Multimodal Interactions: Embedding New Meanings to Known Forms and Objects

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Abstract. The way we are experiencing and interacting with our everyday living environment define and anticipate our future behavior and actions. Today new digital technologies vastly diminish boundaries between virtual and physical world. Cross-reality design supported with recent mobile and context aware computing, gradually changed the concept of user interaction and moved it more toward usage of heterogeneous contexts, pervasive computing technologies, and multimodal spatial perception and transformed our living surroundings into smart environments, traditional living object into smart living objects. Ubiquitous computing vision implies more than ever to our lives. In order to make all these changes more human-centered in this paper we are investigated the cognitive and metaphorical aspects of future interface design strategies which could enhance user experience and ideas acceptance, communicated through multimodal interactions. In this paper we are presenting three tangible interfaces that we have developed for design and research purposes and results we collected during their public exposure. Hopefully, the results will give us sufficient insights for further investigations in the field of smart living environments and smart objects development. We believe that to fulfill these goals application and exploration of tangible interfaces frameworks and cognitive methods could be one of the crucial elements for the future research success.

Keywords: Multimodal interactions · Smart environments · Smart living objects · Ubiquitous computing · Interface design · Tangible interfaces · User experience design · Cross-reality design

1 Introduction

In this paper it has been explored how interactive user experience can be enhanced if human values and cognition directs the process of designing content and services for smart living environments [1]. The environments which are augmented with digital technology and widely spread mobile computing, could have a capability to enable automation, interactivity, ubiquity [2] while meeting user expectations and allowing interaction everywhere at almost a subconscious level [1]. Technologies itself are becoming increasingly invisible and personal; in practice this means that interaction is happening with minimal user distraction and with today user mobility at any time

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and everywhere. As pervasive computing technologies (mobile technologies, radio-frequency identification, sensors, microelectronics, wireless technologies, ambient displays, networked video-systems, context-aware systems, etc.) are becoming more reliable and cost efficient, researchers and industry show increasing interest in exploring ways to leverage them for new services design and in the development of multimodal experiential environments where users are enriched with multiple meanings and metaphors. This could have a significant impact on the time-space aspect of user experience embedded into natural living surrounding and their mobility. In such fast environments people can interact any time at any place, in metaphorical way where meaning can be transferred between users and environments, an emotional way by which users will hold a long-term memory of experience, as well as a physical way in which the immediate conscious and unconscious impact takes place through the interaction with the applied technology [3]. Ubiquitous workspaces, augmented reality, online social interactions, wearable computers, mobile applications and multimodal environments, could become key contributors into innovative service development implemented into everyday living surrounding. The concept we be followed in our experiments, as relevant to achieve those ideas, is cross-reality design.

Cross-reality is an informational or media exchange between real- and virtual-world systems that closely conceptually correlates to idea of a smart living environments development [4]. For example, environments built upon cross-reality principles could serve as a bridge across sensor networks and Web-based virtual worlds, improving people's interactions with each other and with the physical world [5]. With the potential of bringing together two worlds that have been disjoint and of enriching user experiences, companies have started to change their service logic and are beginning to implement cross-reality ideas into widely used consumer devices such as: location and orientation in mobile phones (e.g. GPS in the mobile phones), biometrics in clothing (e.g. pedometers in Nike shoes), on-body gesture recognition in gaming controllers (e.g. accelerometers in the Nintendo Wii), off-body gesture recognition in gaming consoles (e.g. cameras in the Microsoft Xbox Kinect).

Together with the researches related to cross-reality as design concept (embraced with several major themes including augmented reality, mixed reality, ubiquitous computing, and wearable computing) interface design has become an important issue to deal with in realization of this concept and evolved toward exploration of the relationship between physical representation and digital information. Important first steps were done by Fitzmaurice, Buxton, and Ishii who described a new conceptual framework in their discussions about "graspable user interfaces" [6]. In further development Ullmer and Ishii extended the idea and proposed the term "tangible user interfaces" [7]. The framework supports concept where interface should not be just an input device but rather artefact which simultaneously integrated physical representation and control. Despite traditional graphical user interface approach where exists clear distinction between input (mouse, keyboard) and output devices (monitor), tangible interfaces tends to diminish this distinction.

