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Know Thyself: A Theory of the Self for Personal Informatics

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Running Head: A Theory of the Self for Personal Informatics

ABSTRACT

Although Personal Informatics stresses the importance of "self"-awareness and "self"-knowledge in collecting personal data, a description of the "self", to which all these knowledge endeavors are addressed, is missing in the current debate. In this article we first review how the different theoretical assumptions that currently inform the design of Personal Informatics tools lack to convey a convincing image of the self which ought to be quantified by these technologies. We then move on to the outline of a theory of the self that may ground the current discourse in Personal Informatics. Building on this theoretical framework, we propose a set of design guidelines as its implications, which may drive the

design of future self-tracking technologies. Finally, we outline a research agenda, organized around such guidelines, in the form of research questions to be addressed in the future.

CONTENTS

1. INTRODUCTION

The popularity of Personal Informatics (PI) is rising thanks to the advancements in wearable technologies and portable devices that increasingly allow the automatic gathering of personal data. The primary purpose of these tools allegedly is to enhance self-reflection and support self-knowledge, promising users to gain a better understanding of themselves and of the factors that may influence their lives.

HCI researchers have widely explored how people use PI systems in order to improve their designs, by focusing on barriers that users experience (Li, Dey, & Forlizzi, 2010; Harrison, Marshall, Bianchi-Bertouze, & Bird, 2015; Rapp & Cena, 2016), questions they have about the data collected (Li, Dey, & Forlizzi, 2011), their motivations to track (Rooksby, Rost, Morrison, & Chalmers, 2014) and varying goals (Epstein, Ping, Fogarty, & Munson, 2015), how they react to different kinds of visualization (Epstein, Cordeiro, Bales, Fogarty, & Munson, 2014), how they assess the accuracy of a tracking instrument (Yang, Shin, Newman, & Ackerman, 2015), and why they abandon devices (Lazar, Koehler, Tanenbaum, & Nguyen, 2015; Clawson, Pater, Miller, Mynatt, & Mamykina, 2015), as well as the needs and practices of long-term self-trackers (Fritz, Huang, Murphy, & Zimmermann, 2014), and Quantified Self members (Choe, Lee, Lee, Pratt, & Kientz, 2014; Whooley, Ploderer, & Gray, 2014).

Despite this attention to the real-world practices in the use of PI systems, reflections on the theoretical foundations of PI are surprisingly scarce. The theoretical models and constructs used by the HCI community in the design and the development of novel PI systems are mostly borrowed from theories of behavior change, also encompassing a utilitarian perspective on personal data and self-knowledge. Although these instruments were initially devised to provide users with a better knowledge of their

"self" and to increase their "self"-awareness and "self"-reflection, the rhetoric of PI is currently dominated by a focus on behavior and on the uses that individuals may make of their personal data.

It appears to be taken for granted that the self that PI tools supposedly help to understand can be reduced to the atomic parameters tracked by these instruments, or defined through a simple reference to the different aims that individuals have to track. However, this theoretical attitude produces a *de facto* disappearance of the self within the current debate of PI in favor of the individual behaviors that should be its external manifestations.

We will claim that PI needs to ground itself on a renewed theoretical background to meet its original aim of providing individuals with a better knowledge of themselves. We will try to answer the following questions: What are the main conceptual issues in the theories that inform current PI technologies? What is the "self" that PI systems should be designed for? How should PI systems be designed to promote an effective self-understanding and possibly a change based on it? What are the main challenges that PI should explore in the future?

Our contribution to HCI community and PI aims to be threefold. We will first review how the different theoretical assumptions that currently inform the design of PI tools lack to convey a convincing image of the self which ought to be quantified by these technologies. Second, we will propose a paradigm shift in PI discourse by outlining a theory of the self based on the phenomenological and constructivist traditions: this will move such discourse from behavior and its objective data to the self and its subjective meanings. On the basis of this renewed theoretical scaffold we will propose a set of design guidelines as implications of the theory, which could drive the design of future PI technologies. Finally, we will suggest a research agenda, organized around the guidelines proposed, in the form of research questions to be addressed in the future. These questions will embody our understanding of

what theoretical issues are the most important to explore and our recommendations of specific research directions to follow.

2. THE SELF IN PERSONAL INFORMATICS

PI systems are commonly defined as "those that help people collect personally relevant information for the purpose of self-reflection and gaining self-knowledge" (Li et al., 2010, p. 558). This definition stresses the main promise that these technologies appear to make to their users: to improve life based on a renewed self-understanding.

Curiously, however, a description of this "self", to which these knowledge endeavors are addressed, is missing in the current debate within PI. PI systems emphasize the benefits that allegedly derive from "self"-reflection and "self"-knowledge, but what is the "self" they are designed for? At first sight, the answer may appear to be obvious: an individual's self shows from the plethora of personal data gathered by PI tools. Nevertheless, on a closer look, this self turns out to be void, due both to the lack of a theoretical framework capable of capturing its essence and features, and to the attempt to reverse the natural way of looking at the self, namely from a subjective point of view.

2.1. Self and behavior

First, it must be noted that most PI tools merely collect and display behavioral/physiological information like the number of steps taken, or the blood pressure level (Li, Dey, & Forlizzi, 2012). The self that these instruments quantify thus is reduced to the data pattern referred to the single behavior/parameter tracked, and the self-knowledge that they actually provide is mere information about how the user behaved in the past.

However, the vanishing of the self within the rhetoric of PI is not only a matter of what these tools display and how, but is rooted in theoretical assumptions that, although not always explicit, deeply affect the PI discourse. In fact, the frameworks that inform most PI technologies are borrowed from behavior change theories, resulting in a focus shift from the self to the behavior to be changed. The self that these tools should help unveil, therefore, actually becomes fragmented in the individual behaviors that have to be modified.

Consolvo et al. (2008), for example, designed UbiFit Garden, a mobile phone application that aims at providing frequent opportunities for self-reflection, accounting for a range of physical activities. Despite a strong emphasis on self-awareness, the system is mainly grounded in theoretical constructs addressed to change an individual's behavior, e.g. by "providing simple rewards for goal attainment and for performing the desired behavior" (Consolvo et al., 2008, p. 55). Li et al. (2012) stressed that "information about the factors that affect physical activity may be needed for deeper self-reflection and increased self-knowledge" (Li et al., 2012, p. 7:1). By emphasizing the role of context, they seemed to move toward a more comprehensive self-knowledge. In the end, however, this knowledge turns out to be an understanding of "the behavior and what causes the behavior" (Li et al., 2012, p. 7:3). In the same vein, Bentley et al. (2013) appeared to make a step forward toward providing a real understanding of the self and its evolution over time, by focusing on mining wellbeing and contextual data streams for correlations, long-term trends and deviations over months of data. Nevertheless, by relying on persuasive theories (Fogg, 2003; Consolvo, McDonald, & Landay, 2009) to articulate their discourse, even they "focus[ed] on specific behaviors to change" (Bentley et al., 2013, p. 30:21).

An attitude that values behaviors over the self that produces them is perhaps more clearly visible in the emphasis given in the current PI debate to the reactive effects of self-monitoring. Reactivity is the phenomenon whereby the very process of recording a behavior causes that behavior to change (Cooper, Heron, & Heward, 2007): it has been suggested that PI technologies should look for ways to enhance

reactive effects so that people can gain therapeutic outcomes from self-tracking (Choe, 2014; Li, 2012). However, the importance of reactivity is mostly stressed in behaviorist psychology, where self-monitoring is usually applied to specific target behaviors in order to solve relevant problems (e.g. smoking). Of course the self has no place in behaviorism, where mental entities are considered unobservable and therefore explanatory fiction (Cooper et al., 2007). Reactivity effects, here, are explained without involving the self, but referring, for example, to the comparison that the self-monitor makes between the behavior recorded and a standard performance, rewarding or punishing herself for having met or failed to meet such standard (Kanfer, 1977). By emphasizing the importance of reactivity, thus, PI implicitly bypasses the role of the self.

In the different arguments that inform these examples we can see how the self is substituted for with the behavior to be changed, and how theoretical constructs such as "behavior", "awareness", and "change" are directly derived from behavioral theories. This operation brings on a set of implicit assumptions that are accepted in the current rhetoric of PI without any particularly profound discussion: for example, that "behavior" is an atomistic entity that can be addressed without referring to the individual's inner life (e.g. her memories, meanings, and so on); that self-knowledge consists in retracing behavioral sequences we performed in the past; that change will occur as a new stage, after an individual has rationally determined a "newfound understanding" of her behavior; and that such change will affect the target behavior alone.

2.2. A utilitarian view of the self

Focusing on behavior change has the immediate consequence that PI frames itself within a utilitarian perspective whereby the self is shaped along the aims that people may have to track. This tendency is also evident in PI models, which have been developed in years for providing designers with a

theoretical background to ground and drive new designs in the field. Here the focus on self-reflection is meant more as a means to a further goal rather than as an end in itself.

For example, the first and most common model to understand how individuals use PI systems was proposed by Li et al. (2010). It is composed of five stages through which people transition when using PI tools: i) *preparation*, where the user starts collecting personal information; ii) *collection*, where she gathers data about herself ; iii) *integration*, where the information collected are prepared and transformed for the user to reflect upon; iv) *reflection*, where the user reflects on her data; v) *action*, where she chooses how to behave on the basis of her newfound understanding of herself. By placing *action* (meant as enacted behavior) as the final stage of their model, Li et al. stress how self-knowledge supports and is in service of behavior change (Li et al. 2010). This emphasis on behavior and its change mainly comes from the Transtheoretical Model of behavior change (TTM), a framework commonly employed in health behavioral interventions, which describes how health behavior change involves progress through different stages of change (Prochaska, Redding & Evers, 2008). By taking this framework as a source of inspiration, Li et al. partially renounced to their initial definition of PI, positing its final aim not in the support of *self*-reflection and *self*-knowledge, but in the accomplishment of a behavior change goal. *Reflection*, here, mirrors the *consciousness rising* described in the TTM, an activity that people *use* to progress toward a specific behavioral goal (Prochaska et al., 2008).

Li et al.'s model has since been expanded and modified (e.g. Li et al., 2011; Choe et al., 2014), but the perspective on the self has remained the same: a self that becomes shaped by its behavior change goals.

Rooksby et al. (2014) noted how activity trackers can be used in five different ways, namely to reach a goal, to document activities, to link different things together, to register achievements, and for a pure interest in data and technology. They also introduced the term 'lived informatics' to describe people's

real practices about tracking data. Based on these results, Epstein et al. (2015) proposed a revised model of how people use self-tracking tools not only for behavior change, but also to obtain a record of a particular behavior, to get rewards and achieve social benefits, and for curiosity. Going beyond the exclusive focus on behavior change, and framing PI within a range of lived activities, Epstein et al.'s research deserves merit for shifting attention toward how PI is experienced and made accountable by people in their everyday lives. However, it still maintains a utilitarian view of the individual's self and of the act of self-reflection, which remains a means for "external" ends. Although not explicitly mentioned, the self here is actually defined by the motivations that people have to track their data and by the use they made of them.

To summarize, the debate on PI appears to paradoxically forget the self in favor of an "externalistic" perspective on human beings. There are two reasons for this. One is that PI technologies and models rely on theories of behavior change that were originally developed to assess and intervene on specific behavioral problems. Not only do these theories emphasize behavior to the detriment of the individual's inner life, but they also take a static view of the latter, rarely accounting for changes in internal states (Clawson et al., 2015). Moreover, the kind of change they imply is only recognized and assessed when it produces visible effects on the individual's external behavior. The second reason is that the PI debate currently is focused on a utilitarian perspective that crystallizes the user's self in what she *does*, instead of accounting for the ever changing nature of what she *is*. Such criticalities have been noted outside the PI/HCI terrain, especially within social sciences. It has been highlighted that discourses concerning self-tracking present, on the one side, the self as a mere conglomerate of quantifiable data that can be revealed using digital devices (Lupton, 2016), and, on the other side, self-tracking regimens as aimed to produce an optimized self (Ruckenstein, 2014), enhancing the individual's efficiency (Lupton, 2014). Schüll (2016) further noted how Quantified Self (QS) metaphors entail a notion of the self as a database, whose truth lies in scattered points, associations and

dynamic accretions, which does not correspond to the phenomenological self. However, Sharon & Zanderbergen (2016) showed how actual self-tracking practices may go beyond their underlying rhetoric, as Quantified Selfers often re-contextualize their data into qualitative narratives and insist on the idiosyncrasy of individual bodies and psyches resisting the categories that are built into devices (Nafus & Sherman, 2014). For this reason, Sharon (2016) suggests to shift the emphasis from the current QS rhetoric toward self-tracking practices, while Lomborg & Frandsens (2016) propose to focus on the experiential value and meaning of the self-tracking practices, conceptualizing them as communicative phenomena.

Given these premises, we think that outlining a theory of the self viable for PI is crucial to inform the future designs of technologies that might allow us to understand and change our selves. Of course we do not want to undermine previous work done in PI: it certainly is licit to frame PI within the wider landscape of behavior change technologies. Nevertheless, we would like to start to reflect on how PI systems could meet a grander ambition, focusing the debate on what may be their specificity, namely the capability of revealing something of the individual's self. Calls for a more experience-centered approach to PI, going beyond a mere utility view of personal data, begin to emerge also in the current debate within HCI (Elsden, Kirk, Selby, & Speed, 2015). Ohlin & Olsson (2015a) for example, emphasize the need of analyzing PI technologies in a way that encapsulates the entire life-world situation for human agents through postphenomenology, while Elsden, Kirk, and Durrant (2016) propose to shift attention to how PI is experienced and made accountable to people's everyday lives. Nafus et al. (2016) suggest that designers take into account the fundamental unpredictability of what people will see in their data, supporting an exploration thereof that leaves interpretive control with end users.

Building on these insights, we want to move from an "external take" to a subjective perspective in dealing with personal data. In doing this, we also wish to reframe the ways in which PI can produce a

change in its users, starting from their inner self instead of their behavior. To this aim, we will now illustrate a theoretical framework that aims to account for the “internality” of the individual.

3. A THEORY OF THE SELF FOR PERSONAL INFORMATICS

The main theoretical contribution we want to offer with this paper is the proposal of a shift of the PI discourse about the self from the cognitive-behavioral paradigm to the phenomenological and constructivist paradigm. The resulting theory should function as a scaffold for the design of novel PI tools, meant to support self-knowledge rather than modify behavior. Behavior follows, if ever, from internal states.

Our approach, thus, starts from the premises of the phenomenological and constructivist paradigm, namely that the self is subjectivity, that our take on reality and ourselves is subjective, and that our knowledge and self-knowledge are dynamically constructed. Once these premises are accepted, like one would accept the basic assumptions of any normal scientific paradigm, we will claim that several consequences follow analytically. One is, for example, that our sense of the past does not literally consist in the storing of archived images in an inner deposit from which they can literally be retrieved. What we will call "the past self" can only be (re)created in the here and now. The same, in reverse, holds for the future self. And so on.

