The Role of Affordance in Cyber-Physical Systems for Behavioral Change

Federica Cena[1(✉)], Amon Rapp[1], Alessandro Marcengo[2], Adelina Brizio[3], Dize Hilviu[3], and Maurizio Tirassa[3]

[1] Department of Computer Science, University of Torino, Turin, Italy
{cena, rapp}@di.unito.it
[2] Telecom Italia - Research and Prototyping, Turin, Italy
alessandro.marcengo@telecomitalia.it
[3] Department of Psychology and Center for Cognitive Science, University of Torino, Turin, Italy
adelina.brizio@yahoo.it, dize.hilviu@gmail.com, maurizio.tirassa@unito.it

Abstract. Cyber-Physical Systems are the next generation of embedded ICT systems, interconnected through the Internet of Things and endowed with data gathering functions and able to provide some output to users. Thanks to their features, if opportunely designed, they can affect user behavior on two levels: by means of the data gathered, promoting self-awareness to motivate change in the long term, and by means of direct physical cues, inviting users to perform some action in real time. The concept of affordance becomes crucial to the latter aspect: it is necessary to design novel, intuitive object affordances that foster a particular behavior.

Keywords: Cyber-Physical systems · Internet of things · Affordance · Behavioral change

1 Introduction

Cyber-Physical Systems (CPS) are the next generation of embedded ICT systems, interconnected through the Internet of Things and endowed with data gathering and communication functions. These systems are not technological devices as PC or smartphone, but everyday objects ad hoc enhanced with some reasoning capabilities. Due to their integration in the user environment and/or in the user body, they can track a variety of user data: physiological states (such as blood glucose level), psychological states (such as mood), behaviors (such as movements), and habits (such as food, sleep); but also environmental parameters (such as CO_2) and contextual information (such as places). All these data, related to different aspects of people daily lives, can provide the user with a "mirror" of herself, a complex representation of interests, habits, activities, etc. in her life [1]. This can support new forms of **self-***awareness* and *self-knowledge*, which can foster behavior change, promoting more sustainable or healthier behaviors, discouraging bad habits, sustaining therapeutic compliance, managing chronic diseases

R. Giaffreda et al. (Eds.): IoT360 2014, Part I, LNICST 150, pp. 82–86, 2015.
DOI: 10.1007/978-3-319-19656-5_13

[2, 3]. Self-monitoring is an effective strategy to increase a person's awareness of a targeted behavior and its level of achievement [4]. Cadmus Bertram et al. [5] have proved the efficacy of electronic self-monitoring in adopting healthier life styles.

Thus, CPSs have the potentiality to promote some degree of change in users' behaviors, and several CPSs have been developed in order to try to modify a behavior by means of self-monitoring, such as [6, 7]. This may happen at two levels:

- an immediate behavioral activation by means of cues from the object, i.e., physical output such as light, vibrations, heat, etc., which may invite the user to reflect on her current situation, thus possibly triggering a corrective action. For example, a vibration can notify the user about a wrong sitting posture;
- a long-term behavioral change, by affecting the user self-awareness via the data gathered. For example, having data about my food practice might make me aware of my bad habits and thus motivate me to change them.

As regards the former level, *affordances* [8] can play a crucial role. According to Gibson, objects naturally offer a set of functionalities to the external world: the nature of the activities that they afford depends on how a specific individual or type of individuals (like all the members of a species, or those that belong to a certain sub-group, characterized e.g. by a certain culture) can conceive of the interaction with them. Affordances thus are at the interface between the individual(s) and the world. In the case of CPSs, how to design the affordances that they offer in such a way that users may be motivated change some of their behaviors, leveraging the potentialities of the CPSs, is still an open issue in the literature. In this paper we aim at (i) presenting a complex CPS capable of promoting behavior change at the two levels mentioned above, (ii) pointing out reflections for the design of affordances in CPSs.

2 A CPS for Impacting User Behavior

To design a CPS that may promote some kind of behavioral change we need three elements:

- a smart object integrated in the everyday life of people, able to gather user data in a transparent way, and to provide some intuitive feedback to users
- a complex data structure that integrates the gathered data
- a reasoning engine able to correlate different data and to provide meaningful data visualizations and complex recommendations.

In the following, we will present a use case for showing how a CPS with the above features may promote a particular behavior, in particular *decrease sedentary habits*. A sedentary lifestyle is one of the most devious features of life in affluent societies since it causes a relapse of disease of varying severity in the population with high costs for health care services. Despite the many attempts to overcome this problem, with or without the use of ICT ad hoc solutions, sedentary habits still are a major issue in contemporary society [9]. To tackle this problem, we want to design a novel CPS exploiting e-textile, i.e., materials that enable digital components and electronics to be embedded in fabrics (e.g., clothes, covers, …), which represents the new frontier for integrating CPS in everyday life. E-textile allows to continuously and transparently gather a wealth of user behavioral data, not only about user's movements, but also about the physical environments by means of sensors embedded in the fabrics. The CPS should also have a knowledge structure to integrate these data, and advanced forms of reasoning about them so to correlate different aspects of the user's behavior from day to day (for example, to correlate mood with physical activities). To foster the behavior, CPS should provide two types of feedback: (i) on the physical level, simple feedback from the object as affordance to do a specific action: this might be a vibration or a change in the color of the object aimed at inviting the user to stand up; (ii) on the virtual level, more complex feedbacks for triggering long-term behavior change: such as recommendations and data visualization.

An open issue in this scenario is the role of affordance, as discussed in the next section.