2 Related Research

The researchers have been working for more than a decade on meaningful concepts for integration between real and virtual space. Followed by technology improvements, cross- reality ideas started widely to appear in projects ranging from interactive art installations, like Drew Harry's Stiff People's League installation (see http://labcast.media.mit.edu/?p=26) or The Parcer, an online interactive art installation based on the instrument capable to facilitate multiuser composition in a collaborative environment [4], to augmented reality in a Touring Machine project [8] or ubiquitous workspaces like the work by Gloria Mark [9] focusing on intensive design activities such as the design of NASA space missions or complicated software. Collaboration between participants, user-generated content together with intention to improve communication using 3D visualization were primary aspects to explore within the first experiments in cross-reality design [4]. Second Life, an online virtual world launched by Linden Lab in 2003, has been chosen by a group of researchers as the virtual platform for cross-reality experiments Shadowlab [10] with environments that supported user-generated content. A new approach to the visualization of information, which is one more considerable aspect of multimodal pervasive technology application, can be seen in projects such as Google Earth visualizations of the James Reserve done by the Center for Embedded Network Sensing [11]. Domain of data visualization was among the first to accept commercial implementations of cross-reality in the projects such as IBM's visualization of data center operation (see http://www.ugotrade.com/2008/02/21/the-wizard-of-ibms-3d-data-centers/) or VRcontext's Walkinside visualization software (www.vrcontext.com). Cross-reality systems also have the potential to reconfigure service environments into creative workspaces with high flexibility as a core design principle for certain collaborative projects [12]. Collaborative space made of sensate media [13], responsive furniture, paper-based interfaces and a mappable project space [14], could be a creative playground for future users of a living environments co-created by themselves.

Transformations we are experiencing continuously through new media have changed the way we are interacting, sensing and engaging with the objects in our everyday environmental space. What we can see from the examples above is that usage of cross-reality systems and concept of tangible interfaces could help us for example to extend collaborative tools into networked space, enrich user engagement in the experience of virtual space and move perception toward advanced levels. With such potential, we believe that cross-reality and interface design concepts based on usage of everyday objects and representations of known forms have a potential to radically affect the way we are experiencing services embedded in our living environment. This could lead to redefinition of existing interface and design communication practices and possibilities for application within the multimodal cross-reality smart living context: meaningful end user experience (collaborative, metaphorical, contemplative, creative, aesthetical).

3 Interaction and Communication

Merleau-Ponty's integrated view of action and perception makes an interesting starting point for a discussion of meaningful interactive experiences together with meaningful design. Based on his theory it is possible to lead users into interactions with the computer that are meaningful at a very basic level. With an application of Merleau-Ponty's philosophy to human-computer interaction, we get a new understanding of interaction as perception. We consider interaction as perceptual process which involves both human mind as well as human body, then distinction between tool and media disappears. Involvement of total body into perception transform it into active process and it is no longer the passive reception of information through a medium. When action in the same way is seen as an expression of our being-in-the-world, it no longer has meaning to see as a purely body activity.

From the other side, Activity Theory emphasizes the distinction between internal and external activities. The user experiences, raised on multimodal interactions, in three interactive installations (MindCatcher, Inner Body and Ciklosol) presented in this paper relate to internal processes such as perception, cognition and emotion and express them through external activities represented by participants' behavioral changes. The theory also highlights the importance of interface development for further mediation between internal and external human activities [15]. This opens the experimental space to usage of known objects and forms, with already embedded meanings, into development processes of contextually enriched environments, interaction and interface design. Hence, the importance of metaphors and aesthetic in design process could be pursued more comprehensively through Activity Theory [16]. According to Activity Theory human nature correspondence between the level of aesthetics and the activity level is driven by complex motives, of which the individual actors are seldom aware [17]. Engestrom also argues that the level of Activity is mediated by 'imaginative artefacts' that give identity and comprehensive perspective to human practice. Based on that theoretical foundations, we developed three experimental interactive installations where we investigated several different approaches to contextual and interface design applied in a meaningful and aesthetically conceptualized responsive environment.

4 The Floor, the Bicycle and the Heart

As mentioned previously, the term Tangible User Interfaces (TUIs) was presented by Ishii and Ullmer [7] in 1997 and defined as user interfaces that augment the real physical world by coupling digital information to everyday physical objects and environments. Terminology varied from within various researches, e.g. "passive real-world props" [18], "graspable" [6], "manipulative" [19], or "embodied" [20], till eventually Ullmer and Ishii [21] did suggest to adopt the most common phrase, tangible, to refer to them collectively. They all share the same basic paradigm of a user manipulation of some physical object(s) via physical gestures which are detected by computer system and gives feedback accordingly.