We use the term paradigm in Kuhn's (1962) acceptation. Differently from what happens in other sciences, however, paradigms in psychology typically coexist rather than substitute for each other. This is because each has its merits and, at the same time, is unable to cast the silver bullet capable of consigning its rivals to the dustbin of history. Thus, components of one paradigm are often transferred to another paradigm with no substantial modifications. Of course, this only seldom, if ever, may concern ontological or epistemological premises, but typically happens with experimental results,

insofar as, for example, the description of what a rat in a cage actually does is at least partially independent from the scientist's theoretical approach. As we said, silver bullets, for example in the form of dichotomic experiments capable of decisively favoring a theory or paradigm against another, are dishearteningly scarce in the field.

Even more interestingly, transfer between paradigms also happens with more abstract, theoretical constructs. The notion of self-efficacy, to name one, despite being initially couched in social cognitive theory (Bandura, 1986), holds pretty well in whichever paradigm one adopts, so much so that nowadays it is accepted by most or all school of thoughts in psychology. Where paradigms differ is on the explanatory theory devised to account for the particular evidence or construct at hand. Paradigms, thus, are often permeable, which of course may give rise to various kinds of inconsistencies, but at least allows them to work even under puzzling conditions, as all those that pertain to the mind are. This is the reason why, sometimes, we also made our theory account for empirical evidence and theoretical constructs originally developed in other paradigms.

3.1. Premise

There is no way to sum up 150 years of scientific theorizing about the mind in a couple of pages. As we have noted, psychology is better viewed as a multiverse than a linear succession of substantially consensual paradigms and ideas. Positions widely held in psychology about the nature of the mind are, for example, that it is to be viewed as a flow of subjective experience (which is our position as well); that it is a software program or set of programs; that it just does not exist; that it might as well exist but, being unobservable from the outside, is not a worthy object of study; that it is completely reducible to the material functioning of the brain; and others. As regards the notion of self, it may be conceived of as a part of the mind, more or less on a par with others; as a supervisory system in charge of monitoring the functioning of other subsystems; and so on. Since we identify the mind with phenomenal,

subjective experience, as we will see below, to us the terms “mind” and “self” are substantially synonyms.[1]

This said, one of the accepted definitions of the mind in the cognitive sciences is that it is the control system of a *behaving* system/organism (Newell, 1990; Sloman, 1993). This notion of control system basically is that of classic cybernetics (Wiener, 1948) and is taken to refer to the part of a complex system that plays a major or exclusive role in governing the functioning of the whole system. However, each paradigm has its own view of the nature, structure, extension, and functioning of such control system (see Manera & Tirassa, 2010).

Here, we define the mind and the self as the control system of an individual's interaction with the environment (Brizio & Tirassa, 2016), which ties the idea of the self as a control system to the phenomenological paradigm. In fact, this definition does not mention *behavior*, highlighting only *interaction* instead. There are at least two reasons for this. One is that the notion of behavior is unilateral, as if the agent performed in a passive world, while that of interaction emphasizes the agent's embeddedness within a world which co-participates in the ongoing events. The other is that behavior typically is construed from the vantage point of an external observer. The notion of interaction, instead, when fully taken into account, points to the subjective view of an agent endowed with meanings, reasons, thoughts, and emotions of her own. This “view from within” (as opposed to the “view from nowhere” criticized by Nagel, (1986)) allows to recover the natural way we have to look at ourselves, which precisely is in the first person. It also makes sense of the observation that every concept used in psychology can only be defined subjectively (e.g. *fear*, *thought*, *intention*, *belief*). This is the starting point of the philosophical and psychological paradigm known as *phenomenology*: this paradigm begins by conceiving the mind and the self as subjectivity, and our take on reality, as well as on ourselves, as subjective (e.g. Husserl, 1962, 1976; Heidegger, 1982; Gallagher & Zahavi, 2008).

[1] Justification for this position may be found e.g. in Bruner (1990), Guidano (1987, 1991), and Maturana and Varela (1980).

Within HCI, Ehn (1988) adopted Heidegger's phenomenology to argue in favor of a tool-based approach to design. Dourish (2001) then employed it as a lens to look at tangible interfaces and social computing, while Svanæs (2013) further showed its relevance to a theory of embodied interaction. Ohlin & Olsson (2015a) claimed for its use in PI. Following this line of research, we argue that phenomenology can contribute to a redefinition of PI. The first shift that we want to propose in the debate on PI, therefore, is from the externality of behavior to the internality of the interacting subject.

But what is this control system, from the ontological point of view? The bulk of scientific psychology during the second half of the 20th century was provided by computationalism, based on the postulate that the mind is a set of algorithms and rules not different from a computer program (e.g., Pylyshyn, 1984; Boden, 2006). Despite the substantial demise of computationalism around the turn of the century (Manera & Tirassa, 2010), its conceptual infrastructure largely informs the paradigms that have substituted for it, namely the several varieties of reductionism that are endorsed by the cognitive neurosciences (e.g. Churchland, 1986), autonomous robotics (e.g. Maes 1991), and mainstream evolutionary psychology (e.g. Pinker, 1997). In different ways, these perspectives share the idea that the sole causally relevant events are those that happen in the material substrate of the brain or the body, by conceiving the self being just the irrelevant byproduct of such events.

We do not subscribe to either computationalism or reductionism, instead opting for a third major area, which has historically been a marginal voice in the psychology community, yet appears to be highly resilient through the decades. This is the heterogeneous area that conceives the self as subjectivity, constructed, maintained and reconstructed moment by moment by the understanding that we have about the world and ourselves (e.g., Bruner, 1990: Guidano; 1987, 1991; Maturana & Varela, 1980; Searle, 1992; Varela, Thompson & Rosch, 1991). Since this knowledge is not objective, but is comprised of subjective meanings (Watzlawick 1984; Mate & Tirassa, 2010; Tirassa & Vallana, 2010), the phenomenological conception of the self entails a form of *constructivism*. That this knowledge is

subjective does not mean that it is arbitrary, but that it is actively constructed by the self: what the self knows is meaning-laden entities, and meanings can only be subjectively construed by it (Clancey, 1997; Mate & Tirassa, 2010).[2] The self in its turn is shaped by the very same knowledge. In other words, the self constructs itself through the construction of its self-knowledge. Phenomenology and constructivism, here, go hand in hand, as the latter follows from the former.

Self-knowledge is intrinsically dynamic: the self recreates its knowledge from instant to instant through the interaction with the world, with the others, and with itself (Guidano, 1987, 1991; Clancey, 1997; Mate & Tirassa, 2010). This mutability is essentially due to the situated, temporal and social nature of the self: the self is a *being-in-the-world* (Heidegger, 1927), cast in time, and open to others. Its situatedness derives from its continuous interaction with the environment, while its social nature basically comes from the fact that meanings are socially and culturally shared (Cole, 1996). Phenomenology has also always insisted on the temporal nature of the self (see Zahavi, 2012): to Heidegger, for example, "Dasein [i.e. the self] is intentional only because it is determined essentially by temporality" (Heidegger, 1982, p. 268), while to Husserl (1962) the concrete structure of all lived experiences entails a temporal horizon. However, to claim that the self is subjectivity also implies that the self only exists in the here and now (a sentence like "I exist yesterday" does not make much sense) (Varela, Thompson & Rosch, 1991; Brizio & Tirassa, 2016). This means in its turn that all the representations that we have of ourselves in different times and places (e.g. in the past, in the future, etc.), following from our situated, temporal and social nature, are (re)constructions of the current self. Such multiple "alternate selves", which contribute to shape the current self, are also non-fixed structures, subject to change as long as the knowledge about them is modified and the self's current situation changes.

[2] Both knowledge and meaning are often socially construed and socially shared. This does not make them objective or less subjective, it only makes them intersubjective.

Therefore, the second shift that we want to propose in the discussion within PI is from a concept of the self as a static, frozen entity that can be revealed by simply looking at data, to an idea of the self as multiple and mutable, which is actively (re)constructed by the individual. Within HCI, constructivism has been applied to interactive learning environments (Roussou, 2004), design methods (Winterbottom & Blake, 2008), and interactive machine learning (Sarkar, 2016), but never with reference to PI.

We will split the rest of this discussion into subsections concerning four different facets of the self: the *present self*, the *past self*, the *future self* and the *interconnected self*. The *present self* follows from the idea of the self as situated subjectivity; the *past* and the *future selves* are instead a consequence of its temporal nature, and the *interconnected self* derives from its social nature. This is only made for the purpose of description and is not meant to convey the idea that there exist four (or any other number of) autonomous, independent selves. As we said, the present self is the only self that can literally be said to exist, the others being its projections in different times and places.

We can now operationally define such selves as follows:

- The *present self* is a flow of meaningful subjective experience (Brizio & Tirassa, 2016). This definition emphasizes that it only exists in the here-and-now and is characterized by its situatedness.
- The *past self* is a construction of the present self, a representation of itself at a time which supposedly has already been experienced and which is recalled through the act of remembering. This definition incorporates the constructive nature of the past and the fundamental role of memory in experiencing it.
- The *future self* consists of representations of ourselves as we might exist in alternate times. This definition stresses the hypothetical nature of the future self and the fact that it is not or not completely constrained by reality, framing it in the domain of possibility and likelihood.

- The *interconnected self* consists of all the images of ourselves that come from our social interactions. This definition emphasizes how the construction of our self is inextricably connected with those of other people.

(Figure 1 about here)

These definitions will be explored and their consequences on PI outlined in the next subsections (see Figure 1 for a summary). Each subsection will include design guidelines aimed at connecting its main theoretical elements to the relevant issues in PI and suggesting research directions for reimagining the PI territory. Some of these guidelines explore paths not yet covered by any PI tool. Others stress the importance of pursuing lines of research already explored in PI or in other application fields. Some guidelines are thought to be employed in combination, others to be mutually exclusive. They are not meant to be prescriptive. At the end of each guideline, we will propose a set of research questions that embody our research agenda, pointing to the main theoretical and design, rather than technological, challenges that PI ought to face in the next years.

3.2. The present self

We defined the present self as a flow of meaningful subjective experience. This has several implications. First, it means that the self only exists in time, as a subjectivity in the here-and-now which continuously reproduces itself with the slight variations that are induced by the interaction ongoing in each current instant. Conversely, it is capable of making present what is relevant to it, by eliciting specific aspects of itself (e.g. my academic self), by recalling its past images (e.g. my past student self), and by forecasting its future projections (e.g. my future self as retired). These can be seen as dynamic schemas whose meaning, nevertheless, can truly be enacted only when they are encountered by the present self. From a phenomenological point of view, in fact, the sole point in

which we may have experiences of ourselves and the world is the here-and-now (see also Zahavi, 2012). We may say that what "exists" exists inasmuch as it is present in our current subjectivity. This perspective rejects the idea of a stable, objective and time-independent ontology of the self and its features, where, for example, common notions like "personality traits" can be conceived of as entities with a proper ontology that exist out of time.

Second, the word *meaningful* is used in the definition of the present self because what we see, represent, or think about is inextricably intertwined with the meaning-laden affordances that we find in the world. The present self views the world as a living dynamic environment made up of meaningful entities, events, and processes. Each such entity, event or process is an *affordance* (Gibson, 1979) offering opportunities for interaction. However, the very existence, the nature and the features of such offer depend on the meaning that the entity, event or process has to the self. Ontology – that is, the types of objects, relations, events and so on, which a mind is prepared to acknowledge and to interact with – thus is subjective: it is what the mind finds in the world, rather than any kind of allegedly "objective" catalogue, established from the outside once and for all (Guidano, 1991). Subjective ontology is rooted in the biological history of the species and in the ontogenetic history of each individual within it: the former delimits the area of possible paths of the latter, providing a set of guidelines along which the latter unfolds (Gould, 2002; Lewontin, 2000). An agent may now be defined as a conscious organism who lives in a situation and strives continuously to make it more to her liking, pushing the world toward some more desirable evolution (Brizio & Tirassa, 2016; Pollock, 1993; Tirassa, 1999). In other words, if, on the one side, the interaction is meaningful because it is afforded by the situation in which the self is cast, on the other side the situation is the self's subjective, dynamic, and open experience of the world.

This view, therefore, rejects the idea of the self-as-a-database, in which "you are your data" (Schüll, 2016), and data are seen as scientifically neutral and exact compared to the less reliable information

coming from our sensations and self-reflection (Lupton, 2014). Instead, it may account for what Sharon & Zandbergen (2016) noted in many Quantified Selfers' real practices, where data are new elements in "a continuous process of identity construction".

The dynamics of each present self are highly idiosyncratic: this is due not only to the differences in their interactional and experiential paths and in the autobiographical memory that supports them (see below), but also to the different motivation systems that characterize them. Our definition of an agent as striving to make the world more to her liking is meant to emphasize the latter issue. Since a theory of emotion, feeling, and motivation goes beyond the scope of this article, we will limit ourselves to an example of where and how such a theory should be inserted. In the seventies Gray (1973) introduced a two-faced motivation system, which, albeit simplistic, may illustrate the point. It is comprised of a positive-incentive motivation system (behavioral activation system or BAS) and a behavioral inhibition system (BIS) which regulates sensitivity to threat cues. Individual responsiveness of the BIS and BAS varies widely, which basically means that different people may react differently to the "same" situation, or, in a more constructivist vein, that each individual experiences different situations independently of how "similar" they are defined by the observer. The implication for PI is that the same design may have a different impact on different users, as we will see in the next sections.

Within this view of the self, change acquires a different character from the accounts commonly employed in the current rhetoric of PI. As it is well known in clinical psychology happening outside of cognitive-behavioral therapy (e.g. Guidano, 1987, 1991), change happens in the self and only then may affect behavior, often in unpredictable ways. It does not normally occur as a singular event, or as a transition through a fixed series of stages (as proposed by Li et al., 2010). Instead, it is a subtle continuous process nurtured by our interaction with the world, while major and enduring changes derive from a substantial shift of the perspective that we have on ourselves (Fosnot, 1996; Bruner, 1990): this is made possible by the novel meanings that we gradually acquire, by being cast in new

situations, by interpreting our past and our future differently, or by seeing ourselves through the eyes of the others. In other words, if we may say that the sense of our stability is granted by the fact that we constantly tell stories about ourselves (Schechtman, 2007), change occurs as we begin telling different ones. A modification in the individual's behavior becomes possible, but not necessary, as an outcome of the deeper renovation in her gaze upon herself. To PI, this means that the primary focus ought to be on the wellness of the self, instead of on the resolution of specific dysfunctional behaviors.

Guideline 1. PI should reverse the point of view through which it looks at its constitutive elements, by providing subjective meanings instead of supposedly objective information, by supporting the construction of interpretations instead of the examination of numbers, and by focusing more on the self's wellness than on behavior change.

This guideline emphasizes the role of the self in PI, pointing to a different perspective on data, self-knowledge and change with respect to that which is shared in the present debate on PI.

