Towards Designing Persuasive Ambient Visualization

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ABSTRACT
This paper discusses an alternative application area for ambient information systems, coined as 'persuasive visualization'. It investigates the recent evolution of ambient displays, from simply aiming to inform people about data patterns towards increasing awareness of themes underlying the data. Accordingly, this paper proposes the potential of ambient display techniques to encourage users to modify their behavior. First, the evolution of past ambient display applications is analyzed according to their persuasive capabilities and environmental contexts, ranging from large-scale installations towards more personalized applications of ubiquitous and wearable computing. Accordingly, ambient displays could become a useful platform for unobtrusive, aesthetic applications that can augment our awareness and encourage positive behavior modifications relating to socially relevant issues.

Keywords
persuasive technology, ambient display, information visualization, wearable computing

INTRODUCTION
The concept of *ambient visualization* or *ambient display* is defined as a category of data representations that conveys time-varying information in the periphery of human attention. According to Mankoff's evaluation model [12], an ideal ambient display should adhere up to eight different heuristic principles that are founded from functional, effectiveness and aesthetical considerations. Most ambient displays are similar to classic data visualization techniques in the focus on conveying meaningful visual patterns to augment the understanding of the dataset. However, ambient displays and data visualizations are different in that ambient representations can be quite ambiguous and non-intuitive to interpret. In other words, ambient metaphors "may not be immediately understandable, but users should be able to discover meaning through subtle interaction." [17]. Accordingly, by including aspects of *ambiguity* in their designs [5], multiple, potentially competing, interpretations are created, which can stimulate user engagement and augment the user experience [5]. Ambient displays thus aim for more artistically inclined and emotionally engaging ways of data representation, going beyond simply 'informing' people of specific data patterns. An ambient display tends to be calm, non-obtrusive and opportunistic, revealing meaningful information only for interested users who are willing to invest time and effort. The value of interpreting an ambient display by long-term or repeated exposure is further enhanced by its general lack of direct user interaction, such as the exploration, filtering or selection of information.

Because such a display is able to convey information in a subjectively pleasant way over a relatively long period of time, this paper claims that particular ambient display techniques have the potential to be used for persuasive applications. Persuasive technology uses specific techniques to encourage behaviour, belief or attitude change by providing personalized messages at teachable moments, at the right time and right place, when a person is receptive to information [4]. Persuasive applications are different from normal feedback displays in that they require active involvement of those being monitored in attaining a desired behaviour change. Various persuasive techniques are founded on increasing human awareness, often by informing people explicitly of relevant aspects that sustain or underlie specific attitudes or behaviours. An ambient display could increase human awareness by conveying such relevant issues within a relevant and timely environmental context. It can make important influential factors visible and tangible, to allow people to better understand their personal attitudes. Furthermore, the aesthetic and opportunistic qualities of an ambient display allow for a long-term sustained usage, and reduces the risk to "nag" or annoy users.

This paper proposes that ambient display is currently changing character and is becoming increasingly persuasive. It investigates the evolution of ambient display techniques from relatively large-scale spatial installations towards more personalized applications in the realm of ubiquitous and wearable computing. Accordingly, it discusses various design and evaluation considerations for a new visualization direction, coined as *persuasive visualization*, which aims to modify human behavior by augmenting the awareness of people within an appropriate context and in a non-obtrusive way.

Figure 1. Spatial ambient display examples (see also [15]). Left: a plant display showing the traditional country flowers in relation to what products people buy in a coffee shop (Designers: Huong Nguyen et al.). Right: a wallpaper style display capturing real-time environmental parameters in three computer labs (Designers: Mitchell Page et al.).

SPATIAL AMBIENT DISPLAY

Most ambient displays take form as large-scale, spatial installations placed within public settings. Such displays tend to represent dynamically changing, non-critical information that is relevant to their actual environmental context (e.g. time, location and people), such as the weather [8] or local bus schedule [12]. Because of their physical context, such displays are closely integrated within the architectural setting. They stimulate the human senses in a direct way, including vision (e.g. projections), sound (e.g. data sonification), touch (e.g. wind fans, temperature changes) or smell (e.g. odor emitters) [18].

