# 9 Peripheral Interaction in Desktop Computing

## Why it's Worth Stepping beyond Traditional Mouse and Keyboard

**Kathrin Probst**[1]

**Abstract** When computers entered our workplaces and other areas of our everyday life, many of the opportunities to use our physical abilities diminished. The macro-monotony of large movements in, e.g. line production has become the micro-monotony of small movements in computer-based office work. At the same time, looking at our everyday activities that do not involve technology, we naturally make use of our perception and motor abilities, and continually interact with our surroundings. Our research has thus focused on achieving similar fluidness in our interactions with the digital world. While traditional desktop work usually involves controlling computers by pressing buttons, dropping menus, and sliding bars, we invite **users** to act with their physical surroundings, i.e., furniture embodied as handles to actions in the digital world. Based on our research on peripheral embodied interaction through smart furniture, and insights from related research, we provide a conceptual overview of the seemingly minor, yet accumulatively powerful, benefits that this interaction style can provide as additional input dimension in desktop settings.

*Keywords: Desktop Computing; Physical Computing; Embodied Interaction; Gestures; Metaphors*

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## 9.1 Motivation

Today, many people find themselves spending a majority of their working day in front of a computer screen. Computer technology has become an integral part of our work activities: we use web browsers to gather information on the internet, e-mail clients and instant messengers for electronic communication, word processors for writing and reading documents, etc. We deal with multiple applications in parallel, constantly switching between multiple windows on the screen, reacting to digital notifications, or communicating with our co-workers. Multitasking and the parallel management of multiple activities, tasks, and working spheres has become everyday practice for most of us (González and Mark 2004).

### *9.1.1 The Reality of Everyday Desktop Computing*

While doing so, we are surrounded by omni-present graphical user interfaces, which have been introduced decades ago with the development of mouse and keyboard, and the rise of the personal computer (Shneiderman 1998). In fact, aside from a slightly improved mechanical construction and visual polish, the input and output devices connected to average desktop computers today are virtually identical to first-generation computers (see Fig. 9.1). Although there have certainly been several developments along the way, such as improved graphics, trackpads, flat-panel displays, and touch screens, we still fundamentally operate our computers with a single pointing device and a keyboard. In the light of other domains like mobile computing, wearable computing, or digital entertainment systems increasingly making use of novel input technologies, many have predicted death of the mouse and keyboard (Lee 2010). However, the reality of everyday desktop computing, seems to persistently stick with the same “point-and-click” interaction.

**Fig. 9.1** Today’s desktop interface is virtually identical to first-generation personal computers. (Image via: DigiBarn Computer Museum).

Reflecting upon the evolutionary development of this “traditional” computer interface, we can identify some of the critical factors for the mouse and keyboard's endurance: Typing technology has come a long way over the past centuries, starting with the invention of early mechanical typewriters, changing shape over the years, and finally resulting in the birth of the keyboard as we moved into the age of computers. Typing speed with minimum effort (two-handed typing allowing visual focus to stay on the screen, without paying much attention to actual finger movements) was one of the main reasons why it became so successful. The invention of the computer mouse then, brought a major shift towards direct interaction on a graphical user interface (Smith et al. 1982). Precision with minimum effort (moving quickly to a specific point on the screen, without needing to move one's hand very far) was the main advantage that it added to the desktop interface. Even today, these features make up for mouse and keyboard as our number one input devices in desktop computing – which remains to be the habitat of most *productivity tasks*, where it’s all about getting things done in a fast and accurate way.

More recently, many innovations for interacting with computers have followed the invention of the keyboard and mouse. New generations of input technologies have opened up a whole new space of interactions via gesture control (e.g., Apple Magic Trackpad, LeapMotion), vision control (e.g., Tobii Eye Tracking), or voice control (e.g., Siri, Cortana). To date, such solutions have not succeeded in replacing mouse and keyboard as primary input devices due to various practical limitations (e.g., speed, recognition reliability, pointing accuracy, physical effort). However, we believe they provide great potential for peripheral interaction in desktop computing to complement high-precision mouse-and-keyboard with an additional input domain that naturally blends into our existing digital workflows. In particular, our research interest lies in *peripheral gestural interaction* to extend the traditional desktop interface with inattentive, bodily actions in the physical world.

### *9.1.2 Taking the Step Beyond*

Comparing our everyday activities on the screen with our activities that do not involve technology, the physical world often seem so much easier to handle: We naturally make use of our perception and motor abilities, continually interact with our surroundings, and deal with numerous parallel activities in the periphery of attention (e.g., relying on our spatial memory when grabbing a mug from a kitchen board, coordinating our hands when pouring coffee into the mug, reading a newspaper while drinking the coffee). In contrast, interactions with computing technologies usually involve deliberate actions in the focus of attention.

Based on this argument, we identify two main properties of mouse and keyboard, which on the one hand make up for their versatility, on the other hand come with inherent interaction gaps that are discussed in the remainder of this section. Addressing these gaps, Sec. 9.2 points out the potential of peripheral interaction to bridge these gaps by providing a powerful add-on to traditional desktop settings.

#### 9.1.2.1 Digital vs. Physical

First, traditional desktop interfaces provide a generic interaction style that is consistent across a wide variety of applications and actions in the digital world. On the one hand, this allows interactions to be achieved with minimum effort by employing the same bodily actions, i.e., clicking, scrolling, typing. Mouse and keyboard can thus function as general-purpose input devices providing access to a wide range of functions with a small set of basic operations. On the other hand, this means that the richness of human skills is exploited only to a limited extent, as the underlying actions are the same across applications.

From an evolutionary perspective, we have traded the variety of skilled movements that we once used to perform in crafting and agricultural domains against the macro-monotony of large movements in industrial production, and later against the micro-monotony of small movements in desktop work. When computers entered our workplaces and other areas of our everyday life, many of the opportunities to use our physical abilities diminished. Having an office job today, all too often involves sitting all day at a computer, making the same small repetitive movements with our fingers, hands, and eyes over and over again (see Fig. 9.2), while the rest of our body remains largely unchallenged (O'Sullivan and Igoe 2004). As a result, work-related disorders have become one of the most common chronic diseases, often resulting from years of poor posture and sedentariness at the workplace (Owen et al. 2009; McCrady and Levine 2009).

**Fig. 9.2** Limited number of senses are challenged with present-day desktop interfaces: Fingers are engaged in clicking, scrolling, or typing on mouse and keyboard. Eyes continuously watch the visual results on the screen. Ears come in from time to time when audio feedback is provided.

From an interaction perspective, we have traded the direct mapping between form and function that we once found in artisan tools against reduced numbers of mechanical controls on machines and early computers, and later against the basic operations of point-and-click interaction in desktop computing. The shape, size and form of computing technology have reduced the physical actions that are possible to perform as human-machine interfaces moved from a one-function-per-control towards a many-functions-per-control approach. In traditional desktop interfaces, there is no longer a perceptually meaningful link between actions, form and feedback. Very different functions are triggered by the same actions, which result in similar output. As a result, they increasingly challenge users' cognitive skills to learn and remember various digital functions and input sequences, while largely neglecting their perceptual-motor skills (Djajadiningrat et al. 2007).

