Being, Having, Doing, and Interacting: A Personal Informatics Approach to Understanding Human Need Satisfaction in Everyday Life

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ABSTRACT

A grand challenge for computing is to better understand fundamental human needs and their satisfaction. In this work, we design a personal informatics technology probe that scaffolds reflection on how time-use satisfies Max-Neef's fundamental needs of *being, having, doing,* and *interacting* via *self-aspects, relationships and organizations, activities,* and *environments*. Through a combination of a think-aloud study ($N = 10$) and a week-long *in situ* deployment ($N = 7$), participants used the probe to complete self- aspect elicitation and Day Reconstruction Method tasks. Participants then interacted with network visualizations of their daily lives, and discovered insights about their lives. During the study, we collected a dataset of 662 activities annotated with need satisfaction ratings. Despite challenges in operationalizing a theory of need through direct elicitation from individuals, personal informatics systems show potential as a participatory and individually meaningful approach for understanding need satisfaction in everyday life.

CCS CONCEPTS

• **Human-centered computing** → **Empirical studies in HCI**; **HCI theory, concepts and models**; **HCI design and evaluation methods**; **Empirical studies in collaborative and social computing**.

KEYWORDS

personal informatics, quantified self, everyday life, day reconstruction method, design for the self, human need, Max-Neef, multiple self-aspects framework, think-aloud, technology probe, personal and visual analytics, network visualization, reflection, sustainable consumption corridors

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1 INTRODUCTION

Understanding human needs and supporting satisfaction of those needs is a central challenge in computing [82, 101, 105] and other fields including psychology [111], development economics [74], and environmental sustainability [104]. Our interest in contributing to this ongoing dialogue is animated by a overarching interest in sustainability; that is, in helping society to "meets the needs of the present without compromising the ability of future generations to meet their own needs" [86], by better understanding "how human needs can be provisioned equitably and sustainably within biophysical limits" [104]. However, progress in this endeavor is challenging, largely because there is significant uncertainty about how to operationalize the many existing theories of fundamental human needs [25].

The many theories of need have led to a diversity of methods for assessing needs and need satisfaction, including psychological instruments [15, 26], community workshops [59, 75], and analysis of large datasets [29, 106, 112, 113]. However, there is a lack of scalable methods for directly eliciting need satisfaction from individuals in the context of their daily experiences.

By design, personal informatics systems can be participatory [100] and scalable [38], and they have the potential to shed empirical light on how individuals experience and satisfy their needs. In this paper, we investigate the use of personal informatics systems for understanding human needs and their satisfaction in everyday life. We design, deploy, and evaluate a reflective technology probe that enables individuals to collect and visualize data on need satisfaction, grounded in time-use in daily life. This approach aims to address the challenge of operationalizing theories of human need and provides a method for understanding how individuals experience need satisfaction in daily activities.

While personal informatics systems have been developed in the domains of physical health [65], mental health [13], productivity [57], and more. However, the application of such a system for directly assessing the satisfaction of fundamental human needs remains largely unexplored. Our work seeks to address this by posing the following research question:

- **How could a personal informatics system support data collection, visualization, and reflection on need and satisfaction in daily life?**

To explore this question, we used a mixed-methods approach that combined a think-aloud study with a week-long deployment of a personal informatics system in the form of a reflective technology probe. The probe uses McConnell's multiple self-aspects

framework [76] and Kahneman's Day Reconstruction Method [52] to scaffold data collection across the four existential categories of human need suggested by Max-Neef [74, 75]: *being* (aspects of the self [76]), *having* (people and organizations), *doing* (daily activities), and *interacting* (locations). In the think-aloud study, $n = 10$ participants completed a series of tasks using the probe while thinking aloud their thoughts, helping us to understand how individuals think about how their daily activities meet their needs. Seven participants continued with the deployment, collecting need satisfaction data about their daily activities for up to one week, in addition to a closing interview where they explored visualizations of their data and reflected on their experience of using the probe. This combination of methods allowed us to gain insight into how individuals completed the specific tasks scaffolded by the probe and how individuals engage with need and satisfaction data over time.

The expected contributions of this work include the following:

- Developing and evaluating a personal informatics system for collecting and reflecting on data about the experience of need satisfaction in daily life.
- Identifying challenges and opportunities in operationalizing a theory of need based on a think-aloud study.
- Publishing an anonymized dataset of 662 activities and corresponding need satisfaction ratings from the weeklong *in situ* deployment.[1]
- Providing evidence for the usefulness of new methods (the Day Reconstruction Method), theories (Max-Neef's theory of fundamental human needs [75] and McConnell's multiple self-aspects framework [76]), and visualization strategies (self-as-network) in personal informatics systems, more generally.
- Demonstrating benefits of reflection across multiple timescales of the self, including the potential for self-directed behavior change.

The organization of the paper is as follows. First, we provide background on theories of human need and the importance of studying human need in daily life, alongside current methodologies for assessing human need satisfaction. We then describe how the field of personal informatics is well suited to contribute to a better understanding of the individual experience of need satisfaction, but has not yet explored this domain. We detail the design of our reflective technology probe, and describe our think-aloud study, weeklong deployment, and qualitative and quantitative evaluation methods. Next, we describe the findings of our think-aloud study, data collected from the system, and the participant outcomes and evaluation of the use of the system. We discuss challenges in operationalizing a theory of human need, and how our methods may be useful to personal informatics system design more broadly.

2 BACKGROUND AND RELATED WORK

In the section, we briefly review existing theories of need, how HCI has engaged with theories of need, and current methods for assessing need and satisfaction. Next, we provide an overview of personal informatics before moving on to the design of the technology probe.

[1]Data is available online at https://osf.io/xnzaq/ [79]

2.1 Theories of Human Need

Perhaps the most common needs-related theory used in HCI research comes from self-determination theory (SDT) [94] and one of its sub-theories, basic psychological needs theory (BPNT) [95]. BPNT proposes that human well-being and growth is a natural inclination and largely a function of satisfaction (or frustration) of a discrete set of basic psychological needs: *autonomy*, *competence*, and *relatedness* [95, 108]. Although BPNT is commonly used in HCI research, BPNT does not attempt to describe a *complete* set of basic human needs [111]; it is limited only to psychological needs. BPNT therefore does not cover all aspects of general human need, which would be necessary for understanding what it means to live "the good life" [31].

However, BPNT aligns closely with the eudaimonic approach towards well-being [93], embodied by seeking meaning and flourishing in life, as opposed to the hedonic approach, which emphasizes positive feelings [51]. A eudaimonic approach to understanding well-being has been initially explored in the HCI community, such as by measuring the degree of eudaimonic vs. hedonic user experiences in technology use [78, 81] and in arguing for eudaimonic design considerations related to gamification [27].

While HCI research has historically had a focus on generally meeting the "needs" of users in particular contexts (such as interaction design [9] or gamification [110]), most work is not intended to support or operationalize existing theories of need. This gap has been noticed in the literature, resulting in a call for researchers to advance a "research agenda based on human needs" [82] and create a "handbook of human needs" [101]. Similarly, *collapse informatics* calls for researchers to design "sociotechnical systems with basic human needs at the heart of the process" [109].

These directions aligns with recent work of environmental scientists in their efforts to develop the concept of *sustainable consumption corridors*, which posit a minimum level of consumption necessary to meet human needs, and a maximum level of consumption, beyond which, planetary boundaries are exceeded [28, 39]. The design and operationalization of sustainable consumption corridors requires an understanding of human needs—what is needed to live "the good life" within limits [31, 42]. This deeply aligns with the OECD's goal of helping people meet needs without sacrificing the ability of future generations to meet their own needs [86].

However, there is no apparent consensus as to the constituents of a universal set of basic needs. Multiple theories of basic human need have been proposed, with needs that differ from those included in SDT. Sen and Nussbaum's capabilities approach proposes ten fundamental capabilities [84, 99], while Doyal and Gough suggest only two basic needs:*physical health* and *autonomy* [32]. Maslow outlined a list of basic needs in both his original 1943 paper [70] and his later update [71]. Max-Neef proposed a matrix of needs along axiological and existential categories [74]. More recently, Seligman developed the PERMA model of flourishing, with five needs [97], and Kaufman reimagined Maslow's hierarchy as having three security-oriented and three growth-oriented needs [54]. As Dean puts it, "[Despite its importance] need is also a concept that is interpreted in a mind-boggling variety of ways" [25]. One commonality across these approaches is that measurement should be *participatory* [25], as "effective and informed participation on the

part of the population whose needs are being assessed is vital" [32, p. 168].

A key distinction made by Max-Neef is the difference between *needs* and *satisfiers*, the ways in which needs are satisfied. According to Max-Neef, needs are "finite, few, and classifiable" [75], while satisfiers are culturally dependent and vary from individual to individual across time and space [74]. In other words, humans always have the same needs, but the ways in which they meet them changes. Max-Neef created a matrix of needs and satisfiers, with fundamental needs corresponding to the intersection of ten axiological needs (*subsistence, protection, affection, understanding, participation, leisure, creation, identity, freedom, and spirituality*) and four existential categories (*being, having, doing, and interacting*) [74, 74]. In this study, we chose to use Max-Neef's theory to ground the work for three reasons. First, it does attempt to provide a complete accounting of all fundamental human needs (as opposed to SDT's limited scope). Second, Max-Neef's existential categorization of needs corresponds well with data that could be captured by a personal informatics system (*being, having, doing,* and *interacting*). Lastly, Max-Neef's theory has a precedent for use in environmental science and sustainable consumption corridor research [11, 112], and has also been used in HCI research for collapse informatics [109] for games exploring willingness for AI to satisfy needs [56], and transition design [49, 50].

2.2 Computational Approaches to Assessing Need and Satisfaction

Scholars have approached need satisfaction using top-down and bottom-up computational methods. Vita et al. attempted to estimate the societal-level carbon cost of meeting each need from Max-Neef's matrix, using a database of 200 product categories linked to their environmental impact [112], and estimating satisfaction from a variety of 35 indicators, such as the social progress index [88]. At a level closer to the individual, researchers in natural language processing used machine learning to classify sentences from blog posts according to their related human need (drawing from both Max-Neef and Maslow's theories) [29, 30, 87]. In both cases, researchers made decisions about which needs were being satisfied, assumed the patterns of need satisfaction were uniform across individuals, and limited satisfying activities to either economic consumption or inferences from blog posts.

While future efforts to scale assessment of human need may benefit from these computational approaches, we believe it is premature to rely heavily on these results for three primary reasons. First, as we will discuss later, the satisfaction of human need is a deeply personal phenomenon. Individuals doing the same activity may experience a completely different kind of satisfaction, in both category and scale. Secondly, the data is at least one step removed from the "substance of everyday life" [62], and likely fails to capture how needs are satisfied in daily life. Lastly, as there is still no consensus on the construct of human need [25], an important first step is to seek to understand how individuals think about their own need and satisfaction before seeking automation with computational methods. These reasons help to motivate our participatory approach of using a think-aloud study and personal informatics technology probe to understand how need satisfaction is uniquely experienced by individuals, in the context of time-use and money-use in daily life.

2.3 Workshop Methods for Eliciting Satisfiers

Perhaps the closest related works are the human scale development approach (HSDA) workshops that seek to understand the set of satisfiers (both inhibiting and satisfying) prevalent in a specific community, and identify future potential satisfiers to improve need satisfaction [59, 75]. While a full review of these workshops is beyond the scope of this paper, Spiering and del Valle Barrera provide an overview of these methods and describe methodological considerations [103]. In general, the process of HSDA workshops involves three stages. The first, a diagnosis stage, involves identifying positive and negative satisfiers for each need, resulting in a current state matrix of needs and satisfiers. Second, a synthesis stage, results in groups selecting and prioritizing satisfiers. Lastly, an action planning stage leads communities to find potential "bridges" from the current set of satisfiers to an improved future state.

Our probe design is motivated by these workshops, especially the *participatory* intention—that individuals engage directly with a theory of need and have agency to describe life in their own terms. No assumptions are made about which activities satisfy which needs, or to what extent those needs are satisfied. However, our approach differs from these workshop methods in that we treat the elicitation of needs and satisfiers as a primarily individual (instead of group) exercise, and ground the satisfiers in objective time-use and money-use. In addition, our probe does not facilitate any particular change process, but simply seeks to provide a scaffolding for reflection on time use with respect to fundamental human needs, and create a complete record of time use with respect to need satisfaction. Lastly, the digital approach offers the potential to scale the collection of need satisfaction data to large populations, which is difficult to do via collaborative workshops. In this paper, we create and deploy a prototype system to elicit a systematic record of everyday life activities and how they relate to the satisfaction of basic human needs, drawing on methods from personal informatics and psychology, explained next.

