InGrid: Rethinking the Embodied Space

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Abstract
In this paper, we discuss the embodied perceptual and personal spaces that lead to the design of InGrid, an Interactive Grid table. InGrid offers several affordances to the user that could not only interact with tangible and intangible objects but also with other users.

Author Keywords
Interactive surfaces; multi-touch; tabletops; peripersonal and extrapersonal spaces. embodied space.

ACM Classification Keywords
H5.2 [Information interfaces and presentation]: User Interfaces: Input Devices and Strategies, Interaction Styles.

General Terms
Design, Human Factors.

Introduction
The way technology changes our relationship to our body and space changes not only our acquisition of knowledge but also our interaction with cognitive tools. This aspect of embodied cognition raises interesting questions related to the way tools or technology can be perceived or felt as being an extension of the body. On

one hand, tabletops are a very good example of embodiment; they extend the user's actions but also they modify her perceptual and personal space. On the other hand, they are a good paradigm for natural User Interface (NUI) and tangible user interfaces (TUI). In this paper we discuss the concept of embodied personal and perceptual spaces while using interactive tabletops that has been the starting point of designing InGrid; an interactive grid table.

Related Work

Multitouch tabletops and surfaces are not a new concept in HCI. Several interaction techniques were developed such as vision based detection [13], tiled LCD displays [10], fingerprints [7], or finger orientation [17]. They all share two characteristics in common: i) they are designed for collaborative interaction, and ii) their cost limits their usage to work or research environment, although some research tend to develop tabletops for living spaces [15]. Recent research development focuses on the blended interaction aspect of surfaces, i.e. interaction in both physical and virtual objects. For instance, IdeaVis and AffinityTable both used paper based interaction techniques and offer the possibility of personal space [4], [5]. NiCe and CRISTAL allow also the interaction between tangible and intangible interfaces. For instance, CRISTAL allows controlling electronic appliances in a room through a touch screen coffee table. The whole concept has been designed to bring this technology to household setting [15]. In a work setting, the "future meeting room", not only blends the interaction between different types of display (small and large screens) but can keep the personal space private if desired during the interaction with touch-screen tablets. Finally, Sprindler et al. extended the interaction space to the 3D space above the table by using small screen displays [16]. All these concepts deal with the embodied perceptual and personal spaces detailed below.

Embodied perceptual space

When interacting with virtual content, the perceptual space can be divided into physical and virtual spaces [18]. Both spaces can be divided in turn into embodied and disembodied spaces. The disembodied space is any tangible or intangible space that does not necessary extend physically or virtually the body; while the embodied space is the space where knowledge acquisition and human experience take place. It is the space of perceptual experience and consciousness [12], the space where a user interacts not only with tangible but also intangible (virtual) objects. Indeed, embodied cognition is where the body and mind are. Actions in the world affect our knowledge acquisition and human experience and, in turn, knowledge, experience and consciousness affect the way we act in the world.

Collaborative tabletops are an interesting concept to study the embodied space; Not only they extend the users' sensorimotor capacities but also their cognitive abilities. While interacting with collaborative tabletops or touch-screen tablets, the tangible and/or intangible object can be felt as "temporary" extending the body sensorimotor space. As explained by Lenay [11], the temporary aspect of "feeling of ownership" is that the tool extension ceases when the user is not anymore in contact with the object. When the user is not touching anymore the touch-screen the embodiment extension stops.

Another important aspect of tabletops is that the embodied perceptual space can be intangible. Indeed, if

the user is observing other agents interacting with the virtual content on the multi-touch tabletop, and thus being cognitively engaged in the task without necessarily touching the screen, the embodiment extension would remain at a cognitive level even if it terminated at the sensorimotor level. Costantini et al. demonstrated that observing someone else acting with a tool may extend the representation of peripersonal space and shape the way we coordinate and integrate our own actions with those of others [2]. In summary, the embodied space in collaborative environments depends not only on the user's interaction in a specific spatial configuration, which defines her peripersonal space but also on the way other users are interacting with the same display, the same space, or the same content, which can represent, at some degree, their extrapersonal space.