Furthermore, Ishii and Ullmer defined them as one that eliminates the distinction between input device and output device, although interesting interaction regimes are

highlighted by relaxing these expectations [21]. According to Fishkin [22] broad scenario that characterizes TUIs would be:

1. *Some input event occurs.* This input event is typically a physical manipulation performed by users with their hands on some "everyday physical object," such as tilting, shaking, squeezing, pushing, or, most often, moving.
2. *A computer system senses this input event*, and alters its state.
3. *The system provides feedback.* This output event is via a change in the physical nature of some object – it alters its display surface, grows, shrinks, makes sound, gives haptic feedback, etc.

In case of three experiments with tangible interfaces and cross-reality, we are presenting in this paper, the different scenarios were used in the following manner:

The interactive installation MindCather was based on floor interface as input device and monitor as output device were input occurs when round colored circles enriched with sensors were pressed by foot (Fig. 1). As respond to that input, computer system played sound and generated colored circles on the screen, which were positioned according to contextual logic of the system. Multimodal interactions on the floor interface had two important manifestations, individual and collective in physical and virtual environment as participants were in position to collaborate between each other directly on the interface as well as joint generated digital content into one co-created artefact. The system direct feedbacks to the users during the interaction were light and sound indications which corresponded to user behavior on the floor interface. Aesthetically the floor interface represents completely authentic artefact without any reminiscence on surrounding everyday objects. So the way users perceived the interface was abstract and metaphorical, based on reaction on recognizable and sensory manifestations which forms through multimodal did not disturb desirable multimodal interactions offered by the responsive systems.

The interactive installation Ciklosol uses exercise bicycle as input device, and monitor as output device. The input occurs when users are starting with paddling the bike interface (Fig. 2). Speed of paddling correlated directly with the speed of projected sunflower rising. Multimodal interaction in this case consisted of sound effects

Fig. 1. The MindCatcher floor interface with colored circle switches (Color figure online)

Fig. 2. The Ciklosol bike interface where paddling is trigger to the system

which referred to sound of wind and birds in the field, interaction with the exercise bike interface through paddling and visual representation of the digital information generated from user inputs. Conceptual idea behind this interactive experiment was to connect body actions and movement based interaction with the metaphorical message of connection between people and the environment and how important is human role and invested energy in environmental preservation.

The interactive installation Inner Body had a model of human heart as input device, and the output device was wall projection. Users had to touch and grab by their hand the heart sculpture placed on the tube which was filed with the blood in same amount as it is in human body (Fig. 3). The system reacted on human touch and triggered audio-visual respond to the user. The interaction concept was based on simulated medical examination as the system made feedback on user gesture of grabbing the heart interface. Despite first two interface appearance, MindCatcher's abstract floor interface and Ciklosol's everyday living object (bike) interface, the Inner Body interface manipulated with a human heart as a symbolic representation of vitality, begging and end, living and dying, health and sickness.

Many researches today are directed toward realization of the ubiquitous computing vision which has in the core of its idea distribution of computing in everyday life. In order to fulfill such environmental concept transformation of traditional objects (known to us in meaningful and functional way) into so-called *smart living object*s which are augmented with digital technology and enhanced with additional functions affecting user experience with new interactions and multi-sensory perception. We could say that concept of tangible interfaces and tendencies to enrich living environments with *smart*

Fig. 3. The Inner Body Heart Interface, the output occurs when user grab it

living objects correlate closely between each other and lead us to sustainable design choices. Some questions has been raised from these choices such as in which direction we should extend functions (in correlation with their traditional features) or even more important perception and human understanding of new interactions we are capable of adding. Also important question to answer in this research was, to what extend user feels embodiment of the system feedback with physical environment where interaction is happening and how that depends on connection between input and output?

Fishkin [20] suggested four levels of tangible interfaces embodiment characteristics: *full* – is characterizing the output device which is at the same time the input device, *nearby* – characterizing the output that takes place near the input object, typically, directly proximate to it, *environmental* – is characterizing the output placed somewhere around the user, such as audio, light or heat levels, *distant* – is characterizing the output placed on another screen, or even another room. In all three experiments we are presenting in this paper we could say that the interface audio-visual attention is switched between the input (the floor interface, the bike interface, the heart interface) and the output (the wall or monitor projection), and as such the floor interface combines *distant* and *environmental* and the bike and the heart interfaces belong to *distant* type of tangible interfaces category.