PI should start to think of the information gathered by self-tracking tools not as objective data, but as subjective meanings. Our knowledge of the world and of ourselves is intrinsically subjective and is driven by the needs, desires, memories, and expectations of our present self. PI should strive to inform data with personal meanings, so to let the user build a corpus of subjective knowledge, from which mere data only acquire their meaning and value. Davis (2013) noted how the emphasis on objectivity in QS rhetoric does not stand to the facts from its premises: data require subjective interpretation and qualitative story telling. Sharon (2016) emphasized that a view of the Quantified Selfers as data fetishists is limiting and that quantitative data are often an additional layer that contributes to self-narratives. On the same line, Elsden et al. (2016) suggested that data must be contextualized and made

accountable to the user's lived experience to be meaningful, proposing to encourage curation of personal data, e.g. through active selection, tagging, and bookmarking.

We think that this subjective appropriation of data and active construction of meaning is a key for raising the value of PI. Since, however, users are unlikely to invest considerable amounts of time in curating their own data, PI should look at new ways to make this information meaningful. For example, the data collection might be enhanced with contextual details coming from the "external environment", to enrich them with elements that pertain to the world. However, these elements should be selected not on an "objective" basis (with a one-size-fits-all approach, as it happens in most current PI systems), but based on the relevance that they may have for the user and the activity she was performing at the time of the data gathering: e.g. if she was cycling for training, relevant contextual details could be the temperature, the weather, and the path travelled; while if she was sitting at work, the relevant parameters could be the location, the levels of CO_2, noise, and the identity of the other persons present. These could be displayed together with the data in the form of brief digests, automatically built up, possibly enriched by pictures, so to provide an episode to be experienced. Moreover, the systems should invite users to add "subjective tags" to the data supplied, so to reflect their internal states like emotions, intentions, goals, etc., thus making the subjective relevance of information apparent. Instead of relying on textual insertions, systems could also leverage visual means like colors, shapes, or signs to let users intuitively apply subjective interpretations to their own data without demanding excessive amounts of time and cognitive effort. In doing so, PI systems could maintain the memory of all or some of the subsequent interpretations provided over time, from those that trace to the specific moments when the data were collected to the latest ones that reflect the current state of the user, also allowing to compare or mesh them.

As a result, data visualization would become more flexible, shaped by the users' subjective interpretations. Nafus et al. (2016) also claimed for more flexibility in PI systems, building a prototype

that supports multiple, simultaneous interactive visualizations. In the same vein, Epstein et al. (2014) designed different modes of visualization to represent data with some shared features. However, these attempts did not incorporate personal meanings in data collection, as well as remained focused on abstract visualizations.

Instead, subjectivity could be better supported by providing representations of data that could make the user closer to the information she collected, going beyond graphs and stats to be analyzed. Bentley et al. (2013), for example, presented connections among behavioral data by using natural language (e.g. "On weeks when you are happier you walk more"). A further step on this path could be shifting the focus from "objective" statements to pictures that might help the user's self emerge: this could be enacted through first-person narration techniques (e.g. Hullman & Diakopoulos, 2011), highlighting the user's interpretations of the data and answering questions related to the how and why, instead of merely the what (*Why am I happier? What does it mean for me to be happy in that context? How is it related to other aspects of my life?*). Otherwise, they could provide more concrete and intuitive graphical representations, by building, for example, data-driven avatars that may change in real time as the information changes, or reflected images of the user's body meshed with the data themselves (e.g. leveraging shape deformations, color codes, etc.), as if she were looking in a sort of magic mirror.

Finally, PI should consider a different model of change, namely one which stresses the role of the self, instead of that of behavior. PI should essentially aim at enhancing users' self-awareness and self-knowledge, pursuing reflection as an end in itself. This self-understanding will primarily yield a change of the individual's subjectivity, through an enrichment and eventually a reconstruction and reinterpretation of her knowledge of it. In doing this, however, a change in behavior is also likely to be produced. This should not be intended as a process whereby a rational examination of personal data leads to a consequent behavior change (Ohlin & Olsson, 2015a): this perspective rests on the modernist assumption that people are rational actors seeking for optimizing activity on the basis of what they

know (Brynjarsdóttir, Håkansson, Pierce, Baumer, & DiSalvo, 2012). We are not claiming for information to be examined, in fact, but for interpretations to be (re)constructed.

Likewise, here change is not enacted as an automatic reaction, either pursued by the individual in response to the information displayed, as it happens in the *feedback loop* exalted in the rhetoric of self-tracking (Ruckenstein & Pantzar, 2015), or externally proposed by the machine through micronudges, as wished by the wearable industry (Schüll, 2016). Instead, change may spontaneously flourish from a renewed self-understanding, thanks to PI systems that extend the user's capabilities of self-reflection: the main agent is the individual herself, or "her self", incorporating the PI tool so that it becomes "worlded", that is part of her world of meanings and thus *ready-to-hand* (Heidegger, 1927).

For example, by using a PI system, a middle-aged man may be led to know how his attitude toward food is rooted in his past, since he learned to use food as a means for coping with anxiety over time. Through this process of understanding, the man can now reframe what the food means to him and why he sometimes becomes engaged in binge eating. Now, he can reinterpret all the times he did not take care of himself, stop blaming himself, and realize that these actions are functional in regulating his emotional life. He may then try to substitute something else for the food, change a network of interconnected aspects of his life (and not only the "target behavior"), or maybe just decide that his existential equilibrium is more important than physical health. In this perspective, an individual may decide what kind of change will benefit for her self the most, instead of accepting normative social models, as it is often encouraged by current self-tracking tools (Lupton, 2015). This goes together with the idea that self-tracking may also contribute to rethink wellbeing in ways that promote alternative views to those dominant in our society (Ruckenstein & Pantzar, 2015) and thus resist the categories that are built into the market for data (Nafus & Sherman, 2014).

Research Questions

1. How can we motivate and enable users to curate their data?
2. Which kinds of elements are the most important, and in which combination, to help make the user's self manifest? Are there specific aspects of the self that become better revealed by natural language or by graphical metaphors? Could tangible data representations help the self emerge?
3. Can "internal states" tagging be inferred or automatically mined to create a comprehensive image of the user's self without requiring strong efforts from the users? Would this be acceptable to the users?
4. How can PI systems help users become aware that they have reached an important step in understanding themselves? How may the user and the system communicate with each other about the ongoing process of change?

3.3. The past self

We defined the past self as a construction of the present self, a representation of itself at a time which supposedly has already been experienced and which is recalled through the act of remembering. This definition requires a preliminary discussion of the faculty capable of making the past self(ves) present to the present one, that is memory.

Koriat & Goldsmith (1996) noted that research on memory in psychology incorporates one of two competitive metaphors. One is the storehouse metaphor, which depicts memory as a depository of discrete and elementary input elements (Schacter, 1987), and is mainly used in laboratory experiments. The other is the correspondence metaphor, which views memory as a perception or description of the past (Conway, 1991), and is employed by those who study memory in "real life" (e.g. Bartlett, 1932; Gruneberg & Morris, 1992). The correspondence metaphor brings many collateral metaphors with

itself that come from perceptual theory, whereby memory is an active reconstruction of past events (Neisser, 1976) and a direct resource for action (Glenberg, 1997). This perspective definitely appears more sensible for theoretical reasons (Searle, 1992) and more relevant to our aims, both because it fits into a phenomenological and constructivist framework and because it connects more strictly to the issue of the self (Conway, 2005).

Within the correspondence frame, the kind of memory that is capable of constructing different images of our self in the past (past selves) is autobiographical memory (Conway, 2005). This is one of the key elements that shape our identity and make each of us unique (Conway, 2005). It can be described at different level of specificity: *themes* (e.g. working theme), *lifetime periods* (e.g. working at X University in 1989), and *general events* (e.g. my relationship with Prof. Y whom I happened to know there), all representing a form of semantic memory that encompasses general knowledge about the world and ourselves; and *episodic memories* (e.g. my first day as a professor), which point to the recollection or reconstruction of events in specific times and places. Both semantic and episodic forms involve conceptions of the self in the past, but to episodic memory this self-relatedness is fundamental, as it entails the awareness of the self as a conscious entity, allowing us to be aware of the subjective time when a certain event happened (*autonoetic awareness*) (Tulving, 2002). The "mental time travel" metaphor employed by Tulving (2002) captures the capability of the present self of recollecting past episodes "from the inside" (i.e. our past selves), whereby the individual subjectively and consciously relives a previous experience.

This form of memory thus enriches our present self-knowledge with representations of past ourselves. As Elsden et al. (2016) noted, however, data represented by current PI systems are far removed from our ways of remembering, making a mismatch between machine and human memory visible. This makes it necessary to find ways to reduce this gap, if we want to increase our self-understanding through PI.

Besides contributing to shape our self-knowledge, past selves play an active role in ordering our memories. In fact, memories are not distributed equally across the life time, but parallel changes in the self and in goals over time (Rathbone, Moulin, & Conway, 2008). The formation of new self-images at a specific time point in the individual's life results in a heightened retrieval of memories from that time (Conway & Pleydell-Pearce, 2000), suggesting that past selves function as organizing schemas that group together autobiographical memories (Chessell, Rathbone, Souchay, Charlesworth, & Moulin, 2014; Rathbone et al., 2008). These findings support the idea that our experience of the past is organized around the changes of our identity and the emergence of important aspects of our self. This entails that the activation of our past self-images may lead to experience more vividly a network of memories for specific episodes relative to turning points in our life. It thus becomes crucial that PI systems aimed at improving our self-knowledge support the subjective reliving of those self-defining episodes that contributed to the formation of our identities.

Moreover, past selves are not fixed entities that crystallize the past in an immutable picture: the present self shapes the perception of our past self-images according to its mutable needs and goals (Conway, 1996), influencing how individuals recall their past (e.g. Bartlett, 1932; Greenwald, 1980; Singer & Salovey, 1994). For example, individuals are inclined to recall pasts that are coherent with their present self (Albert, 1977), and appraise the past in ways that allow them to view their present self more favorably, e.g. by being motivated to feel farther from past failings than past achievements (Wilson & Ross, 2003). These phenomena show that autobiographical memory may fulfill a self-enhancement function (Wilson & Ross, 2002) and that our subjective experience of time is far less linear and more varied than calendar time (Wilson & Ross, 2003). Such influence of our present on our past selves supports the idea of a more liquid PI past. Elsden et al. (2016) also argued for an amorphous quantified past, easily reproduced, reformed, and remixed in different contexts, while Lupton (2014) emphasized

that our data doubles are mutable and dynamic as new data are added: they are constantly open to reconfiguration, hence re-interpretation.

But if the present acts upon the past, the past can also directly intervene upon the present by supporting the present self's current actions in an almost unmediated fashion. Drawing from empirical evidence about the embodiment of affect, imagery, and memory (e.g. Saltz & Donnenwerth-Nolan, 1981), Glenberg (1997) defined remembering as the ability to mesh patterns of action derived from the properties of the environment with patterns of embodied interaction based on memory. Memory here functions as a guidance for perception and action, mentally meshing the recollection of previous embodied experiences into the agent's present context. It is this relevance to me, namely how I interacted with it in the past, that, for example, makes a certain path my path to my house, making me follow it almost inattentively. From this point of view, thus, to remember is to act, which suggests that by prompting past experiences PI systems could also function as a support for action.

Guideline 2a. Past selves are fundamental for organizing memory since they represent landmarks around which memories are clustered. PI systems should support the self-centric organization of the past, by grouping the data they offer around important events of the individual's life. By highlighting how the self evolved over time, and by helping users experience their past from a subjective point of view, PI could allow them to understand how and why they became what they are.

Over the years, HCI research has explored different technologies for memory (van den Hoven, Sas, & Whittaker, 2012): e.g. technologies aimed at allowing the "total recall" of the user's own life (Bell & Gemmell, 2009), reminding tools and memory aids (Cosley, Schwanda, Schultz, Peesapati, & Lee, 2012), and studies of how artifacts contribute to shape the individual's sense of past (Banks, Kirk, & Sellen, 2012). However, rarely this research has taken into account how past personal data may change

the act of remembering through technology. Exceptions may be represented by Kalnikaite, Sellen, Whittaker, and Kirk (2010), and Zhao, Ng, and Cosley (2012).

Recently, Elsden et al. (2016) proposed insightful suggestions for remembering with PI: for example, to design for producing evocative or emotional engagements with personal data, instead of focusing on insights and self-knowledge; to design for recollecting specific moments; to orient toward events and threads of history that could provide the basis for a more narrative-led cut through one's data. We think that Elsden et al.'s work is crucial for transforming the presentation of PI historical data into memories to be experienced. Building upon their considerations, nonetheless, we aim to shift the focus from memories to the self, somehow overturning their point of view. We want to emphasize that we might use memories to improve the individual's self-awareness and self-knowledge, rather than designing to produce evocative and engaging experience with them.

This means that we as designers first have to ask ourselves: *of what kind of memories should we favor the recollection to help users understand what they were and how and why they have become what they are?* Past data could be subjectively organized around the turning points in the individual's life, when certain events produced crucial changes or favored the formation of new selves. These important episodes could be detected automatically from anomalies in the users' data trends, e.g. by recognizing sudden changes in different parameters at the same time, which may signal changes in the individual's life or significant shifts in her goals, which in turn may suggest the appearing of new self-images. Data mining techniques applied to time series could help in detecting changes in data streams, by discovering novelty (Ypma & Duin, 1997), anomalies (Izakian & Pedrycz, 2014), and rare motifs (Begum & Keogh, 2014). Then, the user could also work with the system to better qualify these changes and ascribe meanings to them.

Such important episodes might also be threaded together to make visible how a certain image of the self evolved over time, when it emerged, when it changed due to the circumstances, and how it turned into the representation that currently belongs to the individual. Differently from Elsden et al.'s threads of history, which focus on different occurrences of a meaningful episode (e.g. all the occasions when the user has listened to a favorite band), these sequences of memories would be addressed to support the exploration of the individual's past selves and their transformations.

For example, a fifty-year-old woman who wants to explore the data relevant to her athletic self should be given the opportunity to find answers to questions like *"Why was I running so much ten years ago? what were my goals back then and how were they formed? what was happening to me at that time? what did happen immediately before and immediately after? what was I feeling and thinking at that time? how have I become what I am?"*.

Designers should also favor the user's re-experience of her past selves from an "internal" point of view, by making her time travel with her mind through autonoetic awareness. To this aim, design might rely on research on memory cues, which have been widely explored in HCI (van de Hoven & Eggen, 2008). However, the point is not only to make memories of a past time vividly present, but also to make the mental states that the user was experiencing then relevant: PI systems could support the recollection of the user's general events or lifetime periods, which may help her better contextualize her past intentions and feelings, by prompting cues referring to both the external (like features of the environment, location, movement, etc.) and the internal (like her goals, tasks, etc.) context (Prekop & Burnett, 2003) of her past.

For example, the fifty-year-old woman introduced above might be helped reconceptualize her athletic self by being provided with contextual cues like the place where she lived and the persons with whom she used to run, making her recollect a long run at dusk from ten years before. The system should also

highlight the goal of that day, e.g. running five kilometers, supporting reflection on the reasons that were behind it. Then, it should elicit the recollection of other similar or connected episodes that happened in the same period, as well as trends in her data and typical contextual factors (like the friends she used to meet or the places she used to visit). With this information, the woman might remember that she was running because she had just come out from a long convalescence; how she initially felt weak and had a "powerless self"; how, nevertheless, she poured a lot of effort in overcoming that situation; and how the self-confidence that she recovered in a few months contributed to shape her present attitude toward life. This might be of help, for example, on a particularly sad afternoon.

