SEPIA, a Support for Engineering Persuasive Interactive Applications: Properties and Functions

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ABSTRACT
Design and creativity call for a large exploration of the design space for getting the design right and the right design [6]. Creativity support tools aim at speeding up this exploration for either saving time or exploring more design alternatives. This paper addresses the design of persuasive interactive systems. It provides designers and developers with a conceptual tool for structuring the exploration of the design space. In the vain of the IFIP properties [1] that are largely used in engineering HCI (e.g., observability), SEPIA (Support for Engineering Persuasive Interactive Applications) elicits a set of properties and functions to be considered when engineering persuasive interactive systems. SEPIA is expected to foster creativity and thereby to make people go beyond the classical monitoring feature.

Author Keywords
Human Computer Interaction, Persuasive interactive systems, Design, Creativity, Design space, Properties, Functions.

ACM Classification Keywords
H.5.2 User Interfaces: User-centered design; H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION

Technology is about changing the world in a positive way. However, some problems cannot be simply changed by applying a technological solution. For example, changing people's attitudes and/or behaviors is highly difficult, and monitoring applications are not sufficient to induce sustainable people's changes in domains such as sport, food, energy consumption, etc. This is exactly the purpose of Persuasive Technology, a multidisciplinary research domain with a dedicated international conference for the past ten years.

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However, it remains difficult to design persuasive interactive systems: people have first to master the state of the art in persuasion and then to reconcile these specificities with their expertise. As a consequence, there is an under exploration of the design space: monitoring is largely practiced whilst simulation remains rare.

This paper targets the engineering human computer interaction community as defined for example by the IFIP 2.7/13.4 working group. People from this vain are used to reason in terms of User Interfaces (UI) properties such as observability, honesty, etc. but they are not expert in persuasive technology. This paper revisits UI properties in the light of persuasion to bridge the gap between these two communities. It proposes SEPIA, a Support for Engineering Persuasive Interactive Applications. SEPIA is a conceptual tool intended to structure the exploration of the design space in terms of properties and functions. As shown in creativity, it should foster a broader exploration of design and engineering alternatives [6] and thereby produce possible solutions to be interestingly considered.

The fourth and fifth sections respectively provide an overview and details of SEPIA. They are illustrated on water consumption described in third section. Before opening on perspectives for the Engineering Interactive Computing Systems (EICS) community, the sixth section discusses and illustrates the applicability of SEPIA.

BACKGROUND IN PERSUASIVE TECHNOLOGY

A thorough review of the state of the art led us identify three main classes of contributions in the field of persuasive technology: those about (1) definition, (2) human behavior and persuasion, and (3) persuasive design principles.

Definition

Persuasive technology refers to "an interactive technology that changes a person's attitudes or behaviors" [13]. Fogg introduces the concept of captology for denoting persuasive technology as research area. It neither includes computer-mediated persuasion nor non-intentional persuasion [14]. Oinas-Kukkonen prefers the concept of Behavior Change Support Systems (BCSS), one specific topic in persuasive technology [28]. Contrary to captology, BCSS can play the role of mediator between two human beings. In both cases, coercion and betrayal are excluded from the field, for ethical reasons.

Human behavior and persuasion

Persuasive technology takes advantage of advances in social and cognitive psychology about human behavior and persuasion. Psychologists have proposed theories and models for understanding human behavior. They have identified cognitive entities and external factors that influence the human behavior. For example, Ajzen states that attitude toward the behavior, subjective norms and perceived behavioral control shape the behavioral intention [2]. Bandura introduces the 'self-efficacy' construct as the representation of the belief in one's own ability to adopt the behavior [4]. Lock and Latham underline the importance of goal setting in the motivation of people to adopt behavior [24].

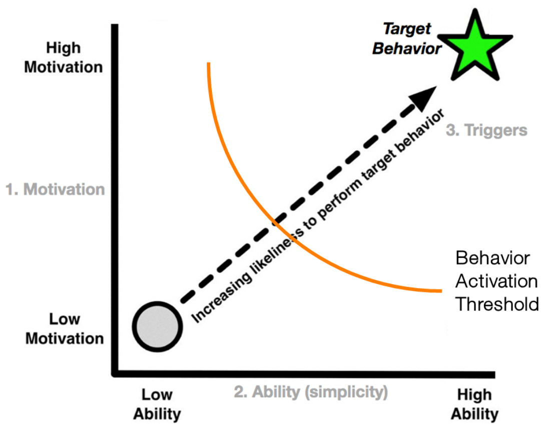

Figure 1: The Fogg Behaviour Model [16].

Some of those theories model the relationship between attitude and behavior. Ajzen identified the attitude as one determinant of the behavior [2]. Festinger sees humans as rationalizing beings as much as rational beings. People are looking for consistency between behavior and attitude but either may change to reach consistency [12].

More behavioral theories and models exist. Some in more specific domains like the technology acceptance model [9], or the Motivation – Opportunity – Ability model [25].

