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Cartographie d'espaces de conception des systèmes persuasifs appliqués à l'énergie et proposition du cadre UP+

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Abstract. This article reviews surveys, design spaces, and frameworks related to the design of persuasive interactive systems, with a particular focus on energy. We first propose a cartography of these conceptual tools. Most previous work focuses on persuasion principles but is difficult to apply for the software design and engineering of persuasive interactive systems. As a result, we propose UP+, a new framework that synthetizes and revisits existing surveys, design spaces, and frameworks from the software engineering perspective of persuasive interactive systems.

Key words: behavior change process, persuasion, design space, cartography.

Résumé. Cet article propose un état de l'art d'espaces de conception et d'études pour les systèmes interactifs persuasifs, en particulier dans le domaine de l'énergie. Nous établissons et proposons une cartographie des principes de persuasion et des caractéristiques des systèmes persuasifs captées par ces outils. Nous observons que la plupart de ces outils sont difficiles à exploiter pour l'ingénierie de ces systèmes. Aussi, à partir de cette cartographie, nous proposons le framework UP+ qui synthétise et revisite ces outils d'un point de vue de l'ingénierie des systèmes interactifs persuasifs.

Mots-clés : processus de changement, persuasion, espace de conception, cartographie.

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1 INTRODUCTION

This article reviews surveys, design spaces, and frameworks related to the design of persuasive interactive systems with a particular focus on energy. Our analysis of the state of the art shows that most previous work on persuasive technologies for energy has focused on principles. Although principles are good tools for thought, they are rarely operationalized, making it difficult for practitioners to apply them for the software design and engineering development of persuasive interactive systems. In addition, the diversity of design spaces and cognitive frameworks makes it difficult to identify the most appropriate tool for a particular situation. Given the plethora of conceptual tools and surveys, we propose a cartography of these tools that provides practitioners with a synthetic and unifying view of the solution spaces developed so far. Based on this cartography, we propose UP+, a new framework aimed at engineering persuasive interactive systems that maps persuasion-oriented principles and concepts into implementable software functions.

This article is composed of three major parts. The following part reviews eight representative surveys, design spaces and frameworks from the literature. This is followed by a synthesis that highlights the similarities and differences between previous works. Based on this synthesis, UP+ is presented in the last part of the article.

2 DESIGN SPACES FOR PERSUASIVE INTERACTIVE SYSTEMS

This part reviews eight surveys, design spaces and frameworks from the literature: Pierce et al's dimensions for Eco-Visualizations (Pierce *et al.*, 2008), Froehlich's (Froehlich, 2009) and Fang's design spaces on feedback technologies (Fang & Hsu, 2010), Froehlich's comparative survey of eco-feedback systems (Froehlich *et al.*, 2010), Hamari et al's review of persuasive technologies (Hamari, Koivisto & Pakkanen, 2014), Cano's design space (Cano *et al.*, 2015) and the SEPIA framework (Laurillau *et al.*, 2016). These contributions have been selected for their coverage. As such, they will serve as a reference set for the rest of this article. Design tools that are relevant to our study such as Bartram's framework (Bartram, 2015), are not described explicitly in this article, as their coverage is included in our reference set.

2.1 Eco-Visualization: feedback type, use-context, and strategies

Eco-Visualization systems (EVs) are a subset of persuasive interactive systems dedicated to the visualization of consumption. They aim at revealing energy usage to promote sustainable behavior. In a critical survey of ten noteworthy EVs, Pierce et al. (Pierce *et al.*, 2008) have identified three dimensions to characterize them: feedback type, use-context and strategies.

Feedback type. As EVs mostly focus on revealing energy consumption as a means to inspire behavior change, the design of feedback plays a crucial role. Pierce et al. focus on the data to be represented and on the visualization technique used.

- *Data*. Consuming energy has an impact at many scales: locally (e.g. at the level of the home) or globally (e.g. at the city level). Data feedback is then characterized in terms of small-scale context of effects such as at a home appliance scale, or in terms of large-scale context of effects such as residential areas.

- *Visualization*. Two styles of visual feedback are considered: pragmatic or artistic. Pragmatic design refers to approaches where the information is illustrated through traditional visual elements such as lines, charts and graphs. This visualization style aims at providing clear and intelligible information or at making patterns of use salient. On the other hand, artistic style provides different kinds of user experience where the same information is presented in artful and abstract manners.

Use-Context refers to "the environmental and cultural conditions of the space in which the EVs are implemented" (Pierce *et al.*, 2008). Pierce et al. use the amount of control to characterize EVs in different use-contexts:

• *Dweller control*: depending on the context, a dweller may have a high level of control on energy consumption (e.g. at home) or a low level of control (e.g. in a public area).

• *Third-Party control*: depending on the context, a third-party may have a low level of control, or a high level of control over the dweller as in business offices.

A use-context is thus characterized as a two-dimensional level of control. At home, a dweller has generally a high level of control. The third-party control should be low in a home but high in a flat part of a housing building. Such a two-dimensional plotting facilitates the identification of the key elements to be considered for the design of an EV.

Strategies. Depending on the use-context, an EV system may use one, or several, of the following 8 persuasive strategies (Pierce *et al.*, 2008):

Scope to conserve goals (clear and useful feedback)
- Offering behavioral cues and indicators,
- Providing tools for analysis.

Scope to create incentives
- Creating social incentive to conserve,
- Connecting behavior to material impacts of consumption.

Scope to create or support new goals
- Encouraging playful engagement and exploration of energy,
- Projecting and cultivating sustainable lifestyles and values,
- Raising public awareness and facilitating discussion,
- Stimulating critical reflection.

From Pierce et al.'s work, we note two interesting elements. First, concerning data visualization in residential context, we appreciate the "artistic route" that may provoke user's reflection towards motivation, interest, and emotion, rather than towards pure utilitarian reasoning. In addition, artful representation can blend with the housing environment and become a valuable part of everyday life. Second, the suggestion for cooperative inhabitants towards a common goal relates to the social support for persuasion discussed by Fogg and Oinas-Kukkonen (refXX).

The authors also uncover two important issues: (1) how to effectively incorporate and apply strategies to different use-contexts; (2) how to ensure long-term change. They recommend designing interactive systems that are able to evolve over time so that they adapt progressively to the user's commitment and understanding.

2.2 Feedback technologies: Froehlich's Design Space

Feedback technologies aim at raising people awareness about their own behavior, and from there, to help them to change their behavior. Froehlich has identified a ten-dimensional design space to characterize feedback techniques targeted at energy consumption (Froehlich, 2009):
- **Frequency**: this dimension characterizes how frequently a system updates its feedback. According to the author, high frequency such as real time rendering, improves people's perception of the link between their actions and the consequences of these actions (Froehlich, 2009).
- **Measurement Unit**: some units are too technical to be easily understood by non-specialists, for example the use of ppm to express the concentration of suspended particles in the air. Froehlich recommends using alternative units such as the number of

trees that may enhance comprehension while providing subtle information that may raise different interests and motivations.