In helping users remember their past selves, PI systems could also experiment different levels of autonomy. Ohlin and Olsson (2015b) discussed possible degrees of cooperation between PI tools and humans, ranging from *human-driven cooperation*, in which users act with PI systems to reach their goals, to *computer-driven cooperation*, where the system initiates the interaction.

Research Questions

1. How can we enable the user to help the system recognize her most important past selves? What kind of tools would be most effective?
2. How can a PI system provide support for exploring the relations between specific past selves (e.g. between the athletic past self and the social past selves)? Should we favor the "proliferation" of past selves, or should we support a more "austere" perspective, whereby only a few crucial events and the selves are stored and fed back?

3. Should we design proactive systems capable of autonomously prompting the user's self past images, or should these be available only "on demand", based on specific requests from the user? Should we make the user remember even what and when she is not willing to remember?
4. What kinds of information and design elements are the most important to help users travel mentally back in time and re-experience their past selves from the inside?
5. How can we handle the short life expectancy of technological devices, supporting instead the need of recording personal data for long periods of time? How can we make data migration among different tools over time simpler?

Guideline 2b. The past is constructed by the present self based on the knowledge and the goals that it currently has and offers a resource for its present actions and plans. PI systems should explore the possibility of reorganizing and presenting the past according to the user's current needs, adapting to her self's changing states and plans.

Within HCI, Harper et al. (2009) argued that the idea of memory should shift from "something in the head" to "a resource for action". They framed their perspective on memory within analytical philosophy (e.g. Wittgenstein, 1953), where it is viewed as a label for different types of action, displaying pertinent knowledge of and reference to the past as relevant to the present. This guideline recommends to adopt a similar perspective, although relying on a different theoretical framework that brings memory back into the realm of the psychological sciences.

PI systems could allow users to intervene upon their own data, modifying them according to their current perceptions, beliefs and feelings. The mutable nature of memory shows how individuals constantly reconstruct their memories depending on the present self's state (van de Hoven & Eggen, 2008). The data collected by PI tools, instead, are numbers that, in their raw state, bring back to a

supposed objectivity and immutability. PI systems could then make them more malleable, data doubles reconfigurable and constantly open to reinterpretation (Lupton, 2014), by allowing users to modify the meanings they associated to them in the past if they do not reflect their current perception anymore; or they might let the users free to directly modify the data themselves, making them more adherent to the user's subjective remembering of the episodes connected to them. In this perspective, the possibility of deliberate forgetting, by selectively altering or deleting past data, or not confirming their interpretation, may become a means to cope with negative emotions, as explored by Sas and Whittaker (2013) in the field of digital possessions.

By modeling and reasoning about the current user's context PI systems could also enable new forms of adaptation and recommendation providing a personalized version of the user's past. Different data mining techniques have been explored to extract high-level information from wearable sensors (Banaee, Ahmed & Loutfi, 2013). In the field of PI, where data mainly come from a plethora of mobile and wearable devices that can be abandoned and changed rather quickly (Lazar et al., 2015; Clawson et al., 2015), data heterogeneity becomes a major concern (Perera, Zaslavsky, Christen, & Georgakopoulos, 2013). Formalizing data structures and terms, then, e.g. with ontologies, may help in addressing such issues. Ontological models of context have been adopted in different architectures for context-awareness, like CoBra (Chen et al., 2004) and Feel@Home (Guo, Sun, & Zhang, 2010). However, since ontologies are not appropriate to deal with uncertainty and vagueness in knowledge (Li, Eckert, Martinez, & Rubio, 2015), they may be complemented with other techniques, like rules (Perera et al., 2013) and fuzzy logic (Bobillo & Straccia, 2011).

By leveraging contextual knowledge, PI systems could then move away from an "objective" chronological organization of the stored data that depends in its turn on the notion of a "veridical" representation of the past. Instead, they could rearrange temporality so to support the user's present self. For example, they might emphasize successful achievements, perhaps those that were the hardest

and more rewarding to obtain, when the user is facing a new challenge, and de-emphasize those that refer to unpleasant experiences, when the user is currently in a bad mood. This way they could fulfill a self-enhancement function, supporting the user's present self in pursuing its objectives and promoting its wellbeing. In doing so, PI systems could look at adaptation techniques used in other fields of applications. Adaptive game Artificial Intelligence, for example, employed machine learning techniques to adapt the behavior of non-playable game characters to human gameplay (Graepel, Herbrich, & Gold, 2004), or to adapt the game's difficulty to the player's skills (difficulty scaling) (Spronk, Ponsen, Sprinkhuizen-Kuyper, & Postma, 2006). Another field from which PI could draw inspiration is that of adaptive user interfaces, which may exploit data mining methods (Frias-Martinez, Chen, & Liu, 2006) to model the user and provide content presentation accordingly (Brusilovsky, 2001).

Moreover, since memories can function as "lessons from the past", data pertaining to past selves could also serve as resources for the current self's reflections. PI tools could provide suggestions based on the experiences of the past selves as real-time recommendations that can take into account both the user's current external (environmental) and internal (e.g. goals, plans, and feelings) contexts. These recommendations may lead to new forms of personalization, flexible and tailored to the individual's past history as well as to her current situation, which could be used e.g. to provide recommendations on how to interpret her current state and even how to act to meet her goals.

Common collaborative recommender systems recommend items that people with similar tastes liked in the past (Adomavicious & Tuzhilin, 2005), thus providing suggestions based on what most others do, while content-based recommenders recommend items similar to those that a given user has liked in the past, with no inherent methods for recommending something unexpected (Lops, de Gemmis, Semeraro,

2010).[3] Here, instead, we propose that suggestions be tailored to the user's idiosyncratic nature, since different users may be differently impacted by the same recommendation (see the BIS/BAS system in 3.2). Recommendations should as also be capable of providing novel perspectives on the user's present situation. Possible sources of inspiration for PI then are life-long user models, which attempt to model user goals, knowledge, and preferences in the long-term to tailor recommendations accordingly (Kay & Kummerfield, 2009), and recommender systems that exploit AI techniques to offer contextual suggestions (Abbas, Zhang, & Khan, 2015) or aimed at proving serendipitous recommendations (Iaquinta et al., 2008).

PI systems might also propose to the user to frame her present situation differently, according, for example, to what happened in previous similar contexts. For example, a university student has become demoralized after a couple of failed attempts to pass a difficult exam, and starts to call herself into question. The PI system might recognize such situation and prompt her past academic efforts and achievements together with the data related to them, making her reflect on why she did not obtain the same results this time. The student becomes aware that in the past she dedicated a larger amount of time to exams of similar complexity. By reframing the situation, she understands how the responsibilities of the present outcome lie not in her vanishing skills, but in her decreased efforts. The emphasis here is not on retrieving intact knowledge structures, but on providing the individual with the means to create situation-specified understandings by prompting prior knowledge appropriate to the problem at hand (Ertmer & Newby, 2013).

[3] Hybrid recommender systems are a third kind which combines the two previous methods.

Research Questions

1. Should PI systems preserve an "objective" point of view on the user's past data, possibly retrievable at her request, or should they endorse her subjective vision, making what has been altered or deleted irretrievable?
2. What kinds of data are essential for building a context profile capable of accounting for the external and the internal factors that may be relevant for the system's decision to provide a certain recommendation? Should these data types change as the user changes over time? E.g. may emotional factors be more important than motivational ones for providing the right suggestions under certain circumstances? Should the relevance of certain contextual cues vary also according to the self in focus? May certain cues be obtrusive to certain selves? How can we automatically mine and infer all these elements?
3. What are the practical benefits of providing users with supplementary resources for reflection immediately before action? Are there also drawbacks, e.g. hampering the role of intuition or slowing down the decision process?
4. Is it conceivable that all users would react the same way, e.g. to alterations in the temporality of their memories? Or would not some users get angry at feeling somehow deceived, and others feel that the tool is just unreliable?

3.4. The future self

The future self, or better the future selves, consists in representations of ourselves as we might exist in alternate times. Imagining ourselves in the future is an essential mental tool that prepares us to action (Macrae et al., 2015). Since we can often anticipate how an event might lead to particular physiological, emotional, and mental states, we can calibrate our present actions according to these predictions (Atance & Meltzoff, 2005). The metaphor of time travel, which Tulving employed for

autobiographical memory, can also be used to describe our capability of *preliving* future events: actually, travels toward the past and the future do not only share phenomenological features, but are also part of the same evolutionary function (Suddendorf & Corballis, 2007).

As it happens for remembering, these acts of prospection are not separate from a representation of the self: we actively construct one or more images of ourselves as the subjects of our simulations, which thus embed an understanding of how we imagine we might be in the future (Cantor, Markus, Niedenthal, & Nurius, 1986). Such selves have been also called "possible selves" to highlight that they belong to the domain of possibility and not to that of necessity: they are a form of self-knowledge that "pertains to how individuals think about their potential and about their future" (Markus & Nurius, 1986, p. 954).

Future selves are neither fixed structures nor isolated entities. Despite the strong emphasis on the future, they derive from representations of the self in the past, such as specific past experiences or prior performances, and are strongly influenced by the present self. For example, if an individual has both the idea of being bad at mathematics and a positive self as a chemist in the future, the probability of the latter coming true will be influenced by the current self when she learns about the importance of mathematics in chemistry (Erikson, 2007). However, differently from the present and the past selves, the future selves are less constrained by autobiographical "reality", which makes them much more malleable than the images of the self anchored in the past (Hoyle & Sherrill, 2006). It is this feature that allows us to talk of future selves as possible selves, insofar as we can represent ourselves in the future in an infinite variety of hypothetical situations[4].

Such selves have two main functions. First, they are intimately connected with the present self in providing it with an evaluative and interpretative context of additional meaning: for example, for an

[4] For this reason, throughout the rest of the paper we will use the terms "possible selves" and "future selves" as synonyms.

individual being disabled for a short time may be a much more unpleasant experience if she has a "weak and powerless" possible self (Hellström, 2001). In fact, our present self is heavily influenced by our self-knowledge of what will happen to us and how we will be in the future (Erikson, 2007). Within HCI, Odom (2015) has noted that writing to, and thus thinking about, the future self makes users reflect upon their current condition. From a PI point of view, this means that having the user think of what she might become in the future may provide her with additional resources for reinterpreting her current situation.

On the other hand, future selves make personal goals manifest and provide incentives for action and change, directing interactions over time by serving motivational functions. This is enacted in different ways, depending on the nature of the possible self considered. Possible selves may represent hoped-for selves as well as feared ones, concretizing what we aim or are afraid to become (Markus & Nurius, 1986). Hoped-for selves embody goals and scenarios concerning strategies and means to achieve them, motivating us to reach such future representation of ourselves (Markus & Ruvolo, 1989). Conversely, the feared selves may motivate an individual to escape the situations they represent (Carstensen, Mikels, & Mather, 2006), or to suppress action, if the representation of her future comes without the strategies for avoiding it (Hooker, 1992). However, when hoped-for selves and feared selves are balanced, individuals may choose strategies that simultaneously increase the likelihood of becoming like the former and decrease that of becoming like the latter (Vignoles, Manzi, Regalia, Jemmolo, & Scabini, 2008; Oyserman, Terry, & Bybee, 2002). This suggests that PI could leverage idealized (or dreaded) representations of the user's future selves to allow her to explore the means for reaching or avoiding their realization.

Guideline 3. Displaying representations of possible future personal data is crucial to enhance self-knowledge and improve strategic thought, motivations, and drives toward change. PI systems should exploit predictions and simulations to provide, first, tools to explore and experiment alternate futures in order to stimulate self-reflection and reframe the present self with an enriched context of meanings; and, second, idealized or dreaded images of the self so to elicit strategies for respectively pursuing or avoiding such future states.

Recent years have witnessed the emergence of several Internet services that allow to send messages to the future. Postulater (Hawkins, Procyk, & Neustaedter, 2014), for example, enables people to send annotated videos or images to themselves or to others in a point in the future, while FutureMe delivers e-mails to one's future self, one to sixty years from now, supporting the user's reflection on her present self (Odom, 2015). These applications have been framed within the Slow Technology movement, which aims to use technology for slowing down certain practices so to grant people sufficient time to think about their choices (Hallnäs & Redstrom, 2001; Odom, Banks, Durrant, Kirk, Pierce, 2012).

Also PI, drawing on attention to machine learning and simulation, has recently started to consider the future when dealing with personal information. Li (2015), for example, argued that adding predictive features to PI tools could help behavior change by suggesting courses of action and predicting opportunities for positive behavior. In his view, a service like Google Now could evolve into a more sophisticated PI tool capable of tracking and analyzing the user's physical activity and location history, and of recommending, for example, locations and times for future physical activity that conveniently fits her schedule and habits. Greis, Schimdt, and Henze (2015) also envisioned how simulating future states based on the user's actual data could provide her with a tool for decision support and problem solving.

Following these insights, this guideline emphasizes that PI systems should implement features for predicting and simulating the future evolution of the data collected, not only as tools for decision making or to suggest courses of actions, but primarily to provide users with additional contexts of meaning for interpreting their present self. Toward these aims, PI could employ time series analysis methods (Brockwell, 2002) and machine learning techniques (Ahmed, Atiya, Gayar, & El-Shishiny, 2010) for prediction. By providing forecasts and trends of what the user will become both in the short and the long term, PI could support her reflections on the current situation in which she is participating. As narrative is a cognitive tool for situated understanding (e.g. Bruner, 1990), these predictions could also take the form of stories.

Although only a handful of applications have tried to implement narrative elements within the flow of data visualization (e.g. Heer et al., 2008; Eccles et al., 2008; Hullman & Diakopoulos, 2011), it has been suggested that transforming personal data into stories could make them more understandable for PI purposes (Hilviu & Rapp, 2015). Moreover, in their everyday practices Quantified Selfers often use their data in a form of "digital storytelling" (Sharon, 2016). PI could then look at Procedural Content Generation for games to build such stories, possibly using AI techniques to automatize their creation (Hendrikx, Meijer, Van der Velden, & Iosup, 2013). For example, Façade (Mateas & Stern, 2005) is an interactive drama about human relationships that employs an AI system that responds to the player's interactions by reconstructing a real-time dramatic performance from story pieces. While, Riedl, Thue, and Bulitko (2011) employed an Experience Manager that uses narrative principles to look ahead into possible futures of the player's experience. This allows for a player's interaction with the story, since the Experience Manager switches to alternative narrative plans depending on the player's action.

To PI, this would mean to allow users to manipulate predictions by varying specific parameters, or to experiment different contexts in which predictions may be realized, so to visualize and experiment different future selves. This would multiply the perspectives from which users could observe

themselves and compare their present condition to alternate future states that might differently frame and enrich their present. For example, a working mother could explore how her working time, her free time and the time she can spend with her children could be allocated in the future, and how this would affect her quality of life, her happiness, her health, her satisfaction and, by and large, her identity. All of this could also be experimented in possible worlds in which she has moved abroad or has decided to change her current job to follow her passion (meshing her future-self-as-a-mother with her future-self-as-a-singer), thus creating several different stories.