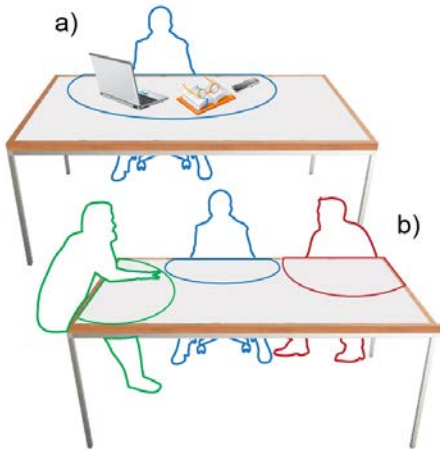

Figure 1: The peripersonal space (shown by half circles) on the same table layout when working a) alone: extended workspace; b) or together: shrunk workspace.

Embodied personal space

From a neuropsychological framework, the embodied personal space is mainly described in terms of peripersonal and extrapersonal spaces[1]. For instance, if a person is working by themselves on a table, they can extend their peripersonal space by surrounding this space by several objects such as books, a laptop, or a cellphone (Figure 1a). Their peripersonal space on the same table would shrink if another person was sitting nearby or several were working at the table (Figure 1b). The sensorimotor invariants in both situations are different because both sensory inputs and space of actions have been modified. Neurological evidences in Monkeys showed that the same neurons that fire for the nearby peripersonal space start firing near the far end of a rake, when the monkey had become skilled in using the tool that extended the reachable space [9]. This suggests that while interacting with flat surfaces or tabletops, the peripersonal space can be modified depending on the tools used to extend the body but also depending whether this space is inside or outside the person's workspace as suggested by another study that showed that neurons are encoded differently whether objects in the peripersonal workspace prevented the monkeys from reaching the area close to the body [1].

Although, according to De Preester's classification [3], an interactive tabletop would be rather a technology incorporated to the body rather than an extended one. De Preester argues that is not a matter of permanence or separability but rather a difference in the feeling of body ownership. Indeed, she distinguishes between embodiment extension and embodiment incorporation depending on whether the tool changes body ownership. Although this distinction raises interesting questions related to embodied cognition, we agree with Lenay, that De Preester's classification needs some clarification. For instance, De Preester claims that perceptual prostheses such as microscopes or telescopes do not change the nature of our perceptual experience and in this sense are more incorporated than extended to the body. However, when observing a planet with a telescope or a micro-organism with a microscope, you can see details that the human eye cannot experience. Zooming, in this case, is an "extended" capacity to the human eye limitation. The sensation at the end of the magnifying tool and the action at focus knob both define the space of sensorimotor invariants [19], [20], [21]. If one

[1] A third space, that is not discussed here, represents the pericutaneous space that consists of the space just outside the body and is also part of the neuropsychological space.

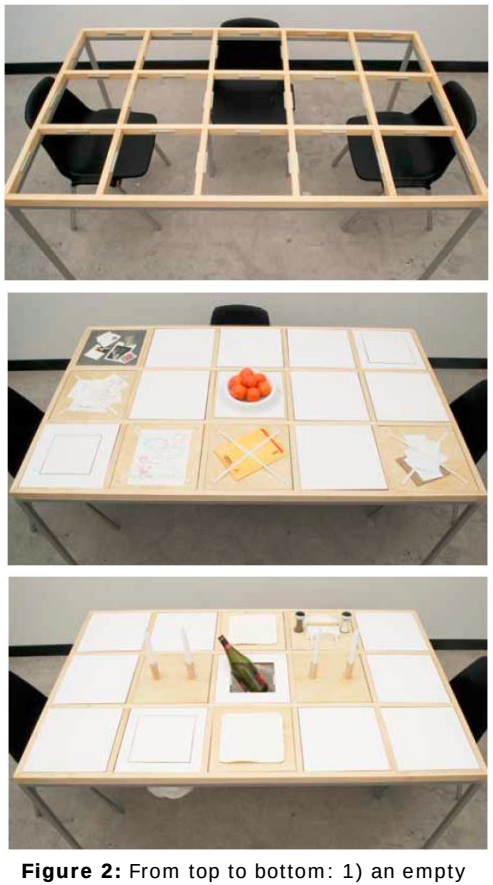

Figure 2: From top to bottom: 1) an empty grid table creates a variety of affordances; 2) fruit basket, writing board, storing mails, cutting board, and drawing area; 3) or a romantic dinner with candle holder, wine bucket, salt and pepper holders, and pot holders.