Beside embodiment, metaphor represents highly important and powerful ingredient of any design and could help us give answers to question related to perception and human understanding of interactions embedded to objects and form users can recognize. Cognitive anthropologists argue that the ability to use metaphor is the ultimate characteristic that separates the minds of early humans from modern humans [23], philosophers of science believe that metaphor lies at the heart of how our theories of the world are created, explained, and communicated [24, 25]. All these studies together with rules of design and principle can be applied to user interface design and its implementation to smart environments, especially considering its physical tangibility. A designer can use a whole realm of physically afforded metaphors such as the shape, the size, the color, the weight, the smell, and the texture of the object to invoke any number of metaphorical links. Mithen [23] argues that the most powerful metaphors are those which cross domain boundaries, such as by associating a living entity with something that is inert or an idea with something that is tangible. If we take into account this statement, then tangible interfaces and cross-reality concepts possess all the required potentials to provide meaningful metaphors. That could lead into deeper immersion and user experience, which was of high importance to be achieved during the development of the three interfaces. In order to quantify the amount of metaphor, Fishkin [22] roughly group metaphor into two types: those which appeal to the shape of an object, which he termed metaphor of noun, and those which appeal to the motion of an object, which he termed metaphor of verb. The more any types of those metaphors are used, the higher would be placed the interface on this scale. He based this grouping on results from cognitive psychology [26], [27], which show that noun and verb are deeply natural and intuitive concepts arising even in deaf–mute children who are taught no linguistic grammatical structure. It is clear that in order to succeed with an application we must take care to raise metaphors as closest as possible to a level of understandable and meaningful end experience or else the power of metaphor can weaken the value of the application, or require an extra level of learning. Furthermore,

Fishkin [22] explains that promotion of metaphors as one of the key factors in interface development could take us to the great body of knowledge about metaphors and its use in other fields. He then refers to a five different fields we could involve and expand domain of this discourse, cultural anthropology – where metaphors vary from culture to culture which could be a crucial knowledge in improving TUI design, evolution of cognition – where research is focused on possibilities of giving additional meaning to the objects and explored the power of metaphor in that context, cognitive psychology – cognitive psychologists have found that nouns and verbs appear deeply ingrained in our consciousness, even for deaf–mute children who are taught no sign languages [26], [27], industrial design – if we are thinking of people who are constantly facing employment of metaphors in their work then industrial designers would belong to the most experienced in this matter. For example Gorbet [28] uses the investigation of "product semantics" in industrial design (examining the employment of metaphor in the design of everyday objects, such as toasters, TV sets, and answering machines), to illustrate the trade-offs of higher and lower levels of metaphor. Obviously there in no unified way we could use metaphor in design process of any tangible user interface such as the floor, bike or heart interfaces we investigated. But, by giving an attention to available choices, we will be able to create more effective design.

In case of the installation Mind Catcher the metaphor of the whole system should have been very clear in order to immerse participants deeply into the creative act. Thus, any unnecessary cognitive overheads could have disturb user experience through mismatch between the operations on the object and those of the analogized object. The floor interface was raised from the conceptual ideas rooted-in the installation Mind-Catcher overall research intention (measuring level of creativity in interactive act) and all the metaphors were designed to achieve specific experiential effect through created aesthetical environment. The metaphors were derived mainly from the shape and forms used for interface was construction, according to Fishkin [22] we could address it to metaphor of noun. Partly the metaphors were derived from body movements, during the interaction, performed by users and their personal attachment to it, metaphors of verb. Hence, during the period of exposure, through our personal observations and interviews with the users, we concluded that the floor interface itself could be re-used in some other applications and could cognitively lend to any number of situations such as stand-alone musical instrument, instructional dance platform or interactive theatre stage. However, by putting it in certain context, the metaphors attached become clear and can leverage the received meanings and ideas from many fields.

The Inner Body heart interface invoked metaphors based on shapes and forms recognition, and on correlation with our physiological and cognitive perception of the used object. Important role in case of the heart interface as well as the floor interface was given to the ambient in which the interaction was happening, together with multimodal perception and embedded metaphors which empowered user experience significantly. Upon this aesthetical foundation, the interactive installation Inner Body tended to induce, through interaction with the heart interface and virtual outputs projected on the wall, fear of dead and sickness through actions and responds participants' were getting from the digitally augmented responsive environment they entered. On a subconscious level the ideas of finality and focusing on real life values were tried to be communicated with the users.

