Touching the dematerialized

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Abstract

Smart phones and tablet computers have flooded the world. With their seemingly intuitive multi-touch interface, they seem to be a step towards embodied interaction. But are they really? In this paper we take off with an analysis of these products and our interaction with them from the perspective of dematerialization. We claim that the multi-touch display is the outcome of a dematerialization process. As it is applied today, it fails to fulfill the promise of embodied interaction, since it results in an impoverished, standardized and computer-like interaction. Next, we introduce our own design perspective, the third stand, which aims to consciously guide dematerialization instead of blindly applying it. We believe this perspective leads to a fresh way of thinking about the multi-touch display. By presenting the design of a novel alarm clock, we emphasize the single-purpose character of the third stand, and reveal its own specific nature. Next, in two design projects, we confront the third stand with the multi-touch display and enhance the latter with specific, meaningful and rich actions. We discuss the results of these two design projects, and end this paper by reflecting on the third stand.

Keywords **–** Dematerialization, Industrial Design, Rich Interaction, Embodied Interaction.

1 Introduction

The embodied interaction [7] research agenda comprises several research domains such as tangible interaction [20], ubiquitous computing [36] and rich interaction [14]. Although each domain has its own character and emphasis, they all share a common flavour: the embodied perspective. This viewpoint considers humans as creatures that live and act in the physical world, and are inextricably linked with it. Therefore, digital technology and information should be mapped on this physical world in order for us to interact with it in a natural way. Today, digital devices have pervaded our everyday world. The most prominent among them are smart phones and tablet computers, both equipped with a multi-touch display. Their seemingly intuitive, direct interface, as well as their proliferation and omnipresence seems to be a leap in the direction of embodied interaction.

But we have some doubts. Embodied interaction does not merely suppose the ubiquity and availability of digital technology. It wants digital devices to "disappear into the background" [36]. Only when they do this, they can be "at hand" [33, 35], i.e. we are "freed to use them without thinking" [36]. Embodied interaction indicates a fundamental change in the interaction with digital devices itself, which should become more fit to the physical world that surrounds us [34] and less computer-like [25]. We feel that, in today's world of smart phones and tablets, this idea is not being operationalized to the full. In this paper, we focus on the multi-touch display from our own viewpoint of dematerialization, and uncover where it falls short. Next, we provide a design approach that opens the gate to a different mindset, which celebrates human values while at the same time embracing the new possibilities that state of the art technology affords.

2 Smart Phones and Tablets as Dematerialized Products

In this section, we take a closer look at today's smart phones and tablets. We focus on the multi-touch display, which determines most of our interaction with them. Next, we introduce our own perspective of dematerialization, its benefits and pitfalls, and its relation to the multi-touch display and its applications. This way, we are able to better articulate the aforementioned shortcoming.

2.1 The Multi-touch Display

The multi-touch display [21] is a touch sensitive screen that allows for discrete and continuous actions with one, two or more fingers. It reacts to tapping or sliding with one finger, or to simple gestures made with more fingers [3, 38]. The interaction that comes with it, distinguishes itself from the interaction with a traditional desktop PC, mainly by the closer integration of input and output. In the traditional desktop computer, input devices, the keyboard and the mouse, and output devices, typically a display, are physically separate entities. In smart phones and tablets, where the user directly touches and manipulates graphical elements on a display, this dichotomy has disappeared. Input and output are highly integrated, and *direct manipulation* [6, 13, 28] is exploited more fully than in the traditional desktop computer setting.

2.2 Dematerialization: Definition

In a previous publication [31], we defined dematerialization as an ongoing evolution where physical artifacts that act as information carriers (music CDs, books, money coins and bills, magazines, newspapers) disappear, or dematerialize. Their content digitizes and moves freely from one digital device to another, be it a PC, a smart phone, a tablet, an MP3 player, a payment terminal or an e-reader (Fig. 1). We described the benefits and the pitfalls of dematerialization. The benefits are found in the apparent limitless flexibility and availability of digital information, that allows us to, anytime and anywhere, have access to our finances, and our whole music and book collection. The pitfalls of dematerialization are related to the loss of physical richness that it seems to cause: with the departure of physical artifacts, a whole range of specific physical action routines vanishes as well. The specific physical shape of the former information carriers offered affordances [16] that appealed to the action abilities of our body. The interaction with the current digital devices that process the dematerialized information is limited to button-pushing or a set of standardized gestures on a display. Where the former artifacts appealed to the perceptual-motor skills of our body, the current generation of digital devices appeals more to the cognitive skills of our brain [26]. Henceforth, we refer to products with a history of dematerialization as *dematerialized products*.

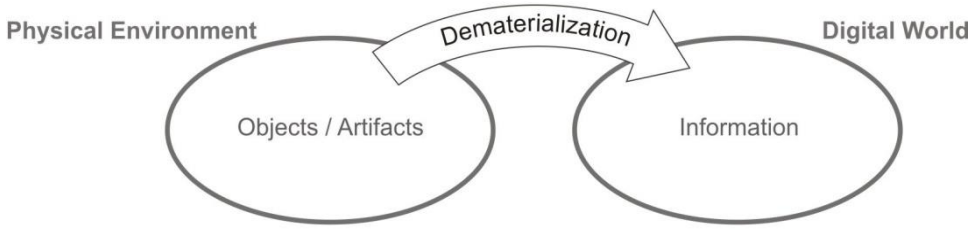


Fig. 1 The process of dematerialization

2.3 Dematerialization and the Multi-touch Display

If we look at the multi-touch display, it can be considered as strongly influenced by a dematerialization process. The multi-touch display has the characteristic that it generates an infinite amount of control elements: push buttons, levers, sliders and dials [9] are all virtually represented on the display and directly manipulated. The multi-touch display has *dematerialized the physical control element*. This dematerialized control element breaks loose from its physical limitations and adopts properties of the digital world:

- it becomes intangible, or rather, less tangible. You can touch it, but you can't feel it. It does not offer the rich inherent feedback that our body knows from interaction in the physical environment [37]. There is no graspable shape, texture, specific temperature, friction, …
- It becomes transient. It loses its persistence [16, 19] and can vanish and reappear at will.
- it becomes dynamic [17, 29]: the multi-touch display offers infinite functionality. It can become a push button, as well as a rotary dial or a slider.

This dematerialization process offers the benefit of flexibility. A product that is equipped with a

multi-touch display becomes very versatile. Smart phones and tablets can adopt myriads of identities. A smart phone is not merely a mobile phone, it is an MP3 player, an internet browser, a GPS system, an agenda, a camera, a remote control. The same goes for the tablet. The pitfall of this process is the physical impoverishment we mentioned earlier. Specific interaction routines with dedicated artifacts (e.g. the exchange of cash money) are replaced by standard gestures on abstract, symbolic representations of control elements behind a glass plate. This representation is a cognitive construct that demands interpretation, thus reflection from the person who interacts with it. Interaction with the multi-touch display consequently leads to a reduction in action and an increase in cognition.

The dematerialization of the control element causes yet another wave of dematerialization. Single-purpose digital products like digital cameras, cell phones, alarm clocks and remote controls tend to disappear, read dematerialize, as they are replaced by applications on smart phones and tablets [11]. Smart phones and tablets are multi-purpose devices that contribute to the current wave of dematerialization, themselves being an exponent of it. They are dematerialized products.

2.4 The Multi-touch Computing Paradigm

This pattern, where different products are replaced by one generic product, sounds peculiarly familiar. We already witnessed it with the rise of the Personal Computer. It was referred to as “the desktop computing paradigm” [12]. One of the most striking effects that the desktop computing paradigm brought about was “the extent to which physical performance of work has homogenized” [22]. In the pre-digital age, tasks like drawing, clay sculpting, reading and text editing demanded actions that were physically unique and therefore typical and demonstrative. Once these tasks could be accomplished with a personal computer, their characteristic actions made place for one versatile, standardized interaction with a display, a mouse and a keyboard.

Today, witnessing the dominance of smart phones and tablets, we think that history is repeating itself. The multi-touch display indeed liberates us from the desktop computing paradigm, or, at least, forms an alternative for it. It provides a computer interface that is more tangible [20] than the widespread WIMP (Windows, Icons, Menus, Pointers) interface [21]. However, because of its flexibility, the multi-touch display tends to generate multi-purpose products and makes single-purpose products disappear. This is where our criticism converges: in smart phones and tablets, mainly the generic character of the multi-touch display is emphasized and exploited (Fig. 2). This way, specific meaningful interaction is expelled. We claim that the desktop computing paradigm is simply replaced with a variation on it, which we name the *multi-touch computing paradigm*. We want to stress that we have nothing against the multi-touch display as such. We just think smart phones and tablets approach it one-sidedly. Smart phones and tablets are generic structures, which, similar to the personal computer, were designed to accommodate a broad range of software applications [5, 14]. When one looks through the varnish of tangibility, the smart phone and the tablet are traditional computers with an interface that is as standardized as the interface of a desktop PC. We think the multi-touch display can and should be approached differently.