2.4 Personal Informatics as a Mechanism for Engaging with Everyday Life

Personal informatics (PI) is the study of personal data collection and sensemaking at the individual level, and has been informed by the "quantified self" community [17, 69], the transtheoretical model of behavior change [89], and stage-based models of system use in daily life [37, 64]. PI systems are participatory—that is, designed to facilitate an individual's collection of data about their lives *in situ*, suggesting that they might be used to better understand how activities of everyday life support need satisfaction. Furthermore, they include affordances for interaction and reflection with collected data [47, 53] and are scalable, holding the promise of being "a mechanism for eliciting information on well-being directly from the population" [80].

Personal Informatics (PI) systems to date have primarily focused on distinct aspects of lived experiences, such as tracking fitness [20, 65], nutrition [22], mood [13], sleep [55], etc., or combination of these domains [90]. Some systems provide more flexibility,

such as *Trackly*, a customizable app for pictorial based tracking, and *OmniTrack*, which allows for user-defined tracking based on self-report and automated sources [58]. The development of a PI system that supports data collection, visualization, and reflection specifically for satisfaction of fundamental human needs, however, remains largely unexplored. In comparison to existing systems, our approach places an emphasis on specific methods for collecting and visualizing need satisfaction data in everyday life.

In order to scaffold data collection specifically on needs, we draw from Max-Neef's existential categories of *being, having, doing, and interacting*, and connect each category to data that can be collected with a personal informatics system.

2.4.1 Being via Self-Aspects. For the *being* category of needs and satisfiers, we draw from McConnell's multiple self-aspects framework (MSF) [76], which suggests that one's *self* is composed of many context-dependent components, called *self-aspects*. Self-aspects can include roles, social identities, relationships, goals, affective states, and specific behavior tendencies, which are "activated" in certain situational contexts [76]. The number and connectedness of self-aspects can lead to more or less *self-complexity* [66], which has been shown to have various effects on general well-being, such as buffering against negative events in life [67]. Although a model of the self has been proposed for personal informatics systems [91], existing HCI research on the self mainly concentrates on product design to help actualize ideal selves [115] or facilitate social role transitions [116]. The integration of the multiple self-aspects framework in designing PI systems has not been widely explored by HCI researchers, although our previous late-breaking work presented preliminary investigations into reflecting on self-aspects in everyday life [46].

2.4.2 Having via Relationships and Organizations. Max-Neef's concept of *having* is expansive, encompassing elements like "friendships, family, partnerships, relationships with nature" and "institutions, norms, mechanisms, tools (not in a material sense), laws, etc." [75]. Given the broad scope of this concept, we narrowed our focus to relationships and organizations for this study, as these were aspects individuals would likely be cognizant of in their daily lives.

While personal informatics research has not extensively explored the role of organizations in individuals' everyday life, there have been efforts to help individuals capture data about relationships and social interactions. Reality mining studies, for instance, have deployed bluetooth phones with data capture capabilities to understand communication patterns between individuals [33]. *Sochiatrist*, a personal informatics system, performs sentiment analysis on user text messages from multiple sources in order to identify mental well-being [72]. These systems utilize large-scale individual data to make inferences, but do not directly prompt individuals to recall episodes of interpersonal interaction for the purpose of collecting meta-data about those episodes—in our case, need satisfaction.

2.4.3 Doing via Time Use. Time provides a context for scaffolding reflection on need satisfaction in the existential category of *doing*. We utilize Kahneman's Day Reconstruction Method (DRM) to capture what an individual *does* in our technology probe. The DRM consists of asking individuals to break their day up into episodes, describe the episode, and provide additional metadata [52]. The DRM attempts to be a middle ground between experience sampling [23] (close to the moment, but interruptive) and a retrospective logbook study (prone to biases and recall errors [34]). The DRM is similar to traditional time use studies (see [6] for a short review) in that it results in a complete record of time, but goes further to emphasize "recovering affective experiences" by "reviving memories" [52].

While some commercially available time tracking systems (such as *Toggl*) allow for a full record of time, these do not utilize the Day Reconstruction Method to recall affective experiences. Previous PI work on time-use has focused on in-the-moment time monitoring and feedback [57], supporting focus work [114], and reducing time spent using technology [19]. This work tends to focus on changing time use in order to improve productivity.

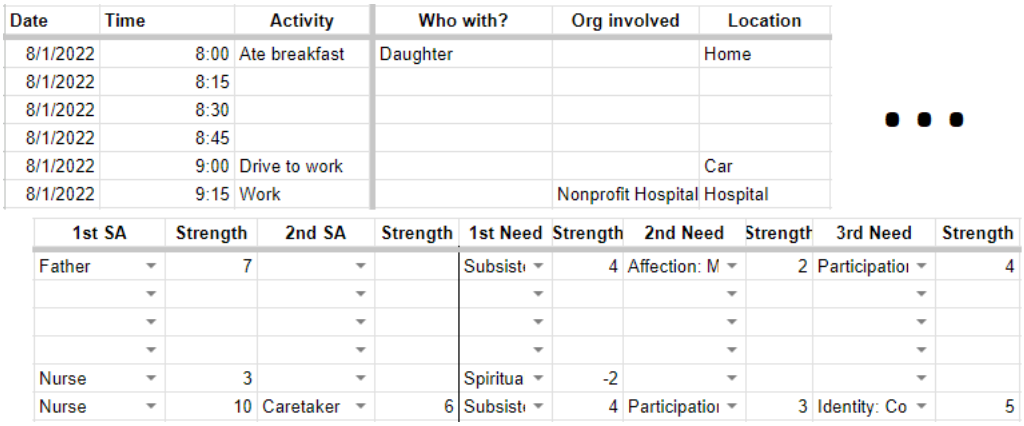
2.4.4 Interacting with Environments. Interacting focuses on "times and spaces" that support satisfaction [75]. There are multiple commercial applications that support continuous self-tracking of location [85], and previous HCI research has utilized continuous self-tracking to create large datasets about a community [2] and to visualize location data using a spiral [61]. Given our use of the DRM methodology (where individuals reflect on the entire day at once), our probe relies on the user to report the environment where their activities took place.

In the next section, we discuss the design of our personal informatics technology probe, which was used to support all three components of our work: the think-aloud study, the *in situ* deployment, and the closing interview.

3 REFLECTIVE TECHNOLOGY PROBE DESIGN

Technology probes are simple, provocative tools meant to explore the potential of new technologies and how individuals interact with them [48]. Technology probes are similar to the build-it-yourself–style tools developed by those who track data about themselves (known as "quantified selfers") to support their home-grown tracking practices [17], suggesting that technology probes might be an effective way for researchers to experiment with new personal informatics systems [3]. Apart from commercially available hardware (such as a *Fitbit* or *Apple Watch*), spreadsheets were the most commonly surveyed method quantified-selfers used for their tracking [17]. In addition, manual tracking methods (as opposed to automated data collection) are suggested to increase users' engagement with data, supporting self-reflection and awareness [17]. For these reasons, we utilized a tabbed data entry form, implemented using Google Sheets, to support data collection activities. While quantified-selfers also commonly use spreadsheets' charting functions to visualize collected data [17], we developed a web-based dashboard (using D3 [10]) to display a suite of researcher-defined, interactive network visualizations of each participant's data for the closing interview.

As a result, our technology probe consists of two separate interfaces: a structured spreadsheet in which individuals complete specific data elicitation tasks, and an interactive, web-based dashboard for viewing and reflecting on visualizations of the data. The spreadsheet helped facilitate gathering data about time-use and annotating activities with information across the four categories



Date	Time	Activity	Who with?	Org involved	Location
8/1/2022	8:00	Ate breakfast	Daughter		Home
8/1/2022	8:15				
8/1/2022	8:30				
8/1/2022	8:45				
8/1/2022	9:00	Drive to work			Car
8/1/2022	9:15	Work		Nonprofit Hospital	Hospital

1st SA	Strength	2nd SA	Strength	1st Need	Strength	2nd Need	Strength	3rd Need	Strength
Father	7			Subsist	4	Affection: M	2	Participatio	4
Nurse	3			Spiritua	-2				
Nurse	10	Caretaker	6	Subsist	4	Participatio	3	Identity: Co	5

Figure 1: Screenshot of the component of the technology probe used to capture the record of an individual's day, utilizing the Day Reconstruction Method (adjusted for width). Individuals record the activities they completed (*Doing*), who they were with and any involved organization (*Having*), location (*Interacting*), self-aspects activated during the activity (*Being*), and needs satisfied or inhibited due to the activity (along with a strength of satisfaction or activation).

of existential needs from Max-Neef's matrix: *being, doing, having,* and *interacting* [74].[2]

3.1 Reflecting on Doing: Time Use

To collect data on *doing*, we adopt the DRM [52] to capture a complete record of time-use and the activities in which our participants engaged. Our probe (screenshot shown in Figure 1) contains a tab with a time grid broken into 15-minute segments arranged vertically for a period of one week (similar to other web-based time grids for time-use studies [14]). Horizontally, each time segment has space for a description of the activity, along with a list of co-present people, any organization(s) involved, a physical location, and space to select self-aspects activated and needs satisfied by the activity. In this sense, time-use serves as the shared ground for satisfaction of *being, doing, having,* and *interacting* needs.

For annotating time-use with need satisfaction, the axiological categories of *subsistence, protection, affection, understanding, participation, leisure, creation, identity, freedom, and spirituality* [75] can be selected from a drop-down menu that lists both the name of the need and example *doing* satisfiers from the matrix. Individuals are prompted to enter the strength of need satisfaction (or inhibition) on a scale from −5 (most inhibits satisfaction) to +5 (provides most satisfaction). We chose an 11-point, end-defined scale as it enables more response points than traditional 5- or 7-point Likert items, and has been shown to not meaningfully bias the resultant data [24]. Participants could associate up to six needs with each activity.

3.2 Reflecting on Being: Self-Aspects

To capture the activation of self-aspects in daily life, we first prompted participants for a global elicitation of their self-aspects. Our probe included a "Self-Aspects" tab that prompts individuals to list out their self-aspects (drawing from previous self-aspect and self-concept elicitation studies [76, 102]). For each self-aspect, individuals are prompted to provide a description and positivity rating from 0–10 from the prompt "how positive do you feel about this aspect of yourself?" (wording from Banas and Smyth [4]). Individuals have the ability to return to this tab at any time to add self-aspects that later become apparent to them.

The self-aspects listed in this first tab are used to autofill a drop-down menu so that participants can assign self-aspect activation to specific activities that occur in daily life during the DRM task. This allows the probe to capture the co-occurence of self-aspect activation with need satisfaction. For each specific self-aspect activation, the participant is prompted to enter the strength of activation of the self-aspect during the activity on a scale from 0 (no activation) to 10 (most activation). Participants could assign up to four self-aspects to each activity.

3.3 Reflecting on Having: Involved Organizations and People Co-Present

For Max-Neef's existential category of *having*, our probe provided structure for gathering data on organizations involved, and people co-present for specific activities. Participants could enter, for example, the name of their company, university, or religious group under "Organization Involved." In a separate column, participants could enter the (comma-separated) names of individuals who were co-present during a specific activity. Participants had the flexibility to record either specific or general descriptions, such as an individual's name or a generic relationship such as "sister" or "friend *A*."

3.4 Reflecting on Interacting: Environments

Max-Neef's existential category of *interacting* is associated with specific places or environments where needs are satisfied. To collect this information in our probe, we prompt participants to enter the location name where each activity is taking place (such as "school," "work," or "home"). Again, participants had flexibility as to the level of specificity of the reported environment.

[2]We modified the order in which these are presented for clarity on how the probe was experienced by participants.