Like in case of the MindCatcher floor interface, the Ciklosol bicycle interface belongs also to interfaces which combine metaphor of noun and verb type. The used traditional object itself was known to everybody as well as it functions, but in this case through cross-reality design and its augmentation with digital technology we tried to extend its original functions and enhance user experience and communicate ideas how important is human engagement in environmental protection initiatives. Through act of paddling, body movement based interaction had intention to deeply immerse participant in their role of saving and raising virtual sunflower projected on the screen.

In all of our three interfaces and installations environment conceptualization metaphors have had important role in our research goals fulfillment. As such, selection of shapes, forms, object, colors and textures we used to design interfaces was of a great importance and directly reflected on user actions and their understanding of embedded meanings. We believe this could be the direction to follow in use of multimodal interactions and cross-reality as a concept for future service design and human-relationships development integrated into everyday living environments.

5 Findings and Future Directions

With the experiments presented, our research goals were to investigate potentials of using tangible interfaces and known objects and forms in case we are extending their functions and embedding new meanings in future development of ubiquitous computing vision, design and innovate services within smart living environments. The idea of making environments enhanced with contemporary digital technologies in order to design more human-centered, emotionally and cognitively attached to everyday living surrounding, directed this research toward better understand of relation between physical world and the digital systems feedback, the way users feel that embodiment and how that could be applied in desired communication between users and devices, users and environments, and users and services. The data in the experiments were collected from the following sources:

- Personal observations (MindCather, Cklosol, Inner Body)
- Recorded user sessions with web camera (MindCatcher)
- User interviews (MindCather, Cklosol, Inner Body)
- Personal data delivered through login process (MindCatcher)
- Paths walked by users from the floor interface (MindCatcher)

The interviews were structured [29] so that the users were firstly indirectly observed during their trying of the installation. The interviews were done in the form of an informal, open conversation with participants. The goal of those interviews was to reveal the participants personalized qualitative impressions/opinions. The questions regarding their perception of the interfaces and the environment where interaction happened, were the following:

1. Describe your experience during interaction with the installation?
2. Describe meanings and metaphors which lead your actions?
3. Do you feel any connection between your inputs and generated outputs?

The MindCatcher research projects lasted for three years. During that period the installation had been exposed publicly three times and throughout that period 112 user sessions were recorded and 63 interview were done with the participants. Even the project was upgraded (in order to leverage user's multimodal interactions and engagement,) mostly in a sense of the system feedback and generated outputs, the floor interface, in all its original aesthetical and functional design, remained the core interaction element of the installation. In this paper we will address only findings which correlate to the research topic of interface design and its application in user perception and cognition. The different visitors had different experiences with computer-enabled environments and as such, the major divergence in the group's answers to the questionnaire were used as a critical measurement. For this research the answers on question regarding metaphors, analogies or resemblance they could attach to the floor visual appearance were interesting as the MindCather floor interface was the abstract artefact assembled from known forms and shapes but nor explicit like ones in the Ciklosol and the Inner Body experiment. The answers were different, based on personal preferences but also on social-cultural differences, so we concluded it reminded them of a big ray fish, solar system they could stand on, interactive garden they could produce music with, etc. This type of analogies directly refers to the potentials of interface design to involve different fields such as cultural anthropology, evolution of cognition, philosophy of science, cognitive psychology which could empower user interaction and increase experience. What was more important for us is how those analogies were affecting users interactions and were involved in dissemination of ideas embedded into context of generated audio-visual outputs. The majority of participants described their experience in the installation as playful, creative and exciting (73 %) or sometimes confusing but dynamic and pleasant (23 %), while only minority of them found it disturbing and pointless (4 %) (Fig. 4). The first two groups were very inspired to describe metaphors which motivated them to continue with interaction, enjoy the feedback they were getting from the interface and deeply immerse with the creation of virtual audio-visual artefact they were connecting with the meanings and metaphors gained from the interface itself. As such, most of them felt that they had good control over the installation, sound, projection and interactivity (58 %), had good control over the floor interface but did not understand how (or not interested) to control projected personal audio-visual creation with it (39 %), had bad control over the installation (3 %) (Fig. 5).