PI systems could also prompt desired and undesired future projections of the user's self, materializing them into concrete representations that give substance to her goals, desires, and intentions, and support her motivations in achieving them. Users could thus become aware of the consequences of their actions: *what will I become if I persevere in my actions? how will I transform myself if I follow an ideal path? and how will I decay if I divert from the main road?* For example, a sedentary middle-aged man, who does not particularly care about his health, weight and blood pressure, could explore how he might become ten years from now. He could display a positive evolution, where a different image of himself as an active and health-conscious individual have led him to love himself more, impacting not only on his physiological parameters, but also on the data about his mood and his relational life. At the same time, however, he could visualize a negative forecast where he would see how his current self has led him not only to put his life at risk, but also to impoverish his social life and emotional states, making him a lonely and depressed individual in the long term. These views could come with suggestions about how to move toward the desired image and away from the undesired one. Differently from the current emphasis on behavior change in PI, however, these images would not be aimed at fostering a modification in a specific user's behavior. After having explored his dreaded and desired selves, in fact, the middle-aged man might decide to maintain his sedentary lifestyle, but focus on preserving his social ties, since those images made him realize that his friends are the most valuable thing in his life.

Research Questions

1. How far in the future should we push the forecast of the self's evolution? How far in the future can we make accurate predictions in the various domains of interest? What is the most important parameter for predictions in PI, accuracy or effectiveness? Are these forecasts valuable even independently on what will really happen, provided that they supply a ground for reflection? For what kind of purposes are short-term predictions most effective?
2. How can we allow users to explore their future data and experiment with alternate evolutions of their selves without falling into abstract manipulations of parameters and numbers? How should the hoped-for and feared selves be represented so to make them the most effective?
3. How can we suggest evolution paths without being prescriptive, providing instead sources for reflection, while leaving freedom to the user's self?
4. How can we satisfy the need to deepen specific aspects of the self and to explore the multiplicity of forms in which it may be articulated, avoiding the risk of having the individual feel lost? How can we highlight the diverse relations that exist between the different selves, located in different times, and the peculiar quality that pertains to each of these relations (causality, analogy, contrast, etc.)?
5. How will different users react to the projection of hoped-for and feared selves? How to deal with unexpected or unwanted reactions? Would it be ethical to use knowledge of which the user has no awareness, like genetic or epidemiological data, to project possible futures? Would it be ethical to instill fears or other negative emotions in the user, even with the aim of helping her take better care of herself?

3.5. The interconnected self

The interconnected self consists of all the representations of ourselves that come from our social interactions. We show different selves to the different groups and individuals with which we interact; in turn, each of these social relations contributes to shape our evolving identities (Bowlby, 1988; Brewer & Gardner, 1996). Significant others, i.e. the persons who are deeply influential in our life, impact our self-definition as it is expressed in relation to others (Andersen, Chen, & Miranda, 2002), showing how knowledge of ourselves is linked to knowledge of others (Andersen, & Chen, 2002). However, each of us belongs to several social groups, be they clearly delimited communities (e.g. lawyers) or more abstract social categories (e.g. Londoners) (Sen, 1999). Each such membership feeds back into our self-perception, self-awareness and the image of the self, and, consequently, our perceptions, emotions and actions (Ellemers, Spears, Doosje, 2002). As a consequence, we derive a great deal of our self-evaluation from such social identities (Brewer & Gardner, 1996), but in highly complex ways that depend on a dynamic interaction between the different feedback we receive (and, of course, how we further react to them).

Thus, both interpersonal relationships and group memberships affect how we look at ourselves, reworking and changing the meanings that we usually associate to our self. The relevance of this for PI is that simply looking at the private self cannot guarantee a satisfactory self-knowledge. Quantified Selfers commonly share their own data (Barta & Neff, 2016), and many PI systems allow users to communicate with and encounter others. Such tools, if well designed, could improve self-understanding through the development of deep connections or the simple presentation of others' experiences.[5]

[5] We are assuming that social interactants aim and are able to be sincere and transparent: a discussion of more complex situations would fall outside the scope and the length of this article, but see e.g. Goffman (1959).

Effective social interaction may lead each individual to incorporate the perspective of the other into her own sense of self (Raskin, 2002), thus modifying it (e.g. Aron, Paris, & Aron, 1995; Watzlawick, Beavin & Jackson, 1967). This may be fruitful if the individuals progressively disclose themselves, i.e. intentionally let the other apprehend aspects pertaining to their private self (Derlega, Metts, Sandra, & Margulis, 1993). Self-disclosure works the best when it is reciprocal: we disclose something about ourselves because we want and expect the others to do the same in their turn (Greene, Derlega, & Mathews, 2006), and by revealing our private self to someone we prepare ourselves to accept her perspective on what we have revealed. For this process to even begin, however, a ground of increasing intimacy is necessary (Derlega, 1984). Self-disclosure is enacted both in dyads and in groups, especially small ones where members can find an intimate climate (Weisner, Greenfield, Room, 1995). Online environments also facilitate self-expression by offering anonymity and the opportunity to locate like-minded partners (Marriott & Buchanan, 2014). PI tools, then, could exploit digital environments to build intimate spaces of self-disclosure.

However, relations do not always need to be so strong to produce a shift in one's self-concept: change may also be generated by the simple presentation of the others' selves and lives, by triggering social comparisons or identification processes. Comparison with the others, in fact, is a fundamental psychological mechanism that influences people's judgments, experiences and identities (Corcoran, Crusius, & Mussweiler, 2011). Social comparison is motivated by a desire to know oneself (Festinger, 1954): actually it does support self-knowledge (Mussweiler & Epstude, 2009), but in different ways, depending on one's needs and on the kind of persons to which one compares. People may select others similar to themselves to gain information for self-evaluation (Festinger, 1954), make downward comparisons to maintain or enhance their self-views (Wills, 1981), or compare with others that they view as superior to improve themselves (Lirgg & Feltz, 1991). However, selecting the "right" others to whom to compare may be an arduous task (Corcoran et al., 2011). For example, to accurately self-

evaluate, one should select the others to whom to compare in accordance with the relevant critical dimension (Wheeler, 1966), or with attributes that are associated with that dimension (Miller, 1984). PI users could therefore gain advantage in being prompted with others' experiences, provided that they are supported in finding the "right" terms of comparison.

The presentation of others, on the other hand, also can boost a process of identification whereby an individual may empathize with the experiences of others. This possibility is grounded in the so-called *Theory of mind* (Baron-Cohen, 2005), namely the faculty of perceiving, inferring, and thinking about the mental states (beliefs, desires, emotions, intentions, etc.) of the others and to reflect on the contents of one's own and others' minds (Bosco, Gabbatore, Tirassa, & Testa, 2016). What matters to PI, here, is that this faculty has consequences on the self: by identifying with others we may experiment new modes of being and open new possibilities for ourselves (Raskin, 2002). On this premise, Kelly (1955) developed a psychotherapeutic technique named *Fixed Role Therapy*, where the client is asked to enact the role of someone who is psychologically different from herself. This helps her explore new ways of behaving and interpreting reality, hopefully leading to a revision of her personal constructs (Raskin, 2002).

Guideline 4a. Allowing users to exchange perspectives on their own personal data with others is essential to improve self-understanding. PI systems should support the creation of closed spaces of intimacy where users can expose the data they gathered, share the experiences connected with them, their feelings, interests, doubts and problems, as well as express and discover themselves through the confrontation with others.

Although many commercial and research PI applications have included features to share collected data (Epstein, Jacobson, Bales, McDonald, & Munson, 2015), empirical studies highlighted that PI users

have an ambiguous attitude toward exposing their data to others. Previous work suggested that sharing data with real-life friends can have positive outcomes in terms of motivation (Toscos, Faber, An, & Gandhi, 2006). However, recent research showed that users rarely exchange data with real-life friends (Fritz et al., 2014): when they do so, it is more to gain support or maintain awareness than to compare for competing (Fritz et al., 2014). PI users, moreover, do not usually share their data on Facebook or Twitter (Rooksby et al., 2014; Fritz et. al., 2014). Instead, they appear to be more inclined to do so with people met in the online communities of the PI application they are using (Fritz et al., 2014). Quantified Selfers also use self-tracking devices as a medium for self-disclosure, self-expression and self-confrontation (Sharon, 2016): in QS meet-ups the numbers presented often serve as a relay for sharing intimate experiences (Sharon & Zandbergen, 2016). Indeed, despite data engagements being discussed in QS discourse in a highly individualistic perspective (Ruckenstein & Pantzar, 2015), QS communities are organized precisely around the members' sharing of their data, creating a bounded, QS space that exists in both physical and virtual realms (Barta, 2016).

PI systems should build on this tendency by creating their own online communities where people can find others. Socially reviewing personal data supports sense making and reflection and helps individuals put what they collected into context, giving them new insights into how to do things differently (Fleck & Harrison, 2015). However, the main focus of this guideline is on connecting people before sharing data, in order to enhance self-reflection and self-knowledge.

To this aim, PI might usefully look at research on Social Networking Sites (SNS) and online communities. SNS designs reinforce self-disclosure by allowing users to have a control on their audiences (Trepte & Reinecke, 2013) and by using social incentives, like providing closer social bonds and higher quality relationships (e.g. Steinfield, Ellison, & Lampe, 2008). PI systems should exploit this design knowledge. However, instead of building large networks for publicly sharing personal data, like PatientsLikeMe, PI systems should aim to create cozy social environments for the support of

mutual understanding, since network size is negatively associated with self-disclosure (Wang, Burke, & Kraut, 2016). Ren et al. (2012) suggested that familiarity and friendliness between individuals may be increased e.g. by providing personal profiles, making activities repeatedly visible to each other, enhancing the perceived similarity among group members, and providing private communication channels.

PI systems should exploit this research to design spaces where people can engage in dyadic and group interactions, to disclose their own experiences and embrace those of the others, which may lead to a re-interpretation of how they look at themselves. For example, a runner who is extremely focused on progression may join a small group of other recreational athletes. As she makes friends with them, she finds herself telling her story and listening to theirs. It turns out that the shared interest in physical activity is experienced in very different ways: she runs as a means to improve herself, others to escape from reality. She starts to reflect on what running truly represents for herself, discovering that her real reason to run was the will to exert an extreme degree of control over her body and mind. Feeling free to self-disclose her inner states with her companions, she begins to rework the role that running has in her life. Of course she may continue on the previous path, only with an increased awareness of the importance of running to her, but she might as well end up viewing it as only an instrument, among many others, that she uses to feel better, and not the unique center of gravity of her days.

Research Questions

1. What is the optimal group size to support self-disclosure while, at the same time, providing a sufficient variety of experiences from which users may learn new perspectives?
2. How can we group users together? Should we leave the users free to select their own groups? Should we allow them to abandon and change their groups whenever they want, or should we

foster continuity and adherence to the group(s) to which the user has been assigned? Should we support membership in multiple groups at the same time?

3. How does group identity influence the interpretation of personal data? May the membership in a group superimpose collective interpretations and identities that can be confounding or detrimental to the users' aim to know themselves?
4. How can we cope with issues of sincerity, reliability, and trust in social interaction, specially when personal data are involved?
5. Should we support the development of friendship relationships in PI communities? Is there any drawback in making friends when exchanging personal data?

Guideline 4b. The presentation of others may strongly affect the individual's self, enriching understanding and producing change. PI system should provide the user with others both to promote social comparison to standards relevant to the self she has in focus and to support identification in different experiences, so to let her experiment different points of view that may enrich her self.

PI systems use social comparison mechanisms to allow users to share and confront performances. Houston, for example, allows to compare progresses toward a daily step count goal in small groups of users, trying to influence them by social pressure (Consolvo et al., 2006). Shakra, instead, aims at increasing the users' enjoyment through competition, by letting them compare their activity levels (Anderson et al., 2007). More recently, social comparison has been mainly employed in gamification design, with the goal of improving performance within a competitive frame. StepByStep tracks walking events and makes users compete through a leaderboard (Zuckerman & Gal-Oz, 2014): however, user observation brought to light that the leaderboard was important to some participants, but less interesting to others. This shows again how different motivation systems may yield a different

sensitivity to the same design (see 3.2). Further research confirmed that this kind of social comparisons sometimes enhances motivation to outperform others, while other times it has smaller or even negative effects (Lin et al., 2006; Hanus & Fox, 2015).

This guideline suggests to go beyond the two frames within which social comparison has generally been inscribed, namely competition as a means and behavior change as its end. It proposes, instead, to employ social comparison to enhance self-knowledge and self-evaluation, maintain a positive self-view and support the improvement of the self-image. To achieve this, PI should select the others to propose to the user for comparison according to their characteristics and momentary needs. Fritz et al. (2014) noted how users that are currently using social features in PI often have difficulties in finding the "right" community to which to compare themselves. PI systems, then, could help users find matches for their self in focus. For example, if the user aims at self-evaluating whether she is athletic or not, the system could select comparison targets that are similar to her on that critical dimension (e.g. people that are very unathletic will not be presented) and its related attributes (e.g. much older persons will not be presented). If the user's mood needs support to maintain her positive self-view, the system could present weaker others, so to make her self appear more positive. Conversely, if she strives for self-enhancement, the system could propose stronger others who may serve as inspirational models. To this aim, PI can look at the techniques and strategies employed in social matching systems, i.e. systems that build user profiles, compute the matches and recommend people to each other (Terveen & McDonald, 2005).

This guideline further proposes to present others in order to foster identification in and empathy toward their experiences. It has been suggested that empathy could be exploited in PI contexts. Balestrini (2013) argued that PI data should be embodied in an external agent like a plant or a pet, with which the user can empathize. Fish'n'Steps (Lin, Mamykina, Lindtner, Delajoux, & Strub, 2006) had already explored this possibility before, by linking the user's daily footstep count to the growth of an animated

virtual character. More recently, Hong et al. (2015) developed a wearable device that embodies data about the user's posture in a virtual plant that can be further nurtured by the user's correct behavior. However, this guideline takes a different view at empathy, looking at *Theory of mind* and at Kelly's (1995) Fixed Role Therapy, where the self may improve its understanding by looking at another's perspective from the inside. Therefore, instead of exploiting the emotional attachment to an "other than self" entity for behavior change, we propose to support the user's identification with others' experiences to enrich her sense of self.

This could be done, for example, by presenting the others' data and experiences as narratives, as we also suggested for the representation of the future selves. Sharon (2016) noted that Quantified Selfers often connect to each other by telling stories. Narratives can foster empathy (Keen, 2006) and identification with the others' perspective (Hilviu & Rapp, 2015), allowing the user to open up to other possibilities for her self. The main character that represents the point of view through which the narration gains perspective could stand for the individual that is collecting her own data (Hilviu & Rapp, 2015). This way, users could identify with others and empathize with them by reading their stories. For example, a woman that connects food with a negative image of her self may be entrapped in ineffective problem solving strategies, like eating when she has to cope with negative emotions, and then blaming herself for having further damaged her self-concept. The system could provide her with the story of other users who shared similar experiences, presenting their data in a narrative form and from their subjective points of view: in these stories their intentions, doubts, attempts, failures, and emotions could be outlined, showing how different experiences may lead to different ways of framing food into their self-understanding. To protect the privacy of these users and prevent self-censorship, which may be enacted when users have to share information that might be considered negative by others (Bales & Griswold, 2013), PI could hide their identity behind a nickname or an avatar. By

reading these stories, the user might experiment novel perspectives that could yield a reconceptualization of her sense of the self and of the role that food plays in it.