Fogg introduces his own behavior model (FBM) in the perspective of persuasive system design [16]. FBM identifies three dimensions in human behavior: motivation, ability, and trigger. Motivation and ability define a 2D-space where both the human behavior and the resistance to change can be characterized (Figure 1). Any trigger received by an individual when being above an activation threshold in the 2D-space should make him adopt the behavior. Motivation can evolve along three dimensions: pleasure/pain, hope/fear, and social acceptance/rejection. Learning new skills being not frequently accepted by people, ability can simply rely on the simplification of human behavior. Fogg distinguishes six possible means: time, money, physical effort, brain cycles, social deviance, and non-routine.

The Transtheoretical Model [32,33] is an integrative, biopsychosocial model to conceptualize the process of intentional behavior change. It is made of six phases (Figure 2): Precontemplation (Not Ready), Contemplation (Getting Ready), Preparation (Ready), Action, Maintenance and Termination. This model is highly interesting in the light of sustainable changes. It reminds the need of maintaining the change, and thereby of using the persuasive system over time.

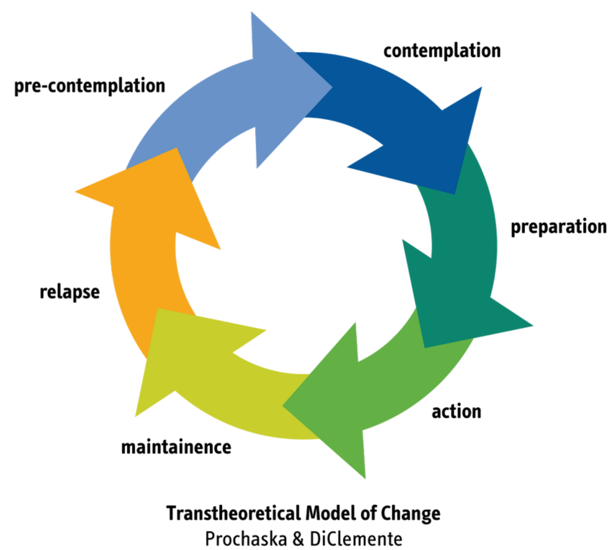

Figure 2: The Transtheoretical Model [32,33].

With the increasing pressure to address societal challenges such as energy or health, persuasive technology is intensively explored in these domains. Next section reviews persuasive technology in the domain of energy and more specifically of water consumption.

Persuasive design principles

Fogg identifies three roles technology can play with regard to the user [14] with about, at least, 16 persuasion strategies in total [15].

As tool, technologies can make activities easier or more efficient to do. The corresponding design principles are 'reduction', 'tunneling', 'tailoring', 'suggestion', 'monitoring' and 'self-monitoring', 'conditioning'. Fogg defines some of these principles as follows [14]:

- *Suggestion*: persuasion power can be increased by offering suggestion about behavior change;
- *Monitoring* and *self-monitoring*: technology "eliminates the tedium of tracking performance" and constitutes a means to reveal behavior or to monitor progress.

- *Conditioning*: positive reinforcement can be used to “transform existing behaviors into habits”.

As media, technology can shape attitudes and behavior by providing compelling simulated experiences. The corresponding design principles are ‘cause and effect’, ‘virtual rehearsal’, ‘virtual rewards’ and ‘simulations in real-world contexts’. For instance, Fogg defines the ‘*cause and effect*’ principle as a means to persuade people for a change as simulation can make observable “the link between cause and effect” [14].

As social actor, technology persuades by giving a variety of social cues that elicit social responses from their human users. The corresponding design principles are attractiveness, similarity, praise, reciprocity and authority. Among these principles, focusing on mobility, ‘social comparison’ is another but related principle [14]: performance comparison with the performance of others can induce a greater motivation.

Applied to a case study about water consumption, [3] identifies seven design principles: ‘value-added design’, ‘automation’, ‘just-in-time prompts’, ‘positive reinforcement’, ‘negative reinforcement’, ‘adaptive interfaces’ and ‘social validation’.

Design methods

Oinas-Kukkonen develops a three-step method for designing BCSS, called Persuasive System Design or PSD [28].

The first step consists in understanding persuasion along seven statements:

- “Information technology is never neutral.”
- “People like their views about the world to be organized and consistent.”
- “Direct and indirect routes are key persuasion strategies.”
- “Persuasion is often incremental.”
- “Persuasion through persuasive systems should always be open.”
- “Persuasive systems should aim at unobtrusiveness.”
- “Persuasive systems should aim at being both useful and easy to use.”

The second step is the analysis of the persuasion context. It includes:

- Recognizing the intent of the persuasion, i.e. determining who is the persuader. It could be “those who create or produce the interactive technology (endogenous); those who give access to or distribute the interactive technology to others (exogenous); and the very person adopting or using the interactive technology (autogenous).”
- Understanding the persuasion event by considering the context of use in terms of user and technology.
- Defining and/or recognizing the strategies in use by analyzing the message and considering the proper route to be used in reaching the user.

The third step elicits Fogg’s design principles sorted in four categories: primary task support, dialog support, system credibility support and social support. He also elicits a set of design principles, reminders and social roles being new compared to Fogg.