Our five senses are naturally designed for different types of interaction, and much potential of the parallel architecture of our brains is lost when human-computer interfaces exploit only few of them. Desktop computing thus faces the challenge of more effectively matching interfaces to the richness of human capabilities. Novel interaction styles hold great potential to move us towards this goal by engaging various parts of our body, and taking advantage of our perceptual and motor skills. Moving actions into the physical world, it has been shown that the bodily, tangible nature of such embodied interaction styles (Dourish 2001) opens up a parallel interaction channel for parallel processing of multiple resources (Wickens and McCarley 2007; Olivera et al. 2011). Increased movement diversity can furthermore decrease the monotony of computing tasks (Silva and Bowman 2009), or improve overall physical activity and mental well-being (Levine 2002).

*Thus, similar to our everyday activities that do not involve technology, where we make use of our perception and motor abilities and continually interact with our surroundings, peripheral interaction around the desktop holds the potential for extending interaction from the screen towards the physical world around us.*

#### 9.1.2.2 Focused vs. Peripheral

Second, traditional desktop interfaces provide a structured environment, where the majority of interaction happens visually, on a computer screen. The interface is usually separated into different workspaces, i.e., a primary workspace that holds the currently active application, a secondary workspace that holds artifacts related to the primary space (e.g., tool palettes), and an off-screen workspace that holds the remaining artifacts (e.g., menus) to be made visible through direct user interaction (Hausen et al. 2013a). On the one hand, this allows interface designers to make efficient use of the available screen space by distributing UI elements across all available workspaces. On the other hand, this causes users to spend too much time manipulating the interface, all too often ending up frustrated by too many layers of point-and-click or cluttered screens due to overlapping windows, hierarchical menus, widely dispersed icons, nested toolbars, etc.

Since the actions that we can perform on the on-screen elements are very simple, they oftentimes need to be repeated or combined to complete a specific operation, which leads to long sequences of simple actions that require users' focused attention to achieve an intended goal. Even very simple tasks often require a context switch, precise pointing or exact knowledge about certain key presses. If we consider the simple task of adjusting one's status in an instant messenger (IM) application for example (see Fig. 9.3), this can usually be achieved in several ways, which all include multiple steps of shifting application windows between foreground and background mode, navigating through menu hierarchies, or revealing hidden controls. Alternatively, keyboard shortcuts can provide direct access to application functions, but require users to remember a number of different key combinations. Either way, people are required to divert attention away from their primary task, which comes at the cost of increasingly interrupted work**.**

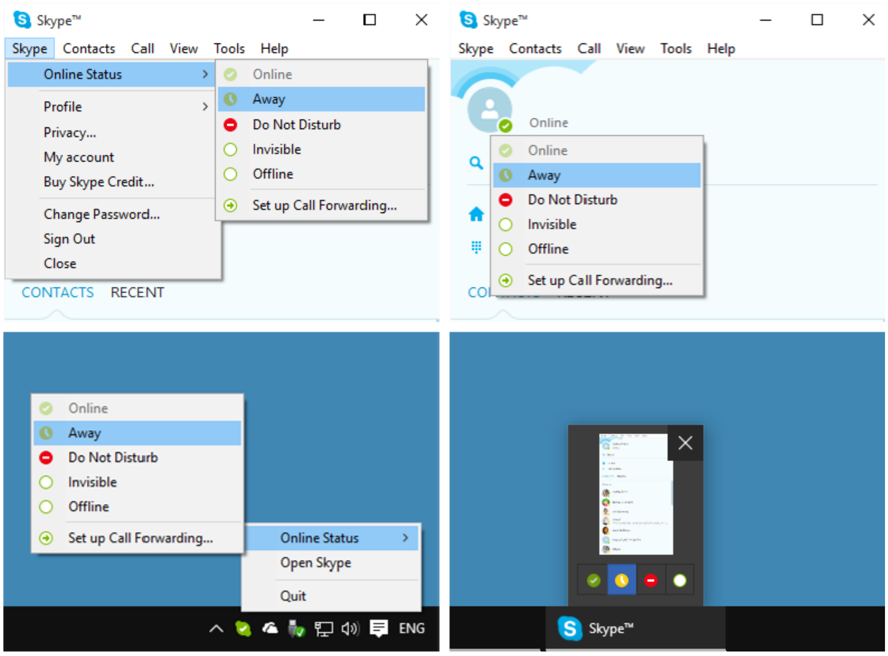


**Fig. 9.3** Possible ways of updating a user's online status in an instant messenger application: by a) navigating through the menu hierarchy in the messenger window, b) accessing a drop-down menu from the current status icon in the messenger window, c) accessing the context menu from the messenger icon in the system tray, d) revealing the hover preview of the messenger window's representation in the taskbar, or e) executing a custom-defined hotkey combination.

In the reality of everyday desktop computing, this is especially relevant for secondary or background tasks, which can take place concurrently with a primary task (Chewar et al. 2002). When the demands of the secondary task cause it to become the user's primary focus, negative performance effects on the primary task can occur (Czerwinski et al. 2004).

Research has consistently documented the negative consequences of interruptions to ongoing work tasks including context-switching costs such as distraction, errors, work delay, stress, and frustration (e.g., (Finstad et al. 2006; Iqbal and Horvitz 2007; Jin and Dabbish 2009)). Considering this problem in the light of Norman's action cycle (see Fig 9.4), we can identify that this is especially relevant for the execution stage, where long sequences of point-and-click interaction lead to a bottleneck in the action cycle.

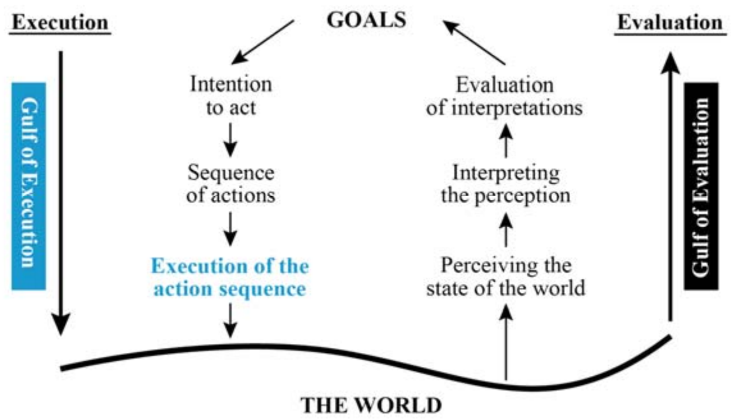


**Fig. 9.4** Seven Stages of Action: *The Stages of Execution* start at the top with the goal, the state that is to be achieved. The goal is translated into an intention to do some action. The intention must be translated into a set of internal commands, an action sequence that can be performed to satisfy the intention. The action sequence is still a mental event: nothing happens until it is executed, performed upon the world. The *Stages of Evaluation* start with our perception of the world. This perception must be interpreted according to our expectations and then evaluated with respect to both our intentions and our goals (reproduced from (Norman 2002))