- **Data Granularity**: a system can present data at different spatio-temporal-source granularities ranging for example from a residential block, a building, and an apartment, to a room (space dimension), from a device to a set of devices (source dimension), from one year, month, day or hour (time dimension).
- **Push/Pull**: Pushed/pulled feedbacks are used to inform people about anomalies or unusual environmental events.
- **Presentation Medium**: feedback can be presented using traditional (paper) or modern (electronic displays) medium.
- **Location**: location of feedback is key to provide information in an effective manner. It could be embodied with the device (e.g. highly localized) or be independent (e.g. a bill).
- **Visual Design**: as in Pierce et al. classification presented above in 3.1 (Pierce *et al.*, 2008), the visual presentation of feedback may be "artistic" or "pragmatic" using numerical values and comprehensible representations such as graphs, or both.
- **Recommending Action**: a feedback system may offer personalized recommendations based on the user's context.
- **Comparisons**: providing means to compare one's behavior with past behavior or with some social norm, is a powerful approach to support behavior change.
- **Social Sharing**: this dimension concerns whether a feedback system uses social sharing feature as motivational incentive.

Despite the overlap between some of the dimensions – typically, a feedback system can support comparisons through its visual design or it can recommend actions through push/pull feedback notifications, this work offers a clear overview of the design of feedback systems. Most noteworthy are the Push/Pull, Recommending Action, Comparisons, and Social Sharing features.

2.3 Feedback technologies: Fang's Design Space

In the same vein as (Froehlich, 2009) and (Pierce *et al.*, 2008), Fang (Fang & Hsu, 2010) considers that research in the design of feedback technologies is still insufficiently fostered. Fang has identified four qualities for the visual design of feedback systems: ambient, aesthetic, emotionally engaging, and metaphorical.

- **Ambient**: this dimension concerns the way a persuasive system presents feedback. Ambient feedback is not intrusive, does not interrupt users in their daily life. Fang considers that an "ambient information consumes little or no awareness" (Fang & Hsu, 2010). The Power-Aware-Cord (Gustafsson & Gyllenswärd, 2005), the Mona Lisa bookshelf (Nakajima & Kawsar, 2012), and the HistoTree (Coutaz et al. 2018) are typical examples of ambient feedback. Informative Art (Ferscha, 2007) is one technique that is used frequently for this type of persuasive systems.
- **Aesthetic**: as people tend to pay more attention to attractive appearance, aesthetics is becoming an important factor in the design of feedback systems. Fish'n Steps (Lin *et al.*, 2006) and the Mondrian weather tiles (Holmquist & Skog, 2003) use this approach.
- **Emotionally engaging**: evoking emotions is an effective approach to promote successful behavior change (Pinder *et al.*, 2018). In particular, (Dillahunt et al, 2008) and (Lin *et al.*, 2006) have used emotional incentives to encourage people.
- **Metaphorical**: metaphors have been used in many studies to enhance user's comprehension and to raise user's interest and curiosity. Some examples of metaphor interfaces include the virtual tree (Ko *et al.*, 2007), (Nakajima *et al.*, 2008), the virtual garden (Consolvo *et al.*, 2008), the virtual apple tree in Ubigreen (Froehlich *et al.*, 2009), the virtual island (Shiraishi *et al.*, 2009) and the polar bear (Dillahunt et al, 2008).

Although specific and strictly centered on the visual design of feedback, Fang's design space shows that motivation can be sustained in multiple ways, typically by evoking emotions and by using aesthetics. This approach strongly relates to the informative art research field (Redström *et al.*, 2000; Holmquist & Skog, 2003; Ferscha, 2007).

2.4 Froehlich's comparative survey of eco-feedback systems

Froehlich (Froehlich *et al.*, 2010) conducted a comparative survey of 133 scientific publications from Environmental Psychology and Human-Computer Interaction (HCI). In this study, they classified eco-feedback systems in terms of persuasive techniques that promote pro-environmental behavior. Feedback is one of the techniques proposed:

- **Information**: information is essential and is the very first vector to inform and to promote concerns for pro-environmental issues. As mentioned above in 3.2, the presentation and the location of information play a significant role to inspire successful behavior change.
- **Goal-Setting**: considered as an effective source of motivation, goal-setting is a means to engage an individual (or a group of persons) towards a particular direction but also to compare performance with past or future goals. Goal-setting is effective when combined with feedback.
- **Comparison**: this dimension is the same as in Froehlich's Design Space discussed above (Froehlich, 2009). Social networks constitute a good approach to support social comparison.
- **Incentive/Discentives** and **Rewards/Penalties**: "Incentives/Disincentives are antecedent motivation techniques whereas Rewards/Penalties are consequence motivation techniques" (Froehlich *et al.*, 2010). Incentives may be financial. Rewarding mechanisms such as points and medals are inspired from games to trigger positive behaviors.
- **Commitment**: making a commitment to a specified goal enhances engagement towards the goal. A person who previously expressed his/her interest about a specific behavior will likely pursue the targeted behavior. Thus, commitment has the potential to enhance the "persuasive-ness" of an interactive system.
- **Feedback:** considered as a vital factor, feedback can be used in conjunction with other motivation techniques in order to convey information in the most effective way.

Froehlich et al.'s classification work provides a notable number of motivational techniques for reducing environmental impact. Although feedback is a key feature for conveying persuasion messages, Froehlich et al. recommend designers to use a combination of the dimensions of their design space. However, if we consider behavior change as a multi-stage process, then it is not clear at which stage and how these combinations should take place.

2.5 Motivation affordances and psychological outcomes

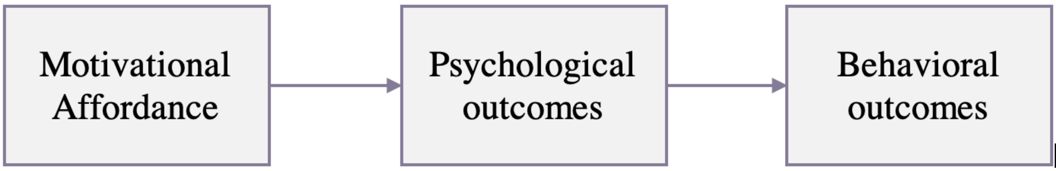
Hamari (Hamari, Koivisto & Pakkanen, 2014) reviewed 95 studies related to persuasion, with the purpose of providing an overview of how motivational affordance, psychological outcomes and behavioral outcomes relate in the process of behavior change (see Figure 1):

- **Motivational Affordance**: Zhang defines motivational affordance for Information and Communication Technology (ICT) as "the properties of an object that determine whether and how it can support one motivational need" (Zhang, 2008). The higher the motivational affordance an ICT system has to offer, the more the user's motivation, engagement, and interest will be achieved. For Hamari (Hamari, Koivisto & Pakkanen, 2014), motivational affordances are design elements embedded in a persuasive interactive system to raise motivation. For instance, motivation needs can be achieved through visual feedback, ranking or rewards.
- **Psychological outcomes**: when motivational affordances meet individual's motivational needs, it induces psychological effects. Hamari categorized the psychological outcomes of the reviewed studies into eleven groups including awareness, engagement, and enjoyment. For instance, for a persuasive interactive system that aims at promoting

energy conservation, providing feedback about resource consumption can promote user's awareness and decision towards a new goal.

- **Behavioral outcomes**: the psychological impacts in one's mind may shape his/her own ways to move towards a specific behavior. Hamari's classification investigates various types of behavioral outcomes including health/exercise, sustainable consumption, and education/learning.

Figure 1. Hamari's conceptual framing (Hamari, Koivisto & Pakkanen, 2014)



As reported by Hamari (Hamari, Koivisto & Pakkanen, 2014), virtuous consumption is the second most studied area for persuasive interactive systems. Of the 95 studies reviewed, 20 (21.1%) considered virtuous consumption as behavioral outcome. Tables 1 and 2 present the main motivational affordances and psychological outcomes reported by the study.