Research Questions

1. How can the system determine the relevant and pertinent attributes for each specific request made by the user? How can it detect and avoid wrong matches, or recover from errors, when the match presented does not meet the user self's needs?
2. How can we motivate users to share their personal data? How can we make them realize that their experiences may be useful to someone else?
3. What kinds of personal data raise the strongest concerns about user privacy? Are there means other than anonymization to reassure users that they will not lose control on their data?
4. What kinds of narratives are the most effective in supporting identification? Should the narratives used be simple and clear so to avoid misunderstanding, or indirect and ambiguous so to foster the individual's handling of complexity and to avoid boredom and rejection? Should we rely more on language-based stories or visual-based stories?

4. CONCLUSION

After discussing the notions of the "self" that appear in the current PI rhetoric, we outlined a novel theory of the self, grounded in phenomenology and constructivism and aiming to provide a basis for the future design of PI systems. We suggested a set of guidelines, construed as implications of the theory, together with a research agenda. Following Hekler, Klasnja, Froehlich, and Buman (2013), we consider these guidelines as "design hypotheses", which will require further testing to prove their validity.

We now want to return to the ways in which the paradigmatic shifts we suggested may produce relevant impacts on the PI debate. The first shift we proposed was from considering the externality of behavior to considering the internality of the interacting subject, through the adoption of a phenomenological paradigm. This may have several consequences on PI.

a) The dominant approach to PI implicitly frames PI tools as a sub-class of behavior change technologies, which yields an emphasis on behavior rather than on the self. Our theory instead emphasizes that the natural way we interact with the world is from an internal point of view, with behavior following as a consequence thereof. This focus on the self opens new design spaces for PI, granting them its specificity, namely that of technologies aimed at helping individuals explore their subjectivity, giving such exploration temporal, logical, or existential primacy over a research of its behavioral consequences.

b) In current PI technologies it is behavior that needs be changed to help users live better. PI tools with a focus on behavior change strive to modify specific behaviors (e.g. sedentariness) on the basis of standards that may not even be chosen by the user (Purpura et al., 2011). By putting the self at the center of the process of change, instead, our theory points to the self's wellbeing. In this perspective, PI tools simply help people look in novel ways at their selves, supporting them in finding their own goals and ways to "happiness" based on their peculiarities. This opens new opportunities for PI to design toward self-exploration, self-discovery, and self-modification.

c) To adopt a phenomenological approach also means to reconfigure the respective roles of humans and technology. While in the common PI rhetoric self-tracking tools appear to merely "present" data for the users to rationally analyze and manipulate them, as they were just *present-at-hand*, in our theory technology aims at becoming a tool *ready-to-hand*, i.e. something that affords to be incorporated in our world of subjective meanings (Svanæs, 2013). This puts the agency back into the individual's

subjectivity: it is the subject who acts, by internalizing the tool as if it were part of her subjective world (Merleau-Ponty, 1945). This opens research opportunities for designing PI tools that can more easily be integrated into the characteristics and the dynamics of the self until they become "natural" and transparent extensions of its capabilities of self-understanding, a prosthesis of the mind, like an "enhanced" limb may represent an extension of the individual's possibilities of movement.

The second shift we proposed was from a concept of the self as a static and crystallized entity that can be revealed by analyzing numerical data, to an idea of the self as multiple and mutable, which is actively (re)constructed by the individual. This, also, may yield several outcomes on the PI debate.

d) The constructive nature of the self and of its knowledge entails that the ontology we view in the world and within ourselves is subjective. To PI this means that "going beyond numbers" is not only a matter of usability, however important the latter may be, but also a need to get closer to how we naturally understand and interpret ourselves. While current PI research is striving to find new tools to support users in data exploration, it is still too focused on the examination of quantitative and allegedly objective information. A main consequence of our theory, instead, is the need for PI to explore different lines of research, capable of accounting for the construction and the interpretation of subjective meanings.

e) That the self is intrinsically mutable means that it changes over time. Our theory highlights that each "temporal stage" of the self has its own features and ways of functioning. For PI this involves the need to account for such differences through different specific designs. Furthermore, saying that the self is mutable also implies that it is open to others. In the current PI designs others are mostly seen as competitors, which turns out to be ineffective for a part of the users. Our theory assigns a more fundamental role to social interactions. For PI, this involves opportunities for researching on designs that can make people encounter, self-express, empathize with, and learn from others.

f) The multiple nature of the self entails that we cannot force the view we have on our self into a single interpretation. We know ourselves the more as we have more different, and even contrasting, perspectives on what we are. Current PI tools mostly provide a univocal take on the user's data, and even when they opt for flexibility and diversification, they nevertheless pursue the "best visualization" to be offered to each user in each moment. Our theory instead argues for a user-controlled proliferation of takes on the users' data: there is no such thing as an "optimal interpretation". For PI, this entails the research of new design possibilities to support, integrate and manage such diversification.

As a conclusion, we also want to emphasize that the theory of the self that we outlined above is meant to have a value of its own, independent of the specific guidelines proposed. It highlights several aspects of the self that we believe are relevant for PI design and that could give birth to different guidelines from those that we proposed here. We did not want to propose an "ultimate", all-embracing theory of the self for PI. What we aimed at was to frame different cases for reflection within a theoretical scaffold that should be considered as a work in progress, where individual parts can and should be added, modified, redeemed on the basis of further empirical investigations and theoretical reflections. We aim, in fact, to inspire several different future strands of research, with the hope that new reflections within the kind of approach we propose would provide further advancements in the PI discourse which we now cannot possibly foresee.

REFERENCES

Abbas, A., Zhang, L., & Khan, S. U. (2015). A survey on context-aware recommender systems based on computational intelligence techniques. *Computing, 97(7),* 667–690.

Adomavicious, G. & Tuzhilin, A. (2005). Toward the next generation of recommender systems: a survey of the state-of-the-art and possible extensions. *IEEE Transactions on Knowledge and Data Engineering, 17(6),* 734-749.

Ahmed, N. K., Atiya, A. F., Gayar, N. E., & El-Shishiny, H. (2010). An empirical comparison of machine learning models for time series forecasting. *Econometric Reviews, 29(5-6),* 594-621.

Albert, S. (1977). Temporal comparison theory. *Psychological Review, 84,* 485-503.

Andersen, S. M., & Chen, S. (2002). The relational self: An interpersonal social-cognitive theory. *Psychological Review, 109(4),* 619-645.

Andersen, S. M., Chen, S., & Miranda, R. (2002). Significant others and the self. *Self and Identity, 1,* 159-168.

Anderson, I., Maitland, J., Sherwood, S., Barkhuus, L., Chalmers, M., Hall, M., Brown, B., & Muller, H. (2007). Shakra: tracking and sharing daily activity levels with unaugmented mobile phones. *Mobile Networks and Applications, 12(2-3),* 185-199.

Aron, A., Paris, M., & Aron, E. N. (1995). Falling in love: Prospective studies of self-concept change. *Journal of Personality and Social Psychology, 69(6),* 1102-1112.

Atance C. M., & Meltzoff A. N. (2005). My future self: Young children's ability to anticipate and explain future states. *Cognitive Development, 20,* 341-361.

Bobillo, F., & Straccia, U. (2011). Fuzzy ontology representation using OWL 2. *International Journal of Approximate Reasoning, 52,* 1073-1094.

Bales, B., & Griswold, W. (2011). Interpersonal informatics: Making social influence visible. *Proceedings of the CHI 2011 Conference on Human Factors in Computer Systems Extended Abstracts*. New York: ACM.

Balestrini, M. (2013). In favour of a multiplied self. Can empathy lead to personal behaviour change?. *Proceedings of Workshop on Personal Informatics in the Wild: Hacking Habits for Health & Happiness at CHI 2013 Conference on Human Factors in Computer Systems*.

Banaee, H., Ahmed, M. U., & Loutfi, A. (2013). Data mining for wearable sensors in health monitoring systems: A review of recent trends and challenges. *Sensors, 13,* 17472-17550.

Bandura, A. (1986). *Social foundation of thought and action: A social cognitive theory*. Englewood Cliffs, NJ: Prentice-Hall.

Banks, R., Kirk, D. S., & Sellen, A. (2012). A design perspective on three technology heirlooms. *Human–Computer Interaction, 27,* 63-91.

Baron-Cohen, S. (1995). *Mindblindness: An essay on autism and Theory of Mind*. Cambridge. MA: MIT Press.

Bartlett, F. C. (1932*). Remembering: A study in experimental and social psychology*. London: Cambridge University Press.

Barta, K., & Neff, G. (2016). Technologies for Sharing: lessons from Quantified Self about the political economy of platforms. *Information, Communication & Society, 19(4),* 518-531.

Begum, N. & Keogh, E. (2014). Rare time series motif discovery from unbounded streams. *Proceedings of the VLDB Endowment, 8(2),* 149-160.

Bell, G., & Gemmell, J. (2009). *Total recall: How the e-memory revolution will change everything*. New York: Dutton.

Bentley F., Tollmar K., Stephenson P., Levy L., Jones B., Robertson S., Price E., Catrambone R., & Wilson J. (2013). Health mashups: Presenting statistical patterns between wellbeing data and context in natural language to promote behavior change. *ACM Transactions on Computer-Human Interaction (TOCHI), 20(5),* 30:1-30:27.

Boden, M. A. (2006). *Mind as machine. A history of cognitive science*. Oxford: Oxford University Press.

Bosco, F. M., Gabbatore, I., Tirassa, M., Testa, S. (2016). Psychometric properties of the Theory of Mind Assessment Scale in a sample of adolescents and adults. *Frontiers in Psychology, 7(566)*.

Bowlby, J. (1988). *A secure base: Parent-child attachment and healthy human development*. London: Routledge.

Brewer, M. B., & Gardner, W. (1996). Who is this "we"? Levels of collective identity and self representations. *Journal of Personality and Social Psychology, 71(1),* 83-93.

Brizio, A., & Tirassa, M. (2016) Biological agency: Its subjective foundations and a large-scale taxonomy. *Frontiers in Psychology, 7:41*.

Brockwell, P. J. & Davis, R. A. (2002). *Introduction to time series and forecasting*, volume 1. New York: Springer-Verlag.

Bruner, J. S. (1990). *Acts of meaning*. Cambridge, MA: Harvard University Press.

Brusilovsky, P. (2001). Adaptive Hypermedia. *User Modeling and User-Adapted Interaction, 11(1-2),* 87-110.

Brynjarsdóttir, H., Håkansson, M., Pierce, J., Baumer, E., DiSalvo, C., & Sengers, P. (2012). Sustainably unpersuaded: How persuasion narrows our vision of sustainability. *Proceedings of the CHI 2012 Conference on Human Factors in Computer Systems*. New York: ACM.

Cantor, N., Markus, H., Niedenthal, P., & Nurius, P. (1986). On motivation and the self-concept. In R. M. Sorrentino & E. I. Higgins (Eds.), *Handbook of motivation and cognition* (pp. 96-121). New York: Guilford Press.

Carstensen, L. L., Mikels, J. A., & Mather, M. (2006). Aging and the intersection of cognition, motivation and emotion. In J. Birren & K. W. Schaie (Eds.), *Handbook of the psychology of aging* (pp. 343-362). San Diego, CA: Academic Press.

Chen, H., Finin, T., Joshi, A., Kagal, L., Perich, F., & Chakraborty, D. (2004). Intelligent agents meet the semantic web in smart spaces. *Internet Computing, IEEE, 8(6),* 69-79.

Chessell, Z., C., Rathbone, C., J., Souchay, C., Charlesworth, L. & Moulin, C. J. A. (2014) Autobiographical memory, past and future events, and self-images in younger and older adults. *Self and Identity, 13(4),* 380-397.

Choe, E. K. (2014). *Designing Self-Monitoring Technology to Promote Data Capture and Reflection*. Unpublished doctoral dissertation. The Information School, University of Washington.

Choe, E. K., Lee, N. B., Lee, B., Pratt, W., & Kientz, J. A. (2014). Understanding quantified-selfers' practices in collecting and exploring personal data. *Proceedings of the CHI 2014 Conference on Human Factors in Computer Systems*. New York: ACM.

Churchland, P. S. (1986). *Neurophilosophy: Toward a unified science of the mind-brain*. Cambridge, MA: MIT Press.

Clancey, W. J. (1997b). *Situated cognition: On human knowledge and computer representations*. New York: Cambridge University Press.

Clawson, J., Pater, J. A., Miller, A. D., Mynatt, E. D. & Mamykina, L. (2015). No longer wearing: investigating the abandonment of personal health-tracking technologies on craigslist. *Proceedings of the UbiComp 2015 Conference on Pervasive and Ubiquitous Computing*. New York: ACM.

Cole, M. (1996) *Cultural psychology. A once and future discipline*. Cambridge, MA: Harvard University Press.

Consolvo, S., Everitt, K., Smith, I., & Landay, J. A. (2006). Design requirements for technologies that encourage physical activity. *Proceedings of the CHI 2006 Conference on Human Factors in Computer Systems*. New York: ACM.

Consolvo, S., Klasnja, P., McDonald, D., Avrahami, D., Froehlich, J., Legrand, L., Libby, R., Mosher, K., & Landay, J. (2008). Flowers or a robot army? Encouraging awareness & activity with personal, mobile displays. *Proceedings of the UbiComp 2008 Conference on Ubiquitous Computing*. New York: ACM.

Consolvo, S., McDonald, D., & Landay, J. (2009). Theory-driven design strategies for technologies that support behavior change in everyday life. *Proceedings of the CHI 2009 Conference on Human Factors in Computer Systems*. New York: ACM.

Conway, M. A. (1991). In defense of everyday memory. *American Psychologist, 46,* 19-27.

Conway, M. A. (1996) Autobiographical knowledge and autobiographical memories. In D. C. Rubin (Ed.), *Remembering our past: Studies in autobiographical memory* (pp. 67-93). Cambridge, MA: Cambridge University Press.

Conway, M. A. (2005). Memory and the self. *Journal of Memory and Language, 53,* 594-628.

Conway, M. A., & Pleydell-Pearce, C. W. (2000). The construction of autobiographical memories in the self-memory system. *Psychological Review, 107,* 261-288.

Cooper, J. O., Heron, T. E., & Heward, W. L. (2007). *Applied behavior analysis* (2nd ed.). Upper Saddle River, NY: Prentice Hall.

Corcoran, K., Crusius, J., & Mussweiler, T. (2011). Social comparison: Motives, standards, and mechanisms. In D. Chadee (Ed.), *Theories in social psychology* (pp. 119-139). Oxford: Wiley-Blackwell.