Desktop computing thus faces the challenge to bridge this gulf of execution by removing roadblocks that cause extra thinking and actions that distract the user's attention from the task intended, thereby preventing the flow of his or her work, and decreasing the chance of successful completion of the task. Novel interaction styles hold the potential to move us towards this goal by involving multiple of our senses, and naturally taking advantage of our ability for subconscious perception and control of bodily actions. Engaging both the center and periphery of attention, it has been shown (Weiser 1996) that such activity-based approaches (MacIntyre et al. 2001; Bardram 2009) can support common multitasking practices through smooth transitions between primary and secondary workspaces, or offloading of information into the physical environment.

*Thus, similar to our everyday activities that do not involve technology, where we deal with numerous activities at the same time, peripheral interaction through bodily actions in the physical world holds the potential for supporting increasingly subconscious control of secondary tasks in parallel to an ongoing primary task.*

## 9.2 Peripheral Interaction around the Desktop

Research in the areas of embodied interaction (Dourish 2001) and tangible user interfaces (Ullmer and Ishii 2000) have revealed potential benefits of extending the traditional desktop interface with an additional bodily input domain to for peripheral interaction in desktop settings (examples see Fig. 9.5). *Peripheral Tangible Interaction* has shown as “particularly suitable for the office context, complementing the existing monitor, mouse and keyboard, and supporting the performance of auxiliary work activities in parallel with primary workstation-intensive tasks” (Edge 2008). Extending this concept, *Peripheral Embodied Interaction* has shown to “improve multiple task situations by moving secondary tasks from the classical computer interface into the physical world around us” (Hausen and Butz 2011). We believe that such physical manipulators are a natural step towards making the next UI metaphor the real world itself by providing an interaction modality that can be controlled in the periphery of attention.

**Fig. 9.5** Examples of peripheral interaction in desktop scenarios: office-based peripheral TUI (Edge 2008), *StaTube* tangible presence indicator (Hausen et al. 2012), peripheral music controller (Hausen et al. 2013b), *Unadorned Desk* extended input canvas on a physical desk (Hausen et al. 2013a)

Karam et al. (Karam and Schraefel 2005a) were one of the first to consider gestures for the support of secondary task interactions in multitasking environments, by investigating the use of semaphoric hand gestures for control of an ambient music system. Edge et al. (Edge and Blackwell 2009) offered an alternative perspective on tangibility in interaction by presenting an office-based TUI that allowed users to manage auxiliary work activities (e.g., email management, timesheet completion, information sharing) by freely arranging digitally-augmented physical tokens around the periphery of their workspace. Cheng et al. (Cheng et al. 2010) presented the *iCon* prototyping platform that employs a novel approach to utilizing everyday objects in the physical desk environment (e.g., bottles, mugs) as instant tabletop controllers. Hausen et al. designed an ambient appointment projection that supports peripheral interaction with upcoming events through free-hand gestures (Hausen and Butz 2011), the *StaTube* tangible presence indicator that allows users to change their instant messenger state in a peripheral fashion (Hausen et al. 2012), a peripheral music controller and e-mail notification system that compared different input modalities for peripheral interaction (Hausen et al. 2013b; Hausen et al. 2013c), and the *Unadorned Desk* that demonstrates the use of coarse hand gestures to arrange and retrieve virtual off-screen artifacts on a physical desk (Hausen et al. 2013a).

*Overall, this body of research demonstrates that extending traditional desktop interfaces with a supplementary input dimension that smoothly shifts interactions between the focus and periphery of attention is particularly suitable for interaction with background (secondary) tasks in multitasking scenarios. This can help us to overcome some of the problems with traditional interfaces, complement our current interaction vocabulary, and enhance user experience.*

In our research, we have extended this concept towards the physical workspace environment, investigating the potential of body movements on a flexible chair (Probst et al. 2014a), and other of smart furniture prototypes (Probst et al. 2014b) to enable quasi-parallel control of primary and secondary tasks. Based on this research on peripheral interaction through smart furniture, we provide a conceptual overview of the seemingly minor, yet accumulatively powerful, benefits that this interaction style can provide as additional input dimension in desktop settings. In the remainder of this section, we present two themes that we believe are particularly relevant for taking the mundane reality of everyday desktop computing to the next level. The first theme, *from the screen to the world*, describes how our knowledge of our lived body can allow for subconscious control of bodily actions in the world, in parallel to an ongoing primary task. The second theme, *from the world to the mind*, describes how applying basic concepts from our real-world and bodily experience can provide meaningful, understandable shortcuts to application commands. Throughout these themes we discuss relevant theoretical backgrounds, how these are put into practice in the related work on peripheral interaction in the desktop domain, and provide concrete examples from our research on peripheral interaction through smart furniture.

## 9.2.1 From the Screen to the World

*The richness of human knowledge and understanding is far deeper than we can explain. To illustrate this assertion, consider the example of riding a bicycle: we are simultaneously navigating, balancing, steering, and pedaling to smoothly make our way along the road. We are able to sense, store and recall our own muscular effort, body position and movement to build this skill. Yet, it is not possible for us to articulate all of the nuances of this activity when we try to teach somebody how to ride a bicycle.* (Klemmer et al. 2006).

This kind of **procedural (tacit) knowledge** is involved in knowing how to ride a bicycle, how to steer a car, how to swim, how to perform music. It is largely subconscious, but reliable and robust. It is best taught by demonstration and best learned through practice. Even the best teachers usually cannot describe what they are doing.

The basis of this knowledge is our *sensorimotor control*, which is the combination of body movements into intended actions (Weiss and Jeannerod 1998). This involves the integration of proprioceptive information (detailing the position and movement of the musculoskeletal system) with the neural processes in the brain and spinal cord (planning, transmitting, and controlling motor commands). To produce coordinate movements, our brain holds an internal prediction of the sensory consequences of a movement, and compares it with the actual feedback from the joints and muscles. As a result of this continuous comparison, corrective commands are issued, and the prediction is adapted accordingly (see Fig. 9.6).