In the vein of user-centered design, the Behavior Wizard [17] is centered on the type of behavior that is targeted. The method is supported by both a questionnaire for identifying the behavior, and a classification grid of behaviors. This grid is structured into two dimensions:

- The Five Flavors of Behavior:
  - Green: do new behavior, one that is unfamiliar;
  - Blue: do familiar behavior;
  - Purple: increase behavior, intensity or duration;
  - Gray: decrease behavior, intensity or duration;
  - Black: stop doing a behavior;
- The Three Durations of Behaviors:
  - Dot: is done one-time;
  - Span: has specific duration;
  - Path: is done from now on, a permanent change.

Persuasive technology is largely motivated by and illustrated on societal challenges such as sustainable development. Water consumption is one of these, with several systems investigated so far from both academic and industrial sides. Next section provides concrete examples of persuasive technology in the field of water consumption.

CASE STUDY: WATER CONSUMPTION

We first describe examples from the end-user point of view considering the applications as black boxes. Then we open the boxes and take the engineering perspective.

End-user point of view

Hydrao is an industrial electronic showerhead (Figure 3 c) is an capable of projecting colored light, of changing color and of blinking to reflect water consumption. Colors and thresholds (medium and maximum number of liters per shower) are programmable via a mobile phone application that also informs the user about his/her consumption over time.

Basically existing systems monitor water consumption and alert people as soon as a threshold is passed (e.g., the maximum number of liters per shower).

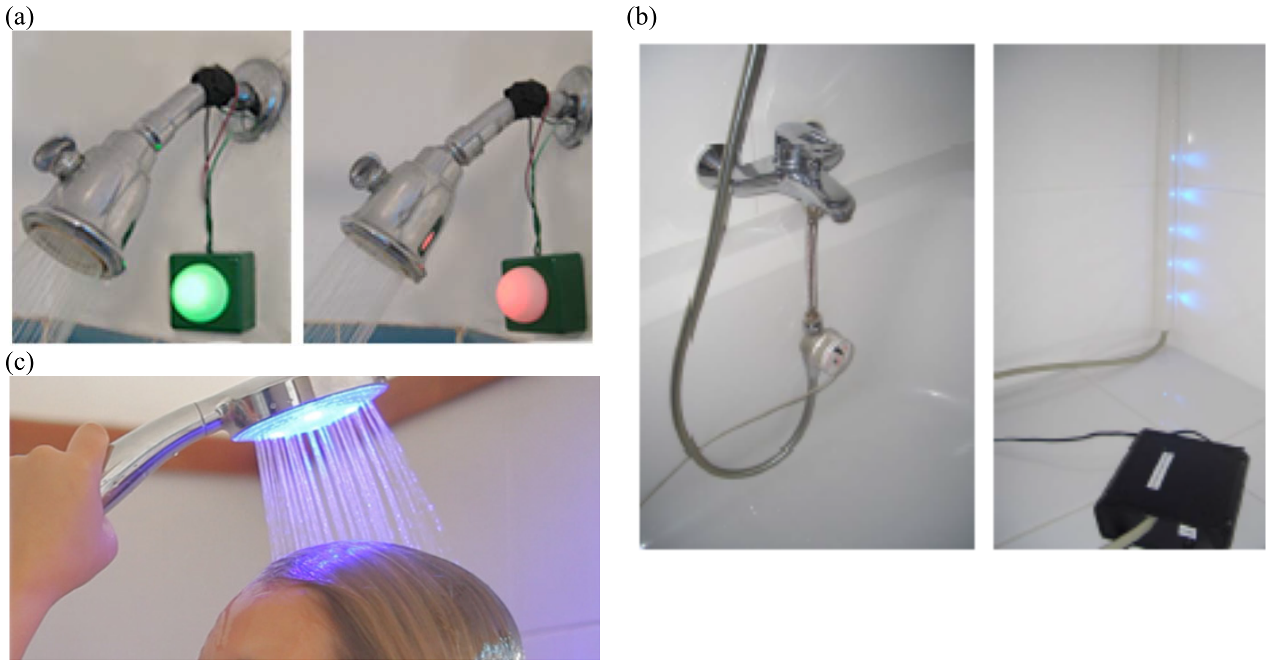

Figure 3 a), one green versus red light in UpStream [22] (b), a set of blue leds in Show-Me [19]; (c) Hydrao.

Several presentations have been explored: for example, a green versus red light in UpStream (Figure 3 a) that reflects a judgment to the user [1] or a set of LEDs in Show-Me (Figure 3 b) that more calmly informs the user about his/her consumption [11]. In both cases, the system reflects the state with regard to the threshold to the user under the shower.

