aadhaar in India, which demonstrated how biometric technologies inform the ideas of identity, individual, and belonging to “Digital India” (Nair 2018; 2019; Rao and Nair 2019; Nair 2021). There have been reports how, despite the official narrative of empowering the poor, the system excluded a large number of people and, by giving unique twelve-digit numbers to all residents, even potentially facilitated criminal activity (Nair 2018; Khera 2019b).

In research of biometrics, there is a continuing discussion between the design studies, often focused on technology, and an anthropological lens, often critically evaluating such interventions. What is not as often emphasized in the literature is the projectification of biometric development. One important characteristic of the infant fingerprinting project at PT was its project-based nature, which meant temporary funding, personnel turn-over, and the lack of resources. The constant trial and error, negotiation across disciplines, interpersonal tensions of team members, and at the time the lack of specific expertise, that lead to learning on the spot, which were all at the core of PT's everyday work, are often omitted in final reports.

The team's assumption, as a community of practitioners, repeated throughout team meetings, formal presentations, and recruitment materials, was that existing adult biometrics did not work well for newborns and young children, who were often left without access to reliable medical records and proof of identity. While vaccination is a complex socio-technical problem, which required input from different disciplines, most team discussions centered around the technological difficulties. Why did that happen? One possible explanation might be that the team managed to successfully solve the recruitment, field operations, the standardization of the process, and needed the device to work properly to move forward to wider implementation. Some important questions were never asked about the ethics of the future device use and misuse probably because it was never fully ready, still in the "research mode." This observation is important for both the social scientists, designers, and engineers who would work in multidisciplinary teams together on similar problems. When and how the research mode ends and what questions are suitable for what stage of the project should be discussed throughout the project.

The processes within the team Pediatric Technology provided a specific case of a much broader trend of multidisciplinary teamwork in biomedical devices for global health applications. Team members believed in the good cause of solving the vaccination gap and providing access to vaccines, even if people did not have necessary paper documents and ID cards. However, as the saying goes, "a road to hell is paved with good intentions." More generalizable findings bring forward the collision of the engineering "research mode" and the role of social scientists, who should participate in the device development and serve as a sounding board for the applications of emergent technologies before they reach the market and get adopted by the governments. Earlier articles like "The Aadhaar debate: Where are the sociologists?" (Khera 2018) and "India as database: Response to Reetika Khera" (Cohen 2019a) have argued for the urgency of ethnographic research of new biometric systems used by the governments, the challenges of such research, and the new opportunities it opens for social scientists.

Fingerprinting has traditionally been used by the government in coercive environments, and most often international borders, restricted areas; the dystopian novel 1984 come to mind. It is a valid concern to be vigilant about state efforts of enforcing any new registration and identification requirements. However, by 2021, millions of people volunteer to use smartphones which unlock using facial recognition or fingerprint scanning, create new entertainment content by using filters and frames augmenting reality (e.g., Instagram, TikTok, Snapchat, FaceTime, etc.). Rapid development of technology is something to be concerned about, especially with the growing potential of all the powerful news tools ending up "in the wrong hands" or being misused. That amplifies the role of humanities and social sciences to discuss and explain to others the possible unintended consequences of all new technologies that emerge.

Overall, the association of fingerprinting with biopolitics, surveillance, and criminality is still quite strong. Back in 2004, an Italian philosopher, a well-known theorist, Professor Giorgio Agamben, rejected an invitation to teach at New York University in protest against fingerprinting, required by the U.S. for all international travelers entering the country (Arenson 2004; Agamben and Murray 2008). He explained that it was not a question of his personal sensitivity but a concern about a biopolitical status of citizens, government manipulation of bodies through biopolitical tattooing, which leads to "the progressive animalization of man" through technology (Agamben and Murray 2008, 201). Indeed, the "new 'normal' biopolitical relation between citizens and the State" (Agamben and Murray 2008, 202), which Agamben is opposed to, has since developed even further.

In my work, by showing the nuanced process of developing one of those technologies, I want to animate an idea that such technology could be benign, and we could influence its application if we participate from the earliest stages of the design and implementation. Note that when the team was finding an infant with no longitudinal matching who "failed on all fingers and palms," they talked about "bad prints" and device errors. They never associated those good or bad prints with greater debates about biopolitics, surveillance, or body politics. They always advocated for a back-up identification and spent some time designing a plastic vaccination card, which caregivers would have as an alternative form of authentication. Nonetheless, one of the most widely spread unintended consequences of any biometric systems failure is that exact problem of excluded population that could not be scanned or have "bad prints." Therefore, the discussion of biometric technology integration should always be more than a technical problem but a design challenge that requires a robust back-up system built based on ethnographic data of each specific region.