Table 1. Motivational affordances (Hamari, Koivisto & Pakkanen, 2014)

Frequency	**Motivational Affordances**
Frequently	Visual or audio feedback Ambient or public displays Social support, comparisons, feedback, interaction, sharing Rewards, credits, points, achievements Objectives and goals Competitions, leaderboards, ranking
Rarely	Social agents Emoticons and expressions Persuasive messages and reminders Suggestions, advice Tracking Subliminal persuasion
Not used	Progress Video-based persuasion Positive reinforcement

According to Hamari, for ecology-related systems, the most often implemented affordances are visual and audio feedback, social features, ambient/public representations and rewards. Most studies feature objectives and goals. Competition is also found to be among the popular implementations. This review shares similar results with the design spaces reported above (Pierce *et al.*, 2008; Froehlich, 2009; Fang & Hsu, 2010; Froehlich *et al.*, 2010).

Table 2. Psychological outcomes (Hamari, Koivisto & Pakkanen, 2014)

Frequency	**Psychological outcomes**
Usually	Awareness
Frequently	Motivation Engagement, encouragement
Rarely	Enjoyment, "fun"

	Negative attributes
Not used	Attitude Self-efficacy Trust, credibility Commitment Sense of community Adherence

In terms of psychological impact, raising awareness about current consumption seems to be the dominant outcome. This is consistent with Laurillau et al.'s observation (Laurillau *et al.*, 2016). Motivation and engagement are used frequently, and a number of studies are also concerned with enjoyment and the negative attributes of persuasive systems. Psychological impact as well as motivational elements, are important factors that deserve deeper analysis.

2.6 Cano's Design Space

Cano et al. (Cano *et al.*, 2015) present a critical analysis of 10 persuasive systems dedicated to energy. In their survey, they propose a design space composed of 6 dimensions. As Table 3 shows, these dimensions include the application domains covered by a persuasive interactive system, persuasion functions, data representation, user-system interaction, scales and devices. Some dimensions are refined into sub-dimensions.

Table 3. Cano's six dimensions design space (Cano *et al.*, 2015).

Concerns	Possible values
Domains	Energy, etc.
Persuasion functions	Mirror (details of appliances, feedback, history, comparison) What-if (future projection, simulation payment) Explain What-for Recommend Suggest-and-Adjust
Representation	Textual, Realistic, Symbolic, Artistic, Quantitative
Interaction	Multi-Device Management History navigation Annotations Gamification Objectives, Goals Personalization
Scales	Time (past, present, future) Space (room, house, neighborhood) Human (individual, family, community)
Devices	Smartphone, tablet, PC, web application, ambient

Although the domain dimension is intended to cover any domain, Cano's design space has been applied to energy consumption only. In turn, a persuasive function may belong to one of the following classes:

- **Mirror**. This class of functions makes observable the current users' behaviors in terms of energy consumption. For instance, an implementation could be a visualization of energy consumption on a per appliance basis.
- **What-if**. This class of functions allows users to simulate a possible future behavior and to observe the consequences. The goal is to provide users with a means to explore and

experiment various possible behaviors in order to identify a feasible and appropriate future behavior.

- **Explain**. This class of functions aims at explaining, enlightening users and making them understand, not only the effects but also the causes of their current behaviors.
- **What-for**. This class of functions aims at guiding users towards the achievement of their objectives. It allows the selection of a desirable effect and to explore the actions to be achieved to obtain this effect.
- **Recommend**. This class of functions aims at providing users with the appropriate recommendations and suggestions based on the user-context to promote and support behavior change.
- **Suggest-and-Adjust**. This class of functions aims at facilitating the decision-making process through a user/system negotiation approach. For instance, the system may suggest situations, then adjust them based on user's responses.

The third dimension deals with the types of information representation: textual, realistic, symbolic, artistic, and quantitative. It echoes the design spaces discussed above (e.g. Fang's design space (Fang & Hsu, 2010)). The fourth dimension is concerned with user-system interaction as a way to convey persuasion. This dimension is original compared to the design spaces discussed above. For instance, providing interactivity to support the exploration of past consumptions is a means to implement Mirror and Explain persuasive functions. The fifth dimension is concerned with information scale. It echoes the data granularity found in Froehlich's work (Froehlich *et al.*, 2010). Finally, the sixth dimension corresponds to the devices used for interacting and for conveying the persuasive features.

The analysis of Cano's design space reveals some interesting insights about persuasive interactive systems for energy. First, the Mirror function is used in most existing persuasive systems. This finding is consistent with other results from the literature (Froehlich *et al.*, 2010; Hamari, Koivisto & Pakkanen, 2014; Laurillau *et al.*, 2016). By contrast, the What-for function is absent from the other conceptual tools. Second, despite being widely used, the quantitative/numerical/symbolic representations are not always considered as appropriate ways to induce behavior change. Finally, Cano's design space brings interactivity to the fore. We believe that, in addition to traditional interaction/navigation techniques, it is worth considering new interactive techniques for supporting persuasion.

2.7 SEPIA framework

SEPIA adopts an engineering perspective, making it explicit the properties that a system should satisfy to support persuasion via human-system interaction (Laurillau *et al.*, 2016).

Table 4. SEPIA design space.

Properties		Phenomenon		
Classes		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

Inspired by the properties used to qualify user interfaces (i.e. observability), SEPIA propose six persuasion-oriented properties organized as two sets: the properties related to action – the doing related-properties, and the properties that support understanding – the understanding-related properties (see Table 4). These properties are: Observability, Intelligibility, Learnability, Protectability, Accountability and Maintainability. Each property is considered through the prism of a phenomenon characterized in terms of cause, effect, and causality. Consequently, as shown in Table 4, SEPIA proposes 18 classes of interactive functions that support persuasive-ness.

Observability. This set of user interface (UI) properties aims at making users aware of their behavior:

- **Reveal.** Making visible the effects of the user's current behavior related to the phenomenon under study.
- **Reflect.** Making human activity visible.
- **Discover.** Making visible the relationship between the causes of a behavior and its effects.

Intelligibility. This set of UI properties aims at better understanding the reasons of current behaviors:

- **Situate**. Making sense of the current behavior effects by providing means to compare with others, and putting the current situation into context.
- **Recommend**. Suggesting appropriate situations to reach a desired behavior.
- **Explain**. Explaining the relationship between the causes and its consequences (effects).

Learnability. This set of UI properties aims at allowing users to discover and learn new behaviors:

- **Induce**. Based on a system provided simulation engine, this function aims at helping users to identify the suitable behaviors that should lead to the defined goals.
- **Deduce**. Based on a system provided simulation engine, this function aims at helping users to identify the possible effects of a defined behavior.
- **Experiment**. Facilitating the induce/deduce iteration. This function allows users to find the compromise between their desired goals and behaviors.

Protectability. This set of UI properties aims at protecting users from undesired behaviors and/or contexts:

- **Alert**. This function alerts users of an actual undesired situation (effects).
- **Prevent**. This function prevents users from undesired behaviors (causes).
- **Anticipate**. This function anticipates the potential causes that could produce undesired situations and helps users to avoid such situations.

Accountability. This set of properties aims at engaging users in the achievement of new behaviors:

- **Target**. This function helps users to identify and set goals towards a new behavior.
- **Engage**. This function engages the user in an action loop to achieve the new behavior (i.e., notification mechanism).
- **Control**. This function controls the causes and effects in a way that balances user's actual behaviors and desired outcomes.