Figure 1 shows two typical spatial ambient displays, developed as part of an undergraduate studio design course at the University of Sydney [15]. On the left, a collection of flowers represents the country of origin of products as they are purchased at a local coffee shop. On the right, an organic-style wallpaper displays the real-time network usage and sound levels within four computer labs, while rhythmically alternating light bulbs convey the waiting time of the printing and plotting devices placed below. Although not noticeable on first sight, these ambient displays were initially motivated by persuasive intentions. For instance, the coffee shop installation aimed to change unsustainable shopping behavior: by indirectly increasing the awareness of the amount of foreign products purchases, it was expected that customers would choose more local products that require less transportation costs and lead to less environmental impact. Similarly, the wallpaper concept aspired to influence the decisions of students of which computer lab to go to, for instance the one that is the most quiet, least occupied, and with the fastest network. However, these persuasive considerations have not been clearly translated, as they were diluted by concerns about the physical adaptation to the environmental context, the general acceptability by users and a desire for artistic originality. Because the display designs concealed the true intentions and their environmental contexts were too broad for accurate interpretation, the resulting persuasive impact was low.

Figure 2. Ambient display artifact examples. Left: an egg shaped USB device that wiggles and moves in reaction to emotions communicated during online chat conversations (Designer: James Kim); Right: a working computer mouse that changes temperature hot/cold depending on the input of textual humans emotions (Designer: Irene Chen).

AMBIENT DISPLAY ARTEFACTS

More recent ambient display applications focus on producing small-scale physical artifacts. Although influenced by physical computing, product design and electronic gadgetry, the design of these data-driven objects still largely follows traditional ambient display heuristics. The prototyping of these displays has become possible due to the recent appearance of community-driven physical computing platforms (e.g. Arduino, Processing), which aim to reduce the technical complexity of programming micro-electronic devices for the enthusiastic interaction designer. Existing ambient display artifacts vary from elaborate robotic plants that convey the recycling behavior of people [9], to simple color-changing objects such as the Ambient Orb, commercialized by Ambient Devices Inc. Figure 2 shows two typical ambient artifacts developed by postgraduate students. On the left, an egg-shaped and color-changing device wiggles and rocks in different motion typologies in reaction to the human emotions depicted during an online chat conversation. On the right, the fabric surface of a working computer mouse changes temperature (i.e. hot or cold) depending on the emotions detected in textual computer documents.

Both examples show how ambient display artifacts aim for alternative, non-graphical (or non screen- or projection-based) ways of communicating information. They demonstrate more explorative design approaches that are more inspired by digital, interactive art works than traditional data mapping algorithms. By deliberately exploring the borders of human's cognitive perceptive capabilities through infotropic stimulation by way of motion, light, or temperature, these displays deliberately provoke unpredictable interpretations. However, because the objects are more directly related to their environmental context, the resulting interpretations are more narrow than for spatial installations. Whereas typical ambient displays focus on conveying simple but meaningful patterns within datasets, ambient artifacts 'utilize' the data to communicate a more elaborate, subjective message. In other words, the representation of patterns *within* the data is overturned in

favor of interpretative meanings that *underlie* the data. Instead of augmenting knowledge about a dataset, such displays aim for changing subjective attitudes of users. The dataset is then reduced to a medium, used as a real-world context and justification for the existence of the artifact. Such displays do not aim for objective observation, but rather provoke personal interpretation, quite similar to good works of art. As ambient artifacts convey underlying messages related to real-time data, they are able to inform and involve people. It is this capability to stimulate higher level reasoning based on information that forms the persuasive potential of ambient display applications.