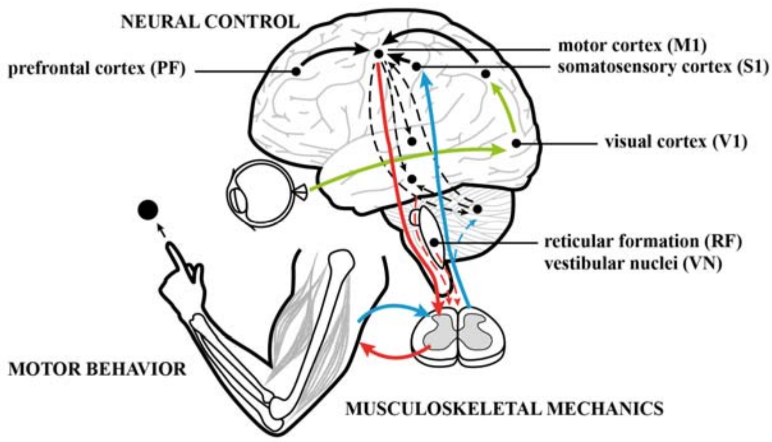


**Fig. 9.6** The basic brain circuit for sensorimotor control: At the lowest level, the spinal cord integrates motor output and sensory input from skin, muscles and joints to basic movements and reflexes. At the second level, brainstem regions (RF, VN) improve these patterns with postural control and locomotion patterns. At the highest level, the cerebral cortex supports a large and adaptable motor repertoire. The diagram illustrates some of the key regions that are involved in goal-directed reaching movements: PF for action goals and planning, M1 for motor planning, V1 for visual feedback, S1 for somatosensory feedback. (reproduced after (Scott 2004))

Essential for this sensorimotor control is our *kinesthetic sense (proprioception)*, which allows our body to keep track of the joint position in the body and their location in space, and regulate the muscular effort that we use to move our bodies. As a key component for hand-eye coordination and kinesthetic memory, it is how we can position our hand to catch a ball, or touch our nose with our eyes closed. Humans are remarkably fast and accurate at using tactile and kinesthetic cues to locate and recognize objects without vision (Lederman 1987; Huynh et al. 2010). On keyboard and mouse, users can thus rely on their proprioception to develop a rough idea of the physical location of keys and buttons (e.g., bumps on the F and J keys support correct positioning of the hands).

The appropriate integration of proprioceptive input enables us to walk without watching where we put our feet, or drive a car without watching the pedals and gearstick. The kinesthetic sense is essential whenever learning a new motor skill, and forms the basis for various forms of procedural knowledge:

- *Two-handed (bimanual) coordination* and *hand-foot coordination* allow us to interact with both hands at the same time (e.g., when tying our shoe laces, or eating with knife and fork), or move our hands and feet in a coordinated manner (e.g., when playing football, or swimming). Using keyboard and mouse, this allows us to interact with both hands in parallel (Buxton and Myers 1986).
- *Kinesthetic memory (muscle memory, motor memory)* involves consolidating a specific motor task into memory through repetition. When a movement is repeated over time, a long-term muscle memory is created for that task. Once an activity is encoded in muscle memory, it requires little conscious effort to perform, which allows it to become automated and performed unconsciously in parallel to other activities (Newell and Rosenbloom 1981; Wickens and McCarley 2007). Examples can be found in many everyday activities that require rapid bodily responses for which planning by explicit cognition is simply too slow, e.g., driving a car, riding a bike, or playing an instrument.
- *Spatial memory* involves the recording of information about one's environment and its spatial orientation. It is a cognitive process that enables a person to remember different locations as well as spatial relations between objects. This allows us to remember where an object is in relation to another object, e.g., when navigating through a familiar city, or recalling the location of items in a room. In computer interfaces, users can thus rely on spatial memory to recall the locations of keys on a keyboard, or on-screen controls in a GUI (Scarr et al. 2012).

Put together, this kind of procedural knowledge is the reason that we can perform multiple actions simultaneously, when they are done automatically, with little or no need for conscious attention:

> "Doing several things at once is essential even in carrying out a single task. To play the piano, we must move the fingers properly over the keyboard while reading the music, manipulating the pedals, and listening to the resulting sounds. But to play the piano well, we should do these things automatically. Our conscious attention should be focused on the higher levels of the music, on style, and on phrasing. So it is with every skill. The low-level, physical movements should be controlled subconsciously." (Norman 2002)

In the context of peripheral interaction around the desktop, the richness of human skills has been successfully applied for secondary tasks to be controlled in parallel to an ongoing primary task. Table 9.1 provides an overview of such actions, and their coverage in the related work (examples see Fig. 9.5).

**Table 9.1** Examples of secondary tasks, and their coverage in peripheral interaction.

| applications | commands |
|---|---|
| application management | launch/exit (Edge and Blackwell 2009; Cheng et al. 2010; Hausen et al. 2013a), switch (Cheng et al. 2010; Hausen et al. 2013a) |
| file management | create (Edge and Blackwell 2009), open/close (Edge and Blackwell 2009) |
| data manipulation | copy/paste (Cheng et al. 2010), undo/redo (Cheng et al. 2010), save (Cheng et al. 2010) |
| navigation | previous/next (Karam and Schraefel 2005a; Cheng et al. 2010; Hausen et al. 2013b), zoom, scroll, rotate (Cheng et al. 2010), bookmark (Cheng et al. 2010) |
| task management | schedule (Edge and Blackwell 2009), track progress (Edge and Blackwell 2009), delegate (Edge and Blackwell 2009) |
| music playback | play/pause (Karam and Schraefel 2005a; Cheng et al. 2010; Hausen et al. 2013b), increase/decrease volume (Cheng et al. 2010; Hausen et al. 2013b), mute/unmute (Cheng et al. 2010) |
| messaging | set status (Edge and Blackwell 2009; Hausen et al. 2012), view status (Edge and Blackwell 2009; Hausen et al. 2012), show, tag, delete message (Hausen et al. 2013c) |

For example, *StaTube* (Hausen et al. 2012) builds on people's ability to sense ambient information in the periphery to let them observe the status of their favorite instant messenger contacts with a tangible presence indicator. Simply turning the topmost layer of the tangible device, they can also change their own instant messenger state in a peripheral fashion. Similarly, *iCon* (Cheng et al. 2010) builds on people's real-world experience with everyday objects that can be sensed with our peripheral awareness, and provide inherent affordances due to their tangible, movable, and graspable properties. The office-based TUI by Edge et al. (Edge and Blackwell 2009) leverages users' kinesthetic sense to allow for distinction of tangible tokens based on their characteristic engravings on the edges. Building on people's bimanual coordination abilities, the system supports two-handed interaction with coarse-grained manipulation of physical tokens under the non-dominant hand and fine-grained manipulation of a control knob under the dominant hand. The *Unadorned Desk* (Hausen et al. 2013a) extends this concept towards utilizing the physical desk space around a computer as input canvas for peripheral interaction with virtual items. Taking advantage of people's proprioception and spatial memory, it demonstrates that users have a good understanding of where items are located, and can easily – even with closed eyes – retrieve such objects.