3 Affordances in CPSs

Digital interactive systems rely on dematerialized affordances like icons, pointers, textual messages, etc., often based on metaphors from everyday activities like sitting at a desktop, watching through a window, etc. Affordances offered by CPSs, on the other hand, actually do belong to the physical world of everyday life. This opens a variety of new possibilities and issues in the design of interactive systems.

Alan Cooper in an affordance sees a stronger correlation between user and action [10]. In his view, affordances may be designed to provide users with information about the actions or activities that can or should be performed on, or with, the artifact. Everyday objects can now be endowed with computational capabilities enhancing not only their "reasoning" skills, but also their "communication" skills, their ability to invite users to perform certain actions in specific ways. The question then is how designers can integrate the physical affordances of everyday objects with some kind of new affordances that can communicate more information to the user. Can these additional information invite users to act towards specific directions, so to improve their lifestyles and wellbeing?

Part of the problem is that an individual's activities and the actions that she performs within them, and therefore her preparedness and will to perceive and act upon a specific (type of) affordance, are in turn circularly interwoven with her cultural background and her narrative situation, so that each term of these dynamics mutually defines and shapes the others [11–13]. That an artifacts like a CPS is designed from scratch is both its strength (because of the freedom that is thus granted to both the designer and the user) and its weakness (because there may exist only a thin layer of already established habits relevant to it).

One way to imagine how these novel kinds of affordances could be integrated in physical objects is provided by the notion of *phatic cue*. This may be envisaged as an affordance that communicates continuously a state and its change in time to the user. It leaves the communication channel open, establishing a continuous "phatic communication" [14] between the user and the object. Such affordance would not use "atomic messages", such as texts, to urge users to perform specific behaviors. Instead, they would use physical communication channels, such as lights, sounds, vibrations, heat, to constantly be in touch with the user. Leaving this communication channel always open can leverage the object physical features, e.g. varying its color, temperature, sound emission, to communicate a variation of its internal status or a change in the user's state.

In the use case presented, an *e-textile* can use modulations of colors or temperature of its surface to constantly keep in touch with the user. In this way, it can suggest a certain behaviors or change of behaviors to the user not through imperative linguistic messages, but via evocative, indirect and continuous affordances. For example, the e-textile in the form of a cover or a pillow, placed on the user's chair, might change its colors to communicate how much the user has been sedentary that day.

Designers and researchers should investigate how to leverage the physical characteristics of everyday objects to create these new kinds of affordances, to give life to new CPSs that, fully integrated in the user's everyday context, are constantly in touch with her.

References

1. Marcengo, A., Buriano, L., Geymonat, M.: Specch.io: a personal QS mirror for life patterns discovery and "Self" reshaping. In: Stephanidis, C., Antona, M. (eds.) UAHCI 2014, Part IV. LNCS, vol. 8516, pp. 215–226. Springer, Heidelberg (2014)
2. Bandura, A.: Social cognitive theory of self-regulation. Organ. Behav. Hum. Decis. Process. **50**, 248–287 (1991)
3. Nakajima, T., Lehdonvirta, V., Tokunaga, E., Kimura, H.: Reflecting human behavior to motivate desirable lifestyle. In: Conference of Designing Interactive Systems, pp. 405–414 (2008)
4. Burke, L.E., Wang, J., Sevick, M.A.: Self-monitoring in weight loss: a systematic review of the literature. J. Am. Diet. Assoc. **111**(1), 92–102 (2011)
5. Cadmus Bertram, L., Wang, J.B., Patterson, R.E., Newman, V.A., Parker, B.A., Pierce, J.P.: Web-based self monitoring for weight loss among overweight/obese women at increased risk for breast cancer: the HELP pilot study. PsychoOncology **22**(8), 1821–1828 (2013)
6. Froehlich, J., Dillahunt, T., Klasnja, P., Mankoff, J., Consolvo, S., Harrison, B., Landay, J.: UbiGreen: investigating a mobile tool for tracking and supporting green transportation habits. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, pp. 1043–1052. ACM, New York, USA (2009)
7. Kay, M., Choe, E.K., Shepherd, J., Greenstein, B., Watson, N., Consolvo, S., Kientz, J.A.: Lullaby: a capture & access system for understanding the sleep environment. In: 2012 ACM Conference on Ubiquitous Computing, pp. 226–234. ACM, New York, USA (2012)
8. Gibson, J.: The theory of affordances. In: Shaw, R.E., Bransford, J. (eds.) Perceiving, Acting, and Knowing: Toward an Ecological Psychology, pp. 67–82. Lawrence Erlbaum Associates Inc, Hillsdale (1977)
9. Cipriani, F., Baldasseroni, A., Franks, S.: Combating a sedentary lifestyle and physical activity promotion. Line – Help. SNLG (2011)
10. Cooper, A.: About Face: The Essentials of User Interface Design. Hungry Minds Inc, New York (1995)

11. Carassa, A., Morganti, F., Tirassa, M.: Movement, action, and situation: presence in virtual environments. In: Raya, M.A., Solaz, B.R. (eds.) Proceedings of the 7th Annual International Workshop on Presence (Presence 2004 – Valencia, Spain, 13–15 October 2004), pp. 7–12 (2004)
12. Carassa, A., Morganti, F., Tirassa, M.: A situated cognition perspective on presence. In: Bara, B.G., Barsalou, L., Bucciarelli, M. (eds.) Proceedings of the 27th Annual Conference of the Cognitive Science Society (Stresa, Italy, 21–23 July 2005), pp. 384–389 (2005)
13. Tirassa, M., Bosco, F.M.: On the nature and role of intersubjectivity in human communication. Emerg. Commun. Stud. New Technol. Pract. Commun. **10**, 81–95 (2008)
14. Jakobson, R.: Saggi di linguistica generale. Feltrinelli, Milano (1996)