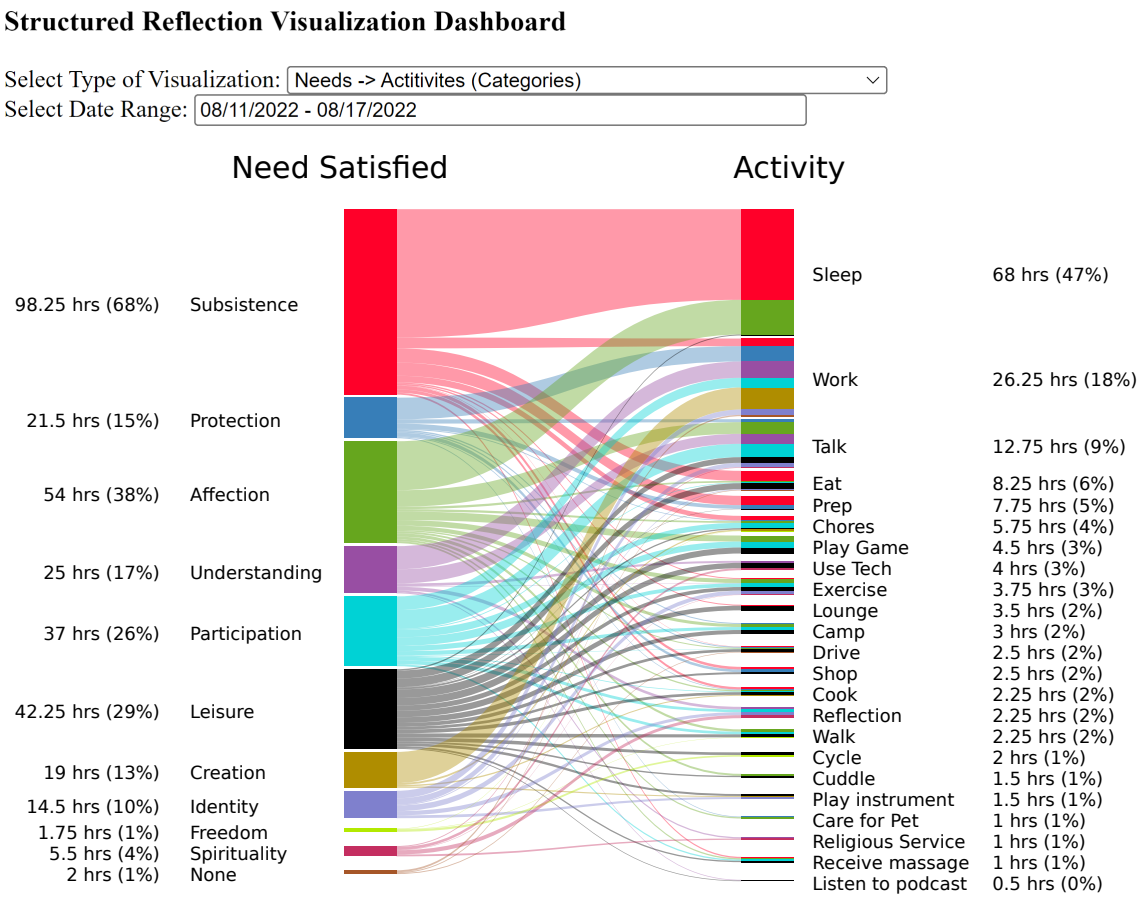


Figure 2: A screenshot of the interactive dashboard showing time-use satisfying each axiological need, corresponding to activities. Users can hover over needs to filter down to activities. Percentages on the left can add up to over 100% as more than one need could be satisfied at a time, so the percentage can be read as *the percent of time this need was satisfied.*

3.5 Interactive Visualization Dashboard

After the deployment of the probe, activity data was manually categorized into broad categories for simpler visualizations (categories were iteratively combined until the visualization reasonably fit on a single computer monitor). An interactive dashboard was created for each participant using D3 [10], and shared as a single HTML file. The dashboard consisted of a dropdown menu with nine choices of visualizations: needs and activities [detailed and categorized], self-aspects and activities [detailed and categorized], people and activities [detailed and categorized], needs and self-aspects, needs and people, and self-aspects and people. To support temporal manipulation (shown to support reflection in PI systems [8]), the dashboard also contained a date range picker allowing the participant to view data aggregated across specific date ranges, such as a single day or an entire week.

The visualizations were inspired by Max-Neef's view that human needs "must be understood as a system," and that "needs are interrelated and interactive" [74]. Given the usefulness of networks for representing and visualizing complex systems [83], and Max-Neef's distinction between need and satisfier, we developed a bipartite network model (and visualization) of need satisfaction. The visualizations utilize an interactive Sankey diagram (a type of bipartite network visualization) to visualize all needs at once, and their many-to-many connections with either activities, people, or self-aspects. Users can hover over particular nodes (needs, people, self-aspects, or activities) to filter down to other connected nodes. Each node is also labeled with a total time use and percent of the timespan that particular node represents. A screenshot of the visualization dashboard is shown in Figure 2.

4 METHODS

This study consisted of three parts, and was approved by the University of Colorado Boulder's institutional review board (protocol 22-0219). The first part included a $N = 10$ think-aloud study [63] consisting of the initial self-aspect elicitation activity [76] and a Day Reconstruction Method task for a single day, using the technology probe previously described (annotating each activity of the day with self-aspect activations, need satisfied/inhibited, location, people co-present, and organizations). The second part was an *in situ* deployment where participants ($N = 7$ after three participants

dropped out) completed the same Day Reconstruction Method for up to seven days. The third part was a one-hour closing interview ($N = 7$) where participants explored the interactive visualization dashboard.

4.1 Participant Training and Think-Aloud Study

We began the study with a 1–2 hour training and think-aloud session over Zoom for each participant. Participants first received an introduction to the theory of multiple self-aspects [76], and Max-Neef's theory of human needs [74, 75]. After explaining the technology probe and study logistics, participants were asked to complete the global self-aspect elicitation activity described earlier. Next, participants completed the Day Reconstruction Method for one day while thinking-aloud their thoughts [63] (for either the current day or prior day, following guidelines for the day reconstruction method [68].

4.2 Week-Long Probe Deployment

After completing the think-aloud study, participants were asked to independently complete the Day Reconstruction Method every day for the next 5–7 days (two days could be missed without losing compensation to give participants more flexibility in the study). Participants could add additional self-aspects at any time during the deployment. Three participants dropped out of the study and did not complete the week-long probe deployment. Two of these participants stopped responding to researcher emails without a known reason, while the third expressed difficulty in using the data collection component of the probe and did not wish to continue after the think-aloud session. Seven participants successfully completed the week-long deployment.

4.3 Qualitative and Quantitative Evaluation

After the week-long deployment, the remaining $N = 7$ participants completed a one-hour closing interview over Zoom where they explored their visualization dashboard (while thinking-aloud) and participated in a semi-structured interview. Participants were asked questions about their experience, any insights they learned about themselves, and they were prompted to provide feedback about the dashboard and the study experience. After the interview, participants completed a closing questionnaire, which included the technology supported reflection inventory (TSRI), a validated instrument for assessing how well a system supports reflection [7], and a net promoter score question [92]. Audio recordings from both the think-aloud activity and closing interviews (a total of roughly 27 hours) were transcribed and analyzed in MaxQDA [41] using inductive thematic analysis [21].

While it is difficult to determine an appropriate sample size for reaching saturation in qualitative research [40], our think-aloud study with $N = 10$ participants falls in within the range of 9-17 participants noted to have reached saturation in a recent review of interview studies [44]. In addition, this work does not attempt to make any statistical claims about the results, but rather explores the potential use of a new technology and reports on how a variety of different people interact with it in a representative use case.

The point of saturation in qualitative research, a complex and nuanced issue [40]. Although our $N = 10$ think-aloud study is within the range of 9-17 participants noted to have reached saturation in a review of previous interview studies [44], it is challenging to determine saturation in the broad context of understanding need satisfaction in everyday life. However, we began to identify recurring themes in the data, indicating at least some level of saturation. Our focus was not on making statistical claims but rather on exploring the potential use of a new technology and documenting diverse user interactions in a representative use case.

Participant Demographics ($N = 10$)	
Age	3 (18–24 years old) 7 (25–34 years old)
Gender	6 male (incl. trans m) 4 female (incl. trans f)
Race	6 Black or African American 2 White 1 Asian 1 Other
Parent Status	3 have children 7 do not have children
Employment	5 for-profit organization 1 non-profit 4 student
Income	1 ($1–$9,999) 4 ($25,000–$49,999) 3 ($50,000–$74,999) 2 ($100,000–$149,999)
Education	1 high school 2 one or more years of college 1 associate's degree 5 bachelors degree 1 masters degree
Location (US state)	Five different states (anonymized for peer review)

Table 1: Participant demographics (presented in aggregate to preserve identity).

4.4 Participants

Participants were recruited broadly through email and social media posts in Facebook groups and Reddit subreddits. Participation was open to anyone over the age of 18 residing in the United States. Participants were compensated up to a total of $40 for completing the entire study: $15 for completing the initial think-aloud study, $3 per day up to five days for completing the daily reflection exercises with the technology probe, and $10 for completing the semi-structured interview and closing questionnaire.

Ten individuals participated in the think-aloud portion of the study, and seven completed the week-long deployment and closing interview. Despite recruiting a convenience sample, the reported demographics (Table 1) represent a relatively diverse set of individuals across most categories. Age is one exception, as all participants reported being under the age of 35. As anonymized participant data is released as part of this study, demographics are presented

in aggregate in Table 1 rather than on a per-person basis to help reduce the risk of unintentional participant identification.

5 RESULTS

5.1 Overview of data collected and system usage

All ten participants completed the first 1–2 hour think-aloud session and completed the day reconstruction activity for the first day. Seven of those ten completed up to seven additional days of reflection using the technology probe, and completed the closing interview. Taking inspiration from Max-Neef's original matrix of needs and satisfiers [75], we constructed a matrix of needs and satisfiers drawn from participants' usage of the technology probe, describing the data collected alongside example satisfiers for each need (Table 2). Collectively, participants completed the reflection exercise for a combined total of 41 days, representing an average of 4.1 days/person.

Participants collectively reported 105 self-aspects, with an average of 10.5 per participant. On average, participants reported 7.9 self-aspects during the self-aspect think-aloud portion of the study, and added, on average, 2.6 self-aspects some time later during the reflection exercise. This suggests that some self-aspects are not readily available during a global evaluation of the self, and may only become apparent when reflecting about activation of the self during daily activities.

Participants reported a combined total of 662 activities, for an average of 66 activities per person and 16 activities per day. On average participants associated 1.5 need satisfaction ratings (or inhibition ratings) with each activity, and 1.1 self-aspect activation ratings with each activity. The maximum number of needs associated with an activity was six, and the maximum number of self-aspects associated with an activity was four. Both of these represent the max number of spaces our probe had for needs and self-aspects, respectively, indicating the possibility that activities could be associated with more needs and self-aspects than our probe made room for.

5.2 Quantitative Evaluation

The scores of the TSRI are shown in Table 3. While the TSRI is perhaps more useful as a comparative instrument, given the different personal definitions of "reflection" [7], the scores for our technology probe lean towards the higher end of the scale in all three subscales. The average net promoter score value was 9.4, with all individuals except for one indicating a 9 or 10 likelihood of recommending this exercise to a friend. These ratings, alongside qualitative data discussed later, indicate that participants found the probe to be useful for reflection and an overall worthwhile exercise.

5.3 Think-aloud on Need Satisfaction

A thematic analysis of the think-aloud study on need satisfaction in daily life identified the following themes: need is experienced and interpreted individually, need satisfaction occurs across diverse timescales, and tradeoffs associated with Max-Neef's theory of needs.

5.3.1 Need is experienced and interpreted individually. Participants used various cognitive processes to assign need satisfaction (or inhibition) to daily activities: recalling affect of an activity, comparing the activity with normative exemplars, evaluating motivation for the activity, and evaluating outcomes of the activity.

For some participants, the affective component of recalled memories played a role in assigning needs to activities. Participants would recall a memory and evaluate if a specific feeling was present, associated with a particular need. For example, when deciding whether to assign leisure to *eating breakfast*, P8 mentioned "I was… trying to remember if I felt very leisurely and if it felt nice to just sit there and not work for a moment."

Other times, participants relied on comparing the memory of the activity to either normative exemplars or counterfactual alternatives to the specific memory of the activity. For example, in assessing the satisfaction of eating breakfast, P8 mentioned they were rushed and "it would have been a lot more satisfying to not [have been rushed]."

Participants also closely associated need satisfaction with motivation for an activity, assigning needs that correspond to reasoning for initiating an activity. For example, after assigning *spirituality* to an activity of prayer, P1 said "I don't think there are any other reasons for why I would be doing this." Or P8 mentioning "that's definitely why I did it" when assigning leisure to listening to a podcast.

Other times, the cognitive process for assigning need was less clear. P2 assigned *freedom* for "sleeping" because "it just reminds me of being free." While P4 appeared to be doing a semantic category-matching process with the activities and needs, eventually saying "I guess this is subsistence" when referring to "bathing."

This diversity of processes for assessing need satisfaction, in part, led to a variety of different reported needs for similar activities. P1, for example, considered "showering" as part of their identity, saying, "it's my identity, it's something that defines me." P3 describes how showering meets their need for *spirituality*, "to me, it's like meditation." P9 described showering as meeting their need for participation, "showing is definitely participating in society." P6 mentioned how showering provides *protection* because "it keeps me free from germs."

Participants varied significantly in the frequency with which they assigned certain needs (see Figure 3). *Identity* resulted in particularly high amounts of variance, as evidenced by the different ways in which individuals thought about identity. For example, P3 mentioned how going to the gym satisfies the need for *identity* because "I feel like I'm inventing a new me.… it requires commitment." P9, on the other hand, had very few activities satisfying *identity* and said "identity is a very, very small portion of me doing activities and… living life."

Participants were more likely to report a positive need satisfaction score (95% of all ratings), rather than a negative need inhibition score (5% of all ratings). This might reflect an inherent difficulty in determining how activities precluded the satisfaction of needs, or a simple availability bias (recent memory of assigning positive need satisfaction prompts more positive need satisfaction assignment). For example, P8 said "I periodically forget there can be negative satisfiers so I have to go back and think."