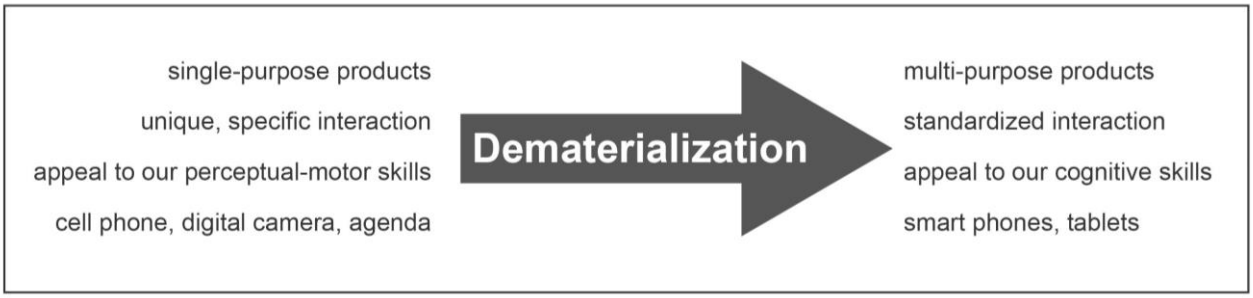


Fig. 2 Smart phones and tablets as the result of a dematerialization process

2.5 Conclusion

If we go back to our introduction, we do not think computers are disappearing into the background, i.e. the physical environment. On the contrary, witnessing the dematerialization of several single-purpose products and their transformation to applications on a multi-touch display, we see that *the physical environment is disappearing into the computer*. We argued that smart phones and tablets, as exponents of dematerialization, propagate a standardized, depleted interaction style that relies on cognition rather than on action. From this view, the alleged intuitiveness of smart phones and tablets is not as profound as it seems.

In the following section of this paper, we will present an alternative way of thinking about the multi-touch display.

3 Building Blocks for Change

In a previous publication [15], we distinguished two ways of approaching dematerialization:

- The first stand: This approach values the rich characteristics of the physical world. It is illustrated by the aforementioned information carriers like LPs, CDs and cash money, with their affordances and specific action routines.
- The second stand: This is the approach of the current generation of digital products. Dematerialization is fully embraced and seen as a way of making things more efficient, mainly because of the digital world's flexibility and availability. As we pointed out earlier, the second stand reaches a climax in smart phones and tablets.

We proposed the idea to open up dematerialization for industrial design [31]. We wanted to consciously guide dematerialization by designing dematerialized products that capitalize on the benefits of both the physical and the digital world, and avoid their respective pitfalls. In between the two existing stands, we formulated a way to combine the richness and meaningfulness of the physical with the flexibility of the digital. We called our approach the *third stand* and explored it through the design of a music player (Fig. 3, left). We don't want to position the third stand as a decisive set of design rules or guidelines, but rather as a perspective on the design process of dematerialized products. Our goal is to inspire, rather than instruct. Nevertheless, the third stand has

its own characteristics, which we describe here:

- It builds upon the Rich Interaction framework. Frens [14] coined rich interaction as a paradigm that, based on an harmonious balance of form, function and action, aims at aesthetic interaction with intelligent products and systems. This aesthetic interaction appeals to all human skills: cognitive, perceptual-motor and emotional skills. The third stand adopts its perspective and principles, and combines them with its own starting point of dematerialization.
- The third stand has a function-specific character. We believe that a balanced integration of the physical and the digital can be optimally created in products that are dedicated to one main task. These products have more opportunities to incorporate physical richness and affordances, since they can be designed around this specific task and the accompanying interaction.
- The central idea of the third stand is that it considers the dematerialized information aggregates (music albums, amounts of money) as tangible entities that are a vital part of the dematerialized product's physical architecture. It does this in a *temporary way*. In our previous publication [31], we illustrated the third stand perspective with a music player. We divided our music player in three different, spatially separated modules, according to its three main functionalities (Fig. 3, right): listening to a music album, browsing through a collection of music albums, and looking at a music album. Each module contained a representational element (a display, a sound element, an actuated element) and a set of controls. The dematerialized music albums flew from one module to the other, pushed back and forth by the user's actions on these controls. Once within the context of a module, the music album got a tangible shape (text, image, movement) through the representational element of that module. It *temporarily re-materialized*. This movement and the consecutive residence in the different modules gave the music album a physical, tangible feel.

Before we implement our third stand in the area of smart phones and tablets, we shall further explore its function-specific character. We discuss a perspective on single-purpose devices that inspired us, and then, through the design project of an alarm clock, we proceed with our own definition of strong specificity.

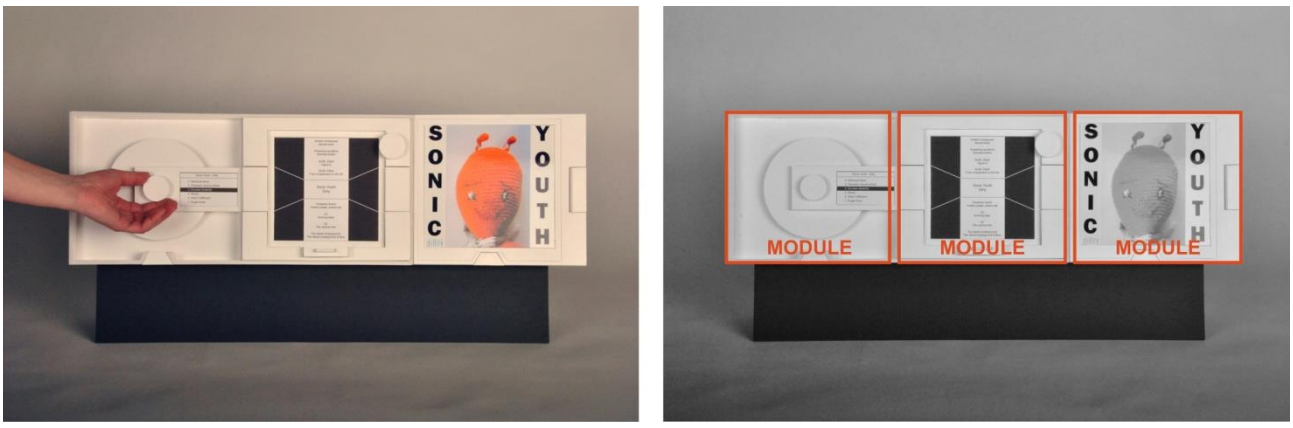


Fig. 3 Our music player (left) and its split-up into modules (right)

3.1 A Perspective on Single-purpose Devices

Buxton [2] introduces the concept of divergence as opposed to the, in the late nineties, dominant model of convergence. The convergence argument implied that different mass media would join, and that the internet would be the common media framework [8]. This meant that the personal computer would be used as a television, a radio, a newspaper. Divergence on the contrary argues that there is more merit in the design of purpose-built tools than in the "one-size-fits-all approach" of the personal computer [2]. These tools, "information appliances", as Buxton calls them, are linked with one another through a digital network, and in that way complement each other. Buxton illustrates this with a lucid comparison between the internet and the Waternet. Attached to the Waternet are specific appliances such as toilets, baths, showers, etc. The internet comes with only one appliance: the personal computer.

The reason for considering these digital purpose-built tools is twofold. First there is *simplicity* [24]. Information appliances deliberately offer less functionality, as opposed to the traditional PC, which is subjected to an ever increasing growth of functionality. Therefore information appliances are easier to understand. Second, there is *specialization* [8, 24]. If a product is dedicated to a specific task, its user interface can be designed around this task and its design can reflect a physical commitment to it. Buxton starts with deepening this idea by mentioning *Design in front of the glass* [2]. Instead of studying and streamlining the graphical user interface on the display, he suggests that HCI researchers should team up with industrial designers, and rethink the whole physical device which sits around the appliance. He illustrates his plea with the examples of the Palm Pilot, web radios and early MP3 players.

We largely agree with the theories of Buxton [2] and Norman [24] and with their tendency towards single-purpose products. However, they were formulated against the background of HCI, i.e. computer science. In line with Van Dijk et al [33], we argue that industrial designers are not primarily concerned with personal computers, but rather with how any digital product can play a meaningful role in the life of a human being. Djajadiningrat [5] makes an important remark when he describes the digital products of the early 21st century: "One would expect that strong specific devices tailored to a single task would feature alternative interfaces that are superior to the weak general PC, which needs to cater for many tasks. However, most electronic products feel very PC-like in interaction style." In other words, he claims that there is something missing in the single-purpose digital products, as Buxton and Norman present them (the Palm Pilot, web radios and MP3 players), something that seems to be overlooked by industrial designers and goes beyond simplicity and specialization. We adopt the expressions *strong specific* and *weak general*, and we explore this blind spot following a research through design approach [39].

3.2 Design Project: Alarm Clock

The first author designed a concept for a typical single-purpose digital product, an alarm clock. This concept is a research vehicle, an exploration as well as a carrier of our insights. It has enough product characteristics to draw conclusions from, but must not be seen as a full-fledged product

proposal. Fig. 4 visualizes the result.

Fig. 4 Visualization of our alarm clock

The design consists of two modules: an outer part, the time module, which displays the time, and a part that resides in the time module, the alarm module (Fig. 4). Since we intended the concept to be mobile, both modules are battery-powered. Let us go through a sequence of using the alarm clock.

At the beginning of the sequence, the alarm module rests inside the time module. Together, both modules form a closed shape (Fig. 5). Only the display of the time module is visible, which displays the time. No alarm time is set.

Fig. 5 The alarm clock with the alarm not activated

3.2.1 Setting the Alarm

To set the alarm, the user slides the alarm module out of the time module (Fig. 6, left). The alarm module comes with two toggle buttons, a display and a speaker (Fig. 4). The speaker holes are positioned around the display. The display shows the alarm time. At this moment the time is set at 0:00h (Fig. 6, right). The user sets the alarm time by toggling the 2 buttons. These buttons are naturally mapped to the displayed time. The left button controls the hours (Fig. 7, left), the right button controls the minutes (Fig. 7, right). Each toggle button has an upper and a lower activation zone (this is not shown on the figures). Pushing the upper zone causes the according number to increase, and vice versa. The user sets the alarm time at 7:00h and slides the alarm module back in the time module (Fig. 8, left), but in a reverse way. A new shape is formed by the 2 components (Fig. 8, right). This shape is larger and more obtrusive than the former one, and shows two displays: the hour display and the alarm display. The speaker holes in the alarm module are uncovered, and its toggle buttons are hidden, since these buttons are not needed at this point. The alarm is now activated.