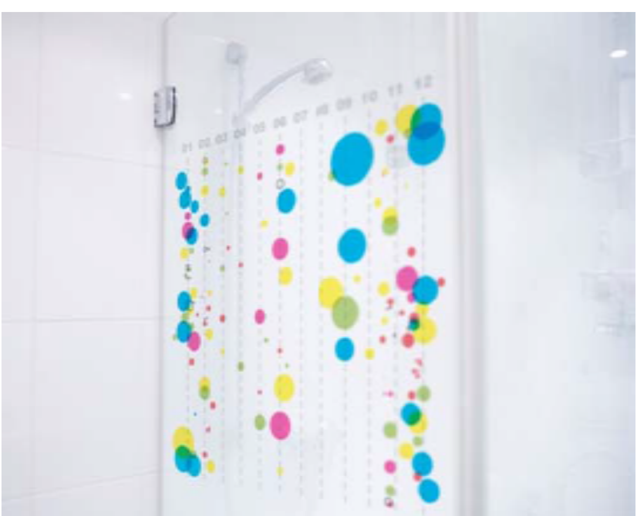

Figure 4 ShowerCalendar [23].

Monitoring over time was generalized to families. ShowerCalendar [23] (Figure 4) is one example, with one color per person, the twelve months being displayed horizontally and the days vertically.

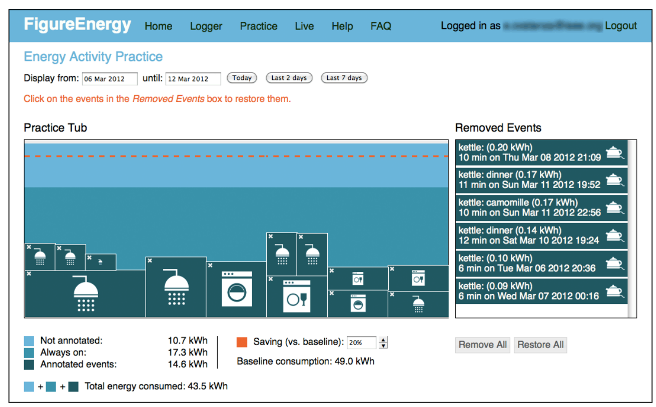

Figure 5 FigureEnergy [11]: practice tub vue.

Whilst previous examples are interfaces that basically reflect users' behavior, FigureEnergy [11] (Figure 5) goes beyond: it involves and proposes interaction to make people understand the phenomenon of water consumption by interaction. The user can remove elements (e.g., the morning shower or the washing machine) to see impact on consumption. The user can also annotate events for example to explain extra consumption (e.g., visit of family, vacation, deep cleaning).

Engineering point of view

In the line of the IFIP properties [1] that are largely used in engineering HCI (e.g., observability), we now analyze the examples in terms of UI properties with the state of the art as background. Six appear as being key.

Observability. The Transtheoretical Model tells us that revealing behaviors is the very first step towards behavior change. Although the systems depicted in the previous part present water consumption in many ways, they share a common property: making the water consumption observable through visual indicators (colored LEDs, visual display). For instance, Show-Me (Figure 3b) informs the user about his/her water consumption during a shower through the lighting of LEDs, each one representing a consumption of 5 liters of water. Another example, Shower-Calendar (Figure 4) reflects user's activity by representing each shower as a dot in a calendar displayed on shower glass door. FigureEnergy (Figure 5) makes observable causality thanks to the waterline of the practice tub: adding consumption blocks in the tub increases the amount of water.

Intelligibility. Additional functionalities support the comprehension of the consequences resulting from a behavior. For instance, in FigureEnergy (Figure 5), the representation of icon-included green-darkish filled rectangles in the practice tub partly explains energy consumption: adding or removing such a box increases or decreases the water line of the practice tub accordingly. Another example, Shower-Calendar (Figure 4) puts water consumption in context through colored dots through that somehow convey social norm: a small dot represents the average water consumption in Germany. By putting dots in context, comparison is possible which makes bigger dots intelligible.

Learnability. As Hydrao system (Figure 3c) uses on a color-based scale indicating water consumption over time, it provides a mobile application to select colors along this scale. As such, it allows a person to tune this scale in order to reduce his/her water consumption, and thereby supports learning of appropriate behaviors through experimentation.

Accountability. Through a user-defined waterline, FigureEnergy supports engagement thanks to a functionality allowing a user to define and target an energy saving percentage, represented as a dashed red line in the practice view (Figure 5). Hydrao also supports this functionality by making it possible for the user to specify the maximum number of liters a day. Hydrao allows users, through a mobile-based user interface, to associate a color to water consumption thresholds (green = 10 liters, blue = 20 liters, and so on). Thus, Hydrao's colored scale might be used to target goals.

Protectability. Hydrao and Show-Me are able to alert a user and thus to prevent consuming too much water. Indeed, Hydrao may emit blinking colored lights if a user-defined threshold of water is reached. Upstream changes its color from green to red, according to the traffic light metaphor.

Maintainability. FigureEnergy provides a functionality that displays the energy saving percentage in real time. According to Fogg's principles, it contributes maintaining an appropriate behavior.

Altogether these academic and industrial examples show the large effort put on monitoring so far, but also the possibility to go beyond as it is done in FigureEnergy for example. This paper aims at broadening the scope of exploration to benefit from advances in persuasive technology. It provides experts in HCI with properties and functions suitable to structure the engineering of persuasive interactive systems, like it is done in engineering HCI in general [10].