Cosley, D., Schwanda, V., Schultz, J., Peesapati, S. T., & Lee, S. (2012). Experiences with designing tools for everyday reminiscing. *Human–Computer Interaction, 27,* 175-198.

Davis, J. (2013). The qualified self. http:// thesocietypages.org/cyborgology/2013/03/13/the-qualified-self/. Last accessed October 1, 2016.

Derlega, V. J. (1984). Self-disclosure and intimate relationships. In V. J. Derlega (Ed.), *Communication, intimacy and close relationships* (pp. 1-10). Orlando, FL: Academic Press.

Derlega, V. J., Metts, S., Sandra, P., & Margulis, S. T. (1993). *Self-disclosure*. California, CA: Sage Publications, Inc.

Dourish, P. (2001). *Where the action is: The foundations of embodied interaction*. Cambridge, MA: The MIT Press.

Eccles, R., Kapler, T., Harper, R., & Wright, W. (2008). Stories in GeoTime. *Information Visualization, 7(1),* 3-17.

Ehn, P. (1988). *Work-oriented design of computer artifacts*. Stockholm: Arbetlivscentrum.

Ellemers, N., Spears, R., & Doosje, B. (2002). Self and social identity. *Annual Review of* Psychology, 53, 161-186.

Elsden, C., Kirk, D., Selby, M., and Speed, C. (2015). Beyond personal informatics: Designing for experiences with data. *Proceedings of the CHI 2015 Conference on Human Factors in Computer Systems Extended Abstracts*. New York: ACM.

Elsden, C., Kirk, D. S., & Durrant, A. C. (2016). A quantified past: Toward design for remembering with personal informatics. *Human–Computer Interaction, 31(6),* 518-557.

Epstein, D. A., Cordeiro, F., Bales, E., Fogarty, J., & Munson, S. (2014). Taming data complexity in lifelogs: Exploring visual cuts of personal informatics data. *Proceedings of the DIS 2014 Conference on Designing Interactive Systems*. New York: ACM.

Epstein, D. A., Jacobson, B. H., Bales, E., McDonald, D. W., & Munson, S. A. (2015). From "nobody cares" to "way to go!": A design framework for social sharing in Personal Informatics. *Proceedings of the CSCW 2015 Conference on Computer Supported Cooperative Work*. New York: ACM.

Epstein, D. A., Ping, A., Fogarty, J., & Munson. S. A. (2015). A lived informatics model of personal informatics. *Proceedings of the UbiComp 2015 Conference on Pervasive and Ubiquitous Computing*. New York: ACM.

Erikson, M. (2007). The meaning of the future: Toward a more specific definition of possible selves. *Review of General Psychology, 11(4),* 348-358.

Ertmer, P. A., & Newby, T. J. (2013). Behaviorism, cognitivism, constructivism: Comparing critical features from an instructional design perspective. *Performance Improvement Quarterly, 26(2),* 43-71.

Festinger, L. (1954). A theory of social comparison processes. *Human Relations, 7,* 117-140.

Fleck, R., & Harrison, D. (2015). Shared PI: Sharing personal data to support reflection and behaviour change. *Proceedings of Workshop on Beyond Personal Informatics: Designing for Personal Experiences with Data at CHI 2015 Conference on Human Factors in Computer Systems*.

Fogg, B. J. (2003). *Persuasive technology: Using computers to change what we think and do*. San Francisco, CA: Morgan Kaufmann Publishers.

Fosnot, C. T. (1996). *Constructivism: Theory, perspectives, and practice*. New York, NY: Teachers College Press.

Frias-Martinez, E., Chen, S. Y., & Liu, X. (2006). Survey of data mining approaches to user modeling for adaptive hypermedia. *IEEE Transactions on Systems, Man and Cybernetics, 36(6),* 734-749.

Fritz, T., Huang, E. M., Murphy, G. C. & Zimmermann, T. (2014). Persuasive technology in the real world: A study of long-term use of activity sensing devices for fitness. *Proceedings of the CHI 2014 Conference on Human Factors in Computer Systems*. New York: ACM.

Gallagher, S., & Zahavi, D. (2008). *The phenomenological mind*. New York: Routledge.

Gibson, J. J. (1979). *The ecological approach to visual perception*. Boston: Houghton Mifflin.

Glenberg, A. M. (1997). What memory is for. *Behavioral and Brain Sciences, 20,* 1-55.

Goffman, E. (1959). *The presentation of self in everyday life*. New York: Doubleday.

Gould, S. J. (2002). *The structure of evolutionary theory*. Harvard, MA: Harvard University Press.

Graepel, T., Herbrich, R., & Gold, J. (2004). Learning to fight. *Proceedings of the CGAIDE 2004 International Conference on Computer Games: Artificial Intelligence, Design and Education*.

Gray, J. A. (1973). Causal theories of personality and how to test them. In J. R. Royce (Ed.), *Multivariate analysis and psychological theory* (pp. 409–463). New York: Academic Press.

Greenwald, A. G. (1980). The totalitarian ego: Fabrication and revision of personal history. *American Psychologist, 35,* 603-618.

Greis, M., Schmidt, A., & Henze, N. (2015). Predicting the Future: Towards Personal Simulation. *Proceedings of Workshop on Beyond Personal Informatics: Designing for Personal Experiences with Data at CHI 2015 Conference on Human Factors in Computer Systems*.

Greene, K., Derlega, V. J., & Mathews, A. (2006). Self-disclosure in personal relationships. In A. Vangelisti & D. Perlman (Eds.), *The Cambridge handbook of personal relationships* (pp. 409–427). New York, NY: Cambridge University Press.

Gruneberg, M. M., & Morris, P. E. (1992) Applying memory research. In M. M., Gruneberg & P. Morris (Eds.), *Aspects of memory*, (vol. 1, pp. 1-17). London: Routledge.

Guidano, V.F. (1987). *Complexity of the self: A developmental approach to psychopathology and therapy*. New York: Guilford.

Guidano, V.F. (1991). *The self in process: Toward a post-rationalist cognitive therapy*. New York: Guilford.

Guo, B., Sun, L., & Zhang, D. (2010). The architecture design of a cross-domain context management system. *Proceedings of PERCOM Workshop 2008 International Conference on Pervasive Computing and Communications Workshops*.

Hallnäs, L., & Redstrom, J. (2001). Slow technology: Designing for reflection. *Personal Ubiquitous Computing, 5(3),* 201-212.

Hanus, M. & Fox, J. (2015). Assessing the effects of gamification in the classroom: A longitudinal study on intrinsic motivation, social comparison, satisfaction, effort, and academic performance. *Computers & Education, 80(0),* 152-161.

Harper, R., Randall, D., Smyth, N., Evans, C., Heledd, L., & Moore, R. (2008). The past is a different place: they do things differently there. *Proceedings of the DIS 2008 Conference on Designing Interactive Systems*. New York: ACM.

Harrison, D., Marshall, P., Bianchi-Berthouze, N., & Bird, J. (2015). Activity tracking: barriers, workarounds and customisation. *Proceedings of the UbiComp 2015 Conference on Pervasive and Ubiquitous Computing*. New York: ACM.

Hawkins, D., Procyk, J., & Neustaedter, C. (2014). Postulater: Slowing the pace of media sharing. *Proceedings of the DIS 2014 Companion Publication on Designing Interactive Systems*. New York: ACM.

Heer, J., Mackinlay, J., Stolte, C., and Agrawala, M. (2008). Graphical Histories for Visualization: Supporting Analysis, Communication, and Evaluation. *IEEE Transactions on Visualization and Computer Graphics, 14(6),* 1189-1196.

Heidegger, M. (1982). *The basic problems of phenomenology*. Bloomington, IN: Indiana University Press.

Heidegger, M. (1927/1990). *Being and time*. Albany, NY: SUNY Press.

Hekler, E. B., Klasnja, P., Froehlich, J. E., & Buman, M. P. (2013). Mind the theoretical gap: Interpreting, using, and developing behavioral theory in HCI research. *Proceedings of the CHI 2013 Conference on Human Factors in Computing Systems*. New York, NY: ACM.

Hellström, C. (2001). Temporal dimensions of the self-concept: Entrapped and possible selves in chronic pain. *Psychology & Health, 16(1),* 111-124.

Hendrikx, M., Meijer, S., Van der Velden, J., & Iosup, A. (2013). Procedural content generation for games: A survey. *ACM Transactions on Multimedia Computing, Communications and Applications, 9(1),* Article 1.

Hilviu, D. & Rapp, A. (2015). Narrating the Quantified Self. *Adjunct Proceedings of the UbiComp/ISWC 2015 Conference on Pervasive and Ubiquitous Computing and International Symposium on Wearable Computers*. New York: ACM.

Hong, J., Koo, B., Ban, S., Cho, J., & Bianchi, A. (2015). beuPo: A digital plant that you can raise and customize with your current posture. *Adjunct Proceedings of the UbiComp/ISWC 2015 Conference on Pervasive and Ubiquitous Computing and International Symposium on Wearable Computers*. New York: ACM.

Hooker, K. (1992). Possible selves and perceived health in older adults and college students. *Journal of Gerontology: Psychological Sciences*, 47(2), P85-P95.

Hoyle, R. H., & Sherrill, M. R. (2006). Future orientation in the self-system: Possible selves, self-regulation, and behavior. *Journal of Personality, 74(6),* 1673-1696.

Hullman, J., & Diakopoulos, N. (2011). Visualization rhetoric: Framing effects in narrative visualization. *IEEE Transactions on Visualization and Computer Graphics, 17(12),* 2231-2240.

Husserl, E. (1962). *Phänomenologische Psychologie, Husserliana IX*. Den Haag: Martinus Nijhoff.

Husserl, E. (1976). *The crisis of European sciences and transcendental phenomenology. An introduction to phenomenology*. Evanston, IL: Northwestern University Press.

Iaquinta, L., de Gemmis, M., Lops, P., Semeraro, G., Filannino, M., & Molino, P. (2008). Introducing serendipity in a content-based recommender system. *Proceedings of the HIS 2008 Conference on Hybrid Intelligent Systems*. Los Alamitos, CA: IEEE.

Izakian, H. & Pedrycz, W. (2014). Anomaly detection and characterization in spatial time series data: A cluster-centric approach. *IEEE Transactions on Fuzzy Systems, 22(6),* 1612-1624.

Kalnikaite, V., Sellen, A., Whittaker, S., & Kirk, D. (2010). Now let me see where I was: Understanding how lifelogs mediate memory. *Proceedings of the CHI 2010 Conference on Human Factors in Computing Systems*. New York: ACM.

Kanfer, F. H. (1977). The many faces of self-control, or behavior modification changes its focus. In Stuart, R. B. (Ed.), *Behavioral self-management: Strategies, techniques, and outcomes* (pp. 1-48). New York: Brunner/Mazel.

Kay, J. & Kummerfield, B. (2009). Lifelong user modelling goals, issues and challenges. *Proceeding of Workshop on Lifelong User Modelling at UMAP 2009 Conference on User Modeling, Adaptation and Personalization*.

Keen, S. (2006). A theory of narrative empathy. *Narrative, 14(3),* 207-236.

Kelly, G. A. (1955). *The psychology of personal constructs*. New York: Norton.

Koriat, A., & Goldsmith, M. (1996). Memory metaphors and the real-life/laboratory controversy: Correspondence versus storehouse conceptions of memory. *Behavioral and Brain Sciences, 19,* 167-228.

Kuhn, T. S. (1962). *The structure of scientific revolutions*. Chicago, IL: University of Chicago Press.

Lazar, A., Koehler, C., Tanenbaum, J., & Nguyen, D. H. (2015). Why we use and abandon smart devices. *Proceedings of the UbiComp 2011 Conference on Ubiquitous Computing*. New York: ACM.

Lewontin, R. (2000). *The triple helix. Gene, organism, and environment*. Cambridge, MA: Harvard University Press.

Li, I. (2015). Beyond Reflecting on Personal Data: Predictive Personal Informatics. *Proceedings of Workshop on Beyond Personal Informatics: Designing for Personal Experiences with Data at CHI 2015 Conference on Human Factors in Computer Systems*.

Li, I., Dey, A., & Forlizzi, J. (2010). A stage-based model of personal informatics systems. *Proceedings of the CHI 2010 Conference on Human Factors in Computer Systems*. New York: ACM.

Li, I., Dey, A., & Forlizzi, J. (2011). Understanding my data myself: Supporting self-reflection with Ubicomp technologies. *Proceedings of the UbiComp 2011 Conference on Ubiquitous Computing*. New York: ACM.

Li, I., Dey, A., & Forlizzi, J. (2012). Using context to reveal factors that affect physical activity. *ACM Transactions in Computer-Human Interactions (TOCHI), 19(1),* Article 7.

Li, X., Eckert, M., Martinez, J-F., Rubio, G. (2015). Context aware middleware architectures: Survey and challenges. *Sensors, 15(8),* 20570-20607.

Lin. J. J., Mamykina, L., Lindtner, S., Delajoux, G., & Strub, H. B. (2006), Fish'n'Steps: encouraging physical activity with an interactive computer game. *Proceedings of the UbiComp 2006 Conference on Ubiquitous Computing*. Berlin: Springer-Verlag.

Lirgg, C. D., & Feltz, D. L. (1991). Teacher versus peer models revisited: Effects on motor performance and self-efficacy. *Research Quarterly for Exercise and Sports*, 62, 217-224.

Lomborg, S., & Frandsen, K. (2016). Self-tracking as communication. *Information, Communication & Society*, 19(7), 1015-1027.

Lops, P., De Gemmis, M., & Semeraro, G. (2011). Content-based recommender systems: State of the art and trends. In F. Ricci, L. Rokach, B. Shapira, P.B. Kantor (Eds.), *Recommender Systems Handbook* (pp. 73–105). New York: Springer.

Lupton, D. (2014). Self-tracking cultures: Towards a sociology of personal informatics. *Proceedings of the OzCHI 2014 Australian Computer-Human Interaction Conference*. New York: ACM.

Lupton, D. (2015). Quantified sex: A critical analysis of sexual and reproductive self-tracking using apps. *Culture, Health and Sexuality, 17(4),* 1-14.

Lupton, D. (2016). You are your data: Self-tracking practices and concepts of data. In S. Selke (Ed.), *Digital self-tracking and Lifelogging - between disruptive technology and cultural transformation* (pp. 61-79). Wiesbaden: Springer Fachmedien Wiesbaden.

Macrae, C. N., Mitchell, J. P., Tait, K. A., McNamara, D. L., Golubickis, M., Topalidis, P. P., & Christian, B. M. (2015). Turning I into me: Imagining your future self. *Consciousness and Cognition, 37,* 207-13.

Maes, P. (Ed.). (1991). *Designing autonomous agents: Theory and practice from biology to engineering and back*. Cambridge, MA: MIT Press.

Manera, V., & Tirassa, M. (2010). Cognitive science. In L. Cummings (Ed.), *The pragmatics encyclopedia* (pp. 55-58). London: Routledge.

Markus, H., & Nurius, P. (1986). Possible Selves. *American Psychologist, 41(9),* 954-969.

Markus, H., & Ruvolo, A. (1989). Possible selves: Personalized representations of goals. In L. A. Pervin (Ed.), *Goal concepts in personality and social psychology* (pp. 211-241). Hillsdale, NJ: Erlbaum.