Needs by Existential Category / Needs by Axiological Category	**Being** (105 Self-Aspects Activated 705 times)	**Having** (66 relationships, 26 organizations)	**Doing** (662 activities over 41 days)	**Interacting** (87 unique locations)
Subsistence (285 ratings)	48 self-aspects (eg., worker, father, productive)	33 relationships, 11 organizations (eg., wife, friend, company)	285 activities (eg., eat, sleep, work)	55 locations (eg., home, work)
Protection (52 ratings)	25 self-aspects (eg., servant, caregiver, partner)	8 relationships, 5 organizations (eg., boyfriend, sister, clinic)	52 activities (eg., shower, visit doctor)	21 locations (eg., home, doctor)
Affection (93 ratings)	37 self-aspects (eg., partner, friend, loving)	29 relationships, 2 organizations (eg., friend, spouse, fast food org)	93 activities (eg., cuddle, talk on phone, donate money)	27 locations (eg., neighborhood, partner's house)
Understanding (64 ratings)	30 self-aspects (eg., student, learner, worker)	25 relationships, 8 organizations (eg., client, peers, university)	64 activities (eg., work, read, class)	25 locations (eg., school, work)
Participation (118 ratings)	41 self-aspects (eg., worker, friend, active)	44 relationships, 8 organizations (eg., coworker, friend, company)	118 activities (eg., hangout, housework, work)	39 locations (eg., home, office)
Leisure (144 ratings)	40 self-aspects (eg., friend, musician, spirituality)	27 relationships, 7 organizations (eg., spouse, friend, restaurant)	144 activities (eg., watch TV, bathe, play instrument)	37 locations (eg., home, park, restaurant)
Creation (76 ratings)	30 self-aspects (eg., creator, worker, perfectionist)	12 relationships, 5 organizations (eg., client, colleague, company)	76 activities (eg., make dinner, program, workout)	12 locations (eg., home, work)
Identity (61 ratings)	30 self-aspects (eg., learner, husband, worker)	18 relationships, 8 organizations (eg., niece, partner company)	61 activities (eg., hike, work, reflection)	20 locations (eg., home, coffee shop)
Freedom (61 ratings)	22 self-aspects (eg., generous, active, spirituality)	10 relationships, 6 organizations (eg., friend, boyfriend, company)	61 activities (eg., sleep, bike, work)	18 locations (eg., home, streets)
Spirituality (38 ratings)	31 self-aspects (eg., spiritual, naturalist, lover)	9 relationships, 2 organizations (eg., spouse, sister, gym)	38 activities (eg., play tennis, attend service, pray)	16 locations (eg., church, home, gym)

Table 2: A matrix of existential and axiological needs, filled in with example satisfiers reported via the technology probe. The total number of satisfiers for each cell is reported. Inspired by Max-Neef's matrix of needs and satisfiers [75].

However, some participants did assign inhibiting satisfaction scores. For example, P6 assigned a -3 to both *leisure* and *freedom* for a work activity, because "it takes up my leisure time" and "I don't have the freedom to do whatever I want." Participants would also assign individual need satisfaction scores from global assessments ("I was putting together a lot of needs and letting the score of my other need impact this [different] need" P9).

Recall of activity outcomes played a large role in assigning need satisfaction scores. This appeared to be a kind of self-evaluation of the activity, such as P5 assigning high satisfaction scores to a work assignment because "I achieved what I planned to achieve." The

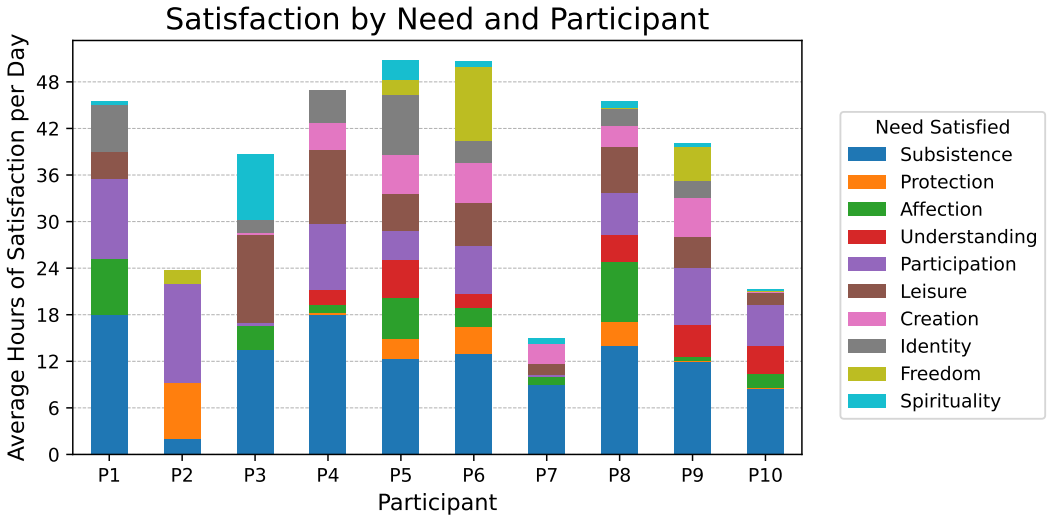


Figure 3: Participant lifestyles led to a large diversity in average hours of need satisfaction. Synergistic satisfiers (activities that satisfy more than one need at a time) allow for more than 24 hours of need satisfaction in a day.

Table 3: Results of the technology supported reflection inventory (TSRI) evaluation, broken down by subscale. The possible range for each subscale is 3–21, while the possible range for the total TSRI is 9–63.

TSRI Component	Min	Max	Mean
Insight	15	20	17.1429
Exploration	15	21	19.7143
Comparison	14	19	16.8571
TSRI Total	49	56	53.7143

response of other individuals might also impact the assessed satisfaction of a particular activity. P9 described rating the *participation* satisfaction of work activity as a four (instead of five) because "one person looked like they were on their cell phone."

5.3.2 Need satisfaction occurs across diverse timescales. Participants reported temporal disparities when assigning need satisfaction to particular activities. A participant might report need satisfaction associated with an activity that acts as a precondition to another activity. For example, when assigning a satisfaction of *participation* to the activity "showering," P1 said "I want to be one with my colleagues and bosses at work…I don't want them to have different opinions of me. I don't stink. I'm okay… it's kind of showing respect to people that you work with." P2 mentioned similar reasoning, for the activity "waking up," in that "when I woke up, it was… participation, because I had to work."

A common temporal difference was between preparing and eating a meal. P8, for example, assigned *subsistence* to both activities, but rated preparing breakfast as a 3, while eating breakfast was a 5. This highlights that time delay in satisfaction might be indicated by a difference in satisfaction strength.

Specific needs appeared to have specific temporal patterns associated with their satisfaction. P8 describes the difference between subsistence, satisfied on a short time scale, and identity, freedom, and spirituality.

> "It's hard for me to identify when I'm satisfying the needs for freedom and spirituality and identity…I see less of the… long term effects of that activity being repeated over time…It's not like with eating…you need to do it…then you just need to do it all over again. But as you're satisfying those [freedom, spirituality, and identity] needs it's something that you build up rather than something that runs out." –P8

The quote from P8 suggests that different mechanisms may be necessary to evaluate need satisfaction across different timescales, as needs with longer time horizons for satisfaction may not be captured within a single week of observation.

5.3.3 Tradeoffs in Using Max-Neef's Theory of Need. While Max-Neef's theory is used to elicit satisfiers of particular communities [73, 103], the set of basic needs proposed is debatable [60]. In the deployment of our technology probe, Max-Neef's theory was put into direct contact with the daily activities of participants. As such, multiple challenges and considerations for using Max-Neef's theory were identified.

One commonly noted theme mentioned by participants is the broadness of the *subsistence* need. For example, P8 said "subsistence is really the catch all for a lot of different things like eating, working, and cleaning… like everything I do is subsistence" and P6 said "subsistence… has to do with the majority of a human's lifestyle." The data concurs, as 48% of reported time use across all participants had a positive subsistence satisfaction score.

Assigning needs to activities required the individuals to keep some representation of the set of needs in their mind. Although each need was listed in the drop down, individuals tended to quickly scan and search for specific needs they knew ahead of time. As such, certain needs could be "forgotten" over short time spans. For

example, participants noted "wow, I haven't really been paying attention to identity" (P8) and "Ohhh this is, this is leisure" (P10). P5 described how this challenge resolved itself over time, saying "it [the study] wasn't that difficult once I got to know what was in there [the list of needs]."

Some needs were perceived as being more flexible in assignment to activities than others. Satisfying the need for *spirituality*, for example, was often perceived as any activity where a certain state of mind was present. Participants assigned spirituality to activities ranging from attending a religious service, showering, playing tennis, and even completing the reflection exercise itself. Other needs appeared to have a more narrow scope, such as *affection* almost always requiring the presence of another person, or *creation* involving some activity that results in a tangible product.

Participants were unsure how to interpret the need for *protection*: "I conceptualized it in a few different ways… I didn't know whether protection was referring to my own protection or protecting somebody else, and so I just did it for both." This distinction, between satisfying one's own needs versus another's, may have also been present in other needs such as *affection* (giving vs. receiving a massage) or *understanding* (attending vs. teaching a class).

Overall, however, participants felt that Max-Neef's set of needs holistically captured important aspects of life. P10 said "[the set of needs] really covered most of what I was doing," and P7 said "I think all of them had a role to play in people's life." P9, compared Max-Neef's theory with another they were familiar with, Maslow's hierarchy [70], "These are all really good needs, and I think that they are very holistic…I think I prefer this [Max-Neef's matrix over Maslow's hierarchy] honestly, because… it kind of put them [the needs] on equal footing."

5.4 Reflection in Data Gathering

Similar to quantified-selfers, our participants reported lessons-learned about the data collection process itself (e.g., [16]). Participants expressed that simply completing the day reconstruction method had some effect or led to insight about their lives, prior to seeing any visualization. For example, after selecting all the needs associated with a work activity, P9 noted "This is making me realize how much I enjoy my job actually." Simply interacting with the list of needs can also highlight missing needs, as P10 said (during the think-aloud), "I have no spirituality… at this time of my life."

The data gathering also led participants to become more mindful about their day-to-day lives and the activities they chose to engage in. P9 noted "It kind of shows you… what needs are being met, why you're doing what you're doing…what is this actually doing for me? Like *why* do I do this habit? I've been doing it for years or months or days but like *why* am I doing it?" After completing the data gathering portion, P8 said "Now that I've completed this and I'm not filling in the spreadsheet anymore, I still sort of think about the things that I do… I had got in the habit for a week of thinking about my days like that [with respect to need satisfaction]." P7 simply found enjoyment in the data collection, asking "this sounds fun, can I tell my friends about this?"

5.5 Reflection in Interacting with the Network Visualization

Seven of the ten participants completed the closing interview, where they interacted with network visualizations of their data in the prototype dashboard. We identified two primary benefits of using such a visualization system: improved understanding of the self and setting priorities in daily life.

5.5.1 Improved Understanding of Lifestyle and Self. All participants reported interacting with the visualization dashboard resulted in learning something new about themselves. For example, P9 said "you see what you are, and places that you can work on to kind of shift those to more to who you want to be, and I feel like this is a really cool tool to like see that visually laid out." Specifically, four participants expressed insight at discovering how much time they spent alone. For example, when looking at the visualization shown in Figure 4, P6 said

> "Ehh no! Wow. It goes to show I need to make more friends. Wow. So my social lifestyle, my social life is a little bit bad. So I think I need to improve on my social life….that's the change I need to make. I need to socialize more, make some friends." -P6

P5 benefitted from the visualization of needs satisfied and people co-present, saying "It makes it much more easier for me to understand the needs that come with being associated with a particular person or being alone." P7 provided an example of this experience when hovering over the node for his girlfriend (thereby filtering for associated needs), saying "I thought affection would pop up, but there's not much affection, more of subsistence." The same visualization helped P7 realize "I do spend most time alone. I don't spend much time with my family, because of work. I'm not really close with my friends because I spent too much time working…it made me realize… that I need to be out there with people" (P7).

P7 also highlighted how this technology probe and visualization helped to make their daily life and routine salient and conscious, directing attention to activities they might otherwise not think of.

> "This study has been quite a journey sometimes. My experience with this study has been fascinating…I do stuff without even knowing it. Seeing this chart and all, and seeing what I do, it feels like I don't do much. It's kind of fascinating that I spend most of the time being alone, just working, watching TV…to see that me being alone is 60-70% of my time…is quite fascinating to me." -P7

The visualizations also highlighted needs that were missing in daily life. For example, when P8 was reflecting on the aggregate view of needs and activities, they noticed the low amount of time spent satisfying *spirituality*, *identity*, and *freedom*, saying "it feels like those are maybe the least nurtured needs of my entire life."

The visualizations also led to insights about the interactions between need satisfaction and self-aspect activation. For example, P8 said "my perfectionist self-aspect is never activated when I'm receiving my need for affection… nor when I am satisfying my need for spirituality… so that's interesting."