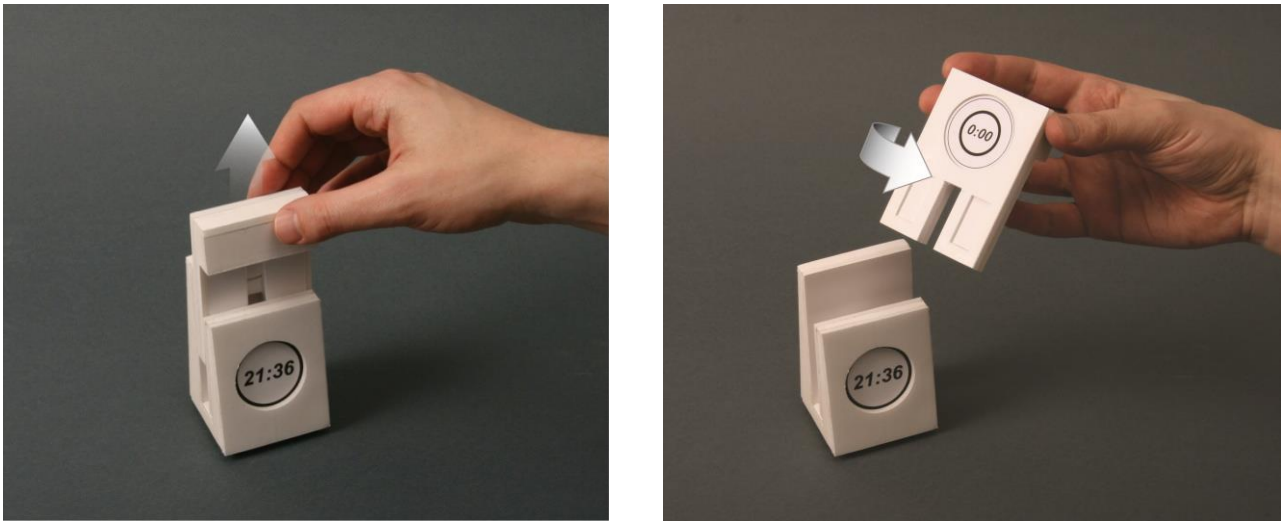


Fig. 6 Left: Sliding out the alarm module. Right: The alarm time set at 0:00h

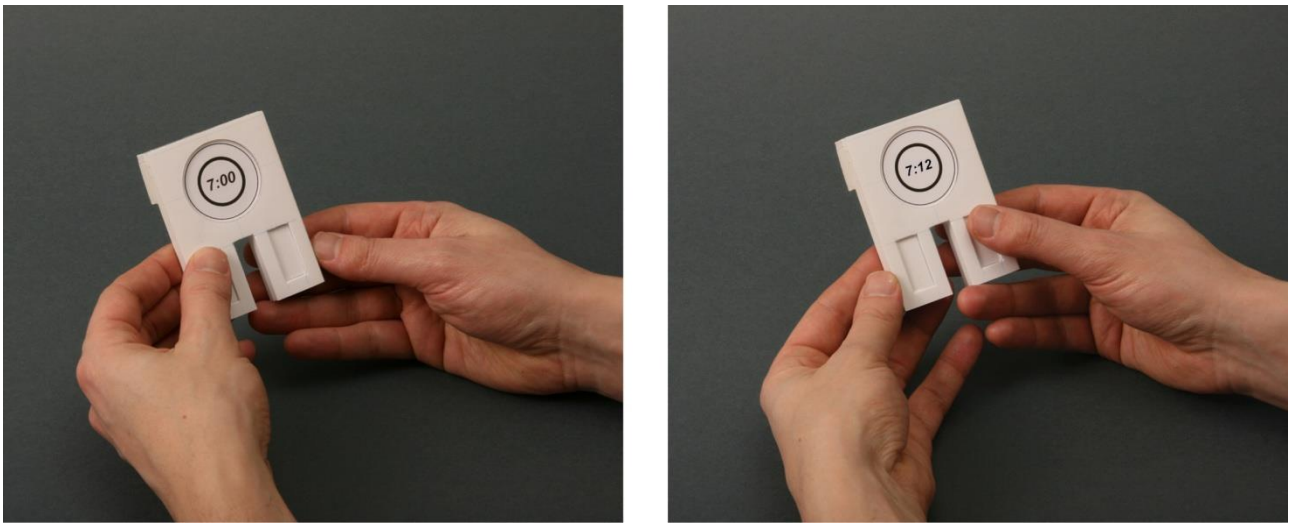


Fig. 7 Setting the alarm time. Left: Setting the hours. Right: Setting the minutes

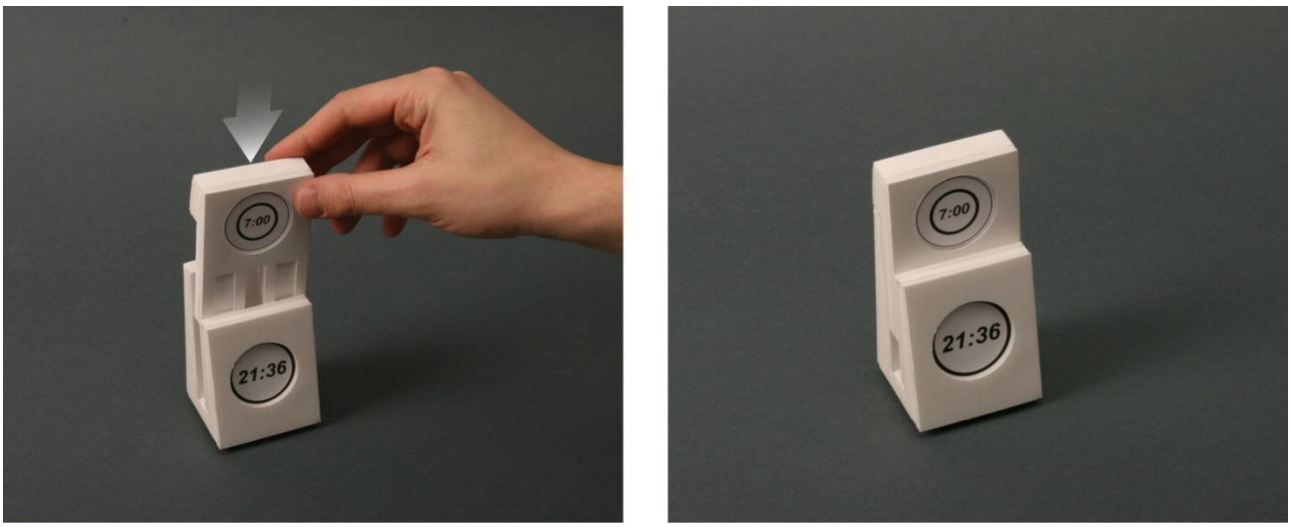


Fig. 8 Left: Sliding the alarm module back in the time module. Right: The alarm is activated

3.2.2 Snoozing and Deactivating the Alarm

When the time module displays the same time as the alarm module above it, both displays colour red and the alarm module produces an alarm sound. The user can temporarily pause the sound by pushing on top of the alarm module (Fig. 9). When the user wants to permanently stop the alarm from sounding, he takes the alarm module out of the time module (Fig. 10, left), and lays it next to it (Fig. 10, right), or slides it in again, this time the other way round.