Marriott, T. C. & Buchanan, T. (2014). The true self online: Personality correlates of preference for self-expression online, and observer ratings of personality online and offline. *Computers in Human Behaviour, 32,* 171-177.

Mate, D., & Tirassa, M. (2010) Knowledge. In L. Cummings (Ed.), *The pragmatics encyclopedia* (pp. 239-242). London: Routledge.

Mateas, M. & Stern, A. (2005). Structuring content in the Façade interactive drama architecture. *Proceedings of the AAAI 2001 Conference on Artificial Intelligence and Interactive Digital Entertainment*. Menlo Park, CA: AAAI Press.

Maturana, H. D., & Varela, F. J. (1980). *Autopoiesis and cognition: The realization of the living*. Dordrecht: Reidel.

Merleau-Ponty, M. (1945/2012). *Phenomenology of perception*. London: Routledge.

Miller, C. T. (1984). Self-schemas, gender, and social comparison: A clarification of the related attributes hypothesis. *Journal of Personality and Social Psychology*, 46, 1222-1229.

Mussweiler, T., & Epstude, K. (2009). Relatively fast! Efficiency advantages of comparative information processing. *Journal of Experimental Psychology: General, 138,* 1-21.

Nafus, D., Denman, P., Durham, L., Florez, O., Nachman, L., Sahay, S., Savage, E., Sharma, S., Strawn, D. & Wouhaybi, R. H. (2016). As simple as possible but no simpler: Creating flexibility in personal informatics. *Proceedings of the CHI 2016 Conference on Human Factors in Computer Systems Extended Abstracts*. New York: ACM.

Nafus, D., & Sherman, J. (2014). This one does not go up to 11: The quantified self movement as an alternative big data practice. *International Journal of Communication, 8,* 1784-1794.

Nagel, T. (1986). *The view from nowhere*. Oxford: Oxford University Press.

Neisser, U. (1976). *Cognition and reality. Principles and implications of cognitive psychology*. San Francisco, CA: Freeman.

Newell, A. (1990). *Unified theories of cognition*. Boston, MA: Harvard University Press.

Odom, W., Banks, R., Durrant, A., Kirk, D., & Pierce, J. (2012). Slow technology: Critical reflection and future directions. *Proceedings of the DIS 2012 Conference on Designing Interactive Systems*. New York: ACM.

Odom, W. (2015). Understanding long-term interactions with a slow technology: An investigation of experiences with FutureMe. *Proceedings of the CHI 2015 Conference on Human Factors in Computer Systems*. New York: ACM.

Ohlin, F. & Olsson, C. M. (2015a). Beyond a utility view of personal informatics: A postphenomenological framework. *Adjunct Proceedings of UbiComp/ISWC 2015*. New York: ACM.

Ohlin, F. & Olsson, C. M. (2015b). Intelligent computing in personal informatics: Key design considerations. *Adjunct Proceedings of the UbiComp/ISWC 2015 Conference on Pervasive and Ubiquitous Computing and International Symposium on Wearable Computers*. New York: ACM.

Oyserman, D., Terry, K., & Bybee, D. (2002). A possible selves intervention to enhance school involvement. *Journal of Adolescence, 25,* 313-326.

Perera, C., Zaslavsky, A., Christen, P., & Georgakopoulos, D. (2014). Context aware computing for the internet of things: A survey. *IEEE Communications Surveys & Tutorials, 16,* 414-454.

Pinker, S. (1997). *How the mind works*. Harmondsworth: Penguin.

Pollock, J. L. (1993). The phylogeny of rationality. *Cognitive Science, 17,* 563-588.

Prekop, P. & Burnett, M. (2003). Activities, context and ubiquitous computing. *Computer Communications, 26(11),* 1168-1176.

Prochaska, J. O., Redding, C. A., & Evers, K. E. (2008). The transtheoretical model and stages of change. In K. Glanz, B. K. Rimer, & F. M. Lewis (Eds.), *Health behavior and health education: Theory, research and practice* (pp. 97-121). San Francisco, CA: Jossey-Bass, Inc.

Purpura, S., Schwanda, V., Williams, K., Stubler, W., & Sengers, P. (2011). Fit4life: The design of a persuasive technology promoting healthy behavior and ideal weight. *Proceedings of the CHI 2011 Conference on Human Factors in Computer Systems*. New York: ACM.

Pylyshyn, Z.W. (1984). *Computation and cognition*. Cambridge, MA: MIT Press.

Rapp, A. & Cena, F. (2016). Personal Informatics for everyday life: How users without prior self-tracking experience engage with personal data. *International Journal of Human-Computer Studies, 94,* 1-17.

Raskin, J. D. (2002). Constructivism in psychology: Personal construct psychology, radical constructivism, and social constructionism. In J. D. Raskin & S. K. Bridges (Eds.), *Studies in meaning: Exploring constructivist psychology* (pp. 1-25). New York: Pace University Press.

Rathbone, C. J., Moulin, C. J. A., & Conway, M. A. (2008). Self-centred memories: The reminiscence bump and the Self. *Memory & Cognition, 36(8),* 1403-1414.

Ren, Y., Harper, F. M., Drenner, S., Terveen, L., Kiesler, S., Riedl, J. & Kraut, R. E. (2012). Building member attachment in online communities: Applying theories of group identity and interpersonal bonds. *MIS Quarterly, 36(3),* 841-864.

Riedl, M. O., Thue, D., & Bulitko, V. (2011). Game AI as storytelling. In P. G. Calero (Ed.), *Artificial intelligence for computer games* (pp.121-150). New York: Springer.

Rooksby, J., Rost, M., Morrison, A., & Chalmers, M. (2014). Personal tracking as lived informatics. *Proceedings of the CHI 2014 Conference on Human Factors in Computer Systems*. New York: ACM.

Roussou, M. (2004). Learning by doing and learning through play: an exploration of interactivity in virtual environments for children. *Computers in Entertainment, 2(1)*.

Ruckenstein, M. (2014). Visualized and interacted life: Personal analytics and engagements with data doubles. *Societies*, 4(1), 68-84.

Ruckenstein, M., & Pantzar, M. (2015). Beyond the Quantified Self: Thematic exploration of a dataistic paradigm. *new media & society*. Published online before print October 7, 2015, doi: 10.1177/1461444815609081.

Sarkar, A. (2016). Constructivist design for interactive machine learning. *Proceedings of the CHI 2016 Conference on Human Factors in Computer Systems Extended Abstracts*. New York: ACM.

Saltz, E. & Donnenwerth-Nolan, S. (1981) Does motoric imagery facilitate memory for sentences? A selective interference test. *Journal of Verbal Learning and Verbal Behavior, 20,* 322-32.

Sas, C., & Whittaker, S. (2013). Design for forgetting: disposing of digital possessions after a breakup. *Proceedings of the CHI 2013 Conference on Human Factors in Computer Systems*. New York: ACM.

Schacter, D. (1987) Implicit memory: History and current status. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 13,* 501-18.

Schechtman, M. (2007). Stories, lives and basic survival: A refinement and defense of the narrative view. *Royal Institute of Philosophy Supplement, 60,* 155-178.

Schüll, N. D. (2016). Data for life: Wearable technology and the design of self-care. *BioSocieties, 11(3),* 317-333.

Searle, J. R. (1992). *The rediscovery of the mind*. Cambridge, MA: MIT Press.

Sen, A. (1999). *Reason before identity. The Romanes lecture for 1998*. New York: Oxford University Press.

Sharon, T. (2016). Self-tracking for health and the quantified self: Re-articulating autonomy, solidarity, and authenticity in an age of personalized healthcare. *Philosophy & Technology* Published online before print April 18, 2016, doi: 10.1007/s13347-016-0215-5.

Sharon, T., & Zandbergen, D. (2016). From data fetishism to quantifying selves: Self-tracking practices and the other values of data. *new media & society*. Published online before print March 9, 2016, doi: 10.1177/1461444816636090.

Singer, J.A., & Salovey, P. (1993). *The remembered self: Emotion and memory in personality*. Toronto, ON: Maxwell Macmillan International.

Sloman, A. (1993). The mind as a control system. In *Philosophy and the Cognitive Sciences*. C. Hookway & D. Peterson, D. (Eds.), *Philosophy and the cognitive sciences* (pp. 69-110). Cambridge: Cambridge University Press.

Spronck, P., Ponsen, M., Sprinkhuizen-Kuyper, I., & Postma, E. (2006). Adaptive game AI with dynamic scripting. *Machine Learning, 63(3),* 217-248.

Steinfield, C., Ellison, N. B., & Lampe, C. (2008). Social capital, self-esteem, and use of online social network sites: A longitudinal analysis. *Journal of Applied Developmental Psychology*, 29, 434-445.

Suddendorf, T., & Corballis, M. C. (2007). The evolution of foresight: What is mental time travel and is it unique to humans?. *Behavioral and Brain Sciences, 30,* 299-351.

Svanæs, D. (2013). Interaction design for and with the lived body : Some implications of Merleau-Ponty's phenomenology. *ACM Transactions on Computer-Human Interaction (TOCHI), 20(1),* Article 8.

Terveen, L., & McDonald, D. W. (2005). Social matching: A framework and research agenda. *ACM Transactions on Computer-Human Interaction, 12(3),* 401-434.

Tirassa, M. (1999). Communicative competence and the architecture of the mind/brain. *Brain and Language, 68,* 419-441.

Tirassa, M., & Vallana, M. (2010). Representation and computation. In L. Cummings (Ed.), *The pragmatics encyclopedia* (pp. 399-402). London: Routledge.

Toscos, T., Faber, A., An, S., & Gandhi, M. (2006). Chick clique: Persuasive technology to motivate teenage girls to exercise. *Proceedings of the CHI 2006 Conference on Human Factors in Computer Systems*. New York: ACM.

Trepte, S., & Reinecke, L. (2013). The reciprocal effects of social network site use and the disposition for self-disclosure: A longitudinal study. *Computers in Human Behaviour, 29(3),* 1102-1112.

Tulving, E. (2002). Episodic memory: From mind to brain. *Annual Review of Psychology*, 53, 1-25.

van den Hoven, E., & Eggen, B. (2008). Informing augmented memory system design through autobiographical memory theory. *Personal and Ubiquitous Computing, 12,* 433-443.

van den Hoven, E., Sas, C., & Whittaker, S. (2012). Introduction to this special issue on designing for personal memories: Past, present, and future. *Human–Computer Interaction, 27(1-2),* 1-12.

Varela, F., Thompson, E., & Rosch, E. (1991). *The embodied mind: Cognitive science and human experience*. Cambridge, MA: MIT Press.

Vignoles, V., Manzi, C., Regalia, C., Jemmolo, S., & Scabini, E. (2008). Identity motives underlying desired and feared possible future selves. *Journal of Personality, 76,* 1165-1200.

Wang, Y.-C., Burke, M., & Kraut, R. (2016). Modeling self-disclosure in Social Networking Sites. *Proceedings of the CSCW 2016 Conference on Computer Supported Cooperative Work*. New York: ACM.

Watzlawick, P. (1984). *The invented reality: How do we know what we believe we know?: Contributions to constructivism*. New York: Norton.

Watzlawick, P., Beavin, J.H., & Jackson, D. D. (1967) *Pragmatics of human communication*. New York: Norton.

Weisner, C., Greenfield, T., Room, R. (1995). Trends in the treatment of alcohol problems in the U.S. general population. *American Journal of Public Health, 85,* 55-60.

Wheeler, L. (1966). Motivation as a determinant of upward comparison. *Journal of Experimental Social Psychology, 2(Suppl. 1),* 27-31.

Whooley, M., Ploderer, B., & Gray, K. (2014). On the Integration of Self-tracking Data amongst Quantified Self Members. *Proceedings of the HCI 2014 International BCS Human Computer Interaction Conference*.

Wiener, N. (1948). *Cybernetics: Or control and communication in the animal and the machine*. Boston, MA: Technology Press.

Wills, T. A. (1981). Downward comparison principles in social psychology. *Psychological Bulletin, 90,* 245-271.

Wilson, A., & Ross, M. (2003). The identity function of autobiographical memory: Time is on our side. *Memory, 11(2),* 137-49.

Winterbottom, C. & Blake, E. (2008). Constructivism, virtual reality and tools to support design. *Proceedings of the DIS 2008 Conference on Designing Interactive Systems*. New York: ACM.

Wittgenstein, L. (1953). *Philosophical investigations*. Oxford: Blackwell.

Yang, R., Shin, E., Newman, M. W., & Ackerman, M. S. (2015). When fitness trackers don't 'fit': End-user difficulties in the assessment of personal tracking device accuracy. In *Proceedings of the UbiComp 2015 Conference on Pervasive and Ubiquitous Computing*. New York: ACM.

Ypma, A. & Duin, R. P. (1997). Novelty detection using self-organizing maps. *Progress in Connectionist-Based Information Systems, 2,* 1322-1325.

Zahavi, D. (2012). The Time of the self. *Grazer Philosophische Studien, 84,* 143-159.

Zhao, O. J., Ng, T., & Cosley, D. (2012). No forests without trees: Particulars and patterns in visualizing personal communication. *Proceedings of the 2012 iConference*. New York: ACM.

Zuckerman, O. & Gal-Oz, A. (2014). Deconstructing gamification: Evaluating the effectiveness of continuous measurement, virtual rewards, and social comparison for promoting physical activity. *Personal and Ubiquitous Computing, 18(7),* 1705-1719.

FIGURE 1. Guidelines for Personal Informatics

Sections	Features relevant for PI	Guidelines	Examples
Present Self		*Guideline 1*	
	Situated in a subjectively experienced world	PI should provide subjective meanings	Subjective tags; narration techniques to "tell the data"; data-driven avatars
	Changes due to changes in self-knowledge	PI should focus on self's wellness	Support for re-interpreting the current situation
Past Self		*Guideline 2a*	
	Organizes memories around important life episodes	PI should adopt s self-centric organization of historical data.	Detection and chaining of significant past episodes
	Is experienced from a subjective point of view	PI should help remember the past from an internal point of view	External and internal past contextual cues to recollect lifetime periods
		Guideline 2b	
	Is construed by the present self	PI should adapt past data to the needs of the user's present self	Adaptation of historical data to support the user's present self
	Provides resources for action to the present self	PI should use past data to support the reinterpretation of the present	Recommendations based on past data to interpret the current situation
Future Self		*Guideline 3*	
	Allows for the exploration of different possible futures	PI should help simulate alternate futures	Interactive narratives of how the selves will evolve in the future
	Can be explored (hoped or feared) serving motivational functions	PI should provide a range of (idealized and dreaded) future images of the self	Projections of ideal paths of evolution as well as worst-case scenarios
Interconnected Self		*Guideline 4a*	
	Is open to exchange with others	PI should create spaces of intimacy for self-disclosure	Small groups, private communication channels between members
		Guideline 4b	
	Is influenced by the comparison with others	PI should help users find others to which to compare	"Social matching" with the current user's self
	Can identify with others' experiences	PI should support users in empathizing with others	Narratives to present others' experience