OVERVIEW OF SEPIA: A SET OF PROPERTIES

SEPIA (Support for Engineering Persuasive Interactive Applications) is a framework (Table 1) intended to structure the exploration of the design space when engineering persuasive interactive systems. It is structured into two dimensions: on the one hand, the phenomenon to address in its causes and/or effects and/or causality (cause-effect relationship); on the other hand, the UI properties to consider. The dimensions are independent giving rise to a set of combinations, each defining a persuasion function.

Cause, effect, and causality

The user behavior to be changed is at the heart of SEPIA: the point is to identify its causes and effects, so that then to be capable of triggering the right persuasion strategies. We emphasize that **SEPIA is phenomenon-oriented**. According to the Oxford dictionary, a phenomenon is defined as "a fact or situation that is observed to exist or

Properties / Phenomenon		Effect	Cause	Causality
Doing-related properties	Maintainability	Benefit	Sustain	Reward
	Accountability	Target	Engage	Control
	Protectability	Alert	Prevent	Anticipate
Understanding-related properties	Learnability	Induce	Deduce	Experiment
	Intelligibility	Situate	Recommend	Explain
	Observability	Reveal	Reflect	Discover

Table 1. SEPIA, a design space for supporting the engineering of persuasive interactive systems.

happen, esp. one whose cause or explanation is in question". For example, water consumption (phenomenon) is impacted by long showers (cause) that in turn induce (causality) extra cost, time to wait for others, no hot water anymore, etc. (effect).

Thus, SEPIA invites to investigate the causes, effects and their causality (relationship between cause and effect) in depth thanks to a set of properties (e.g., observability) to decide the role these entities will play in the interactive system.

Understanding- and/or Doing-related properties

In the light of design and creativity that push forward a coevolution between problem and solution, SEPIA identifies two classes of properties related to either understanding or solving the problem. In both cases, the properties are borrowed from the engineering human computer interaction community, but revisited under the prism of persuasion.

Understanding-related properties are:

1. **Observability** to make the phenomenon perceivable by the user. Being phenomenon-oriented, SEPIA requires first identifying which behavior-related phenomenon is under study, for example water consumption. Thus, this property allows the user to be aware of the problem to be tackled by persuasion: it aims at reflecting (e.g., giving a picture) his/her current behavior, the induced effects as well as the relationships between the latter and the former. In this context, observability echoes Fogg's principles [14] in terms of monitoring, self-monitoring and means "offering exploration and insight". Furthermore, in the light of the transtheoretical model [32,33], we consider observability as a means to support transitions between the precontemplation stage to the contemplation stage as well as reinforcing the latter.
2. **Intelligibility** to make the user understand and make sense of the phenomenon under study. This property allows the user to understand the problem to be tackled by persuasion: it aims at providing comprehension support to understand a behavior (i.e. cause) and its consequences (i.e. effect) as well as a support to change the behavior. In this context, intelligibility echoes Fogg's principles [14] in terms of suggestion or social comparison. Furthermore, in light of the transtheoretical model [32,33], we consider intelligibility as a means to support the contemplation stage, helping people to understand why "their behavior may be problematic" as well as "the pros and cons of changing the behavior". Thus, intelligibility requires observability.
3. **Learnability** to make people learn the dynamics of the phenomenon. This property allows the user to understand the phenomenon dynamics, to simulate behaviors by experimentation, to choose a behavior that fits. In this context, learnability echoes Fogg's principles [14] in terms of cause-and-effect simulation, environment simulation and object simulation. Furthermore, in the light of the transtheoretical model [32,33], we consider learnability as a means to support preparation (determination) stage.

Doing-related properties are:

1. **Protectability** to protect users from risky contexts or misbehaviors in the sense that they might trigger the phenomenon to tackle. This property allows the user to manage and keep appropriate behaviors, to detect and prevent inappropriate actions (i.e. causes), to alert users of upcoming undesired effects and to provide support to anticipate inappropriate behaviors that would lead to inappropriate effects (i.e. undesired causality). This property is related to Fogg's conditioning principle and Arroyo's negative reinforcement principle.
2. **Accountability** to engage people in a change of attitude and/or behavior. This property allows the user to plan what to do for a change (i.e. cause) and how (i.e. causality) in order to reach a user-defined goal (i.e. effect). For instance, according to Marcus [26], setting goals reinforces motivation but also serves to improve the quality of feedback in terms of observability. Furthermore, in light of the transtheoretical model [32,33], we consider accountability as a means to support Preparation (short-term action) and Action (long-term actions) stages.
3. **Maintainability** to make the change sustainable. This property allows the user to maintain a high motivation thanks to positive reinforcement (i.e. Fogg's conditioning principle) of appropriate behaviors (i.e. causes), to gain benefit from reached goals (i.e. effects), to reward (i.e. causality: promoting causes implying appropriate effects may be rewarded). Furthermore, in the light of the transtheoretical model [32,33], we consider accountability as a means to support Maintainance stage.

Next section goes into details and illustration for a precise description of SEPIA.

SEPIA IN DETAILS: A SET OF FUNCTIONS

This section refines each property (Observability, Intelligibility, Learnability, Protectability, Accountability, Maintainability) into functions for each aspect of the phenomenon it addresses (Effect, Cause, Causality).