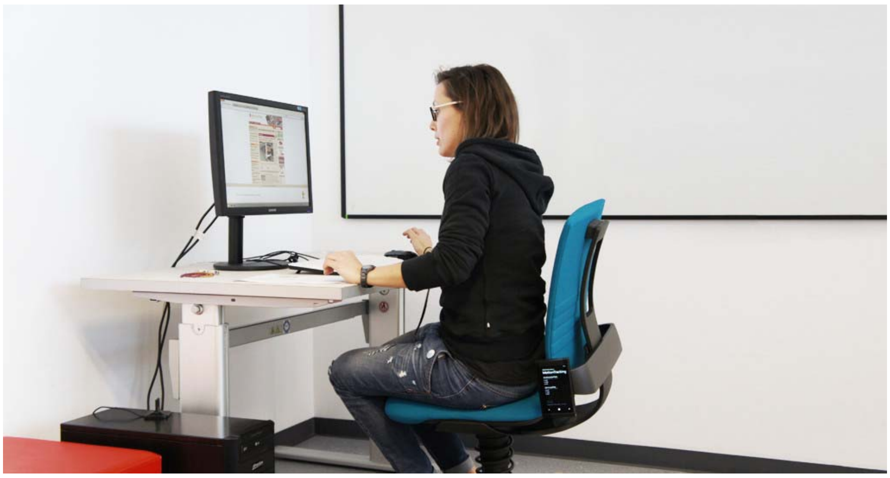

**Fig. 9.7** Prototype for peripheral interaction through smart furniture: interactive office chair.

Similarly, in our research we constructed several prototypes that leverage human's bodily skills and real-world knowledge for peripheral interaction through smart furniture (Probst et al. 2014b). In a first prototype (Fig. 9.7) we explored the potential of gestural chair interaction during desktop computing. By tracking the movements of a seated person, different chair gestures are identified and directly translated into input commands to a desktop computer (e.g., tilting to play the next track in a playlist, bouncing to launch an application, rotating to attend to a notification on a distant screen). This way, the chair becomes a ubiquitous input device (Probst et al. 2013; Probst et al. 2014a). In an iterative design process, we elicited user input on suitable gestures, collected early feedback on the user experience, and evaluated the performance of our chair-based application control. From analysis of the collected data and user interviews, we learned several lessons about how users interact with such an augmented chair interface.

Overall, they agreed that the chair gestures provided a useful add-on to their daily desktop work, which they would preferable use in an *opportunistic, casual* manner whenever they wanted to gain direct access to application functions, or just break up the monotony of traditional point-and-click routines. In a study comparing the performance of the chair interface to traditional keyboard and touch input, task recovery time was significantly shorter with the chair gestures. In line with the related work, this can be largely contributed to the reduced requirements on the visual and motor channels (Karam and Schraefel 2005a), i.e., *eyes-free* interaction as visual focus remains on the primary task, and *hands-free* interaction as people's hands can remain on mouse and keyboard. Based on these unique features, the chair gestures allowed users to effortlessly interact with an application and rapidly re-focus on other ongoing activities. To support this kind of fluid transitions between primary and secondary tasks, we thus learned that bodily gestures for peripheral interaction should be of rather *imprecise and inattentive* nature, i.e., concise, quick to issue, avoiding movements over extended periods of time.

**Fig. 9.8** Prototypes for peripheral interaction through smart furniture: smart furniture modules for under-the-desk kicking, rolling, touching.

In a second prototype (Fig. 9.8) we designed three types of smart furniture modules for under-the-desk interaction, which include a kick interface on the underpart of the desk, a roll interface on the floor beneath the desk, and a touch interface on the underside of the desk surface. Interaction with the modules builds on people's pre-existing real-world skills and knowledge, such as their understanding of naïve physics (e.g., friction, velocity), their bodies (e.g., proprioception), and the environment (e.g., spatial memory). The kick and roll modules leverage motor capabilities to perform basic gestures with the foot (e.g., tapping, nudging). The touch module transfers experience with multi-touch devices towards simple touch gestures on the underside of a desk (e.g., swiping).

In a preliminary study, where users were invited to test our prototypes within their regular work environments, we found that participants assigned the basic hand and foot gestures to a variety of secondary tasks that we identified as particularly suitable for peripheral interaction through smart furniture to smoothly blend into traditional desktop configurations (i.e., music control, status updates, notification handling, task switching, window handling). In line with the related work, this was found to "*reduce barriers to interaction by facilitating the performance of periodic, low-attention activities in parallel with workstation intensive tasks*" (Edge 2008). Over time, participants were increasingly able to perform coordinate hand and foot movements, and recall the spatial location of the individual modules. Previous studies on peripheral interaction confirmed that such interaction styles need to be trained and learned to be effective (e.g., (Hausen et al. 2014)). This may continually develop with routinely execution and further practice. Thus, besides being imprecise and inattentive in nature, we recommend bodily gestures for peripheral interaction to be assigned to *frequently-used input commands* that people would make use of on a regular basis during their daily routine.

### 9.2.2 From the World to the Mind

*At the very core of meaning – the way we categorize, remember, talk about, and act in the world – are our experiences as physical beings in the physical world. To illustrate this assertion, consider the metaphorical concept of time as used in contemporary English in expressions like: spending time, saving time, wasting time, losing time, or running out of time. Time is money, time is a limited resource and time is a valuable commodity are all metaphorical concepts, since we are using our everyday experiences with money, limited resources and valuable commodities to conceptualize time.* (Lakoff and Johnson 1980)

This human ability to project the structure of physical and cultural experiences onto a conceptual domain is what is meant by **metaphor**. The basis for this kind of metaphor is the assumption that basic physical concepts acquired in early infancy and childhood (e.g., time, space, distance, temperature) provide meaningful guides for the development of more abstract, newer concepts (Williams et al. 2009). For example, the understanding that some objects are able to move themselves through space (e.g., people, animals) provides the foundation for the understanding the concept of agency. This allows us to understand or experience one concept in terms of another, which helps us understand complex concepts in a way that appears more real and tangible to us. When cognitive structures of higher-order thinking emerge from recurrent patterns of bodily or sensorimotor experience, they are called *embodied schemata* and *embodied metaphors* (see Fig. 9.9).