WEARABLE / UBIQUITOUS AMBIENT DISPLAY

From building facades to small artifacts, from mobile devices to electronic fashion, information access seems to be reaching the borders of technology miniaturization. At the same time, information becomes increasingly related to the actual environmental context of the user, such as the actual location, situation, activity or social status. The most recent advances in ambient display target the *ubiquitous* or *pervasive* paradigm, or the use of computational devices that enhance the experience of everyday life by interfaces that are embedded within the physical environment [6]. Several potential benefits of ubiquitous computing have been described that demonstrate how technology can support activities and values that are fundamentally different from those that are existing today [3]. Whereas most ubiquitous computing research efforts focus on improving sensor analysis and context recognition performance, only few research projects exist that focus on how such context-related information can be fed back to the users. 'Wearable visualization', the use of wearable computing technology to represent information, is a recently emerging application area based on insights from ambient display and electronic fashion. A wearable visualization uses small computers that can be continuously worn on the human body to communicate information, either to the wearer herself, or to other people in the wearer's vicinity. It differs from more common visual applications on mobile devices in that wearables are specifically designed to be unobtrusively integrated within the user's clothing. By merging visualization with fashion, clothing is considered as a sort of public display that is meant to 'signal' an interpretable meaning [11]. Because of its continuous and public setting, a wearable display can potentially alter the experience of the wearer or of other people present in the immediate vicinity. Ultimately, those onlookers might even be experiencing the presence of the wearer differently. Wearable visualization shifts the context in which people perceive and interpret information from space and architecture (i.e. spatial ambient display), or object affordances and product usability (i.e. ambient artifact), towards the presence of the user herself, who constantly shifts her contextual setting depending on location, activities or time of day.

Figure 3. Wearable ambient visualization. Left: a light-emitting basketball jersey showing game-related information (Designer: Mitchell Page, [14]); Right: a wearable folding device conveying activity information (Designer: Monika Hoinkis, [16]).

Dissimilar to fashion, which is ultimately decided by the wearer, a wearable display determines its visual presence autonomously, depending on sensor-depending instructions. As the wearer thus looses the power to determine her visual presence, such display can become a useful tool for persuasive purposes: to influence the display, the wearer will ultimately need to alter her behavior. Figure 3 shows two wearable ambient displays. On the left, *TeamAwear*, an electronically-enhanced basketball jersey that is capable of displaying publicly available sports data related to the wearer (e.g. fouls, score, time clocks)[14]. On the right, a fashion-neutral wearable device that creates fabric folds depending on environmental data related to the wearer, such as the amount of movements, sounds and social contacts over the time span of a day [16]. The designs of both displays were inspired by the ambient display concept: they both attempt to convey information through "subtle changes in form, movement, sound, color, smell, temperature, or light" [18], are based on 'non-critical' dynamic data streams, can be observed in the periphery of human attention, are meant for a non-expert audience, and are designed with attention to visual aesthetics to increase their general acceptance by the public. Both displays contain subtle persuasive qualities, aiming to alter the behavior of the wearers to some degree. For instance, the TeamAwear's original design hypothesis consisted of providing additional information to the players in a non-intrusive way. By wearing these jerseys, it was expected that players would make better in-game decisions and thus experience a more challenging game-play. However, although the players felt more confident, the highest impact was reported by the referees, coaches and audience members. Similar to an ambient display, the folding display was specifically designed to become understandable over time, only by those people that had extensive exposure to the display, or were personally informed by the wearer about the used data mapping algorithms. Here, the design deliberately used an ambiguous metaphor of fabric folding to 'encrypt' the data in time and effort for obvious privacy reasons. In contrast to the large-scale context of spatial ambient displays,

wearable visualizations represent information within the environmental context of the wearer, with the aim to alter the experience of that context for the wearer and any onlookers. Because of its close relationship to the context, wearable visualization seems to be an ideal platform for persuasive applications.

PERSUASIVE VISUALIZATION

Sustainable living, energy conservation, water management, health prevention trust, social integration, and ethics are only a few examples of potential application areas that often utilize information presentations to increase people's awareness and change their behavior. Imagine being able to ambiently represent the true environmental impact of products, the energy consumption of activities, or the health risks of food items at the exact moment when such decisions are made. Different from other feedback approaches, and because of the ambient qualities, such display should be able to not unnecessarily disturb the user during this activity. Such displays would allow people to make more informed decisions while buying specific products, eating fast food, taking a shower or choosing the stairs or the elevator, but avoid the tendency to nag or annoy users. Such displays should be different from traditional feedback methods, in that they personally involve the user when he or she wishes to do so. Ambient display could become an ideal platform for this task, in its focus on real-time data, context dependency, aesthetics and personal interpretation.