Observability

We refine observability into three classes of functionalities: Reveal centered on effects; Reflect centered on causes; and Discover centered on causal relationship.

Reveal. Functionalities giving users access to raw data or information that inform about a current state or reached situation (i.e. the effect) due to user activity related to the problem tackled by persuasion. The system can reveal water over consumption by detecting facts such as a sudden short-term consumption peak or a long-term average above a regular consumption. Thus, the "Reveal" function makes effects basically observable.

Reflect. Functionalities making the causes observable that reflect user activity related to the problem tackled by persuasion. For instance, such functions could make observable a water leak or a very high number of showers per day.

Discover. Functionalities making explicit the correlation (i.e. causal relationship) between human activity and observed facts. For instance, water consumption is increasing in volume proportionally (i.e. correlation) to the number of showers as the washing-machine's share remains stable (human activities). "Discover" functions serve as a basis to understand the dynamics of the phenomenon under study.

Intelligibility

We refine intelligibility into three classes of functionalities: Situate centered on effects; Recommend centered on causes; and Explain centered on causal relationship.

Situate. Functionalities to put a given effect or current situation into context to better understand its importance and the related behavior. For instance, indicating an average water consumption (e.g. for a country or state) provides a comparison means to situate its own water consumption. Thus, it provides means to better understand and/or decide if a behavior is appropriate by making sense of the information.

Recommend. Functionalities to suggest alternative behaviors (i.e. causes) suitable to solve the problem tackled by persuasion. For instance, the system could recommend someone who takes two showers each day to reduce by one so that to comply with the social norm.

Explain. Functionalities to explain the causal relationship given the current state (i.e. the induced effects). For instance, although a shower currently wastes 80 liters of water, a system could explain that taking a shower should not exceed 10 minutes and waste more than 40 liters. For instance, such functions may illustrate how a phenomenon occurs from thanks to a system-based explanation engine.

Learnability

We refine learnability into three classes of functionalities: Induce centered on effects; Deduce centered on causes; and Experiment centered on causal relationship.

Induce. Functionalities allowing users to generate and identify a set of relevant behaviors (i.e. possible causes), in line with a user-defined goal to reach (i.e. a predetermined expected effect). Such functionalities might be implemented as a simulation environment. For instance, such a system may compute and indicate the longest duration of a shower given a user-defined amount of water.

Deduce. Functionalities allowing users to identify the possible consequences (i.e. possible effects) given a user-defined behavior (i.e. a predetermined cause). Such functionalities might be implemented as a simulation environment. For instance, such a system may compute and indicate a water consumption given a user-defined duration for a shower.

Experiment. Functionalities allowing users to conduct and iteratively evaluate inductive-deductive cycles in order to identify relevant and desired user-defined behaviors and effects. For example, first the user decides to experiment a reduction of the number of showers from 20 a week (each consuming 60 liters) to 15 (deduce #1): the system computes that the whole water consumption drops by 300 liters a week, thereby moving from 1200 liters to 900 liters. Then, the user wants to reduce more than 600 liters a week (induce #1): the system recommends having 10 showers a week. Finally, the user experiments to have 12 showers a week but each consuming at most 50 liters of water (deduce #2): the systems indicates the whole water consumption would be 600 liters.

Protectability

We refine protectability into three classes of functionalities: Alert centered on effects; Prevent centered on causes; and Anticipate centered on causal relationship.

Alert. Functionalities to alert users in case of unwanted consequences (i.e. effects) compared to a desired goal. For instance, while taking a shower, the system may alert the user thanks to a gauge that he/she is beyond a critical amount of consumed water (i.e. threshold), close to a user-defined maximum.

Prevent. Functionalities to prevent users from unwanted behaviors (i.e. causes). For instance, a system may warn that a maximum number of showers is closed to be reached or to indicate a remaining time before ending a shower.

Anticipate. Functionalities allowing users to anticipate and thereby avoid causes suitable to give rise to unwanted effects. For instance, if the system detects that showers are longer for users just getting back from office, it could suggest the user to first have dinner so that to be relax before taking shower and thereby more sparing. A learning machine-based system engine could be used to identify such events and thus to provide recommendations to avoid inappropriate behaviors.

Accountability

We refine accountability into three classes of functionalities: Target centered on effects; Engage centered on causes; and Control centered on causal relationship.

Target. Functionalities allowing users to target desirable effects. For instance, the system could make it possible for the user to set a maximum water consumption (i.e. threshold). Such functionalities can be implemented to support user-defined objectives to complete behavior change (i.e. mission).

Engage. Functionalities allowing users to engage in a desirable change of behavior. For instance, the system could make it possible for the user to take the decision to have one shower a day at best. A reminder system engine, through notification mechanisms, may support user engagement.