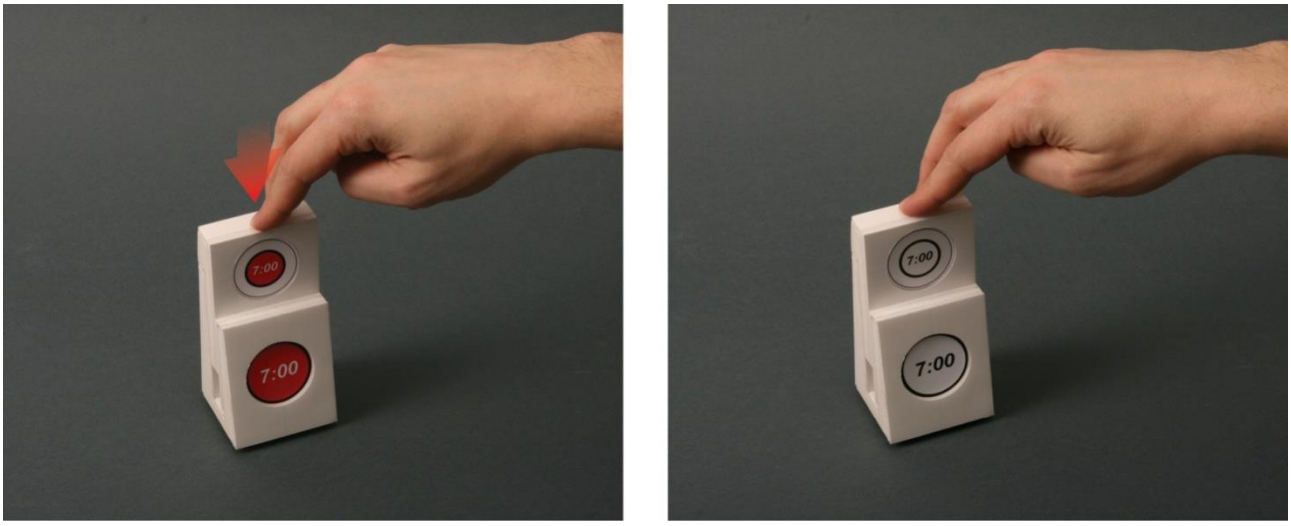


Fig. 9 Snoozing the alarm

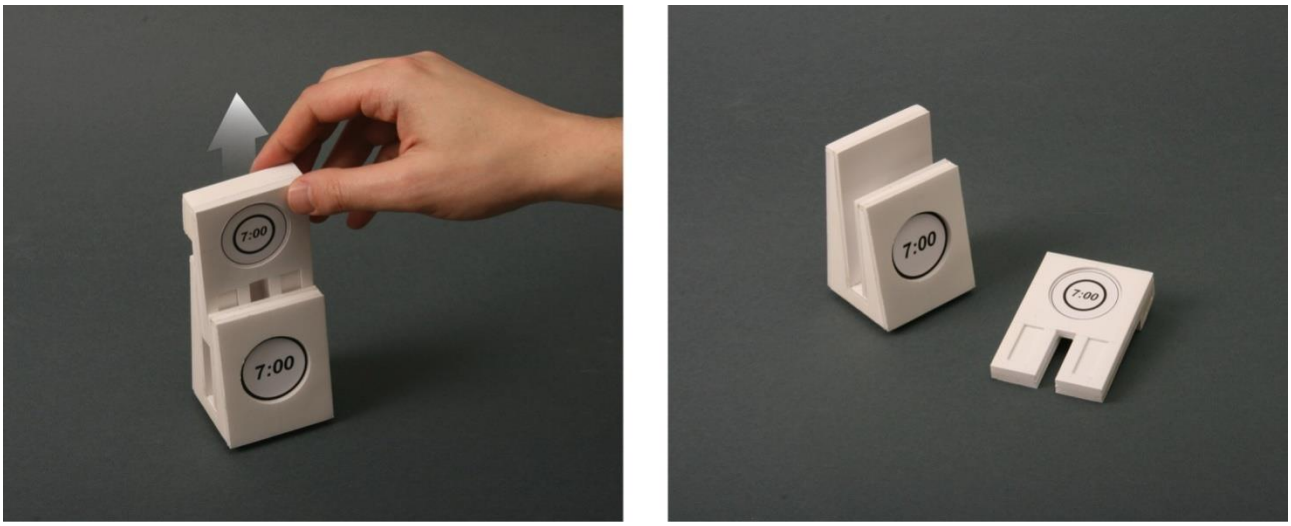


Fig. 10 Left: Taking out the alarm module. Right: The alarm module next to the time module

3.3 A Design-driven View on Single-purpose Devices

What we want to point out, is that we designed a concept for a single-purpose digital product, but in a distinct way. The single-purpose character of our alarm clock lies neither in the fact that it has a single function or purpose (its simplicity), nor in the fact that its physical shape is adjusted to this function (its specialization). It rather forms the blueprint *for the very nature of its interaction concept*, and, in this way, opens the gate to the physical world and rich interaction. Its form and its interaction are integrally designed around its function in a rich, physical way. This is our idea of *strong specificity*. Let us elaborate.

The first author rethought the concept of the traditional digital alarm clock by re-materialising the alarm into a physical entity, splitting the clock in 2 separate physical elements: the clock and the alarm. This way, you can activate the alarm by "loading" the clock with it, and you can deactivate the alarm by taking it out of the clock. These actions are meaningful to us, since they draw upon principles that exist in the physical environment: adding an object to another object and making it visible, and taking it away again or hiding it.

Starting from the idea of what an alarm clock is and does, we designed our interaction with it, before we designed the physical artifact itself [32]. We aimed at making the interaction process rich and physically meaningful, by adopting a perceptual-motor centred approach to design, which takes the human body and its action possibilities as a starting point.

3.4 On Shape Changes

Our alarm clock builds on the principle of physical shape changes. The clock adopts a different shape, depending on the position of the alarm module in the time module. This principle is derived from the rich interaction framework. Frens [14] gave us two powerful concepts to enrich interaction with digital products: MURPS and MR APs. Both build on the idea that the dynamic nature and the volatility of the digital world can partially be captured by products that physically change their shape. These different shape adaptations reflect the state of the product's processor at that particular moment. Djajadiningrat [4] speaks of 4D displays, where the changing shape of a product acts as a

display of its digital status. Frens calls this concept MURPS, mode of use reflected in the physical state. And he goes further. He says that a new shape has the unique property that it can offer new action possibilities to the user. This is what he calls MR APs, mode-relevant action-possibilities. We repeatedly applied both principles in our alarm clock. The idea behind MURPS and MR APs is that these physical shapes appeal directly to our body, instead of a textual message or an icon on a display which mainly appeals to our brain.

4 Another Perspective on the Multi-touch Display

In the previous two sections, we argued that the multi-touch display is the result of a dematerialization process, and that its current applications, smart phones and tablets, imply an impoverished, one-size-fits-all interaction style. We presented our own way to guide dematerialization and further explored its function-specific character. This raises a couple of questions. Is it possible to apply our third stand with its strong specific character on the multi-touch display? Could we enhance the standardized multi-touch interaction that comes with it, with richer and more meaningful actions? And could this throw a new light on the multi-touch computing paradigm and its current representatives? In order to answer these questions, we present two design projects, in which we approached the multi-touch display differently.

4.1 The Pay-Key Concept: Description

Fig. 11 Left and rigt: Two digital payment interaction concepts, both based on the traditional handshake as the confirmation of a payment transaction

We conducted a 6 week design course with 60 students from the 3rd year bachelor in our university. The design brief was to explore the interaction with dematerialized, digital money, and apply the third stand on it [32]. In other words, how does one manipulate money that is not physically present? The students had to, at first, design a meaningful payment interaction. After that, they translated this interaction in a set of products. At the end of the assignment, we got a broad

spectrum of concepts, which were presented through low-fi cardboard models. Fig. 11 shows some of them. One project, the “Pay-Key Concept”, designed by Gertjan Brienen and Collin van Hest, particularly captured our interest, because it succeeds in combining two interaction styles: multi-touch interaction on a display and rich interaction. It is a digital payment system for use in a lounge bar, which comprises a payment terminal, and the “Pay-Key”, a smart phone with a payment application. Fig. 12 shows the cardboard model of the concept. We will give a description of the interaction that comes with it.

Fig. 12 The Pay-Key Concept, with the Pay-Key on the left, and the payment terminal on the right

4.1.1 Communication of the Payment Amount to the Customer

The interaction takes place in a trendy bar. After spending a nice evening, the customer walks over to the bar counter in order to pay. The payment terminal is a rectangular box, standing upright on the bar counter, which separates the customer from the bar tender (Fig. 13, left). Both approach the terminal on opposite sides. The bar tender tilts the payment terminal over to the customer (Fig. 13, right). On top of the terminal is a display, which is activated by the tilting movement, and a round hole. At the end of this movement, the payment terminal literally leans over towards the customer, while displaying the payment amount to him (Fig. 14). The payment terminal is now in reception mode.

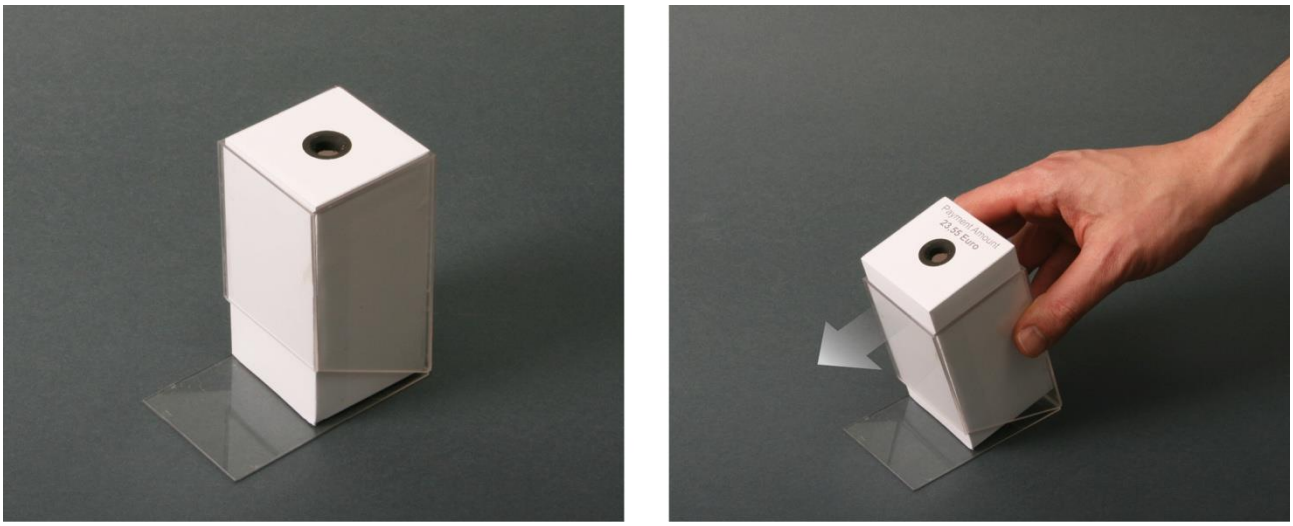


Fig. 13 Left: The payment terminal in passive mode. Right: Tilting the terminal towards the customer

Fig. 14 The payment terminal in reception mode

4.1.2 Preparation of the Customer's Pay-Key

The customer takes his Pay-Key. In fig. 15, the Pay-Key is in smart phone mode, and acts as a common smart phone with two multi-touch displays. It consists of two square elements (displays) and a metal shaft. One element is fixed on the shaft, and the other can rotate and slide on it. The customer rotates the latter element (Fig. 16) and slides it over the shaft next to the first element (Fig. 17, left). The displays change accordingly. The Pay-Key is physically transformed into a "key", with both displays oriented to opposite sides and displaying a green colour (Fig. 17, right). It is now in payment mode.