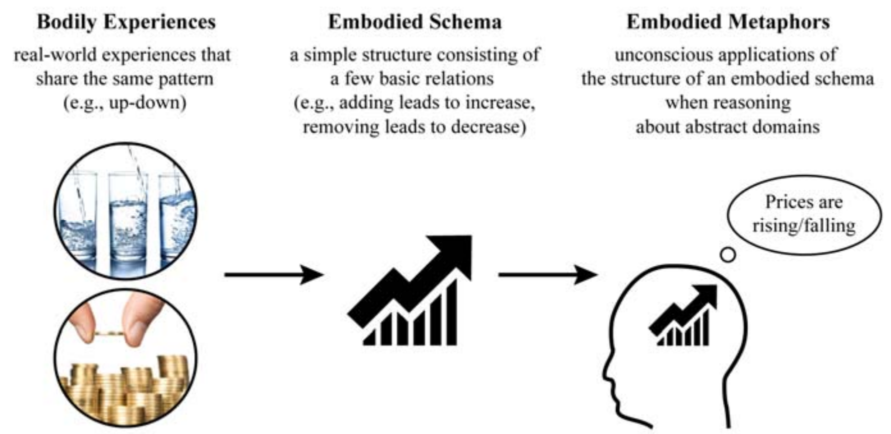


**Fig. 9.9** An example of an embodied schema is the *up-down* schema. The corresponding *more is up* and *less is down* metaphors are grounded in the common experiences of pouring more fluid into a container and seeing the level go up or down, or seeing a pile grow higher or lower as we add or remove things to/from it. These are thoroughly pervasive experiences that we encounter throughout our daily lives. Such embodied schema are used to reason about abstract domains: e.g., when we say “The price is rising” or “Stocks are plummeting”, we (unconsciously) apply the embodied schema *up-down* to structure our understanding of the abstract concept of monetary values. (in analogy to (Bakker et al. 2011))

According to (Lakoff and Johnson 1980), metaphor involves four basic categories:

- An **orientational (spatial) metaphor** involves explaining a concept in terms of spatial orientations, which arise from how our bodies function in our physical environment (e.g., up-down, in-out, near-far, front-back). This allows us to associate abstract concepts with spatial orientations of up and down (e.g., good is up, bad is down; more is up, less is down;), right and left (e.g., progress is right, regression is left), or ahead and behind (e.g., future is ahead, past is behind)[2].
- An **ontological metaphor** involves explaining a concept in terms of basic categories of our physical existence (e.g., entity, substance, container). This allows us to view abstract concepts as entities (e.g., ideas are entities, "*I can't put my ideas into words*"), substances (e.g., vitality is a substance, "*I'm overflowing with energy*"), or containers (e.g., love is a container, "*I've fallen in love.*").
- A **structural metaphor** involves characterizing the structure of one concept in terms of another (e.g., eating, moving, transferring objects from place to place). This allows us to structure one kind of experience or activity by comparing it to another experience or activity (e.g., understanding is seeing, "*I see what you are saying*"; life is a gambling game, "*I'll take my chances*").
- A **metonymy** involves the use of one entity to refer to another that is related to it. For example, this allows us to structure abstract concepts in terms of 'the part for the whole' (e.g. the face for the person), or 'the producer for the product' (e.g., talking about a Picasso when referring to a painting).

Just as metaphors are omni-present our everyday life, so do they occur on digital systems where they provide meaning by representing computer systems with objects and events from a non-computer domain (Wozny 1989). User-interface metaphors for example, incorporate spatial metaphors for quantification and navigation (e.g., vertical sliders increasing towards the top, next buttons pointing to the right), ontological metaphors for illustrating system elements (e.g., a file is an object), structural metaphors for explaining system functions (e.g., storage is filing), or metonymy for iconic representations in menus and toolbars (Barr et al. 2002).

Besides that, novel interactions styles have increasingly made use of metaphors to simplify human-computer interaction. Tangible user interfaces have for example used the affordances of physical objects (e.g., shape, size, color) to invoke metaphorical links (Fishkin 2004). Similarly, different styles of gestures are implicitly based on underlying metaphorical structures, such as *deictic gestures* that involve pointing to establish the identity or spatial location of an object (e.g., pointing to interact on a large-scale display), *manipulating gestures* that apply a tight relationship between the movement of a gesturing hand/arm with an entity being manipulated (e.g., mimicking manipulations of physical objects in VR interfaces), or *semaphoric gestures* that employ a stylized dictionary of static or dynamic hand or arm gestures (e.g., joining the thumb and forefinger to represent the OK symbol) (Karam and Schraefel 2005b).

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[2] As metaphor is largely dependent on culture, their underlying meaning may largely vary across cultures (e.g., progress is right, future is ahead are primarily true for Western countries).

In the context of peripheral interaction around the desktop, our natural understanding for basic metaphors has been successfully leveraged for simple bodily actions that facilitate learning and recall through meaningful mapping to frequently-used application commands. Table 9.2 provides an overview of such simple interactions and their coverage in the related work (examples see Fig. 9.5).

**Table 9.2** Examples of simple bodily gestures, and their coverage in peripheral interaction.

| gestures | commands |
|---|---|
| left-to-right/right-to-left move, swipe, tilt | next/previous (Karam and Schraefel 2005a; Hausen et al. 2013b), decline/show (Hausen et al. 2013c) |
| upward/downward move, swipe, tilt | increase/decrease (Hausen et al. 2013b), bookmark/delete (Hausen et al. 2013c) |
| circular hand motion | play (Karam and Schraefel 2005a) |
| vertical hand in mid-air | stop (Karam and Schraefel 2005a), pause/continue (Hausen et al. 2013b) |
| hover above | preview (Hausen et al. 2013a) |
| touch down/tap | select (Cheng et al. 2010; Hausen et al. 2013a), toggle state (Cheng et al. 2010; Hausen et al. 2013b) |
| clockwise/counter-clockwise object rotation | increase/decrease (Cheng et al. 2010; Hausen et al. 2013b), next/previous (Cheng et al. 2010; Hausen et al. 2012), redo/undo (Cheng et al. 2010) |

For example, the semaphoric hand gestures in the ambient music player control by Karam et al. (Karam and Schraefel 2005a) use basic spatial metaphors (e.g., *progress is right*; left-to-right hand wave for the next song) and structural metaphors (e.g., vertical hand in mid-air signaling a halt gesture to stop playback). In a study comparing the gestures against function keys on a keyboard, results showed that the simple hand gestures were easier to recall than the abstract key assignments. Similarly, Hausen et al. (Hausen et al. 2013b) use spatial metaphors to provide the same shared meaning to peripheral music player commands across different input modalities (e.g., *more is up*; upward tilting of a graspable device, upward swiping on a touch surface, or upward flicking of the hand in mid-air to increase volume). In a second use case of peripheral e-mail notifications (Hausen et al. 2013c), they use a combination of spatial and structural metaphors to provide a consistent mapping of possible actions along the four canonical directions (e.g., *important is up*, upwards movement to flag a message; *unimportant is down*, downwards movement to delete a message; *pulling is bringing closer*, movement towards the user to show a message; *pushing is moving away*, movement away from the user to mark message as read). *iCon* (Cheng et al. 2010) extends this concept for metaphors to provide meaningful mappings of computer commands to physical affordances of everyday objects (e.g., tap object to play/pause, open/close, bookmark; drag or rotate object to show previous/next, zoom-in/out, undo/redo).

**Fig. 9.10** Peripheral interaction through smart furniture: rotating, tilting, and bouncing gestures on an interactive flexible office chair.