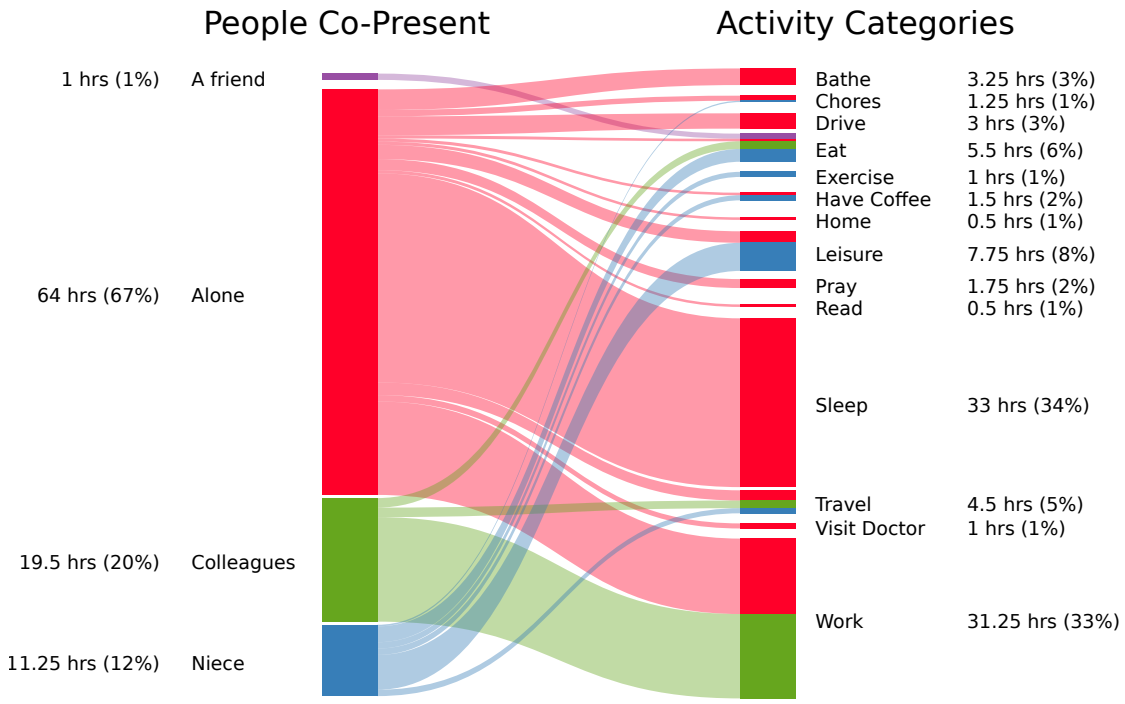


Figure 4: A participant's time use presented in a bipartite network relating activities with people the activity was done with. The participant was surprised to see so much time spent alone.

5.5.2 Setting Priorities in Daily Life. The dashboard presented visualizations of self-aspects elicited via a global evaluation alongside the activation of those same self-aspects in daily life. As such, the system made visible differences between individuals' perceived selves (or, perhaps, ideal selves [45]) and the way in which they actually live their lives. All participants elicited self-aspects related to family, and many participants were surprised to see they spent relatively little time with their family-related self-aspects activated. For example when P8 looked at visualizations of self-aspects (such as the one shown in Figure 5) they said,

> "So I have nothing for 'daughter' so maybe that should be telling me something… and also nothing for 'sister.' Hmmm. Maybe I should have a weekly Zoom call…with my family." -P8

P10 also realized they spent very little time with family in daily life, saying "I had daughter as one of my self-aspects, but in this week I did nothing to contribute to this… which may mean that I need to… updating my family on how I'm doing and like, asking that in return."

P5 saw the possibilities of using such a tool to focus on meaningful or productive activities, saying "it [the system] can prompt me to try to do things a bit differently, because if I analyze the time I spend on something and I don't see a lot of value out of it, then it can be motivation for me to change the way I do things." P6 expressed similar sentiments, saying "this will enable me to know… where I need to put more effort. With this data I think I can be more productive each day."

6 DISCUSSION

Perhaps the largest challenge in operationalizing the concept of "need" in daily life is the diversity of ways in which individuals think about their needs and need satisfaction. Participants in our think-aloud study appeared to make decisions about need satisfaction based on affective recall of the activity, comparison with normative exemplars, motivation for initiating the activity, and evaluation of activity outcome. This aligns with the philosophical view that needs themselves cannot be felt, per se, but rather are "indirectly manifested in desires, in feelings and in other psychological states" [77]. In other words, needs are not a mental state that can be clearly measured through a single cognitive process, but rather are abstract constructs that can be *inferred* through "sensations, perception, and introspection" [77].

By using a personal informatics system to collect data about multiple facets of daily life, individuals can be supported in inferring how their activities, self-aspects, relationships, organizations, and environments relate to need satisfaction. The remainder of our discussion is structured around Max-Neef's four existential categories of need. For each, we discuss how participants' experience with our technology probe sheds light on collecting need satisfaction data in that category. We also examine the ways in which our probe suggests design considerations for personal informatics systems, more generally.

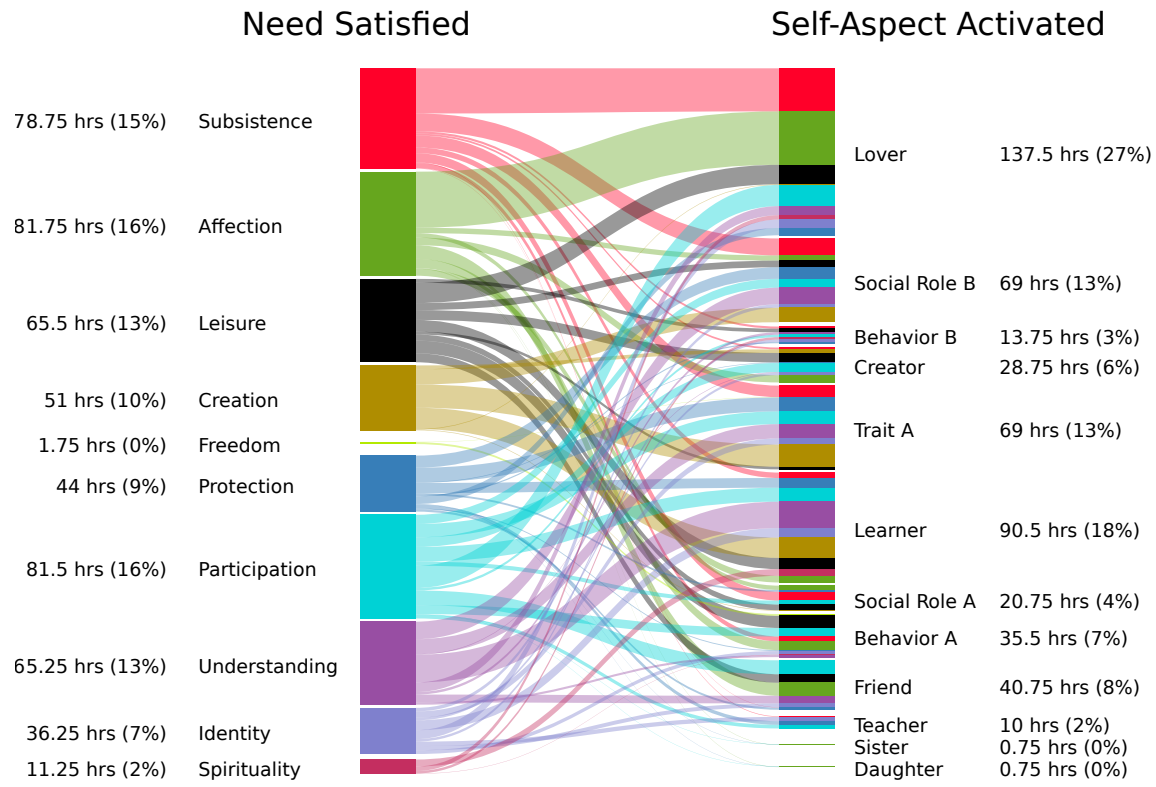


Figure 5: Visualization of a participant's data showing the co-occurrence of need satisfaction and self-aspect activation.

6.1 *Doing*: Using the Day Reconstruction Method in Personal Informatics Systems

This technology probe and visualization prototype represents the first attempt to use the Day Reconstruction Method (DRM) [52] as part of a personal informatics system. A benefit of using the DRM was the ability to capture a complete record of the day, as opposed to an experience sampling method, which only provides momentary snapshots of experience [43]. While most personal informatics systems focus on a specific domain of life (such as fitness or screen time), the DRM allowed for participants to see everything they did over the course of one week, with meaningful annotations that *they* provided (needs met, aspects of the self-activated, and people and environments interacted with).

Figure 3 makes salient Max-Neef's concept of *synergistic* satisfier, when a single activity meets more than one need [75]. Some participants averaged less than 24 hours of "need satisfying hours" per day (meaning they had some activities that satisfied no needs), while others had over two days worth of "need satisfying hours" (as they had activities that met more than one need concurrently). PI systems could help to facilitate the sharing of synergistic satisfiers to help improve overall need satisfaction.

The Sankey diagram used for visualizing the data might inadvertently suggest an objective of optimization. The visualization displays the total time spent on various activities and their associated needs satisfied. It might imply that users should aim to maximize their satisfaction by dedicating more time to activities that appear to provide more immediate or visible need satisfaction. Our results show how perceived need satisfaction can occur across diverse timescales, therefore focusing on immediate or easily reportable needs could result in neglecting other needs that might be more challenging to quantify or articulate in short time-spans.

Our results also show that similar satisfiers (activities) can meet different needs across different participants. This contrasts with large-scale quantitative studies that attempt to assess need satisfaction by assuming uniform need satisfaction across all individuals (for a given purchase [112] or written sentence [29], for example).

A challenge of using the DRM was the cognitive burden of completing the task (similar to other time-use studies [12]). P4 lamented: "Am I to do this every day? This is really draining." (They did not continue with the study.) Some participants would copy and paste entire rows of activity data for repeated activities such as sleep, short-circuiting the intended episodic memory recall of the instrument [52]. As engaging in the same general activity can result in different levels of need satisfaction, this could result in an inaccurate record.

To reduce the burden of self-tracking, two participants brought up the idea of using a voice-assistant feature to record spoken narratives of the day. P7 said "writing it down is quite slow and boring, I think it should be more of a [audio] record, me just telling you how my day is, what I did, how it affects me." A voice-recognition and natural language processing system could parse a spoken

narrative of the day into individual activities. While associated needs could be automatically inferred (perhaps using the same method used to classify sentences by human need described earlier [29, 30, 87]), the system might present the parsed activities to the user for need annotation, or utilize some other mix of automated and user-performed tracking (similar to other semi-automated self-tracking systems [58]).

While the Day Reconstruction Method is intended to be a middle ground between the experience sampling method and retrospective reporting, participants still found themselves having difficulty remembering everything that occurred during the day ("sometimes you can forget that you did certain activities… and maybe those activities were important." –P3). Participants mentioned the possibility of relying on digital exhaust [96] in order to help reconstruct the events of a day. For example, "you could even look at my Github commits to see exactly when all this happened" (P8) and "what did I do at ten o'clock today, let me look at my calendar" (P9). This suggests that personal informatics systems may be able to augment the cognitive recall process in the day reconstruction method by supplying digital traces that help trigger memories of specific episodes that occurred during the day, such as the daily photo summaries [18] or other smart journaling features [35] identified in previous lifelogging research [98].

6.2 *Being*: Visualizing the Self

As Levebvre puts it, people "do not know their own lives very well, or know them inadequately" [62]. We see a small example here, in that all participants who saw visualizations of their data (the seven who completed the final interview) reported learning something about themselves, and most (five) said they would change something in their life in response to what they had learned. Notably, multiple individuals had strong reactions to the visualization of their data, prompting changes that they may not have considered earlier (for example, Figure 4). This suggests the individuals were in the *pre-contemplation* stage of behavior change (according to the transtheoretical model), which is a difficult stage for which to design interventions [89].

The probe was designed to gather both a global assessment of the self (via the self-aspect elicitation task), along with a day-to-day record of how the self is activated (via the DRM). Participants then interacted with a dashboard that visualized both the "global self" and a "lived self" (aggregated from records of daily activities) side-by-side. For some participants, the combination of the global self-assessment (seeing oneself as a son, daughter, etc.) and the day-to-day record (seeing little time spent with family), made salient discrepancies between the participant's current behavior and an implicit goal state, leading to identification of areas of potential behavior change.

Notably, our system was not designed with any behavior change intention, but simply helped participants to identify areas of change on their own (similar to the intentions of designing for the self [1]). We can also imagine a more effective system for behavior change might incorporate elicitations of possible "future selves" [91] or "ideal selves," and use that data to create visualizations that highlight the concurrence between actual and ideal selves, rather than leaving the ideal self implicit in the users mind.