Fig. 15 The Pay-Key in smart phone mode

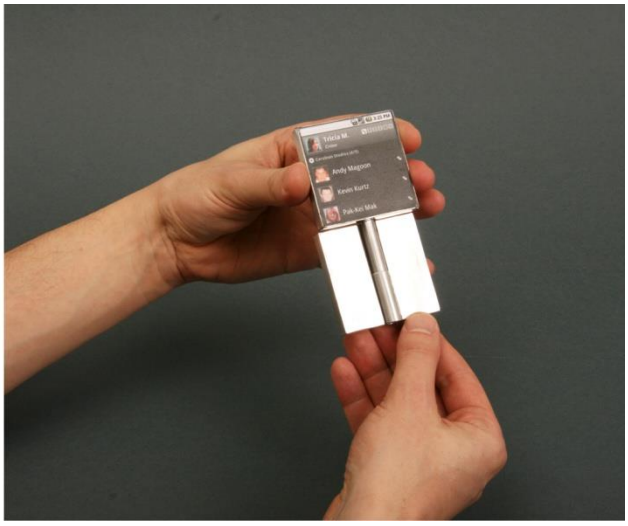
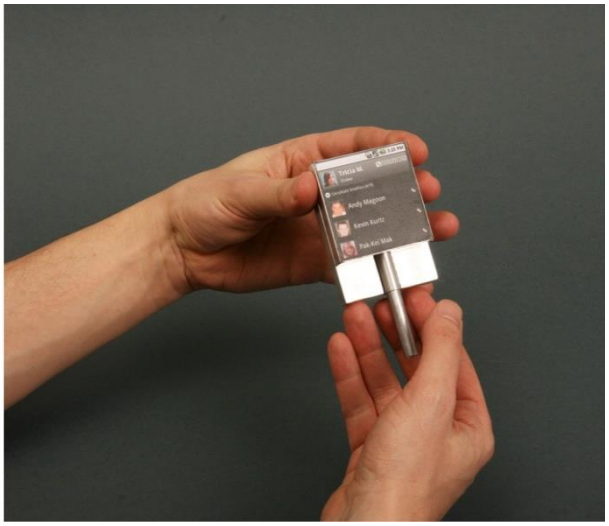


Fig. 16. Rotating the lower element of the pay-key



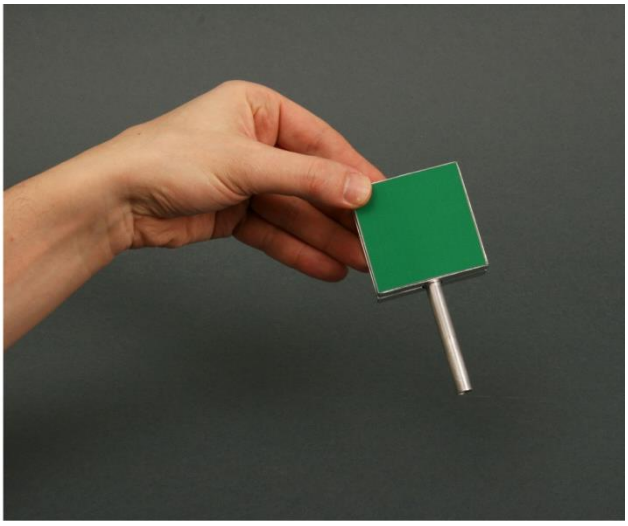


Fig. 17 Left: Sliding the lower element of the Pay-Key. The displays of the Pay-Key change accordingly. Right: The Pay-Key in payment mode

4.1.3 Payment Transaction

The customer inserts his Pay-Key in the hole on top of the payment terminal (Fig. 18, left). By pushing his pay-key towards the bar tender, he tilts the terminal back to its original upright position (Fig. 18, right). Once this position is reached, the green colour visually flows from the Pay-Key into the terminal by means of an array of green LEDs in the latter (Fig. 19). This clearly is a visualization of the transaction of money from the customer towards the bar tender. The customer pulls his Pay-Key out of the terminal (Fig. 20), which displays a confirmation message.

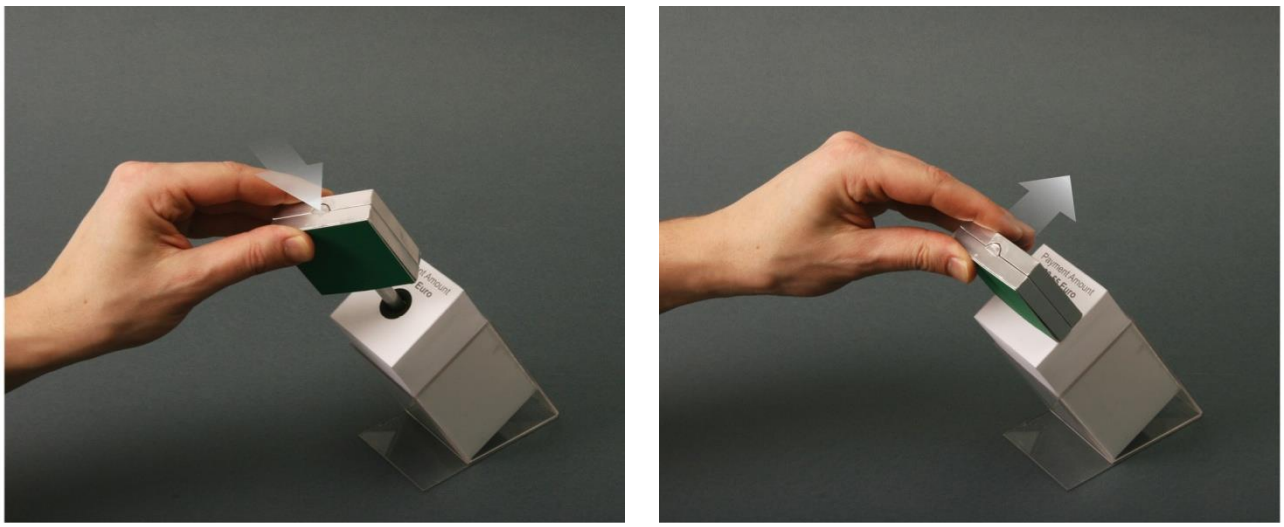


Fig. 18 Left: Inserting the Pay-Key in the payment terminal. Right: Tilting the terminal back to its vertical position

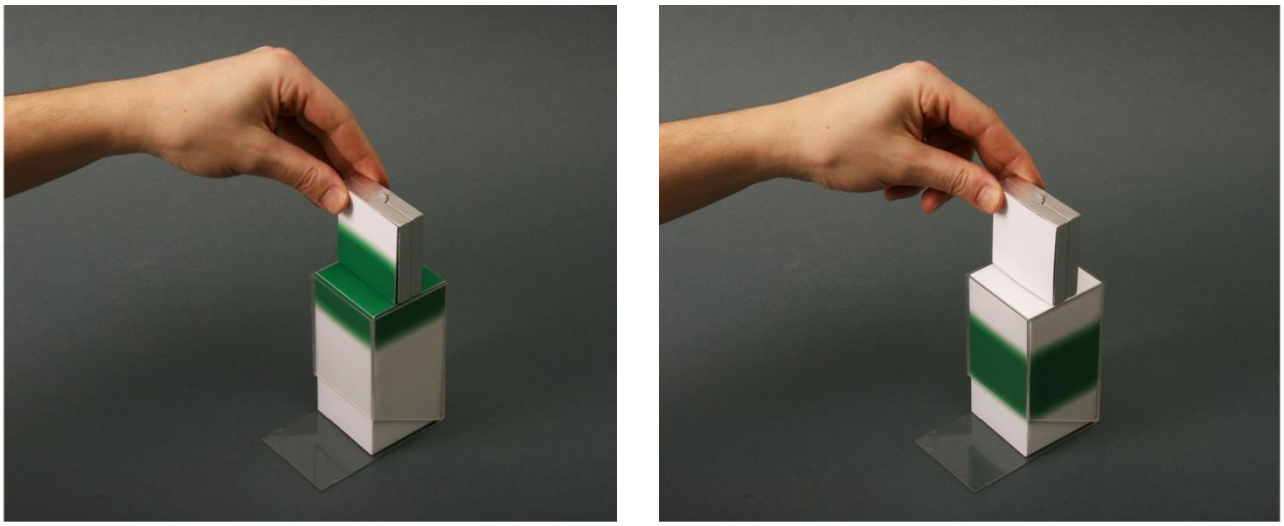


Fig. 19 The green color flows from the Pay-Key into the terminal

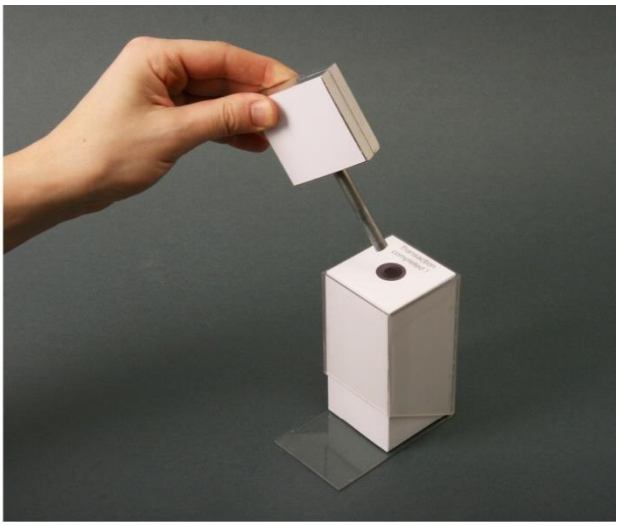


Fig. 20 After the transaction, the Pay-Key is taken out of the terminal

4.2 The Pay-Key Concept: Discussion

We first want to explain how the Pay-Key concept fits in the third stand framework. Then we will discuss why it captured our interest.

The Pay-Key concept is a dematerialized product-set in two respects: it makes use of an interface that, as we discussed before, dematerialized the physical control element, and it manages dematerialized money. It applies the third stand in the following ways:

First, the Pay-Key adopts our idea on strong specificity. It starts from a generic product, a smart phone, and transforms it into a strong specific one, a payment device, hereby opening the gate to rich interaction.