removed one's eye from the magnifying tool, a drastic change occurs in the sensorimotor contingencies [14] and thus in the perceptual experience (i.e. from seeing a living micro-organism to a tiny spot on a microscope slide). We believe that the embodied experience depends on the permanence (temporary or not) of the object in the embodied space and the changes that can bring within sensorimotor contingencies. This can be obtained by having a completely immerged user in the space of interaction. By analogy, interactive tabletops can be experienced as an extension of the body because not only the users are immerged in the sensorimotor space but also through the space of shared and private knowledge. The sensorimotor contingencies of interactive tabletops represent the space of actions and sensations that can be defined by extracting the sensorimotor invariants in both peripersonal and extrapersonal spaces.

InGrid

The Grid Table

The motivation behind the concept of the InGrid was to explore whether it was possible to have a more fluid utilization of surfaces in a domestic household based on the personal space. When interacting with flat surfaces and mainly tables, the users tend to utilize surfaces for:

- Unintended purposes: It is common to use tables for functions that were not initially intended for. For instance, a kitchen table can be used as a desk, a coffee table to rest ones' feet, a dinner table to do homework or read the mail, and so on.
- Taking objects on and off for different functions: Tables can be used as support for food, decorative objects, or personal objects that bring memory back.
- Making flat surfaces adapt to their needs: tables can be used to organize and/or store objects in both peripersonal and extrapersonal spaces.

Table Tile

The tiles' size was designed to stay in the range of the peripersonal space. However, all the tiles together form the shared space that consists of the extrapersonal space. The peripersonal space, and thus the extrapersonal space, depends on the number of persons around the table, the reachable space, and the number of tiles that can be moved around [22]. Each time a tile is flipped, the peripersonal space offers a new perceptual experience and varieties of affordances. For instance, the same table (space) can be used as a working area, gathering area or eating area (Figure 2) depending on the tile that is in the perimeter of the peripersonal space. A cutting board tile would afford the possibility of cutting, while a drawing board tile would afford the action of using a pencil to either write or draw. Finally, it could afford interacting with virtual content while using a tablet tile designed for touch-screens.

Tablet Tile

The tablet tiles were specifically designed around both peripersonal and extrapersonal spaces while interacting with touch-screen tablets. Similarly to the other tiles, they can be flipped on their laminate side or their functional side. Each tablet (here an iPad) is inserted into a protective case that fits into the tile and allows interaction. The case can be set on an angle of 45° or a flat position (Figure 3). The 45° position represents the private mode (the user is connected to the table but she is not sharing her information) while the flat

Figure 3: Tablet tile.

position represents the shared mode (the user decides to share desirable information with another user).

Interaction

InGrid is equipped of pressure and tilt sensors that detect the position of each tile and whether the tile is tilted or at a flat position. It also detects which type of tile is in the peripersonal space of each user by displaying the information on the user's tablet. A user can decide to share the content with other users or keep it private and/or interact with the tiles that are in her peripersonal space. Sharing the information is effected by sliding the virtual content from a tablet A toward the direction of a tablet B. Similar to sliding an object on a table, InGrid allows a similar interaction by detecting the position of the tablets and the direction in which the user is dragging the virtual file. In the future, we are planning to run some psychophysical studies such as collaborative map learning or the effect of interaction on creativity by using InGrid to study embodiment and collaboration.

Figure 4: Six tablets forming a large collaborative screen.

Possibilities of extension

On one hand, the concept can be modified to allow using several small displays as one large single display. On the other hand, it can be extended to work and research environments by blending the usage of small and large screens.

Example 1

The concept of InGrid can be modified to create a large display from small displays. Each tablet will represent, in this case, a small portion of a larger display. Figure 4 shows how it is possible to combine six touch-screens tablets to form a large screen for collaborative interaction.

Example 2

In a working environment, the concept of InGrid can use a blended small-large interaction paradigm. Each user could collaborate in the extrapersonal space on the large screen and use small screen for her peripersonal space. Thus, the user could decide to either share the content on the large screen or keep it private on her small screen (Figure 5).

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Figure 5: Combination of small and large screen interaction.

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