Similarly, in our research we designed interactions with our prototypes to leverage people's natural understanding of metaphors for peripheral interaction through smart furniture (Probst et al. 2014b). To identify meaningful gestures for our interactive chair interface (Fig. 9.10), we performed a guessability-style study where participants were asked to demonstrate movements on a flexible office chair that they would associate spontaneously with common web browser commands (Probst et al. 2013; Probst et al. 2014a). Corresponding to the physical affordances of the flexible office chair, the proposed chair gestures included tilting, rotating, and bouncing movements in various combinations. Building primarily on their understanding of their bodies and the physical environment, participants suggested metaphors like simple tilting/rotating of the chair to navigate between websites and tabs (e.g., *progress is right;* tilt right to navigate to the next website, tilt left to navigate to the previous website), or bouncing for single-command operations (e.g., *sitting down is like coming home*, bounce to navigate to the home screen; *bouncing is like affixing a stamp*, bounce to bookmark).

Studying the defined chair gestures in action, the mapping of gestures to commands was found to provide understandable metaphors that were easy to learn and remember. Interestingly, when experiencing the gestures in practical use, participants generally preferred subtle gestures over vigorous ones, as to minimize physical effort and maximize socially acceptability. Designers of bodily gestures for peripheral interaction may thus carefully consider the tradeoff between sensitivity and robustness of gesture recognition (e.g., by providing appropriate feedback on command invocations, supporting user-friendly mechanisms to enable/disable recognition on demand, avoiding the invocation of commands that may cause unrecoverable results, or providing methods to easily undo falsely activated actions).

**Fig. 9.11** **P**eripheral interaction through smart furniture, under-the-desk foot and hand gestures.

To evaluate our smart furniture modules for under-the-desk kick, roll, and touch interaction (Fig. 9.11), we bundled a variety of secondary task interactions (i.e., music control, status updates, notification handling, task switching, window handling) into a configuration tool, we let users define custom mappings of basic hand and foot gestures (e.g., tapping, swiping, nudging) to corresponding input commands. Although simple and intrinsically limited due to their physical nature, observations showed that the gestures still covered many common usage scenarios across varying degrees of freedom. Kicking was for example applied to single-command operations (e.g., *kicking is pushing away*, kick to decline a notification). Rolling was used for binary state toggles (e.g., *up is active*; roll up for IM status online, roll down for IM status away) or foot-based scrolling. Touching was associated with directional swiping for finite state transitions, or tapping for rapid command invocation (e.g., briefly mute sound to talk to a co-worker).

Overall, the imprecise nature of the gestures seemed to support the habituation process, as participants would increasingly perform interactions in the periphery of attention. Interestingly, we observed participants applying a wide range of different metaphors when defining useful gesture mappings according to their regular working tasks, working styles, and individual preference. Designers of bodily gestures for peripheral interaction may thus take into account the highly personal nature of appropriate input commands and according physical metaphors (e.g., by and providing mechanisms to customize gesture-to-command mappings).

## 9.3 Conclusion

In this chapter, we discussed new peripheral interaction paradigms for human-computer interaction, specific to the domain of desktop computing. After providing a general review on current desktop computing paradigms, and reflecting on the evolutionary development of the traditional mouse-and-keyboard interface, we pointed out two interaction gaps of existing digital interfaces, i.e., the “digital vs. physical” and “focused vs. peripheral” divides between simplistic, parallel actions in the physical and complex, sequential actions in the digital world.

Reflecting upon existing peripheral interaction prototypes and our research on embodied peripheral interaction through smart furniture, we presented two themes that illustrate the huge potential of peripheral interaction to naturally complement the existing desktop interface, i.e., “from the screen to the world” discussing how to increasingly acknowledge our capabilities for diverse bodily interactions in the physical world, and “from the world to the mind” discussing how to increasingly utilize real-world metaphors to improve our understanding of interactions with human-computer interfaces. Throughout these themes, we provided examples of peripheral interaction prototypes that engage multiple of our senses, and support interactions to smoothly transition between the focus and periphery of attention. Traditional desktop interfaces have been shown to benefit from such peripheral interaction styles in terms of *reduced number of interaction steps* by providing direct access to frequently-used applications functions, *reduced physical effort* by supporting simple bodily actions on the physical environment, and *reduced mental effort* by translating abstract commands into meaningful metaphors.

We shared the many lessons we learned from the iterative design and evaluation of our prototypes for peripheral interaction through smart furniture. We hope that they can act as a starting point for researchers and interaction designers to come up with more alternative input modalities that increasingly take into account user’s sensorimotor skills and real-world knowledge in order to bring us one step further beyond traditional mouse-and-keyboard interaction.

# References


Bakker S, Antle A, van den Hoven E (2011) Embodied Metaphors in Tangible Interaction Design. Pers Ubiquitous Comput 16:433–449.

Bardram J (2009) Activity-Based Computing for Medical Work in Hospitals. ACM Trans Comput Interact 16:10.

Barr P, Biddle R, Noble J (2002) A Taxonomy of User-Interface Metaphors. In: Proceedings of the SIGCHI-NZ Symposium on Computer-Human Interaction (SIGCHI-NZ ’02). ACM, New York, NY, USA, pp 25–30

Buxton W, Myers B (1986) A Study in Two-Handed Input. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI ’86). ACM, New York, NY, USA, pp 321–326

Cheng K-Y, Liang R-H, Chen B-Y, et al (2010) iCon: Utilizing Everyday Objects as Additional, Auxiliary and Instant Tabletop Controllers. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI ’10). ACM, New York, NY, USA, pp 1155–1164

Chewar CM, McCrickard DS, Ndiwalana A, et al (2002) Secondary Task Display Attributes – Optimizing Visualizations for Cognitive Task Suitability and Interference Avoidance. In: Symposium on Data Visualization (VISSYM ’02). Eurographics Association, Aire-la-Ville, Switzerland, pp 165–171

Czerwinski M, Horvitz E, Wilhite S (2004) A Diary Study of Task Switching and Interruptions. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI ’04). ACM, New York, NY, USA, pp 175–182

Djajadiningrat T, Matthews B, Stienstra M (2007) Easy Doesn’t Do It: Skill and Expression in Tangible Aesthetics. Pers Ubiquitous Comput 11:657–676.

Dourish P (2001) Where The Action Is: The Foundations of Embodied Interaction. MIT Press

Edge D (2008) Tangible User Interfaces for Peripheral Interaction. University of Cambridge

Edge D, Blackwell A (2009) Peripheral Tangible Interaction by Analytic Design. In: Proceedings of the 3rd International Conference on Tangible and Embedded Interaction (TEI ’09). ACM, New York, NY, USA, pp 69–76

Finstad K, Bink M, McDaniel M, Einstein G (2006) Breaks and Task Switches in Prospective Memory. Appl Cogn Psychol 20:705–712.