Second, the Pay-Key and the terminal temporarily re-materialize the physical control element. The Pay-Key's newly adopted shape and its displays offer new action-possibilities: the key clearly fits in the hole of the tilted payment terminal (Fig. 18, left). After insertion, both products together form an expressive control element. The Pay-key acts as a handle to tilt the payment terminal towards the vendor, while the tilting mechanism is provided by the terminal (Fig. 18, right). Once the product set is tilted in vertical position, gravity "acts on" the green liquid and causes it to flow (Fig. 19).

Third, the Pay-Key concept temporarily re-materializes physical money. Once the Pay-Key is inserted in the terminal, both products form the spatial stage for the interaction to take place. The dematerialized money is symbolized by the green liquid in the Pay-Key, and literally flows from the Pay-Key in the terminal. Its virtual change in location is activated by meaningful, physical movements: the insertion of the Pay-key in the terminal, and the tilting of the terminal. The result is a series of movements, physical ones and on-screen ones, with each a direction, a measurable distance and a pace. These movements harmonize together in a choreography that is meaningful and expressive [23]. The representational elements of both devices play a crucial role in this process. They are not merely carriers of information, but also carriers of matter. They temporarily re-

materialize the money and let it flow from one module to the other.

Why did the Pay-Key stand out and struck us? Because it combines multi-touch interaction on a display and rich interaction. When in smart phone-mode, the Pay-Key is a common multi-touch device (Fig. 15). However, the user can change its physical shape, and transform it into a strong specific payment device (Fig. 16, 17), that, together with the terminal, induces rich interaction. The limitation of the Pay-Key concept is that both interaction styles are applied in different product functions, thereby replacing each other: multi-touch interaction is exclusively applied in smart phone mode, while rich interaction takes over in payment mode. This combination of multi-touch interaction and rich interaction feels rather sequential, and therefore not fully integrated. However, for us, it showed that it is possible and promising to apply the third stand on the multi-touch display. The Pay-Key concept caused a pivotal moment in our thinking about the third stand, since it widened its scope, beyond "traditional" dematerialized products. We decided to further drive the integration of the multi-touch display and rich interaction in another research through design project.

4.3 The E-book: Description

The first author designed a device to read digital books, and paid specific attention to fit the multi-touch display in a rich interaction pattern. The e-book is presented in fig. 21. We illustrate it by walking through an interaction sequence.

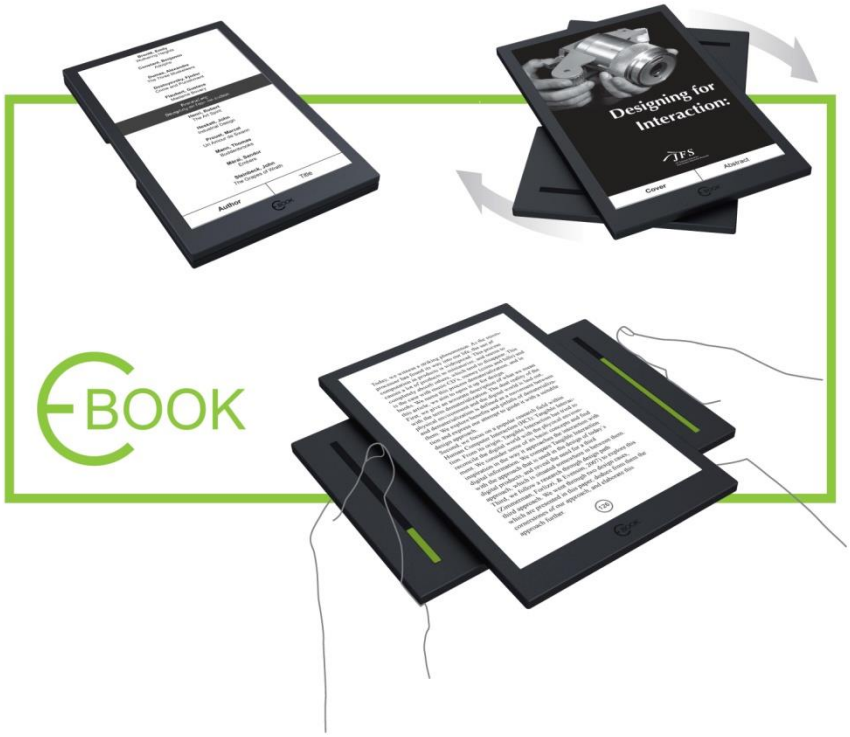


Fig. 21 Visual of our e-book

4.3.1 Activating the E-book

When the e-book is deactivated, it resides in a hard sleeve (Fig. 22, left). The user activates the device by simply sliding it out of the sleeve (Fig. 22, right). The e-book comes with a large multi-touch display, which lightens up when uncovered. A list of books is shown.

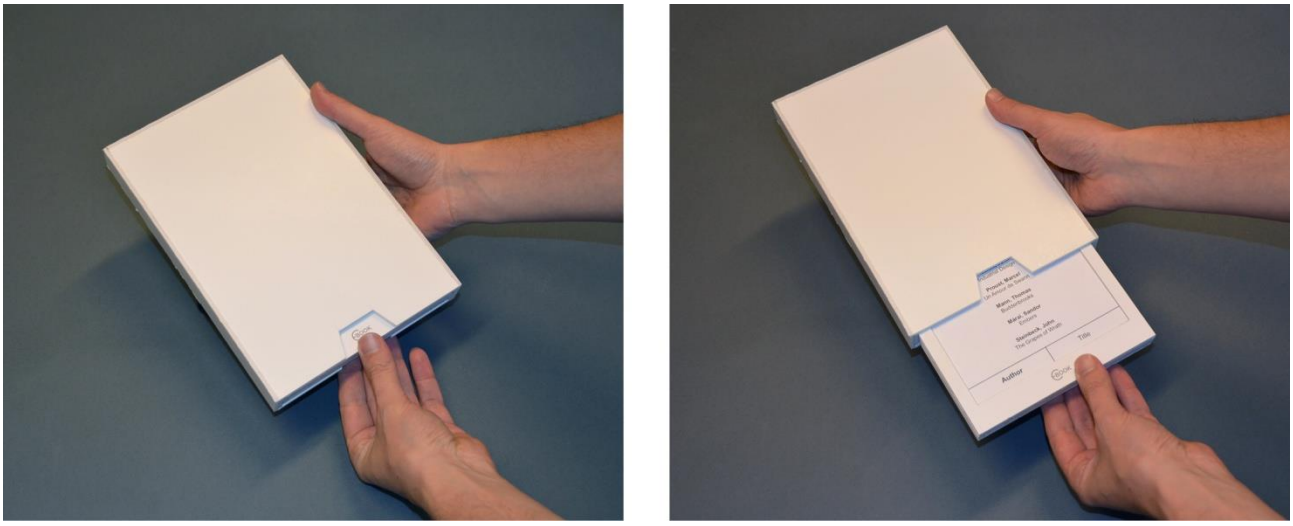


Fig. 22 Left: The e-book in its sleeve. Right: The e-book is activated by sliding it out of its sleeve

4.3.2 The Device in Selection Mode

The user scrolls through the list, and picks the book of his choice, by applying the well-known gestural movements (Fig. 23, left). The e-book then displays the chosen book (Fig. 23, right).

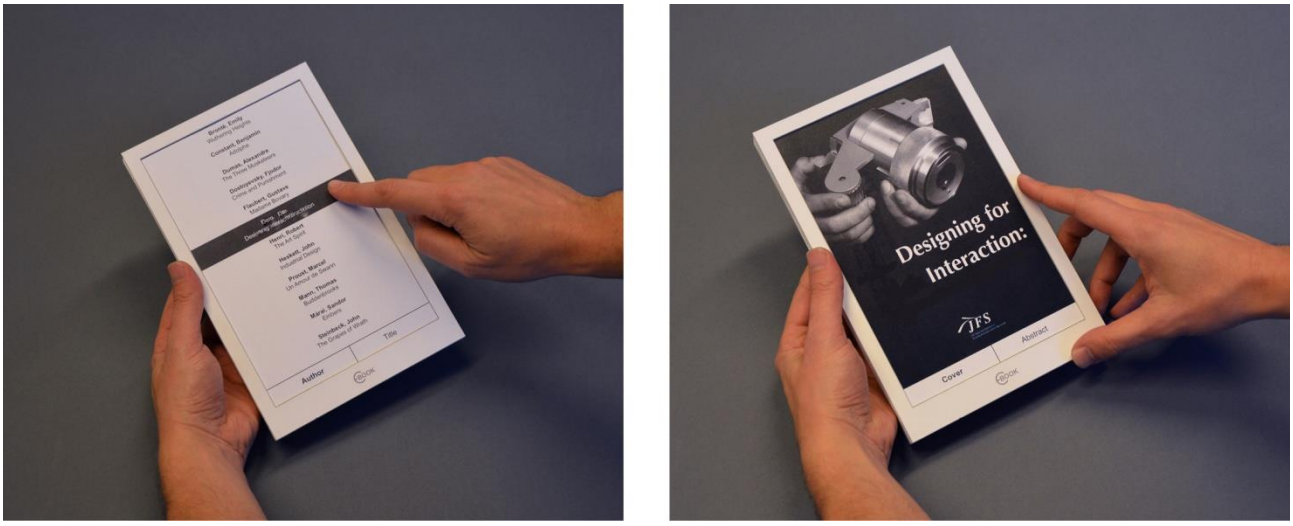


Fig. 23 Left: Scrolling through the book list, and picking the book of choice. Right: The chosen book is shown

4.3.3 The Device in Reading Mode

The device consists of two rectangular plates, which are stacked on each other and connected with a hinge through the middle of the plates. When the user decides he wants to read the chosen book, he rotates the back plate of the device 90 degrees clockwise (Fig. 24, left). The overall form of the device changes from rectangular to cross shaped. The user holds it as in fig. 24, right. The front

plate is in portrait position and displays a page of the book. The back plate is in landscape position, and contains two strips with green LED arrays. The height of the green bars varies with the amount of LEDs that is activated. These bars indicate where the displayed page is situated in the book. The green bar to the left of the displayed page indicates the relative amount of pages that precede it. The green bar to the right of the displayed page indicates the amount of pages that follow it. In fig. 24, right, the page is situated at about one sixth of the total amount of pages. The page shown in fig. 25 is situated at nine tenth of this total amount, so nearly at the end of the book.