Some scholars directly express a concern that biometric registration at birth equals liquidation of US democracy itself (Gates 2008). My personal opinion opposes that point of view and I find it difficult to completely agree with a statement that "there is something that seems inherently authoritarian about the state's effort to make bodies machine-readable, capturing them with scanning devices and storing their digital representations in a database" (Gates 2008, 211). Nonetheless, there is certainly a space for discussion and setting boundaries when the "research mode' becomes surveillance, mining user data, and monetization. Based on my fieldwork, the first database, scanning devices, and the creation of machine-readable formats is often not discussed among the disciplinary specialists that build them. All those procedures, formats, and devices are also inherently human, as they are planned and executed by people during their mundane interactions, filled with human errors and assumptions. I am struggling with the entanglement of both the history of governments and the medical field using technology to criminalize and discriminate against certain groups, and, on the other side, the daily work of people who make such devices.

Finally, any scientific advancement comes with a set of trade-offs. The textbook examples include electricity – it is good at home and as a source of clean energy, but an electric chair is a questionable use case; an automobile has allowed people to travel and be more mobile, yet an incredible number of people die in car accidents while gas and diesel pollute the planet. The same thing happens with fingerprinting, which by itself is not a new technology. A device specifically designed for infants is a combination of known techniques in 3D printing, optics, and data management in a novel way. Is infant fingerprinting going to move us closer to a surveillance state and make certain populations even more vulnerable, or it is going to close disparity gaps and allow more people to get access to reliable medical records and better health care? The choice is ours, and both of those points of view are supported broadly by the engineers on one side and social scientists on the other. In this dissertation, I explored the visions and practices of a biometric project long before either the "elite consensus was manufactured" (Khera 2018, 339) or the technology started to affect individuals' ordinary experiences. How will such technology be designed further, produced, and regulated, all depends on us and the choices we make. One way multidisciplinary groups could coalesce around such complex ideas is through framing the boundary objects in their projects that would allow them to come together and innovate across disciplinary boundaries.

To conclude, I summarize the generalizable findings of my project in the three key takeaways. First, the boundary objects framework is a very useful tool to understanding multidisciplinary teamwork. Everyday work practices produce boundary objects, which change through time and often define the results of multidisciplinary team efforts. Second, the research mode is an important phenomenon. In engineering teams, members refer to a period of exploratory and creative work as the research mode. In my work, I bring attention specifically to the disciplinary division in the understanding of ethics, which happens during the research mode. Based on the most recent studies of Aadhaar national identification system, there are several further issues, which arise when biometric solutions get employed "as is" on a larger scale without proper transition from the research mode. Third, online collaborative tools, like Slack, offer a crucial lens on contemporary teamwork but alongside a promising potential for democratizing work, analytical data from online applications comes with several caveats. By comparing the online and offline interactions in the multidisciplinary team, we found that many generalizations could be harmful if used without a proper ethnographic context.

Appendix I: "I have no use for regimental odes …"

Anna Akhmatova. "I have no use for regimental odes …" 1940. Translated by A.Z. Foreman. Poems in Translation. www.poemsintranslation.blogspot.com/2009/09/anna-akhmatova-i-have-no-use-for.html. Accessed February 10, 2021.

English (Translation)	Russian (Original)
"I have no use for regimental odes …"	**“Мне ни к чему одические рати …”**
I have no use for regimental odes, Or the impassioned elegiac hoax. I make my verses quite beside the point Made by the just, plain folks. I wish you knew the kind of garbage heap Wild verses grow on, paying shame no heed, Like dandelions yellowing a fence, Like burdock and bindweed... An angered yell, the bracing scent of tar, And walls with runic mildew like a sign... And soon a tender, testy poem answers To your delight and mine.	Мне ни к чему одические рати И прелесть элегических страстей. По мне, в стихах все быть должно некстати, Не так, как у людей. Когда б вы знали, из какого сора Растут стихи, не ведая стыда, Как желтый одуванчик у забора, Как лопухи и лебеда. Сердитый окрик, дегтя запах свежий, Таинственная плесень на стене... И стих уже звучит, задорен, нежен, На радость вам и мне.

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