Maintainability. This set of properties aims at maintaining behavior change over time:

- **Benefit**. Making users aware of the effects either desired or undesired in the future.
- **Sustain** Making users aware of the behaviors that could lead to undesired/desired outcomes in the future.
- **Reward**. This function rewards users of either obtaining desired outcomes (effects) or avoiding unwanted behaviors (causes).

Table 5. Characterization of 10 studies with SEPIA framework.

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

The evaluation power of SEPIA has been assessed with ten energy-related persuasive systems (Laurillau *et al.*, 2016). As Table 5 shows, all 10 systems satisfy the "understanding-related" properties. In other words, these systems aim at making users aware of their current behavior as well as helping them to understand the consequences of their behavior. Three (out of ten) provide some means to learn new behaviors. However, these systems do not engage users to achieve new behaviors. If we refer to the TTM behavior change process model (Prochaska *et al.*, 1992; Prochaska & Velicer, 1997), most current systems target precontemplation and contemplation stages. In addition, designers mostly explore the effects of user's behavior, but less the causes nor the causality of their behavior. The SEPIA framework provides a worthy foundation that has been explored further for our framework UP+.

2.8 Persuasive Interactive Systems: Corpus of Classification

Daniel et al. (Daniel *et al.*, 2016) classified 44 existing persuasive systems dedicated to energy using 15 criteria organized into four classes: the system, the user interface, the user, and the context. Interestingly, some of these criteria explicitly address the process aspects of behavior change using the TTM five stages as a structuring basis (Prochaska *et al.*, 1992; Prochaska & Velicer, 1997). In addition, nine persuasion and eight gamification functions are examined. The persuasion functions are: Prediction, Suggestion, Evaluation, Simulation, Immediate Feedback, Cumulative Feedback, Temporal Comparison, Spatial Comparison and Social Comparison. In terms of gamification functions, Challenge, Competition, Collaboration, Progression, Social Interaction, Personalization, Reward and Achievement appear to be key.

None of the 44 persuasive systems covers all the stages of the behavior change process. Surprisingly, all these systems provide functions for maintaining motivation. However, only half of them covers the precontemplation stage and a quarter covers the preparation stage. As expected, most of these systems offer feedback as a persuasive function. The comparison functions are worth considered as they are implemented by half of the systems. However, little seems to address prediction, suggestion, and simulation. Moreover, Daniel's study reveals that the user interfaces are primarily mobile devices or ambient representations. The author suggests to make "graphical and ambient interfaces coexist and complement each other" (Daniel *et al.*, 2016) by combining their different functions, to cover all the stages of TTM.

This work provides a significant overview of current research in persuasive interactive systems, in particular for energy. However, we observe some inconsistencies between the results of this classification and that of others. For instance, Laurillau's and Cano's studies (Laurillau *et al.*, 2016; Cano *et al.*, 2015) have shown the lack of support for the TTM's maintenance stage, although, according to Daniel et al. (Daniel *et al.*, 2016), all the systems they studied claimed to support the maintenance stage.

3 CARTOGRAPHY OF CLASSIFICATIONS FOR PERSUASIVE SYSTEMS

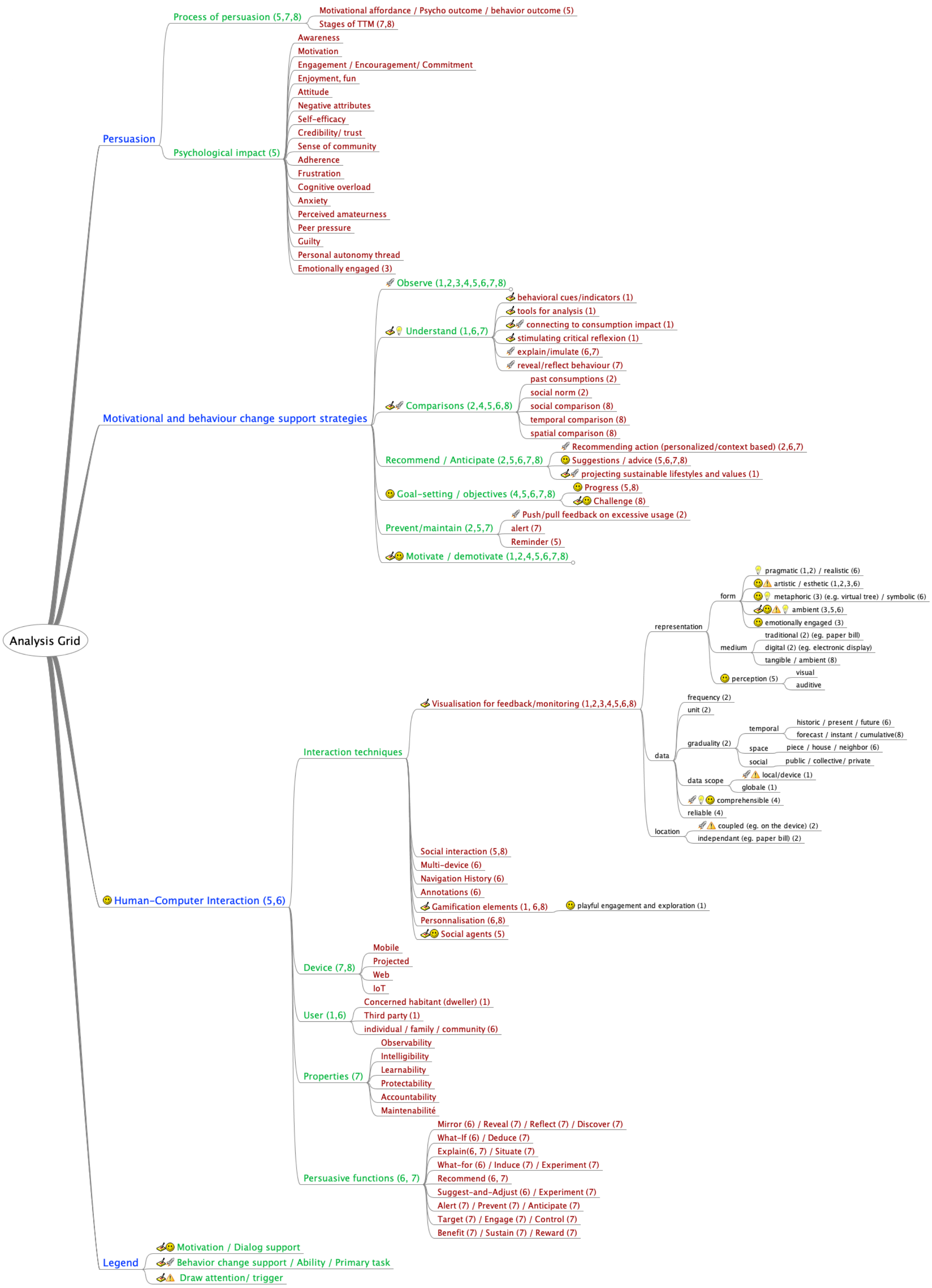
The representative classifications discussed above differ in terms of focus: some of them bring feedback to the fore (i.e. eco-feedback) while others such as Hamari's work, address the perception of motivation (Hamari, Koivisto & Pakkanen, 2014). Most of them overlap and most of them share a lack of concerns for the HCI aspects of persuasion: either HCI properties are secondary or they are implicit. Here, we propose a cartography that brings together the classifications analyzed in Part 2 into a coherent analytical grid.