6.3 *Having*: Privacy Considerations for Personal Data

As the DRM results in a full accounting of daily life, no activity is outside the scope of record. This brings potentially sensitive and private aspects of life into contact with the personal informatics system, a common challenge for informatics systems [36]. While participants knew that all data would be anonymized before use, participants varied in their level of specificity of reported information. For example, some participants always reported the full name of the company they worked for, others simply reported "company." As the probe was intended to place attention on every activity throughout a week, sensitive information was likely either not revealed or missed entirely, which we expect to be partially due to participants knowing that the researchers would have access to and be looking at their data, especially during the think-aloud portion of the study. After explaining the assignment of *affection* to an activity, one participant (P7) said "this is weird to be talking about my girlfriend."

Given the potential for these applications to include *sharing* or *following* features, system design should incorporate features for transforming data into representations with various levels of anonymity depending on the use case, and could benefit by directly applying a risk model (such as k-anonymity [107] or more realistic models [5]) to data anonymization.

6.4 *Interacting*: From Personal Informatics to Transition Design

Although our study recruited diverse individuals from different communities across the United States, the environments where need satisfaction occurs provide a shared context across individuals. PI systems could serve to anonymously aggregate need satisfaction data across individuals who visit particular locations. This data could be used to profile how a specific location (such as *Central Park*) or a generic class of location (such as *home*) helps to satisfy the needs of community members. Community leaders and policy-makers could then use this data to plan public projects that support synergistic satisfiers. This data-driven approach, while in need of robust privacy measures, could also be used to support efforts of transition designers as they "design for the needs of particular groups of people in particular places" [50].

6.5 Future Work

Every participant who completed the closing interview expressed interest in continuing to use the system ("I'm interested in doing more and more of this" –P3) at various intervals (weekly, monthly, or quarterly), and many asked if their friends could participate. As such, we are motivated to build a formal personal informatics system inspired by this technology probe that facilitates data collection on need satisfaction, self, and time-use. Given the lack of consensus on a universal set of basic needs [25], we plan to build a flexible system that can accommodate data collection across any given set of needs drawn from different theories.

As part of this study, we created and released an anonymized dataset of 662 activities, annotated with need satisfaction (or inhibition) strengths and the general location associated with these activities. The dataset, along with a complete data dictionary, can

be found on the OSF repository [79]. We hope that this dataset will spark the HCI community to develop novel ways of visualizing individuals' daily lives and lead to participatory tools for collecting data and reflecting on needs and satisfaction.

In the long run, improved representations of lifestyles and a data-driven understanding of how self, time, and place satisfy fundamental needs can lead to novel applications to support more fulfilling lifestyles. For example, we could imagine creating a *lifestyle recommender system* that identifies new activities that might satisfy needs that are currently unfulfilled or suggest lifestyle changes that would improve need satisfaction while reducing environmental impact.

6.6 Limitations

The generalizability of this study is limited due to a relatively small sample size. In addition, the data collection supported by our probe likely does not capture all components of need satisfaction. We acknowledge the inevitability of building our own values into the design of the technology probe, such as the assumption that time can be broken up into discrete chunks (in this case, 15-minute segments), and that need satisfaction occurs evenly across time (which was an assumption implied by our visualization design).

Moreover, we recognize that our analysis could have delved deeper into the impact of diversity, including race, class, gender, among others, on the articulation and interpretation of needs. While we provided a demographic table, we did not thoroughly analyze how these individual differences influenced the findings, despite acknowledging the variation in individual interpretations of needs. This represents a limitation of the present work, and future research should consider more in-depth examination of these factors in relation to perceived need satisfaction.

7 CONCLUSION

Using personal informatics systems to gather data on need satisfaction represents a middle path between the collaborative workshops conducted by human scale development researchers (relying solely on global self-report of groups) [103] and purely quantitative data-driven approaches (which make assumptions about uniformity of satisfaction) [29, 106, 112]. By having individuals annotate time-use data with need satisfaction information, a personal informatics approach remains both participatory and scalable, as well as being closely connected to daily life.

In this research, we developed, deployed, and evaluated a novel technology probe for capturing data about individuals' daily life and how they satisfy their existential needs of *being* (self-aspects), *having* (relationships and organizations), *doing* (activities), and *interacting* (locations). Our technology probe utilized two methods from psychology, the Day Reconstruction Method and the self-aspect elicitation task, to create a complete record of an individual's time use alongside a global representation of their self-aspects. The probe was used to conduct a $N = 10$ think-aloud study and then deployed *in situ* for $N = 7$ participants for a period of up to a week, resulting in a new dataset of 662 activities in daily life (with associated metadata and need satisfaction scores), which were anonymized and released publicly to stimulate HCI research on need and satisfaction.

Our think-aloud study (1) revealed that participants think about their needs and assign satisfaction ratings in a diversity of ways, (2) showed that perceived need satisfaction occurs across different timescales, and (3) uncovered challenges in operationalizing Max-Neef's set of fundamental human needs. Both qualitative and quantitative evaluation of the experience of using the probe indicated that individuals found that reflecting on the visualizations of their data led to insights about how they live their life, and prompted indications of behavior change. Overall, our results suggest that while there are still open challenges to operationalizing a theory of need via direct elicitation from individuals, personal informatics systems that support reflection on need satisfaction can be useful to individuals and provide meaningful visualizations of how needs are satisfied in everyday life.

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REFERENCES

[1] Elena Agapie. 2019. Designing for the Self: Enabling People to Design Behavioral Interventions. In *Extended Abstracts of the 2019 CHI Conference on Human Factors in Computing Systems (CHI EA '19)*. Association for Computing Machinery, New York, NY, USA, 1–6. https://doi.org/10.1145/3290607.3299080

[2] Nadav Aharony, Wei Pan, Cory Ip, Inas Khayal, and Alex Pentland. 2011. Social fMRI: Investigating and shaping social mechanisms in the real world. *Pervasive and Mobile Computing* 7, 6 (Dec. 2011), 643–659. https://doi.org/10.1016/j.pmcj.2011.09.004

[3] Amid Ayobi. 2018. Informing the Design of Personal Informatics Technologies for Unpredictable Chronic Conditions. In *Extended Abstracts of the 2018 CHI Conference on Human Factors in Computing Systems*. ACM, Montreal QC Canada, 1–4. https://doi.org/10.1145/3170427.3173025

[4] Kasia Banas and Lillian Smyth. 2021. Structure, Content and Inter-relationships between Self-aspects: Integrating Findings from the Social Identity and Self Complexity Traditions. *European Journal of Social Psychology* 51, 7 (2021), 1096–1112. https://doi.org/10.1002/ejsp.2760

[5] Anirban Basu, Anna Monreale, Roberto Trasarti, Juan C. Corena, Fosca Giannotti, Dino Pedreschi, Shinsaku Kiyomoto, Yutaka Miyake, and Tadashi Yanagihara. 2015. A risk model for privacy in trajectory data. *Journal of Trust Management* 2, 1 (Dec. 2015), 9. https://doi.org/10.1186/s40493-015-0020-6

[6] Adrian Bauman, Michael Bittman, and Jonathan Gershuny. 2019. A short history of time use research; implications for public health. *BMC Public Health* 19, S2 (June 2019), 607. https://doi.org/10.1186/s12889-019-6760-y

[7] Marit Bentvelzen, Jasmin Niess, Mikołaj P. Woźniak, and Paweł W. Woźniak. 2021. The Development and Validation of the Technology-Supported Reflection Inventory. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*. ACM, Yokohama Japan, 1–8. https://doi.org/10.1145/3411764.3445673

[8] Marit Bentvelzen, Jasmin Niess, and Paweł W. Woźniak. 2021. The Technology-Mediated Reflection Model: Barriers and Assistance in Data-Driven Reflection. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*. ACM, Yokohama Japan, 1–12. https://doi.org/10.1145/3411764.3445505

[9] Ann Blandford, Dominic Furniss, and Stephann Makri. 2016. *Qualitative HCI research: Going behind the scenes*. Morgan & Claypool Publishers.

[10] Michael Bostock, Vadim Ogievetsky, and Jeffrey Heer. 2011. D3 Data-Driven Documents. *IEEE Transactions on Visualization and Computer Graphics* 17, 12 (Dec. 2011), 2301–2309. https://doi.org/10.1109/TVCG.2011.185

[11] Lina I. Brand-Correa and Julia K. Steinberger. 2017. A Framework for Decoupling Human Need Satisfaction From Energy Use. *Ecological Economics* 141 (Nov. 2017), 43–52. https://doi.org/10.1016/j.ecolecon.2017.05.019

[12] Andrea L. S. Bulungu, Luigi Palla, Jan Priebe, Lora Forsythe, Pamela Katic, Gwen Varley, Bernice D. Galinda, Nakimuli Sarah, Joweria Nambooze, Kate Wellard, and Elaine L. Ferguson. 2022. Validation of an Automated Wearable Camera-Based Image-Assisted Recall Method and the 24-h Recall Method for Assessing Women's Time Allocation in a Nutritionally Vulnerable Population: The Case of Rural Uganda. *Nutrients* 14, 9 (April 2022), 1833. https://doi.org/10.3390/nu14091833

[13] Clara Caldeira, Yu Chen, Lesley Chan, Vivian Pham, Yunan Chen, and Kai Zheng. 2018. Mobile apps for mood tracking: an analysis of features and user

reviews. *AMIA Annual Symposium Proceedings* 2017 (April 2018), 495–504. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5977660/

[14] Stella Chatzitheochari, Kimberly Fisher, Emily Gilbert, Lisa Calderwood, Tom Huskinson, Andrew Cleary, and Jonathan Gershuny. 2018. Using New Technologies for Time Diary Data Collection: Instrument Design and Data Quality Findings from a Mixed-Mode Pilot Survey. *Social Indicators Research* 137, 1 (May 2018), 379–390. https://doi.org/10.1007/s11205-017-1569-5

[15] Beiwen Chen, Maarten Vansteenkiste, Wim Beyers, Liesbet Boone, Edward L. Deci, Jolene Van der Kaap-Deeder, Bart Duriez, Willy Lens, Lennia Matos, Athanasios Mouratidis, Richard M. Ryan, Kennon M. Sheldon, Bart Soenens, Stijn Van Petegem, and Joke Verstuyf. 2015. Basic Psychological Need Satisfaction and Frustration Scale. (2015). https://doi.org/10.1037/t73076-000

[16] Eun Kyoung Choe, Bongshin Lee, and m.c. schraefel. 2015. Characterizing Visualization Insights from Quantified Selfers' Personal Data Presentations. *IEEE Computer Graphics and Applications* 35, 4 (July 2015), 28–37. https://doi.org/10.1109/MCG.2015.51

[17] Eun Kyoung Choe, Nicole B. Lee, Bongshin Lee, Wanda Pratt, and Julie A. Kientz. 2014. Understanding Quantified-selfers' Practices in Collecting and Exploring Personal Data. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '14)*. ACM, New York, NY, USA, 1143–1152. https://doi.org/10.1145/2556288.2557372

[18] Soumyadeb Chowdhury, Philip J. McParlane, Md. Sadek Ferdous, and Joemon Jose. 2015. "My Day in Review": Visually Summarising Noisy Lifelog Data. In *Proceedings of the 5th ACM on International Conference on Multimedia Retrieval (ICMR '15)*. Association for Computing Machinery, New York, NY, USA, 607–610. https://doi.org/10.1145/2671188.2749393

[19] Emily I. M. Collins, Anna L. Cox, Jon Bird, and Cassie Cornish-Tresstail. 2014. Barriers to engagement with a personal informatics productivity tool. In *Proceedings of the 26th Australian Computer-Human Interaction Conference on Designing Futures: the Future of Design (OzCHI '14)*. Association for Computing Machinery, New York, NY, USA, 370–379. https://doi.org/10.1145/2686612.2686668

[20] Sunny Consolvo, David W. McDonald, Tammy Toscos, Mike Y. Chen, Jon Froehlich, Beverly Harrison, Predrag Klasnja, Anthony LaMarca, Louis LeGrand, Ryan Libby, Ian Smith, and James A. Landay. 2008. Activity sensing in the wild: a field trial of ubifit garden. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '08)*. Association for Computing Machinery, New York, NY, USA, 1797–1806. https://doi.org/10.1145/1357054.1357335

[21] Juliet Corbin and Anselm Strauss. 2014. *Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory* (4th ed.). SAGE Publications, Los Angeles, CA.

[22] Felicia Cordeiro, Elizabeth Bales, Erin Cherry, and James Fogarty. 2015. Rethinking the Mobile Food Journal: Exploring Opportunities for Lightweight Photo-Based Capture. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (CHI '15)*. Association for Computing Machinery, New York, NY, USA, 3207–3216. https://doi.org/10.1145/2702123.2702154

[23] Mihaly Csikszentmihalyi and Reed Larson. 2014. Validity and Reliability of the Experience-Sampling Method. In *Flow and the Foundations of Positive Psychology: The Collected Works of Mihaly Csikszentmihalyi*, Mihaly Csikszentmihalyi (Ed.). Springer Netherlands, Dordrecht, 35–54. https://doi.org/10.1007/978-94-017-9088-8_3

[24] Robert Cummins and Eleonora Gullone. 2000. Why we should not use 5-point Likert scales: The case for subjective quality of life measurement. *Proceedings, Second International Conference on Quality of Life in Cities* (01 2000), 74–93.