Through achieved embodiment characteristics which reside somewhere between the environmental and the distant type of interface and the metaphor which could be moved from metaphor of noun to metaphor of noun and verb, the system was capable to communicate different ideas, trigger related emotions and induce user actions. The way users mentally access and experience the interface and the ideas behind installation narrative were of high importance. However, for some of them the fact they were in the interactive responsive space was enough to please their expectancy and behaviour. In case of MindCatcher floor interface, as well as the other two experimental projects, the cross point between virtual reality and physical reality was its tangible designed interfaces. As such, user's interactive freedom and open space for new experiences depended a lot of shape, objects and forms used in their design.

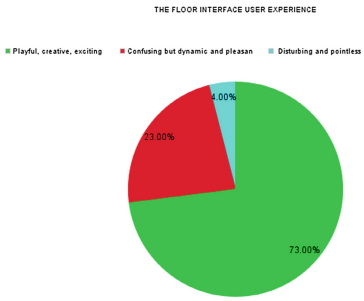

Fig. 4. TFI user experience

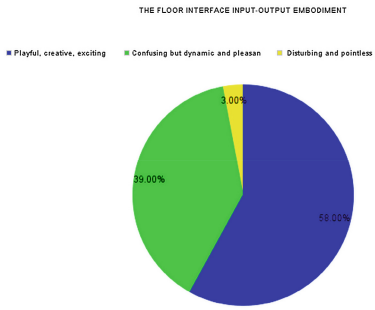

Fig. 5. TFI input-output embodiment

In our second experiment we created interface made of exercise bicycle. In comparison with the floor interface which was abstract this time the interface was made of traditional object we addressed certain functions and attached meanings based on our cognition. We used during the interface conceptualization and design that knowledge in order to maximize user engagement and immersion. The important issue was to extend existing functions and embed additional meanings to the used object. Additionally, to make possible effective transmission of ideas implemented in installation narrative and enhancement of user experience. Hence, we used paddling as a trigger for the system input-output communication. As the users were familiar with the used object we did not have any problems in their understanding of how to use the interface unlike in case of the Mind Catcher project. Participants enjoyed interaction from the start as we embedded it to pleasant physical activity. Second issue we explored by interviewing participants was connected with meaning and metaphors they experienced and how they perceived relationship between their inputs and audio-visual outputs they were getting from the system. From the answers collected we detected that participants were going through three different experiential phases during the interaction. The first phase, in which they were attracted with the traditional functions of the object and the physical environment which differentiate from the rest of the surrounding. In this phase they were enjoying paddling and introducing to the system. In the second phase, after they learned about connection between the inputs they were generating and outputs, they were involving themselves deeper into the responsive environments they were interacting with. They still had weak understanding of metaphors and meanings of the visually presented in outputs. For most of them moving of the virtual sunflower (up and down) according to energy they invested in paddling, was just visual representation of speed they achieved (the same way they were experiencing on the other sport machines). In the last phase, triggered with the multi-sensory perception and exposed to metaphors and meanings, they began to understand they developed emotional relationship (they fought now for life of their personal sunflower by giving it their own energy) with the virtual environment they communicated with during interactions (Fig. 6).

Even not all of them went through all of the three experiential phases, the fact we managed to induce them as part of user experience, showed the potentials of extending functionalities of traditional objects within smart responsive environments.

Fig. 6. The Ciklosol interface connection between user interaction and the system outputs

Third interface we investigate was The Inner Body interface which was stylized model of a human heart and cardio-vascular system. Design language used was metaphorical but not as abstract as in case of MindCatcher. The forms, objects and its representations were known to the participants even though they were not everyday life surrounding like in case of bicycle we used in the Ciklosol. Like in case of bike interface, participants were also familiar with the functions of heart and cardio-vascular system but unlike the Ciklosol humans were not addressing any interaction to the heart as it resides in our inner body. In conceptualization of the gesture which would trigger the system, the idea was to diminish psychological distance between Outside - Inner body and increase awareness of our "other" existences we cannot experience perceptually. That was the reason we instructed participants to grab the model of the heart (a bit bigger than the normal human heart size) in order to start with the so called "medical exam" and trigger the system (Fig. 7). With the intensive tactile gesture performed on the model of a human heart, together with the additional colors, shapes and objects which were part of the interface, we wanted to achieve only one state in desired user experience and that is contemplative. Hence, to provoke such fast and radical immersion of the users we paid a lot of attention to environment where interactions were happening so we used white textile, we used smell characteristic for the