3.1 Method and graphical meta-classification

For the definition of our grid, we first identified three top-level categories: (1) Persuasion *per se* in terms of process of change and psychological impact; (2) Strategies to support motivational and behavioral changes; and (3) HCI features related to persuasion. Then, we filled each category with the criteria used by our reference set of classifications. Criteria shared by several classifications are annotated with a number (i.e. the last digit of the corresponding section number of Part 2). We reused the terminology of our reference classifications as much as possible to denote groups of criteria. Otherwise, we chose a category's name semantically close to that of the group. In addition, we annotated the criteria with the following generic aspects of persuasion: (1) motivation and related psychological factors; (2) behavioral change support; (3) attention stimulation (i.e. triggers). The result of this process is a meta-classification represented graphically in Figure 2.

As Figure 2 shows, the top-level branches correspond to the three top-level categories. Nodes are tagged with icons whose legend is made explicit as a fourth branch of the graphics: a smiley denotes a node related to motivation (i.e. a motivational affordance or a psychological outcome); a rocket indicates that a node is related to behavior support; a warning sign is used for a node related to attention stimulation and a light bulb indicates that a node is related to understanding.

Figure 2. Analysis grid of the eight representative studies, the numbers in the brackets refer to the subsection index in Part 2 (i.e. number 2 for section 2.2). Icons represent the effects in terms of motivation, ability, etc.



3.2 Analysis

In this section, we discuss how the eight representative classifications of Part 2 cover each of the three top-level categories.

Persuasion. This branch is in turn decomposed into two sub-branches, the first one to cover the persuasion process, the second one to account for the psychological impacts of persuasion. Hamari et al.'s classification (Hamari, Koivisto & Pakkanen, 2014) is the only proposal that addresses the psychological aspects of persuasion as a three-step conceptual process: motivational affordance, psychological outcome and behavior outcome. They have identified several psychological outcomes (awareness, enjoyment, engagement, commitment, etc.) represented under "Psychological impact" in Figure 2. Whereas Hamari et al. use a three-stage psychological process, Daniel's study (Daniel *et al.*, 2016) and SEPIA (Laurillau *et al.*, 2016), both use the five-stage process of the Transtheoretical Model. As highlighted by Pinder et al. (Pinder *et al.*, 2018), "behavior change is a long-term process". Consequently, they advocate tailored persuasive interactive systems designed for long-term user interaction. In other words, the process dimension is key.

Motivational and behavior change support strategies. Although all of our selected classifications promote either motivational strategies (e.g. incentives and rewards) or behavior change support strategies (e.g., comparison and objectives setting), most of them promote techniques that combine motivational strategies with behavior change strategies indistinctly. For instance, tracking (i.e. capturing the consequences of a behavior) is a motivational affordance for Hamari et al. (Hamari, Koivisto & Pakkanen, 2014). As another example, goal setting (e.g. planning a behavior change) is a source of motivation for Froelich et al. (Froehlich *et al.*, 2010). Consequently, no classification clearly distinguishes motivational strategies from behavior support strategies as stressed in the PSD model (Oinas-Kukkonen & Harjumaa, 2009) (PSD's primary task support is related to behavior change support strategies while dialog support is related to motivational strategies). Although SEPIA does not consider motivational strategies clearly, SEPIA (Laurillau *et al.*, 2016) and Daniel's work (Daniel *et al.*, 2016) are two classifications that explicitly consider behavior change strategies based on the Transtheoretical Model of behavior change. With regard to behavior change support strategies, only a small set of classifications considers strategies to explain a behavior so that people can understand the consequences of this behavior (cause-effect-causality). The same holds for strategies to maintain change over time.

Human-Computer Interaction. Among the interaction techniques used to support persuasion, feedback and eco-feedback are the most prevalent and investigated approaches to reduce energy consumption. In particular, most classifications restrict persuasive user interaction to data visualization. By contrast, gamification is mostly considered as motivational although it has an impact on user interaction. In the same vein as Cano et al.'s work (Cano *et al.*, 2015) and SEPIA (Laurillau *et al.*, 2016), we advocate fostering persuasion in terms of HCI. This is addressed by the UP+ framework presented next.

4 THE UP+ FRAMEWORK

UP+ is intended to serve as an analytic tool for the state-of-the-art in existing persuasive interactive systems for energy as well as a conceptual tool for structuring the exploration of the design space for the development of future persuasive interactive systems. Compared to the classifications discussed above, UP+ focuses on the engineering aspects of HCI for persuasive interactive systems. It builds on the key features of UP (Laurillau *et al.*, 2018) and of SEPIA (Laurillau *et al.*, 2016).

Basically, UP+ covers the behavior change process as modeled in TTM (Prochaska *et al.*, 1992; Prochaska & Velicer, 1997)) as well as the psychological aspects of persuasion. In turn, the behavior change process and the psychological aspects are addressed according to three dimensions:

- User-system interaction to support behavior change in the long term, or macro level support, based on the TTM stages.
- Phenomenon-based user-system interaction described in terms of "cause-effect-causality" to support behavior change in the short term, or micro level support,
- Psychological affordances and outcomes through user-system interaction.

As these three dimensions are independent, they can be combined in multiple ways where a combination defines a class of functions that designers should consider when developing a persuasive interactive system. As a practical tool for system designers, UP+ makes these classes of functions explicit in a "macro-level X micro level" matrix. Table 6 shows the principles of this matrix where the cells will be exemplified through sections 5.2 to 5.3. In 5.1, we show how Norman's theory of action, which is familiar to HCI specialists, can be reconciled with the process-oriented Habit Alteration Model developed for persuasive systems. This mapping is used in UP+ to show in section 5.4 how principles from HCI such as affordances relate to persuasive principles such as outcomes.

Table 6. The UP+ principled matrix

		Macro-level – long term			
		Pré-contemplation Contemplation	Planning	Action	Maintenance
		Enlightener	Recommender	Facilitator	Protector
Micro-level – short term	Cause (behavior)	Understand =>	Decide =>	Act =>	Maintain
	Effect (situation)				
	Causality				

4.1 Norman's theory of Action and the Habit Alteration Model reconciled

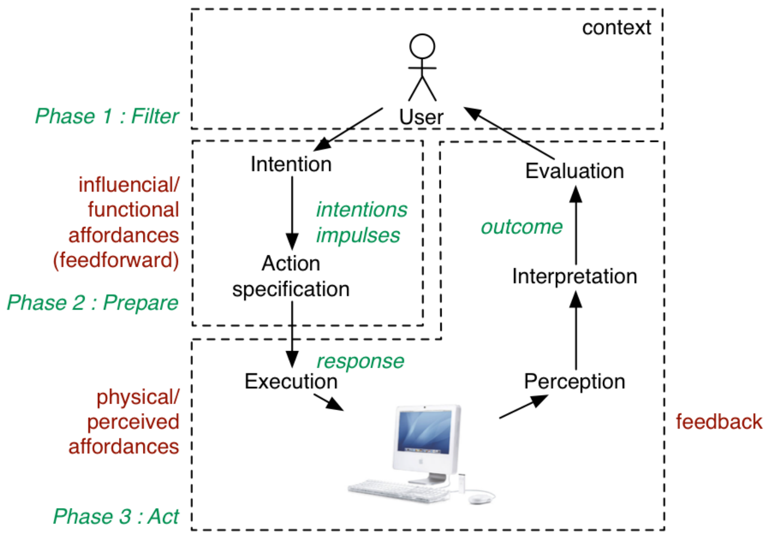
In his seminal work on cognitive engineering, Norman has suggested as an approximate theory of action, that the performance of a task with an interactive system may involve seven stages: from goal formation, a user has to form an intention, then to specify and execute an action plan to go through the gulf of execution, followed by the perception, interpretation, and evaluation of the system state to go through the gulf of evaluation. All, or a subset of these stages, are repeated in this order, or not, until the goal is reached. One important take away from Norman's model is that these stages define intervention points that designers should consider when developing an interactive system. The same should apply for persuasive interactive systems.