[25] Hartley Dean. 2010. *Understanding Human Need*. Policy Press.

[26] Edward L. Deci, Richard M. Ryan, Marylène Gagné, Dean R. Leone, Julian Usunov, and Boyanka P. Kornazheva. 2019. *Basic Psychological Need Satisfaction at Work Scale*. Technical Report. American Psychological Association. https://doi.org/10.1037/t71065-000

[27] Sebastian Deterding. 2014. Eudaimonic design, or: Six invitations to rethink gamification. In *Rethinking Gamification*, Mathias Fuchs, Sonia Fizek, Paolo Ruffino, and Niklas Schrape (Eds.). meson press, Lüneburg, Germany, 305–331. https://doi.org/10.25969/mediarep/727

[28] Antonietta Di Giulio and Doris Fuchs. 2014. Sustainable Consumption Corridors: Concept, Objections, and Responses. *GAIA - Ecological Perspectives for Science and Society* 23, 3 (July 2014), 184–192. https://doi.org/10.14512/gaia.23.S1.6

[29] Haibo Ding and Ellen Riloff. 2018. Human Needs Categorization of Affective Events Using Labeled and Unlabeled Data. In *Proceedings of the 2018 Conference of the North American Chapter of the Association for Computational Linguistics: Human Language Technologies, Volume 1 (Long Papers)*. Association for Computational Linguistics, New Orleans, Louisiana, 1919–1929. https://doi.org/10.18653/v1/N18-1174

[30] Haibo Ding, Ellen Riloff, and Zhe Feng. 2019. Improving Human Needs Categorization of Events with Semantic Classification. In *Proceedings of the Eighth Joint Conference on Lexical and Computational Semantics (*SEM 2019)*. Association for Computational Linguistics, Minneapolis, Minnesota, 198–204. https://doi.org/10.18653/v1/S19-1022

[31] Steve Dodds. 1997. Towards a 'science of sustainability': Improving the way ecological economics understands human well-being. *Ecological Economics* 23, 2 (Nov. 1997), 95–111. https://doi.org/10.1016/S0921-8009(97)00047-5

[32] Len Doyal and Ian Gough. 1991. *A Theory of Human Need*. Guilford Press, New York, NY.

[33] Nathan Eagle and Alex (Sandy) Pentland. 2006. Reality mining: sensing complex social systems. *Personal and Ubiquitous Computing* 10, 4 (May 2006), 255–268. https://doi.org/10.1007/s00779-005-0046-3

[34] William D. Ellison, Alec C. Trahan, Joseph C. Pinzon, Megan E. Gillespie, Logan M. Simmons, and Kendel Y. King. 2020. For Whom, and for What, Is Experience Sampling More Accurate than Retrospective Report? *Personality and Individual Differences* 163 (Sept. 2020), 110071. https://doi.org/10.1016/j.paid.2020.110071

[35] Chris Elsden, Abigail C. Durrant, and David S. Kirk. 2016. It's Just My History Isn't It? Understanding Smart Journaling Practices. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*. Association for Computing Machinery, New York, NY, USA, 2819–2831. https://doi.org/10.1145/2858036.2858103

[36] Daniel A. Epstein, Clara Caldeira, Mayara Costa Figueiredo, Xi Lu, Lucas M. Silva, Lucretia Williams, Jong Ho Lee, Qingyang Li, Simran Ahuja, Qiuer Chen, Payam Dowlatyari, Craig Hilby, Sazeda Sultana, Elizabeth V. Eikey, and Yunan Chen. 2020. Mapping and Taking Stock of the Personal Informatics Literature. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies* 4, 4 (Dec. 2020), 126:1–126:38. https://doi.org/10.1145/3432231

[37] Daniel A. Epstein, An Ping, James Fogarty, and Sean A. Munson. 2015. A lived informatics model of personal informatics. In *Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing - UbiComp '15*. ACM Press, Osaka, Japan, 731–742. https://doi.org/10.1145/2750858.2804250

[38] Clayton Feustel, Shyamak Aggarwal, Bongshin Lee, and Lauren Wilcox. 2018. People Like Me: Designing for Reflection on Aggregate Cohort Data in Personal Informatics Systems. *Proc. ACM Interact. Mob. Wearable Ubiquitous Technol.* 2, 3, Article 107 (sep 2018), 21 pages. https://doi.org/10.1145/3264917

[39] Doris Fuchs. 2021. *Consumption Corridors; Living a Good Life within Sustainable Limits*. Routledge.

[40] Patricia Fusch and Lawrence Ness. 2015. Are We There Yet? Data Saturation in Qualitative Research. *The Qualitative Report* (Sept. 2015). https://doi.org/10.46743/2160-3715/2015.2281

[41] VERBI GmbH. 2019. MAXQDA 2020. https://www.maxqda.com

[42] Ian Gough. 2020. Defining floors and ceilings: the contribution of human needs theory. *Sustainability: Science, Practice and Policy* 16, 1 (Dec. 2020), 208–219. https://doi.org/10.1080/15487733.2020.1814033

[43] Joel M Hektner, Jennifer A Schmidt, and Mihaly Csikszentmihalyi. 2007. *Experience sampling method: Measuring the quality of everyday life*. Sage.

[44] Monique Hennink and Bonnie N. Kaiser. 2022. Sample sizes for saturation in qualitative research: A systematic review of empirical tests. *Social Science & Medicine* 292 (Jan. 2022), 114523. https://doi.org/10.1016/j.socscimed.2021.114523

[45] E Tory Higgins. 1987. Self-discrepancy: a theory relating self and affect. *Psychological review* 94, 3 (1987), 319. Publisher: American Psychological Association.

[46] Michael Hoefer and Stephen Voida. 2023. Tracking the Experience of Self in Everyday Life. In *Extended Abstracts of the 2023 CHI Conference on Human Factors in Computing Systems (CHI EA '23)*. Association for Computing Machinery, New York, NY, USA, 1–8. https://doi.org/10.1145/3544549.3585785

[47] Dandan Huang, Melanie Tory, Bon Adriel Aseniero, Lyn Bartram, Scott Bateman, Sheelagh Carpendale, Anthony Tang, and Robert Woodbury. 2015. Personal Visualization and Personal Visual Analytics. *IEEE Transactions on Visualization and Computer Graphics* 21, 3 (March 2015), 420–433. https://doi.org/10.1109/TVCG.2014.2359887

[48] Hilary Hutchinson, Wendy Mackay, Bosse Westerlund, Benjamin B Bederson, Allison Druin, Catherine Plaisant, Michel Beaudouin-Lafon, Stéphane Conversy, Helen Evans, Heiko Hansen, Nicolas Roussel, Björn Eiderbäck, Sinna Lindquist, and Yngve Sundblad. 2003. Technology Probes: Inspiring Design for and with Families. *New Horizons* 5 (2003), 8. https://doi.org/10.1145/642611.642616

[49] Terry Irwin. 2015. Transition Design: A Proposal for a New Area of Design Practice, Study, and Research. *Design and Culture* 7, 2 (April 2015), 229–246. https://doi.org/10.1080/17547075.2015.1051829

[50] Terry Irwin, Gideon Kossoff, and Cameron Tonkinwise. 2015. Transition Design Provocation. *Design Philosophy Papers* 13, 1 (Jan. 2015), 3–11. https://doi.org/10.1080/14487136.2015.1085688

[51] Daniel Kahneman, Edward Diener, and Norbert Schwarz (Eds.). 1999. *Well-being: Foundations of Hedonic Psychology*. Russell Sage Foundation, New York, NY.

[52] Daniel Kahneman, Alan B. Krueger, David A. Schkade, Norbert Schwarz, and Arthur A. Stone. 2004. A Survey Method for Characterizing Daily Life Experience: The Day Reconstruction Method. *Science* 306, 5702 (2004), 1776–1780. https://doi.org/10.1126/science.1103572

[53] Maria Karyda, Elisa Mekler, and Andres Lucero. 2021. Data Agents: Promoting Reflection through Meaningful Representations of Personal Data in Everyday Life. In *CHI 2021 - Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems.: Making Waves, Combining Strengths*. ACM. https://doi.org/10.1145/3411764.3445112

[54] Scott Barry Kaufman. 2021. *Transcend: The New Science of Self-Actualization.* TarcherPerigee, New York, NY.

[55] Matthew Kay, Eun Kyoung Choe, Jesse Shepherd, Benjamin Greenstein, Nathaniel Watson, Sunny Consolvo, and Julie A. Kientz. 2012. Lullaby: A capture & access system for understanding the sleep environment. In *Proceedings of the 2012 ACM Conference on Ubiquitous Computing (UbiComp '12)*. ACM, New York, NY, USA, 226–234. https://doi.org/10.1145/2370216.2370253

[56] Moon K. Kim and Ethan Trewhitt. 2022. SatisfAI: A Serious Tabletop Game to Reveal Human-AI Interaction Dynamics. In *Adaptive Instructional Systems (Lecture Notes in Computer Science)*, Robert A. Sottilare and Jessica Schwarz (Eds.). Springer International Publishing, Cham, 174–189. https://doi.org/10.1007/978-3-031-05887-5_13

[57] Young-Ho Kim, Jae Ho Jeon, Eun Kyoung Choe, Bongshin Lee, KwonHyun Kim, and Jinwook Seo. 2016. TimeAware: Leveraging Framing Effects to Enhance Personal Productivity. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (CHI '16)*. Association for Computing Machinery, New York, NY, USA, 272–283. https://doi.org/10.1145/2858036.2858428

[58] Young-Ho Kim, Jae Ho Jeon, Bongshin Lee, Eun Kyoung Choe, and Jinwook Seo. 2017. OmniTrack: A Flexible Self-Tracking Approach Leveraging Semi-Automated Tracking. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies* 1, 3 (Sept. 2017), 67:1–67:28. https://doi.org/10.1145/3130930

[59] Hideki Kobayashi, Yoshinori Sumimura, Chuc Nguyen Dinh, Minh Tran, Hidenori Murata, and Shinichi Fukushige. 2019. Needs-Based Workshops for Sustainable Consumption and Production in Vietnam. In *Sustainable Design and Manufacturing 2019 (Smart Innovation, Systems and Technologies)*, Peter Ball, Luisa Huaccho Huatuco, Robert J. Howlett, and Rossi Setchi (Eds.). Springer, Singapore, 35–47. https://doi.org/10.1007/978-981-13-9271-9_4

[60] Gideon Kossoff. 2015. Holism and the reconstitution of everyday life: a framework for transition to a sustainable society. *Design Philosophy Papers* 13, 1 (Jan. 2015), 25–38. https://doi.org/10.1080/14487136.2015.1085698 Publisher: Routledge _eprint: https://doi.org/10.1080/14487136.2015.1085698.

[61] Jakob Eg Larsen, Andrea Cuttone, and Sune Lehmann Jørgensen. 2013. QS Spiral: Visualizing Periodic Quantified Self Data: CHI 2013 Workshop on Personal Informatics in the Wild: Hacking Habits for Health & Happiness. *Proceedings of CHI 2013 Workshop on Personal Informatics in the Wild: Hacking Habits for Health & Happiness* (2013).

[62] Henri Lefebvre. 2014. *The critique of everyday life: The one-volume edition.* Verso Books.

[63] Clayton Lewis. 1982. *Using the "Thinking-Aloud" Method in Cognitive Interface Design.* Technical Report RC 9265. IBM T. J. Watson Research Center, Yorktown Heights, NY. https://dominoweb.draco.res.ibm.com/reports/RC9265.pdf

[64] Ian Li, Anind Dey, and Jodi Forlizzi. 2010. A stage-based model of personal informatics systems. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '10)*. ACM, New York, NY, USA, 557–566. https://doi.org/10.1145/1753326.1753409

[65] James J. Lin, Lena Mamykina, Silvia Lindtner, Gregory Delajoux, and Henry B. Strub. 2006. Fish'n'Steps: encouraging physical activity with an interactive computer game. In *Proceedings of the 8th international conference on Ubiquitous Computing (UbiComp'06)*. Springer-Verlag, Berlin, Heidelberg, 261–278. https://doi.org/10.1007/11853565_16

[66] Patricia W. Linville. 1985. Self-Complexity and Affective Extremity: Don't Put All of Your Eggs in One Cognitive Basket. *Social Cognition* 3, 1 (March 1985), 94–120. https://doi.org/10.1521/soco.1985.3.1.94

[67] Patricia W. Linville. 1987. Self-complexity as a cognitive buffer against stress-related illness and depression. *Journal of Personality and Social Psychology* 52, 4 (April 1987), 663–676. https://doi.org/10.1037/0022-3514.52.4.663

[68] Kai Ludwigs, Lena Henning, and Lidia R. Arends. 2019. Using the Day Reconstruction Method - Same Results when Used at the End of the Day or on the Next Day? *International Journal of Community Well-Being* 2, 1 (May 2019), 61–73. https://doi.org/10.1007/s42413-019-00017-x

[69] Deborah Lupton. 2016. *The quantified self.* John Wiley & Sons.