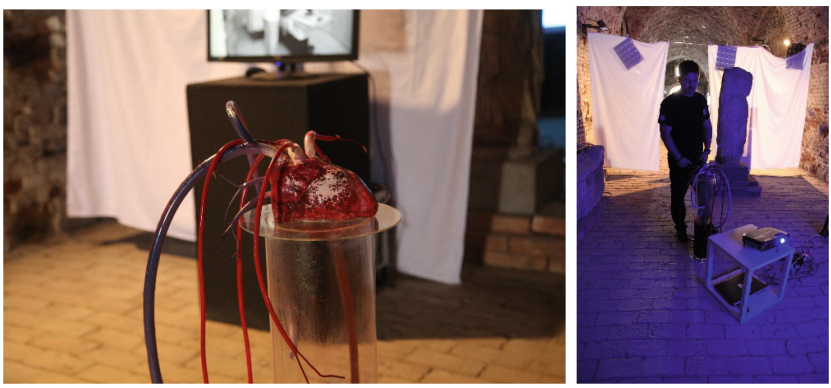

Fig. 7. The Inner Body model of a human heart and cardio-vascular system interface

hospitals, played magnet resonance sound and loud beats of the heart during the fake examination, played video with real author's magnet resonance exams before entering the interaction space. People were frightened no matter they knew it was not real and that all was a part of directed performance. All of them understood the metaphors and the communication between them and the system was clear and easily understandable. What we used in this case to provoke desirable effects were deeply inherited fears in our consciousness we react on subconsciously. After interviewing the participants we concluded that even they were absolutely aware that it was fake exam, they were afraid of results and panicking during the session.

Presented experiments showed us several factors and circumstantial parameters we could use in service design concepts and strategies which are directed toward usage of interaction, cross-reality and smart environments. We are referring in that sense to the urban surroundings which are augmented, with contemporary digital technologies and everywhere computing. We also found that metaphors and meanings we embedded to surrounding objects and forms by using technology and interaction, could play crucial role in future service or social well-being ides acceptance. The way we add functions to the objects as well as the conceptualization of the environment where interactions will happen, has also high impact on user experience and engagement. Tangible user interfaces such as the MindCatcher floor, Cikolos bike and the Inner Body heart are abandoning the conventions of computer virtual world and taking steps into the physical world and reveals many interesting areas for future researches. By moving interfaces toward cross-reality technologies we are changing the whole design approach from philosophy computer–human interfaces into the realm of human interfaces in general. Our further research will be directed toward experimentation with the various objects as interfaces and the most sufficient way we can embed different metaphor types and appearances in user experience and in its understanding. This could lead us to better usage of everyday objects and forms within smart environments. Also it could become a key factor in shortening the learning curve throughout the process of accepting new technologies and ideas important for further society and community development.

References

1. Weiser, M., Brown, J.S.: The coming age of calm technology. In: Denning, P.J., Metcalfe, R. M. (eds.) Beyond Calculation: The Next Fifty Years of Computing. Copernicus, Göttingen (1998)
2. Muller, J., Alt, F., Michelis, D. (eds.): Pervasive Advertising, pp. 1–30. Springer, Berlin (2011)
3. Van Waart, P., Mulder, I., De Bont, C.: Meaningful advertising. In: Muller, J., Alt, F., Michelis, D. (eds.) Pervasive Advertising, pp. 57–79. Springer, Berlin (2011)
4. Coleman, B.: Using sensor inputs to affect virtual and real environments. IEEE Pervasive Comput. **8**(3), 16–23 (2009)
5. Dindar, N., Balkesen, C., Kromwijk, K., Tatbul, N.: Event processing support for cross-reality environments. IEEE Pervasive Comput. Mag. **8**(3), 34–41 (2009). Special Issue on Cross-Reality Environment