Control. Functionalities allowing users to control both causes and effects, making it possible for him/her to adjust either causes and/or effects. For instance, a user may define as an appropriate behavior a maximum number of showers a week (as well as a maximum amount of consumable water). Thus, he/she may adapt his/her behavior if he/she observes that on the last day of the week, he/she may take an additional shower because the amount of consumed water is significantly below its maximum. In line with Fogg's behavior model, the system may allow the user to define and to set intermediate motivation and ability levels to reach an intermediate behavior change.

Maintainability

We refine maintainability into three classes of functionalities: Benefit centered on effects; Sustain centered on causes; and Reward centered on causal relationship.

Benefit. Functionalities making the user aware of desirable (respectively undesirable) effects now or in the future. For instance, the system may indicate the corresponding financial saving.

Sustain. Functionalities making the user aware of appropriate (respectively inappropriate) behaviors or of behaviors suitable to become valuable (respectively risky) in the near future. For instance, a system might emphasize unplanned/unengaged efforts.

Reward. Functionalities rewarding the user either achieving a valuable behavior or escaping a risky behavior. For instance, the system may display greetings (i.e. positive feedback) to the user if he/she succeeded to maintain an appropriate behavior (e.g. having reduced the number of showers by 30% within a week with a water consumption dropped by 20 liters per day).

DISCUSSION

Before describing how to use SEPIA, it is important to note that the key point is its structuring in two dimensions for holistically reasoning about persuasion while keeping an engineering approach with properties and functions. As any model, SEPIA is a simplification of the real world, and of course the boxes are tight. For example, there is an implicit inclusion relationship between the understanding-related properties: Learnability requires Intelligibility, which in turn requires Observability. This is illustrated in Show-Me where the LEDs cover both observability (i.e. reflect) and learnability (i.e. deduce). This shows that a design decision may cover several classes of properties and functions.

Given this precision, this section discusses the benefits of SEPIA by considering the three powers notations might bring [5]:

1. Descriptive power: the ability to describe a significant range of works;
2. Evaluative power: the ability to help assessing multiple design alternatives; and
3. Generative power: the ability to help designers creating new designs.

Descriptive power of SEPIA

To demonstrate the descriptive power of SEPIA, we enlarge the field of the case study to energy. We consider ten works that we characterize at coarse grain using the SEPIA properties (Table 2): EnergyLife [18], PowerAdvisor [20], Limit eco-feedback [30], Personalized Eco-feedback [31], Handy Feedback [35], Neighborhood watch [11], Powerviz [29], Customizable dashboard [27], Abstract ambient [34]. Of course, this analysis is not a systematic literature review. We selected ten papers about persuasive technology in the field of energy to show the characterization support that SEPIA provides.

For each system, the first step consisted in identifying the phenomenon under study. For instance, power consumption in PowerAdvisor [20] is the phenomenon under study. As a second step, we analyzed UIs and their descriptions in the articles to capture the SEPIA functions they support. As example, we fully illustrate the characterization of

Properties / Phenomenon		Effect	Cause	Causality
Doing-related properties (3)	Maintainability (1)	Benefit	Sustain	Reward
	Accountability (3)	Target	Engage	Control
	Protectability (0)	Alert	Prevent	Anticipate
Understanding-related properties (10)	Learnability (3)	Induce	Deduce	Experiment
	Intelligibility (5)	Situate	Recommend	Explain
	Observability (10)	Reveal	Reflect	Discover

Table 2. Characterization of ten existing works using SEPIA. The numbers in brackets indicate the number of works that cover the corresponding properties. Background darkness is used to pinpoint this density.

Properties / Phenomenon		Effect	Cause	Causality
Doing-related properties	Maintainability	Benefit	Sustain	Reward
	Accountability	Target	Engage	Control
	Protectability	Alert	Prevent	Anticipate
Understanding-related properties	Learnability	Induce	Deduce	Experiment
	Intelligibility	Situate	Recommend	Explain
	Observability	Reveal	Reflect	Discover

Table 3. Evaluation of FigureEnergy using SEPIA. Background darkness is used to convey the extent to which the function is covered.

PowerAdvisor based on SEPIA:

Observability. Several views are available revealing the power consumption (in kWh) in descriptive manners (e.g. graphs indicating power consumption over time) as well as in injunctive manner (i.e. traffic light metaphor-based consumption gauge). However, the system does not provide any information about the sources of power consumption (reflect and discover).

Intelligibility. Power consumption is situated as it is compared to average power consumption, based on a Danish power company's database. Although recommendations are given as messages in terms of expert's advice and tip of the day, it is unclear whether identified causes are considered or not.

Accountability. PowerAdvisor enables users to compare their current consumption with a user-defined goal. However, it is unclear how users can set such goal.

Maintainability. Users receive greetings through messages as well as smileys. The benefit is given in terms of kWh saving.

We found no clues to conclude whether Power Advisor supports Learnability and Protectability properties not.

In a summary, this critical analysis shows that understanding-related properties are much more investigated than doing-related properties (ten against three). Even more it shows that observability attracts most attention (ten works).

Evaluative power of SEPIA

To demonstrate the evaluative power of SEPIA, we use it as an evaluation grid of an existing work: FigureEnergy [8]. Green cells in Table 3 indicate functionalities clearly covered by the work.