Background

Several visualization projects already exist that directly or indirectly aim to encourage human behavior modification, and could be classified under the term "persuasive visualization". For instance, the original Bus Schedule visualization was evaluated by measuring whether more students were logging off the university computers in tact with the bus schedule after the display was installed [12]. DiMicco et al. [2] conducted a behavioral study to examine how a shared graphical display of individual speaker-participation rates impacted the behavior of a group during a collaboration task. A visualization of the power consumption of radiators helped people understand and reflect upon their energy usage [7]. Several creative design interventions in public space aimed to promote energy awareness, increasing awareness and provoking responses and discussion [10]. A short evaluation study showed how a subtle plant display positively influenced the recycling habits of students [9]. The impact of this display resulted in more than just informing people about their recycling habits, as people effectively changed their recycling behavior. Morris [13] recently developed a social network visualization with sensor-generated and self-reported data, to foster awareness and empowerment of social health. Other researchers developed a semi-graphical mobile phone application to encourage physical activity [1]. These examples prove how socially relevant information can be represented in persuasive ways. They shift simple information representation towards augmenting human awareness of underlying principles, and ultimately aim to encourage behavioral changes. However, it is still undefined whether the unique qualities of ambient displays are more suitable for such purposes than direct feedback or self-reporting methods.

Design and Evaluation Considerations

The goals and expectations of persuasive visualization require that the current assumptions and heuristics of ambient display need to be reassessed. For instance, the concerns about aesthetic quality should reach beyond adapting the design to its environmental setting. Instead, a persuasive visualization could be assessed on how it 'convinces' or 'encourages' behavioral change, alters opinions and attitudes, augments human awareness or leads to 'reflection' or 'discussion'. New evaluation methods are required to objectively measure behavioral change. As novelty and curiosity might initially be the major factors that drive behavioral changes, longitudinal studies are required to assess user compliance and long-term sustained effects. However, traditional long-term behavior and attitude capturing methods, including self-monitoring techniques such as diaries and retrospective reporting, have typical low success rates. They either require physically carrying around a diary or the retrospective completion of reports at the end of the day. The effort of carrying around a diary results in a low long-term user compliance. Retrospective reporting is relatively unreliable due to recall bias and cognitive errors. In addition, the continuous self-monitoring ultimately might even influence the behavior change more than the displays, either positively or negatively. However, alternative evaluation opportunities exist in measuring behavioral changes over random intervals, or by monitoring the direct effects of behavior changes, instead of the attitudes themselves.

Ethical Considerations

A persuasive visualization is different from an ambient display in that people need to rely on and trust the information shown, so that they are willing to alter their behavior. Whereas all visualizations should be trustworthy, no real danger is involved when an international weather diagram is miscomprehended. However, an ambient local bus schedule might immediately loose its functionality, and probably never recover, when people stop trusting its accurateness. Naturally, this concern shifts even further when people should become willing to modify their personal behavior based on what they understand from the display, for instance when purchasing more healthy food products, conducting a more sustainable lifestyle or making social contacts. This issue becomes even more evident for persuasive purposes that rely on personal data, such as health information or physiological sensor readings, which could potentially lead to adverse behavior changes.

CONCLUSION

This paper discussed a recent shift in ambient information systems, which can be coined as a focus towards 'persuasive visualization'. It identified a recent tendency of ambient displays to become smaller, more personal and more persuasive, and showed how ambient displays increasingly aim beyond informing people to instead communicate subjective phenomena that underlie the dataset. Such displays utilize data to justify the relevance and significance of the representation by focusing on the meaning of the data, instead of detecting any patterns hidden inside it. By presenting such higher-level information in a continuous and non-obtrusive way, ambient displays have the potential to encourage people to alter their attitudes or behaviors while maintaining an enjoyable user experience.

Following questions remain: What are the design considerations for a persuasive ambient display? How can ambient characteristics augment persuasive capabilities? And how can persuasive quality be accurately evaluated?

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