6. Fitzmaurice, G., Ishii, H., Buxton, W.: Bricks: laying the foundations for graspable user interfaces. In: Proceedings of the CHI 1995 Conference on Human Factors in Computing Systems, Denver, Colorado, pp. 442–449 (1995)
7. Ishii, H., Ullmer, B.: Tangible bits: towards seamless interfaces between people, bits, and atoms. In: Proceedings of the CHI 1997 Conference on Human Factors in Computing Systems, Atlanta, Georgia, pp. 234–241 (1997)
8. Feiner, S., MacIntyre, B., Hollerer, T.: A touring machine: prototyping 3D mobile augmented reality systems for exploring the urban environment. In: Proceedings of the 1st International Symposium Wearable Computers (ISWC 1997), pp. 74–81. IEEE, CS Press (1997)
9. Mark, G.: Extreme collaboration. Commun. ACM **45**(6), 89–93 (2002)
10. Lifton, J., Laibowitz, M., Harry, D., Gong, N., Mittal, M., Paradiso, J.: Metaphor and manifestation: cross reality with ubiquitous sensor/actuator networks. IEEE Pervasive Comput. Mag. **8**, 24–33 (2009)
11. Askay, S.: New visualization tools for environmental sensor networks: using Google earth as an interface to micro-climate and multimedia datasets. Master's thesis, Department Environmental Sciences, University of California, Riverside (2006)
12. Reilly, D., Voida, S., McKeon, M., Le Dantec, C., Edwards, W.K., Mynatt, E., Mazalek, A.: Space matters: physical-digital and physical-virtual co-design, in the inspace project. IEEE Pervasive Comput. **9**(3), 54–63 (2010)
13. Mistree, B.F.T., Paradiso, J.A.: ChainMail – a configurable multimodal lining to enable sensate surfaces and interactive objects. In: Proceedings of TEI 2010, pp. 65–72 (2010)
14. Reilly, D., Tang, A., Wu, A., Echenique, A., Massey, J., Mathiasen, N., Mazalek, A., Edwards, W.K.: Organic UIs and cross-reality spaces. In: 2nd International Workshop on Organic User Interfaces (OUI 2011), TEI 2011, Madeira, Portugal (2011)
15. Nardi, B. (ed.): Context and Consciousness: Activity Theory and Human-Computer Interaction. MIT Press, Cambridge (1996)
16. Leont'ev, A.N.: Activity, Consciousness, Personality. Prentice Hall, Englewood Cliffs (1978)
17. Engeström, Y.: Learning, Working and Imagining: Twelve Studies in Activity Theory. Orienta-Konsultit Oy, Helsinki (1990)
18. Hinckley, K., Pausch, R., Goble, J.C., Kassell, N.F.: Passive real-world interface props for neurosurgical visualization. In: Proceedings of the CHI 1994 Conference on Human Factors in Computing Systems, Boston, Massachusetts, pp. 452–458 (1994)
19. Harrison, B., Fishkin, K., Want, R., Gujar, A., Mochon, C.: Squeeze me, hold me, tilt me! An exploration of manipulative user interfaces. In: Proceedings of the CHI 1998 Conference on Human Factors in Computing Systems, Los Angeles, California, pp. 17–24 (1998)
20. Fishkin, K., Moran, T., Harrison, B.: Embodied user interfaces: towards invisible user interfaces. In: Chatty, S., Dewan, P. (eds.) Engineering for Human–Computer Interaction, pp. 1–18. Springer Science + Business Media, New York (1998)
21. Ullmer, B., Ishii, H.: Emerging frameworks for tangible user interfaces. In: Carroll, J.M. (ed.) Human–Computer Interaction in the New Millennium, pp. 579–601. Addison-Wesley, New York (2001)
22. Fishkin, K.P.: A taxonomy for and analysis of tangible interfaces. J. Pers. Ubiquit. Comput. **8**(5), 347–358 (2004)
23. Mithen, S.: The Prehistory of the Mind. Thames and Hudson, London (1996)
24. Brown, T.: Making Truth: Metaphor in Science. University of Illinois Press, Champaign (2003)
25. Kuhn, T.S.: Metaphor in science. In: Ortony, A. (ed.) Metaphor and Thought, 2nd edn, pp. 1–539. Cambridge University Press, Cambridge (1993)

26. Goldin-Meadow, S.: Structure in a manual communication system developed without a conventional language model: language without a helping hand. In: Whitaker, H., Whitaker, H.A. (eds.) Studies in Neurolinguistics, vol. 4, pp. 125–209. Academic Press, New York (1979)
27. Goldin-Meadow, S.: The representation of semantic relations in a manual language created by deaf children of hearing parents: a language you can't dismiss out of hand. Ph.D. thesis (1975)
28. Gorbet, M.: Beyond input devices: a new conceptual framework for the design of physical–digital objects. Masters thesis, MIT Media Laboratory, Cambridge, Massachusetts (1998)
29. Kuhn, D.: The Skills of Argument. Cambridge University Press, Cambridge (1991)