Similarly, the Habit Alteration Model (HAM) is based on a stage process model to explain and describe habit formation and habit disruption (Pinder *et al.*, 2018). As shown at the top of Figure 3, the process starts with the user in context. In HAM, context is defined as a set of "internal cues" such as mood and physiological state, and of "external cues" such as the physical location and social state of the environment. A subset of these cues is acquired through the filter stage to give rise to impulses and/or intentions to act in the Prepare phase. Impulses can be goal-response links learnt from sufficient repetitions in a stable context, or simply instinctive behavior. By contrast with impulses, intentions are formed consciously, requiring explicit cognitive resources. As shown in Figure 3, the Prepare stage covers Norman's Intention and Action specification stages. The HAM Act stage includes Norman's execution of action(s) called behavioral response in HAM as well as outcome such as changes in the environment or rewards. Response and outcome both feed back into the model.

Whereas Norman's stages involve an implicit single cognitive process, HAM uses the Dual Process Theory. This theory stipulates that behavior results from the interplay between two systems: System1 – non-conscious, fast and automatic, and System2 – conscious, slow, and rational, requiring explicit cognitive resources. In HAM, the three-stage "filter-prepare-act" process applies to the two systems that operate in parallel, mutually influencing each other to explain or predict behavioral responses to input cues.

UP+ uses the reconciled HAM-Norman's theory for covering short-term, micro-level, phenomenon-based behavioral changes through user-system interaction, and uses the Transtheoretical model (TTM) for covering long-term, macro-level, behavioral changes. This is detailed next.

Figure 3. Norman's theory of action and HAM reconciled (color green denotes HAM concepts; red denotes UP+ concepts).



4.2 Long-term user-system interaction: Enlighten, Recommend, Facilitate and Protect

According to TTM, behavior change is a multi-stage process (Prochaska *et al.*, 1992; Prochaska & Velicer, 1997):

- in the precontemplation and contemplation stages, people understand the situation that results from their behavior,
- next, in the preparation stage the individual decides to target a different behavior,
- followed by the action stage where the individual acts consequently to reach this new behavior,
- then making efforts to protect themselves from unwanted behaviors in the maintenance stage.

As a practical tool for system designers, UP+ maps the 4 human-centered cognitive stages identified by TTM into 4 classes of system functions to support users in going through the main stages of the behavior change process: *enlighten* for helping users to understand, *recommend* for encouraging decision making, and *protect* to facilitate positive actions and to avoid negative behavior.

Enlighten. This set of interactive functions aims at *making observable* people's current behavior and at *making intelligible* its determinants, notably the contextual cues that triggered this behavior. Enlighten echoes the first stages of TTM in which people, at the precontemplation stage, have to understand their current behavior to move to the contemplation stage. For the latter, people need to understand the pros and the cons of their current behavior to decide for a change. Similarly, Pinder et al. (Pinder *et al.*, 2018) underline the importance of raising awareness about System1 undesired habits that are unconscious in order to move towards System2 consciously desirable new behaviors. Social influence and cognitive dissonance are often used to raise people awareness about their own behavior. Monitoring and self-monitoring can be recruited as well (Fogg, 2002) (Oinas-Kukkonen & Harjumaa, 2009) as they both aim at helping individuals to self-reflect the situation: the identification of the causes and their explanation can raise the individual's ability and confidence in self when they often lack knowledge about the problem, thus provoking a sense of personal control and belief in self. The fact that individuals fully understand their current behavior (not only the effects) can motivate them to decide to change. The reference classifications presented in Part 2, mostly promote feedback to make behavior observable based on interactive visualization techniques. To support intelligibility, Pierce et al. (Pierce *et al.*, 2008) recommend strategies that "provide tools for analysis" and that "stimulate critical reflection". Comparison is another strategy to make behavior intelligible using multiple socio-spatio-temporal representations.

Recommend. This set of interactive functions aims at supporting decision making, and at preparing people for a change. It corresponds to the preparation stage of TTM in which people build action plans such as the "baby steps" observed by Fogg. At this stage, it is desirable to encourage people to develop a plan that leads them to their first concrete actions towards change. Suggestion and simulation are typical strategies (Fogg, 2002; Oinas-Kukkonen & Harjumaa, 2009) to support decision making. Recommending actions or providing generic advice are two of the strategies uncovered by Froehlich et al. (Froehlich, 2009) and by Hamari et al. (Hamari, Koivisto & Pakkanen, 2014), including simulation through "projecting and cultivating sustainable lifestyles and values" (Pierce *et al.*, 2008).

Facilitate. This set of interactive functions aims at helping users to facilitate their commitment to achieve a new and desired behavior, and to support the achievement of their action plan over time. It echoes the action stage of TTM. It is also related to Fogg's principles – persuasion as a tool (Fogg, 2002) and to the PSD model – primary task support (Oinas-Kukkonen & Harjumaa, 2009). Setting goals is the most common strategies to support this stage (Froehlich *et al.*, 2010; Hamari, Koivisto & Pakkanen, 2014; Cano *et al.*, 2015). Although goal setting is an effective strategy for this stage, external psychological factors such as the sense of community and adherence can also be recruited. In addition, positive reinforcement (compliment, rewards, etc.) can be used to stimulate intrinsic motivation and satisfaction.

Protect. This set of interactive functions aims at keeping users within the process – to stay motivated, at protecting them from giving up as well as to alert them when moving away from the desired behavior. Protect corresponds to the maintenance stage of TTM. According to Fogg's principles and to the PSD model, reward is a means to sustain behavior change. The reference classifications of Part 2 suggest many strategies related to rewarding. However, only few of them such as Froehlich's "Push/pull feedback on excessive usage" consider prevention (Froehlich, 2009).

In conformity with Oinas-Kukkonen et al.'s postulate, we strongly believe that behavior change is a process and that the stages of this process are iterative and incremental (Oinas-Kukkonen & Harjumaa, 2009). This is backed up by Pinder et al. who stipulate that in order to build a new habit, the desired behavior must go through a cycle that is repeated sufficiently in stable contexts to become a new habit (Pinder *et al.*, 2018). As a result, a persuasive interactive system should be designed to operationalize this macro process of behavior change. In addition, we claim that the user interface should adapt its content as well as the user interaction depending on the current stage in order to bring forward the relevant features, to maximize the persuasive effect and to keep the user in the process of change over time.

Having identified functions to support behavioral changes through long-term user-system interaction (enlighten, recommend, facilitate, and protect), we need now to explore behavioral change at the short-term user-system interaction level.