Fishkin K (2004) A Taxonomy for and Analysis of Tangible Interfaces. Pers Ubiquitous Comput 8:347–358.

González V, Mark G (2004) “Constant, Constant, Multi-tasking Craziness”: Managing Multiple Working Spheres. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI ’04). ACM, New York, NY, USA, pp 113–120

Hausen D, Boring S, Greenberg S (2013a) The Unadorned Desk: Exploiting the Physical Space around a Display as an Input Canvas. In: Proceedings of the 14th IFIP TC13 Conference on Human-Computer Interaction (INTERACT ’13). Springer, Berlin, Germany, pp 140–158

Hausen D, Boring S, Lueling C, et al (2012) StaTube: Facilitating State Management in Instant

Messaging Systems. In: TEI 2012. pp 283–290

Hausen D, Butz A (2011) Extending Interaction to the Periphery. In: Embodied Interaction: Theory and Practice in HCI, Workshop at CHI 2011.

Hausen D, Richter H, Hemme A, Butz A (2013b) Comparing Input Modalities for Peripheral Interaction: A Case Study on Peripheral Music Control. In: Proceedings of the 14th IFIP TC13 Conference on Human-Computer Interaction (INTERACT ’13). pp 162–179

Hausen D, Tabard A, Von Thermann A, et al (2014) Evaluating Peripheral Interaction. In: Proceedings of the 8th International Conference on Tangible, Embedded and Embodied Interaction (TEI ’14). ACM, New York, NY, USA, pp 21–28

Hausen D, Wagner C, Boring S, Butz A (2013c) Comparing Modalities and Feedback for Peripheral Interaction. In: Extended Abstracts on Human Factors in Computing Systems (CHI EA ’13). pp 1263–1268

Huynh K, Stepp CE, White LW, et al (2010) Finding a Feature on a 3D Object Through Single-Digit Haptic Exploration. In: IEEE Haptics Symposium. IEEE, pp 83–89

Iqbal S, Horvitz E (2007) Disruption and Recovery of Computing Tasks: Field Study, Analysis, and Directions. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI ’07). ACM, New York, NY, USA, pp 677–686

Jin J, Dabbish L (2009) Self-Interruption on the Computer: A Typology of Discretionary Task Interleaving. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI ’09). ACM, New York, NY, USA, pp 1799–1808

Karam M, Schraefel M c. (2005a) A Study on the Use of Semaphoric Gestures to Support Secondary Task Interactions. In: Extended Abstracts on Human Factors in Computing Systems (CHI EA ’05). ACM, New York, NY, USA, pp 1961–1964

Karam M, Schraefel M c. (2005b) A Taxonomy of Gestures in Human Computer Interaction.

Klemmer SR, Hartmann B, Takayama L (2006) How Bodies Matter: Five Themes for Interaction Design. In: Proceedings of the 6th Conference on Designing Interactive Systems (DIS ’06). ACM, New York, NY, USA, pp 140–149

Lakoff G, Johnson M (1980) Metaphors We Live By. University Of Chicago Press

Lederman S (1987) Hand Movements: A Window Into Haptic Object Recognition. Cogn Psychol 19:342–368.

Lee J (2010) In Search of a Natural Gesture. XRDS Crossroads 16:9.

Levine J (2002) Non-Exercise Activity Thermogenesis (NEAT). Best Pract Res Clin Endocrinol Metab 16:679–702.

MacIntyre B, Mynatt E, Voida S, et al (2001) Support for Multitasking and Background Awareness Using Interactive Peripheral Displays. In: Proceedings of the 14th Annual ACM Symposium on User Interface Software and Technology (UIST ’01). ACM, New York, NY, USA, pp 41–50

McCrady S, Levine J (2009) Sedentariness at Work: How Much Do We Really Sit? Obesity (Silver Spring) 17:2103–5.

Newell A, Rosenbloom P (1981) Mechanisms of Skill Acquisition and the Law of Practice. In: Cognitive Skills and Their Acquisition. Lawrence Erlbaum Associates,

Norman DA (2002) The Design of Everyday Things. Basic Books

O'Sullivan D, Igoe T (2004) Physical Computing: Sensing and Controlling the Physical World with Computers. Thomson

Olivera F, García-Herranz M, Haya P, Llinás P (2011) Do Not Disturb: Physical Interfaces for Parallel Peripheral Interactions. In: Proceedings of the 13th IFIP TC 13 International Conference on Human-Computer Interaction (INTERACT '11). pp 479–486

Owen N, Bauman A, Brown W (2009) Too Much Sitting: A Novel and Important Predictor of Chronic Disease Risk? Br J Sports Med 43:80–1.

Probst K, Lindlbauer D, Greindl P, et al (2013) Rotating, Tilting, Bouncing: Using an Interactive Chair to Promote Activity in Office Environments. In: Extended Abstracts on Human Factors in Computing Systems (CHI EA '13). ACM, New York, NY, USA, pp 79–84

Probst K, Lindlbauer D, Haller M, et al (2014a) A Chair as Ubiquitous Input Device: Exploring Semaphoric Chair Gestures for Focused and Peripheral Interaction. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '14). ACM, New York, NY, USA, pp 4097–4106

Probst K, Lindlbauer D, Haller M, et al (2014b) Exploring the Potential of Peripheral Interaction through Smart Furniture. In: Peripheral Interaction: Shaping the Research and Design Space, Workshop at CHI 2014.

Scarr J, Cockburn A, Gutwin C (2012) Supporting and Exploiting Spatial Memory in User Interfaces. In: Foundations and Trends in Human–Computer Interaction. pp 1–84

Scott S (2004) Optimal Feedback Control and the Neural Basis of Volitional Motor Control. Nat Rev Neurosci 5:532–546.

Shneiderman B (1998) Designing the User Interface: Strategies for Effective Human-Computer-Interaction.

Silva M, Bowman D (2009) Body-Based Interaction for Desktop Games. In: Extended Abstracts on Human Factors in Computing Systems (CHI EA '09). pp 4249–4254

Smith D, Irby C, Kimball R, et al (1982) Designing the Star User Interface. Byte 7:242–282.

Ullmer B, Ishii H (2000) Emerging Frameworks for Tangible User Interfaces. IBM Syst J 39:915–931.

Weiser M (1996) Designing Calm Technology. Powergrid J.

Weiss P, Jeannerod M (1998) Getting a Grasp on Coordination. News Physiol Sci 13:70–75.

Wickens C, McCarley J (2007) Applied Attention Theory. CRC Press

Williams L, Huang J, Bargh J (2009) The Scaffolded Mind: Higher Mental Processes are Grounded in Early Experience of the Physical World. Eur J Soc Psychol 39:1257–1267.

Wozny L (1989) The Application of Metaphor, Analgoy, and Conceptual Models in Computer Systems. Interact Comput 1:273–283.