Observability. As previously highlighted, FigureEnergy satisfies the observability property. Indeed, consumption graphs reveal global consumption history. In the graph view, icons reflect human activities, i.e. the causes of consumption events. The tagging of consumption peaks with activity icons (e.g. television, breakfast) in the consumption graph helps the users to discover the causality between consumption events and the sources of consumption.

Intelligibility. The user-driven annotation functionality constitutes the means to put into context (i.e. situate). To explain the relationship between global energy consumption and individual consumption events, the system allows users to tag the consumption graph with events (e.g. a shower, a washing machine, etc.). Indeed, the authors have adopted a constructivist approach in order to help users to self-explain consumption events.

Learnability. Once events are tagged, users "can play what-if scenarios" by removing or adding boxes (i.e. user-chosen causes) in the practice view and can deduce how it decreases or increases the global energy consumption (i.e. effects). It allows the user to understand the underlying dynamics of the phenomenon, i.e. the impact of the number of individual energy consumption events (represented as boxes) on the water line evolution.

Protectability. The system allows users to target a saving percentage: in real-time, the system compares this user-defined goal with a baseline (dashed red line in Figure 5) and indicates if there is a benefit or not. Thus, the joint visual representation of the target (dashed red line) with the global energy consumption line (light blue) acts as an alert to warn the user if energy consumption is close or above the target. In addition, in the real-time view, the user may anticipate if a behavior is right thanks to a message indicating a predicted consumption for the upcoming week.

Accountability. In the practice view, the user can set a saving percentage (red dashed line) as a goal (i.e target).

Maintainability. In the real-time view, the system indicates the saving's consumption percentage as well as the financial saving as a benefit.

Although the observability property is fully covered (Table 3), we may observe that other properties are covered only partially at best.

Properties / Phenomenon		Effect	Cause	Causality
Doing-related properties	Maintainability	Benefit	Sustain	Reward
	Accountability	Target	Engage	Control
	Protectability	Alert	Prevent	Anticipate
Understanding-related properties	Learnability	Induce	Deduce	Experiment
	Intelligibility	Situate	Recommend	Explain
	Observability	Reveal	Reflect	Discover

Table 4. Generation of additional features to FigureEnergy using SEPIA.

Generative power of SEPIA

To demonstrate the generative power of SEPIA, we suggest several extensions to FigureEnergy [8], providing additional uncovered functionalities (blue cells in Table 4).

In order to **recommend**, based on consumption history and machine-learning mechanisms, the system may suggest an appropriate number of dishwasher use per day or per week.

In order to **induce** appropriate behaviors, in the practice view for instance, the system could highlight boxes to be removed for a user-given consumption amount (user-chosen effect). Moreover, in order to **experiment**, in the practice view, the system may compute and present different sets of behaviors based on a minimum number of boxes (i.e. consumption sources) and a maximum amount of consumption set by the user.

In order to **engage**, in the practice view, the system may allow users to target and set a maximum number for each category of consumption sources (shower, washing-machine, hair dryer, etc.) within a week. Moreover, to **control** his/her engagement according to a desired target, the system may allow the user to set a level of difficulty as well as a policy (promoting/demoting a behavior). Such settings can be used by the system to decide whether or not to notify a reminder.

In order to **prevent** users from undesired or inappropriate behaviors, as users are able to tag history consumption events, such a system might highlight critical moments of the day (e.g. back home after work) that aggregate many individual consumption events. Thus, the system would suggest alternatives to reduce the number of events related to comfort. For instance, if many events are related to heating, the system may prevent users from augmenting the temperature and suggest wearing comfortable and warm clothes (transferred comfort).

In order to **sustain** desired or appropriate behaviors, such a system might greet engaged efforts (e.g. reduced number of showers). For instance, a user may target to reduce the number of showers but the system could also greet his/her efforts when the system detects that media appliances are unplugged more than often. Moreover, in order to **reward**, the system may greet the user for achieved difficult actions.

Furthermore, such a system might emphasize unplanned/unengaged efforts: it could help break routines in terms of planned efforts and move the focus to other behaviors. Thus, as there may be inclusion relationships among classes, maintainability is linked to accountability, as maintainability implicitly requires accountability as a first step. Moreover, this link can be seen as an iterative loop.

PERSPECTIVES

We presented SEPIA, a two dimensional framework to structure the exploration of the design space when engineering persuasive interactive systems. SEPIA promotes six properties decomposed into three classes of functionalities. It promotes a complementary approach to other existing frameworks (e.g., Consolvo [7], Oinas-Kukkonnen [21]) as SEPIA comes first as phenomenon-oriented and user-centered framework. Then, it is mapped onto the other frameworks (e.g. PSD model [21]) to deliver at the end well-thought valuable systems. For instance, SEPIA's "Reveal" functions may be mapped onto Fogg's and PSD model's "Self-monitoring" persuasive system functions.

Based on the state-of-art, we illustrated the descriptive, evaluative and generative powers of SEPIA. In a near future, we aim at integrating SEPIA into a software architecture model devoted to persuasive systems, as well as in a toolkit for supporting the engineering of persuasive interactive systems.

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