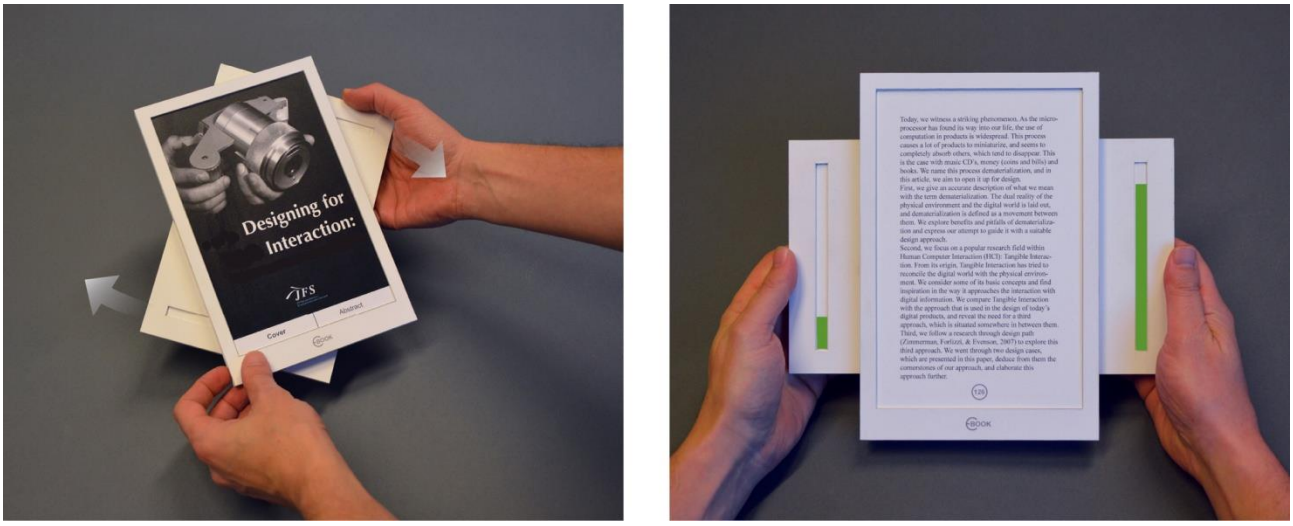


Fig. 24 Left: rotating the back plate to go to reading mode. Right: the device is in reading mode, at one sixth of the total amount of pages

Fig. 25 The device in reading mode, at nine tenth of the total amount of pages

4.3.4 Moving from Page to Page

When the user wants to see the next page, he blocks the display with his left hand (in Fig. 26, left,

with his left thumb), and pushes the side of the back plate with his right hand. This side is a spring loaded slider, and moves to the left. The displayed page moves accordingly to the left and makes place for the next page (Fig. 26, right). When the user wants to see the former page, he performs the opposite action: he blocks the display with his right thumb, and pushes the page to the right with his left hand (Fig. 27). This way the user navigates from page to page. The green bars on both sides of the display change height accordingly. When the device is in reading mode, it only offers a tactile interaction, as there is no multi-touch functionality present.

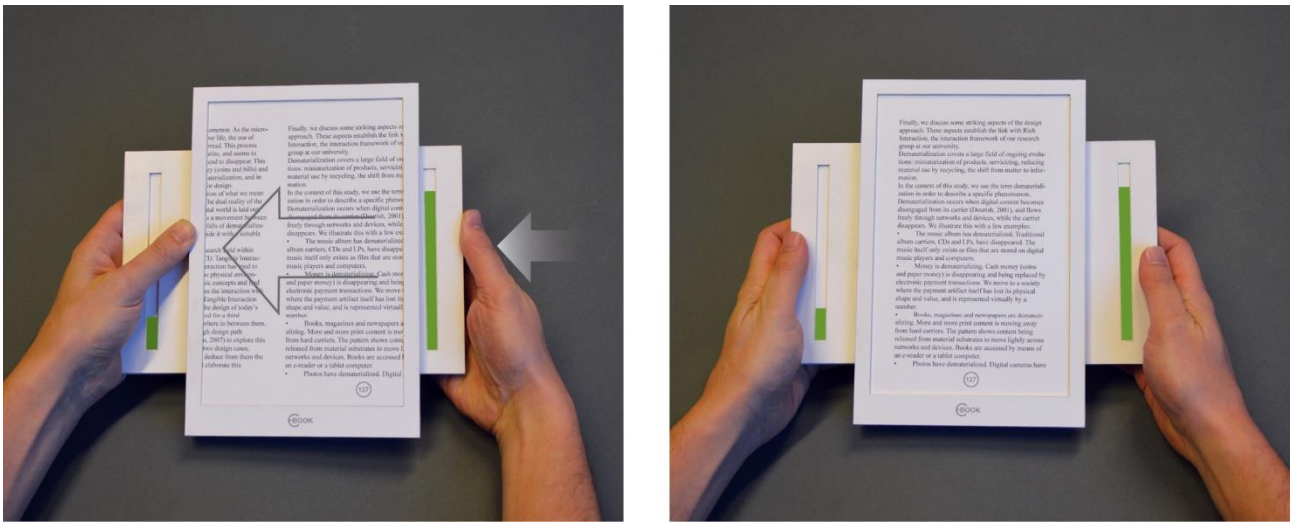


Fig. 26 Going to the next page by “pushing the pages” to the left

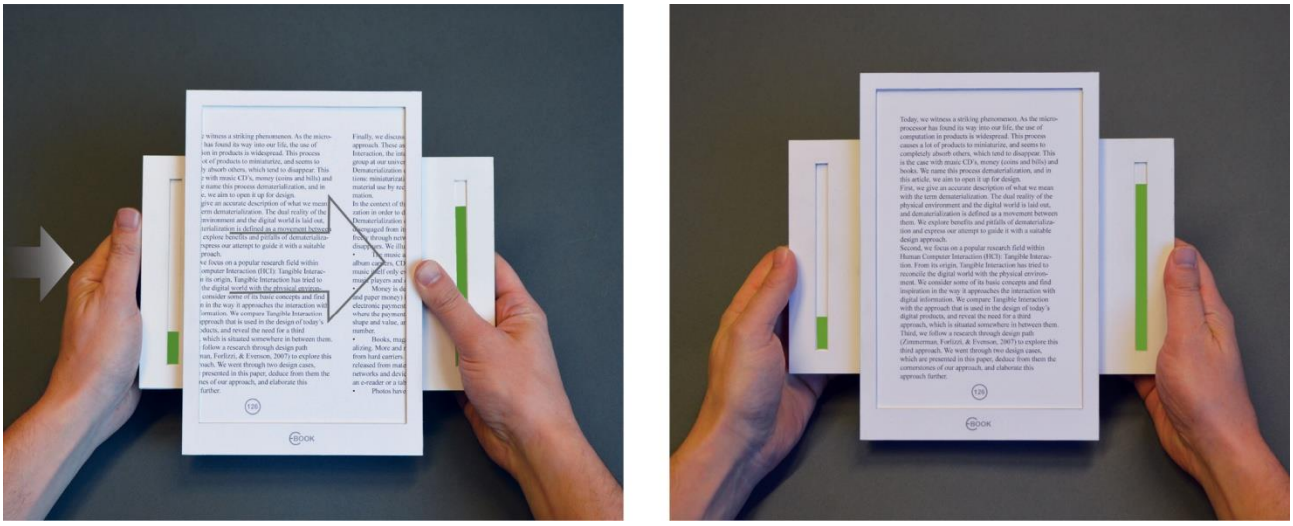


Fig. 27 Going to the former page, by “pushing the pages” to the right

4.3.5 The Device in Browsing Mode

To browse quickly through the e-book, the user pushes both sliders at once towards the display (Fig. 28). When they both reach their stop, they are magnetically held in place, and “disappear”, i.e. their action possibility disappears. The two green LED-bars deactivate and “jump” onto the screen. They now explicitly display their connection graphically at the bottom of the display. At the same time, some menu buttons appear on top of the display. The device is again in multi-touch mode. The user

can touch a position on the green scale, and the device will navigate to the page that corresponds with it. Or he can push the green scale back and forth, to quickly browse through the e-book (Fig. 29, left). The user reaches extra functionality like character size or placing a bookmark by touching one of the menu buttons (Fig. 29, right). When he wants to go back to reading mode, he touches the text page itself (Fig. 30, left). The green bars jump on the two sliders, which are released and move outwards (Fig. 30, right). The device is again in reading mode.