4.3 Short-term user-system interaction: the Phenomenon dimension as Cause, Effect, and Causality

The second dimension phenomenon-oriented of UP+ is concerned with the micro level short-term behavior in terms of cause, effect and causality. According to the Oxford dictionary, a phenomenon is defined as "a fact or situation that is observed to exist or happen, esp. one whose cause or explanation is in question". For users to understand a particular behavior and for supporting the achievement of new behaviors, not only the effect that results from their behavior should be observable and explained, but also the causes as well as the causality (i.e. the relationship cause-effect) should be made observable and explained. This is fully in line with the primary task support principles of the PSD model as well as with Fogg's "cause and effect" principle. However, as highlighted in Part 2, the reference classifications focus primarily on the effects, not on the causes, even less on causalities. We therefore consider the necessity for exploring the cause-effect-causality process. We believe that, in order to decide to change, individuals not only need to observe the effects (environmental, financial, etc.) but also to understand how and why these consequences occurred. Observing and understanding cause-effect-causality happen performed through user-system interaction. We draw on the reconciled HAM-Norman's theory of action of Figure 3 to analyze how user-system interaction supports the observation and understanding of cause-effect-causality.

As shown in Figure 3, a particular behavior is a set of actions/responses, the causes of this behavior are intentions or impulses as well as the internal and external contextual cues that are the determinants of these intentions and impulses. The consequences of the behavior are conveyed through system feedback, which in turn is perceived and interpreted as an outcome, which is then evaluated. Then, causality is the relationship between the top-down part and the bottom-up part of this micro process. In HCI, the challenge for the system designer is to minimize the cognitive effort that users need to recruit to go through each stage of the top-down and bottom-up parts of the process. Higher is the cognitive effort, larger are the gulf of execution and the gulf of evaluation, lesser is the goal to be reached successfully. This gap metaphor introduced by Norman applies to persuasive interactive systems as well.

Persuasive strategies such as tunneling and reduction, are "primary task support" principles (PSD model (Oinas-Kukkonen & Harjumaa, 2009)) that aim at facilitating the achievement of a behavior. In addition to SEPIA (Laurillau *et al.*, 2016) and Cano et al.'s work (Cano *et al.*, 2015), Pierce et al. (Pierce *et al.*, 2008) recommend strategies that consist of "offering behavioral cues and indicators", "connecting behavior to material impacts of consumption", and "projecting and cultivating sustainable lifestyles and values". Froehlich indirectly considers cause/effect in terms of incentives/discentives and rewards/penalties (Froehlich *et al.*, 2010).

By reconciling Norman's theory of action with HAM, we are able to identify intervention points for "motivational", by extension for psychological, affordances and outcomes. This is the third dimension of UP+ discussed in following section.

4.4 Psychological impact: motivational affordances and psychological outcomes

The third dimension of UP+, psychological impact, is orthogonal and complementary to the two dimensions corresponding to the long-term-macro and short-term-micro levels of user-system interaction. Instead of using the term "motivation", we prefer to reason in terms of psychological impact. Persuasion first affects attitude and then behavior. In psychology, attitude has three components: cognitive (thoughts or beliefs about someone or something), affective (feelings, emotions), and conative (inclination to act), and motivation has multiple sources: physiological, emotional, cognitive and social (Bernstein *et al.*, 2018). Our reference classifications mostly consider strategies related to the conative as well as to the social components of attitude. Some of them consider emotions and feelings by the way of artistic feedback (e.g., (Pierce *et al.*, 2008; Froehlich, 2009; Fang & Hsu, 2010)), or of playfulness through gamification (e.g., (Pierce *et al.*, 2008; Daniel *et al.*, 2016)).

As illustrated in Figure 3, user-system interaction may be designed to have a psychological impact in terms of affordance, feedback, and context. In HCI, affordance plays a role in intention forming and execution. A well-designed user-system interaction with the right affordance reduces the gulf of execution (functional affordance for intention forming, and physical affordance for action execution). Similarly, an effective persuasive user interaction requires the right motivational affordance (e.g., playfulness through gamification, social comparison). As well, to reduce the gulf of evaluation, feedback should be carefully designed to provide understandable messages. Similarly, an effective persuasive user-system interaction requires delivering the right psychological outcome (e.g., reward, greetings). Finally, as underlined by Pinder et al. (Pinder *et al.*, 2018), context plays a key role in persuasion. As a result, the user-system interaction of a persuasive interactive system should dynamically adapt to the context of use as developed by Calvary et al. for user Interface plasticity (Calvary *et al.*, 2003).

4.5 Classes of interactive persuasive functions

Table 7. UP+ exemplified with persuasive classes of functions

User / System / Phenomenon	**Understand**	**Decide**	**Act**	**Protect**
	Enlightener	*Recommender*	*Facilitator*	*Protector*
Cause (Behavior)	Reflect behavior	Recommend actions	Engage	Prevent
Effect (Situation)	Reveal situation	Suggest situation	React	Alert
Causality	Explain	Simulate	Manage	Anticipate

By crossing the first two dimensions "macro x micro processes" of behavior change, UP+ invites the designer to investigate cause-effect-causality for each of the macro roles a persuasive interactive system may play. This role may be that of an Enlightner, a Recommender, a Facilitator, and/or a Protector. Table 7 summarizes the core functions where, for each role, we propose classes of functional features for Cause, Effect, and Causality respectively.

4.5.1 Enlightener

The enlightener role provides three classes of functions: "reflect behavior" centered on causes; "reveal situation" centered on effects; and "explain" centered on the causal relationship between cause and effect.

- **Reflect behavior**. Consists of making observable the human activity that causes/caused the phenomenon of interest. For instance, providing objective quantitative indicators such as the consumption average at the country level may help to understand whether one's behavior is appropriate or not.
- **Reveal situation**. Consists of functions that provide users with access to raw data or to information that are relevant to the current state or reached situation (i.e., the effect) due to user's activity.

- **Explain**. Consists of functions that explain the causal relationship between human actions and the current system state (i.e. the induced effects). For example, an e-coach developed to guarantee thermal comfort, explains that opening the window of the hall way will reduce the temperature by 2°C in the bedroom in the next two hours (Alzhouri et al., 2018).

4.5.2 Recommender

The recommender role includes three classes of functions: "Recommend actions" centered on causes; "Suggest situation" centered on effects; and "Simulate" centered on causal relationship.

- **Recommend actions**. Consists of recommending alternative behaviors (i.e. causes) suitable for solving the phenomenon of interest.
- **Suggest situation**. Consists of suggesting alternative situations (i.e. effects) that should be reached. For instance, indicating a social norm provides a comparative means that suggests an alternative situation to be reached.
- **Simulate**. Consists of functions that allow users to conduct and iteratively evaluate inductive-deductive cycles in order to identify relevant and desired user-defined behaviors and effects.

4.5.3 Facilitator

The facilitator role covers the following functions: "Engage" centered on causes; "Reward" centered on effects; and "Manage" centered on causal relationship.

- **Engage**. Consists of functions that allow users to engage in a desirable change of behavior.

- **React**. Consists of functions that make the user aware of desirable effects, now or in the future, and that react through rewarding and greetings, for instance.

- **Manage**. Consists of functions that make possible for users to manage the behavior change process in a way that balances actual behaviors with the desired outcomes. Mapping with Fogg's behavior model, the system may allow the user to plan and to set intermediate motivation and ability levels to reach an intermediate behavior change. A machine learning-based engine could be used to help users with automatic mundane actions while keeping them in control for important rewarding actions.

4.5.4 Protector

The protector role covers: "Prevent" centered on causes; "Alert" centered on effects; and "Anticipate" centered on causal relationship.

- **Prevent**. Functions that prevent users from unwanted behaviors.
- **Alert**. Functions that alert users in case of unwanted consequences compared to a desired goal.
- **Anticipate**. Functions to make the user aware of appropriate (respectively inappropriate) behaviors or of behaviors suitable to become valuable (respectively risky) in the near future. As for "Manage", machine learning is a good candidate for implementing this class of functions.