[70] Abraham Harold Maslow. 1943. A theory of human motivation. *Psychological review* 50, 4 (1943), 370.

[71] Abraham H Maslow. 1981. *Motivation and Personality.* Prabhat Books, New Delhi, India.

[72] Talie Massachi, Grant Fong, Varun Mathur, Sachin R. Pendse, Gabriela Hoefer, Jessica J. Fu, Chong Wang, Nikita Ramoji, Nicole R. Nugent, Megan L. Ranney, Daniel P. Dickstein, Michael F. Armey, Ellie Pavlick, and Jeff Huang. 2020. Sochiatrist: Signals of Affect in Messaging Data. *Proceedings of the ACM on Human-Computer Interaction* 4, CSCW2 (Oct. 2020), 1–25. https://doi.org/10.1145/3415182

[73] Manfred Max-Neef. 1992. *From the Outside Looking in: Experiences in Barefoot Economics.* Zed Books.

[74] Manfred Max-Neef, Antonio Elizalde, Martin Hopenhayn, Felipe Herrera, Hugo Zemelman, Jorge Jataba, and Luis Weinstein. 1989. Human Scale Development: An Option for the Future. (1989), 140.

[75] Manfred A. Max-Neef, Antonio Elizalde, and Martín Hopenhayn. 1991. *Human scale development: conception, application and further reflections.* The Apex Press, New York.

[76] Allen R. McConnell. 2011. The Multiple Self-Aspects Framework: Self-Concept Representation and Its Implications. *Personality and Social Psychology Review* 15, 1 (Feb. 2011), 3–27. https://doi.org/10.1177/1088868310371101

[77] Stephen K. McLeod. 2011. Knowledge of Need. *International Journal of Philosophical Studies* 19, 2 (June 2011), 211–230. https://doi.org/10.1080/09672559.2011.561616

[78] Elisa D Mekler and Kasper Hornbæk. 2016. Momentary pleasure or lasting meaning?: Distinguishing eudaimonic and hedonic user experiences. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (CHI '16)*. ACM Press, New York, NY, 4509–4520. https://doi.org/10.1145/2858036.2858225

[79] Michael Hoefer and Stephen Voida. 2023. Activity Data from Everyday Life: Time Use and Need Satisfaction. https://doi.org/10.17605/OSF.IO/XNZAQ

[80] Salvatore Monni and Alessandro Spaventa. 2013. Beyond GDP and HDI: Shifting the focus from paradigms to politics. *Development* 56, 2 (June 2013), 227–231. https://doi.org/10.1057/dev.2013.30

[81] Livia J Müller, Elisa D Mekler, and Klaus Opwis. 2015. Facets in HCI: Towards understanding eudaimonic UX – Preliminary findings. In *Extended Abstracts of the 33rd Annual ACM Conference on Human Factors in Computing Systems (CHI '15)*. ACM Press, New York, NY, 2283–2288. https://doi.org/10.1145/2702613.2732836

[82] Michael J. Muller, Cathleen Wharton, William J. McIver, and Lila Laux. 1997. Toward an HCI research and practice agenda based on human needs and social responsibility. In *Proceedings of the ACM SIGCHI Conference on Human factors in computing systems (CHI '97)*. Association for Computing Machinery, New York, NY, USA, 155–161. https://doi.org/10.1145/258549.258640

[83] Mark Newman. 2018. *Networks.* Oxford university press.

[84] Martha Nussbaum. 2000. Women's Capabilities and Social Justice. *Journal of Human Development* 1, 2 (July 2000), 219–247. https://doi.org/10.1080/713678045

[85] Fredrik Ohlin, Carl Magnus Olsson, and Paul Davidsson. 2015. Analyzing the Design Space of Personal Informatics: A State-of-practice Based Classification of Existing Tools. In *Universal Access in Human-Computer Interaction. Access to Today's Technologies (Lecture Notes in Computer Science)*, Margherita Antona and Constantine Stephanidis (Eds.). Springer International Publishing, Cham, 85–97. https://doi.org/10.1007/978-3-319-20678-3_9

[86] World Commission on Environment and Development. 1987. *Our common future.* Oxford University Press, Oxford.

[87] Debjit Paul and Anette Frank. 2019. Ranking and Selecting Multi-Hop Knowledge Paths to Better Predict Human Needs. In *Proceedings of the 2019 Conference of the North American Chapter of the Association for Computational Linguistics: Human Language Technologies, Volume 1 (Long and Short Papers)*. Association for Computational Linguistics, Minneapolis, Minnesota, 3671–3681. https://doi.org/10.18653/v1/N19-1368

[88] Michael E Porter, Scott Stern, and Michael Green. 2014. *Social progress index 2014.* Citeseer.

[89] James O Prochaska and Wayne F Velicer. 1997. The Transtheoretical Model of Health Behavior Change. *American Journal of Health Promotion* 12, 1 (Sept. 1997), 38–48. https://doi.org/10.4278/0890-1171-12.1.38

[90] Mashfiqui Rabbi, Shahid Ali, Tanzeem Choudhury, and Ethan Berke. 2011. Passive and In-Situ Assessment of Mental and Physical Well-being Using Mobile Sensors. In *Proceedings of the 13th International Conference on Ubiquitous Computing (UbiComp '11)*. ACM, New York, NY, USA, 385–394. https://doi.org/10.1145/2030112.2030164

[91] Amon Rapp and Maurizio Tirassa. 2017. Know Thyself: A Theory of the Self for Personal Informatics. *Human–Computer Interaction* 32, 5-6 (Nov. 2017), 335–380. https://doi.org/10.1080/07370024.2017.1285704

[92] Frederick F Reichheld. 2003. The One Number You Need to Grow. *Harvard Business Review* (2003), 12.

[93] Richard M Ryan and Edward L Deci. 2001. On happiness and human potentials: A review of Research on hedonic and eudaimonic well-being. *Annual Review of Psychology* 52, 1 (Feb. 2001), 141–166. https://doi.org/10.1146/annurev.psych.52.1.141

[94] Richard M Ryan and Edward L Deci. 2018. *Self-Determination Theory: Basic Psychological Needs in Motivation, Development, and Wellness.* Guilford Publications, New York, NY.

[95] Richard M Ryan and Jennifer G La Guardia. 2000. What is being optimized?: Self-determination theory and basic psychological needs. In *Psychology and the Aging Revolution: How We Adapt to Longer Life*, Sara Honn Qualls and Norman Abeles (Eds.). American Psychological Association, Washington, DC, 145–172. https://doi.org/10.1037/10363-008

[96] Matthew J Salganik. 2019. *Bit by Bit: Social Research in the Digital Age.* Princeton University Press.

[97] Martin E P Seligman. 2012. *Flourish: A Visionary New Understanding of Happiness and Well-being.* Free Press, New York, NY.

[98] Abigail J. Sellen and Steve Whittaker. 2010. Beyond total capture: a constructive critique of lifelogging. *Commun. ACM* 53, 5 (May 2010), 70–77. https://doi.org/10.1145/1735223.1735243

[99] Amartya Sen. 2005. Human Rights and Capabilities. *Journal of Human Development* 6, 2 (July 2005), 151–166. https://doi.org/10.1080/14649880500120491

[100] Katie Shilton. 2012. Participatory personal data: An emerging research challenge for the information sciences. *Journal of the American Society for Information Science and Technology* 63, 10 (2012), 1905–1915. https://doi.org/10.1002/asi.22655

[101] Ben Shneiderman, Catherine Plaisant, Maxine Cohen, Steven Jacobs, Niklas Elmqvist, and Nicholoas Diakopoulos. 2016. Grand challenges for HCI researchers. *ACM Interactions* XXIII.5 (Oct. 2016), 24. https://interactions.acm.org/archive/view/september-october-2016/grand-challenges-for-hci-researchers#R3

[102] Carolin Showers. 1992. Compartmentalization of Positive and Negative Self-Knowledge: Keeping Bad Apples Out of the Bunch. *Journal of Personality and Social Psychology* 62, 6 (1992), 14. https://doi.org/10.1037//0022-3514.62.6.1036

[103] Salina Spiering. 2020. How to?! Practical knowledge for transformative science – facilitation guidelines for two applications of the Human Scale Development Approach. (2020), 77. http://hdl.handle.net/10419/215828

[104] Julia K. Steinberger, William F. Lamb, and Marco Sakai. 2020. Your money or your life? The carbon-development paradox. *Environmental Research Letters* 15, 4 (March 2020), 044016. https://doi.org/10.1088/1748-9326/ab7461

[105] Constantine Stephanidis, Gavriel Salvendy, Margherita Antona, Jessie Y. C. Chen, Jianming Dong, Vincent G. Duffy, Xiaowen Fang, Cali Fidopiastis, Gino Fragomeni, Limin Paul Fu, Yinni Guo, Don Harris, Andri Ioannou, Kyeongah (Kate) Jeong, Shin'ichi Konomi, Heidi Krömker, Masaaki Kurosu, James R. Lewis, Aaron Marcus, Gabriele Meiselwitz, Abbas Moallem, Hirohiko Mori, Fiona Fui-Hoon Nah, Stavroula Ntoa, Pei-Luen Patrick Rau, Dylan Schmorrow, Keng Siau, Norbert Streitz, Wentao Wang, Sakae Yamamoto, Panayiotis Zaphiris, and Jia Zhou. 2019. Seven HCI Grand Challenges. *International Journal of Human–Computer Interaction* 35, 14 (Aug. 2019), 1229–1269. https://doi.org/10.1080/10447318.2019.1619259 Publisher: Taylor & Francis _eprint: https://doi.org/10.1080/10447318.2019.1619259.

[106] Jina Suh, Eric Horvitz, Ryen W. White, and Tim Althoff. 2021. Population-Scale Study of Human Needs During the COVID-19 Pandemic: Analysis and Implications. In *Proceedings of the 14th ACM International Conference on Web Search and Data Mining (WSDM '21)*. Association for Computing Machinery, New York, NY, USA, 4–12. https://doi.org/10.1145/3437963.3441788

[107] Latanya Sweeney. 2002. k-Anonymity: A Model for Protecting Privacy. *International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems* 10, 05 (Oct. 2002), 557–570. https://doi.org/10.1142/S0218488502001648

[108] Minmin Tang, Dahua Wang, and Alain Guerrien. 2020. A systematic review and meta-analysis on basic psychological need satisfaction, motivation, and well-being in later life: Contributions of self-determination theory. *PsyCh Journal* 9, 1 (2020), 5–33. https://doi.org/10.1002/pchj.293

[109] Bill Tomlinson, M. Six Silberman, Donald Patterson, Yue Pan, and Eli Blevis. 2012. Collapse informatics: augmenting the sustainability & ICT4D discourse in HCI. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '12)*. Association for Computing Machinery, New York, NY, USA, 655–664. https://doi.org/10.1145/2207676.2207770

[110] April Tyack and Elisa D. Mekler. 2020. Self-Determination Theory in HCI Games Research: Current Uses and Open Questions. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems (CHI '20)*. Association for Computing Machinery, New York, NY, USA, 1–22. https://doi.org/10.1145/3313831.3376723

[111] Maarten Vansteenkiste, Richard M. Ryan, and Bart Soenens. 2020. Basic psychological need theory: Advancements, critical themes, and future directions. *Motivation and Emotion* 44, 1 (Feb. 2020), 1–31. https://doi.org/10.1007/s11031-019-09818-1

[112] Gibran Vita, Edgar G. Hertwich, Konstantin Stadler, and Richard Wood. 2019. Connecting global emissions to fundamental human needs and their satisfaction. *Environmental Research Letters* 14, 1 (Jan. 2019), 014002. https://doi.org/10.1088/1748-9326/aae6e0

[113] Vasiliki Voukelatou, Lorenzo Gabrielli, Ioanna Miliou, Stefano Cresci, Rajesh Sharma, Maurizio Tesconi, and Luca Pappalardo. 2020. Measuring objective and subjective well-being: dimensions and data sources. *International Journal of Data Science and Analytics* (June 2020). https://doi.org/10.1007/s41060-020-00224-2

[114] Steve Whittaker, Vaiva Kalnikaite, Victoria Hollis, and Andrew Guydish. 2016. 'Don't Waste My Time': Use of Time Information Improves Focus. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (CHI '16)*. Association for Computing Machinery, New York, NY, USA, 1729–1738. https://doi.org/10.1145/2858036.2858193

[115] John Zimmerman. 2009. Designing for the self: making products that help people become the person they desire to be. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '09)*. Association for Computing Machinery, New York, NY, USA, 395–404. https://doi.org/10.1145/1518701.1518765

[116] John Zimmerman, Kursat Ozenc, and Bong-keum Jeong. 2008. New Methods for the Design of Products That Support Social Role Transitions. *Artifact* 2, 3-4 (Sept. 2008), 190–206. https://doi.org/10.1080/17493460802527113