4.6 Projecting psychological impact on persuasion functions

In our reference classifications, social influence, gameful experience, and aesthetics have been found to have a strong impact on persuasion (Hamari, Koivisto & Pakkanen, 2014; Daniel *et al.*, 2016). In the following, we show how the UP+ classes of persuasive functions – Understand, Decide, Act, and Protect, can take advantage of these psychological factors.

Social influence. Social influence theory has a long history in psychology (Cialdini, 20; French Jr. & Raven, 1959; Friedkin, 1998). PSD (Oinas-Kukkonen & Harjumaa, 2009) dedicates one dimension to social influence. As observed by (Hamari, Koivisto & Pakkanen, 2014), social features are widely used in persuasive systems for energy, namely social support, social comparisons, social feedback, social interaction and social sharing. Then, how social influence maps to the UP+ functions classes? Social comparison is used in revealing user's current consumption, which compared with that of others increases user's *understandability* and awareness. As well, social influence may help to drive *action* through settings goals (based on what others are doing) or making observable progress of the change towards a desired behavior. Social incentives, challenges, or leaderboard can also be used to drive *decision* and *action*. Social sharing is another strategy to support *decision* through advice. Software agents acting as social pets can *protect* users from relapse.

Aesthetics. Multiple classifications, in particular the classifications related to eco-feedback, promote aesthetics as a means to improve persuasion through appealing ambient, metaphorical, or symbolic representations. Aesthetics triggers the affective component of attitude (intrinsic motivation): pleasure, beauty, calm, etc. Attractiveness is one of Fogg's design principles (Fogg, 2002). Similarly, Pierce et al. (Pierce *et al.*, 2008) propose aesthetics as one approach to provide alternative and meaningful way to communicate data with users. Users appreciate both artistic metaphors and numerical representations as they complement each other (Froehlich, 2009). Fang (Fang & Hsu, 2010) investigates aesthetics as one dimension of their design space. Consolvo (Consolvo *et al.*, 2009) introduced goals/strategies for promoting everyday behavior change in which aesthetic and abstract/reflective representations happen to be the two key principles for the design of persuasive systems. Attractiveness is a strategy to support awareness (thus to *understand* current behavior) as well as to maintain change over time (thus, to *protect*).

Gameful experience. Gamification has been considered as means to "engage people and enhance positive patterns in using service, such as increasing activity, interaction, or quality and productivity of actions" (Orji *et al.*, 2018). It is believed that persuasive gameful systems are effective tools for motivating behavior change (Orji *et al.*, 2018). Thus, many studies have featured gamification functions into the design of persuasive systems. In particular, Daniel (Daniel *et al.*, 2016) proposes the following seven functions: challenge, competition, collaboration, progression, reward, achievement, personalization, and social interaction. Orji (Orji *et al.*, 2018) chooses to investigate ten persuasive strategies often employed in gameful systems. Tondello (Tondello *et al.*, 2017) presents a novel model of eight groups of gameful elements into three categories: individual motivations, external motivations and social motivations. It conveys playfulness, enjoyment, and social interactions. These features support *action* (goal setting, challenges, rewards, greetings, etc.) and *prevent* relapse (social inclusion). Virtual reality-based simulator may be considered as a gameful experience and often used to fight fear when it comes to *act* in the real world.

Other psychological factors. The cartography of Figure 2 shows additional psychological factors such as trust and credibility. Although trust and credibility are important psychological factors (cf. PSD), Hamari et al. (Hamari, Koivisto & Pakkanen, 2014) have not found any persuasive interactive system that addressed these factors. Cognitive overload is another factor. Typically, reminders, which support *Act* and *Protect*, are means to reduce cognitive overload. Some classifications target the cognitive component to make feedback *understandable* using pragmatic representations (Froehlich *et al.*, 2010). As well, behavioral cues (*Understand*) and the projection of sustainable lifestyles (*Decide*) also trigger the cognitive component of attitude.

5 CONCLUSION

5.1 Summary of our contributions: a cartography of classifications for persuasion, and UP+

We have presented and analyzed eight classifications for persuasive interactive systems that are representative of the state of the art. We have noted a diversity of concerns as well as some conceptual complementarity and terminological overlaps. Most of these previous works ignore the process nature of behavioral change, and psychological factors are mostly limited to the conative component of attitude. Crucially, interaction is not considered as a key component for persuasion, as interaction is limited to feedback visualization techniques. To synthesize the state of the art, we have proposed a *cartography* that brings together these classifications into a coherent grid where human computer interaction is a first class component along with persuasion *per se* decomposed into behavior change process and psychological impact, and with *strategies* to support behavior change.

Building on this cartography as well as on our own previous work on persuasive technologies – UP (Laurillau *et al.*, 2018) and SEPIA (Laurillau *et al.*, 2016), we propose *UP+*, a new process-oriented framework that offers a structured set of interactive and persuasive functions that system designers may, or should, consider for the development of persuasive interactive systems. This set is organized as a “4-column x 3-line” matrix where the columns (understand, decide, act, and protect) reflect behavioral change as *stages of a long-term macro-process*, and where the lines (cause, effect, and causality) reflect behavioral changes as a phenomenon-oriented, *short-term micro-process*. Additionally, a third dimension, *psychological impact*, makes it explicit how these functions can be enriched with factors such as social influence, aesthetics, and gamification.

UP+ can be used as a generative conceptual tool by designers of persuasive interactive systems. It can also serve as an analytic grid. As a concrete example of analytic use, the e-coach described in (Alzhouri et al., 2018) supports the three micro-steps (cause-effect-causality) for the Understand and Decide stages of the macro-process. It includes a *recommender* that *proposes* an action plan to be performed such as opening and closing windows, and *explains the effects* of these actions on thermal comfort for the next few hours. In addition, through *interaction*, the user can suppress actions from the plan or simply not perform them. The recommender dynamically shows the *consequences* on thermal comfort along with *explanations* why thermal comfort is optimal or not, and *generates a new plan* on demand. On the other hand, psychological factors such as social influence and gamification are absent from the actual implementation.

5.2 Limitations: completeness and refinement of the cartography and UP+

The cartography presented in Part 4 is based on 8 classification works that we have selected for their relevance and their coverage of persuasion issues. It is reasonable to expect the emergence of additional classifications elaborated from a different perspective as that proposed by (Caraban et al., 2019) for classifying nudges. Therefore, our grid should be considered as a basis for further extension and refinement.

The UP+ classes of functions are domain agnostic: **enlighten** for making the user *understand*, **recommend** for helping the user to *decide*, **facilitate** positive *actions* and **protect** from negative behaviors. Although, in general, genericity is desirable, we cannot guarantee that they cover all the functions that are necessary to promote sustainable change. We believe that there might be space for more domain-specific functionalities to inspire behavioral change in context.

Similarly, It is certainly necessary to refine the three psychological factors (social influence, aesthetics, and gameful experience) used in UP+ to enrich the persuasive-ness of functions. For example, Hamari's et al. classification includes additional dimensions for psychological impacts that needs to be considered (Hamari, Koivisto & Sarsa, 2014). The same holds for motivational affordances and psychological outcome.

Although these limitations show room for improvements, the cartography is still useful as a synthesis of a plethora of classifications, and UP+ provides HCI practitionners with a framework that operationalizes the key concepts of persuasion and that they can extend to fit a particular context of use.

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7 BIOGRAPHIE

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