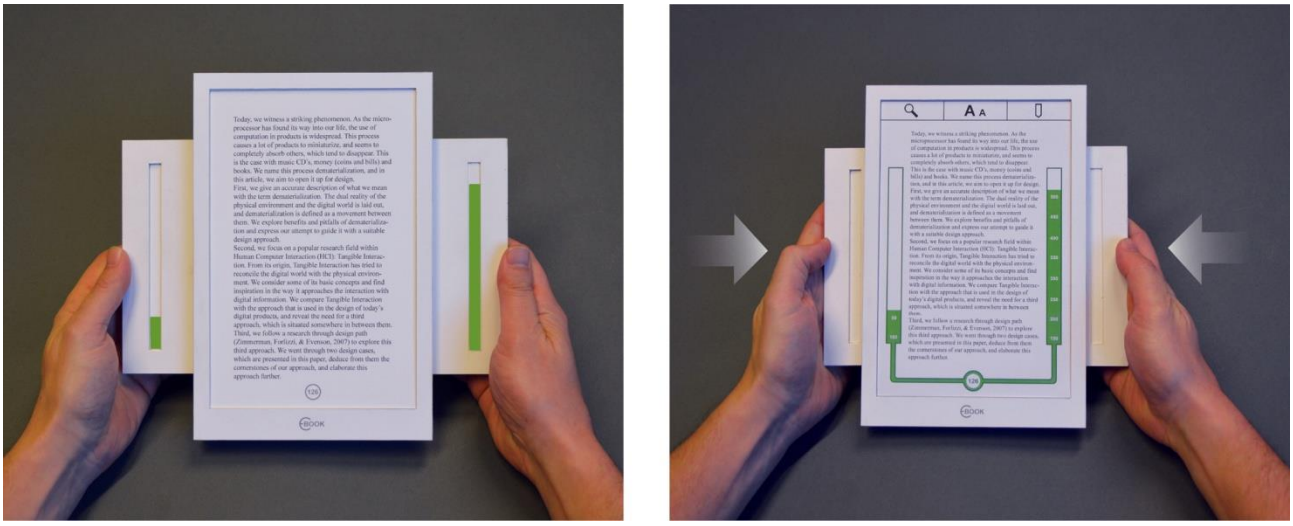


Fig. 28 Pushing both sliders towards the display to go to browsing mode. The green LED bars "jump" on the display

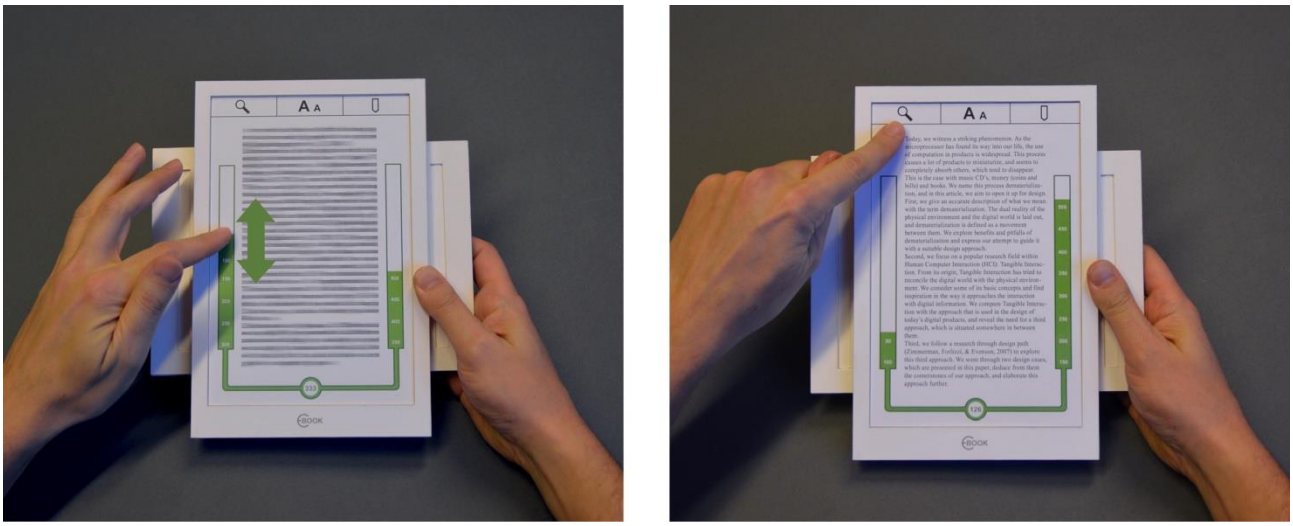


Fig. 29 Left: browsing through the e-book. Right: touching the menu buttons at the top of the display

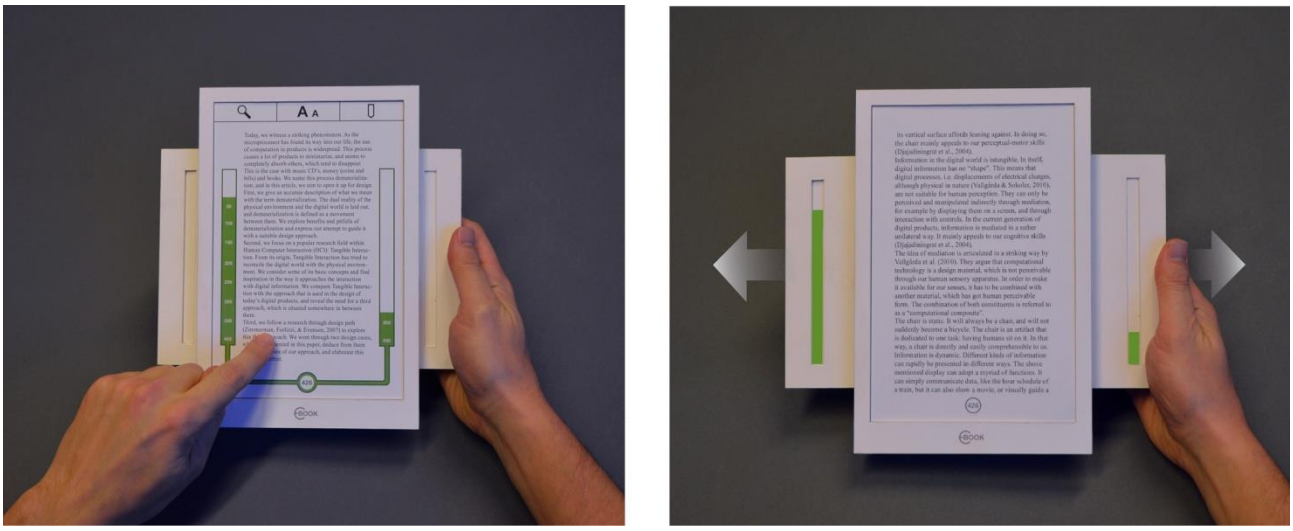


Fig. 30 Left: Touching the text to go back to reading mode. Right: The two sliders are released and move outwards. The green LED bars "jump" on the sliders

4.4 The E-book: Discussion

Just like the Pay-Key concept, our e-book copes with two forms of dematerialization: the dematerialization of physical control elements, and dematerialized books. It does this by building on the third stand, again in three ways.

First, it is a function-specific concept, and it is designed according to our vision on strong specificity. It offers a specific, rich interaction routine.

Second, the e-book temporarily re-materializes the physical control element. Its interaction is a balanced integration of multi-touch actions on a display, and rich actions on physical controls. When in selection or browsing mode, the display acts as a multi-touch display, and the two sliders are unreachable, since they are either rotated under the display (selection mode, Fig. 23), or pushed in and held in place electromagnetically (browsing mode, Fig. 29). When in reading mode (Fig. 25, 26, 27), the sliders are relevant and reachable. The multi-touch functionality is turned off in this mode. The user can only touch the pages by touching the sliders.

Third, our e-book temporarily re-materializes physical book pages. Once in reading mode (Fig. 25, 26, 27), three components are laid out in front of the user: the display and the two green LED strips. All three represent the pages of the book. These dematerialized pages slide back and forth from the green LED strips on to the display, in a horizontal flow. The on-screen movements are activated by physical movements, the manipulation of both sliders. The result is, again, a harmony of virtual and physical movements, which aims at temporarily re-materializing the pages.

What did we learn from this research through design project? While in the Pay-Key Concept, the multi-touch display and rich interaction are only superficially combined, the e-book shows us that both can be integrated in a more profound way. We explain this here. We based our design on the following reflection. In the act of reading a physical book, one can distinguish two mental states:

- the state where the reader finds himself immersed in the world behind the printed book pages
- the state where the reader comes back in the here and now to digest his mental adventures

In the first state, his physical actions are limited to page-turning, a bodily, tactile action for which little mental effort is needed. The book itself has disappeared, and is "ready-to-hand" [35]: the reader acts "through" the book to reside in another world. In the second state, the user executes actions like counting pages, looking up names of characters in previous chapters, reading about the author on the back page, etc.. Through these actions, the book reappears again and becomes "present-at-hand" [35]: the user acts "on" the book, and is aware of it as an object of his activity. We took the distinction between both states as the basis for our design. Our e-book dedicates an interaction style to each state:

- rich interaction to the "ready-to-hand" state (reading mode)
- multi-touch interaction to the "present-at-hand" state (selection or browsing mode)

4.4.1 The e-book in ready-to-hand state

When the user is involved in the act of reading a book (reading mode) with his e-book device, he moves the book pages back and forth through an almost unaware physical manipulation of both sliders (Fig. 26, 27). The physical movement of the sliders seems naturally coupled with the virtual movement of the pages [37], and offers continuous and tactile, thus bodily, feedback to the user. The engagement of the user with the device is one of "embodied coping" [10]. Multi-touch is deliberately deactivated in this mode, so the user is not exposed to involuntarily moving a page or activating another function, while immersed in the realm of the story. We believe the e-book's reading mode approaches the act of reading a physical book.

4.4.2 The e-book in present-at-hand state

When the user is in selection or browsing mode, he deliberately steps out of the book's fictional world, and is back in the present. Multi-touch actions are offered in these modes (Fig. 23, 29), since they can handle a wider range of possibilities and demand more attention, and thus cognitive effort. Fig. 31 summarizes the different interaction styles.

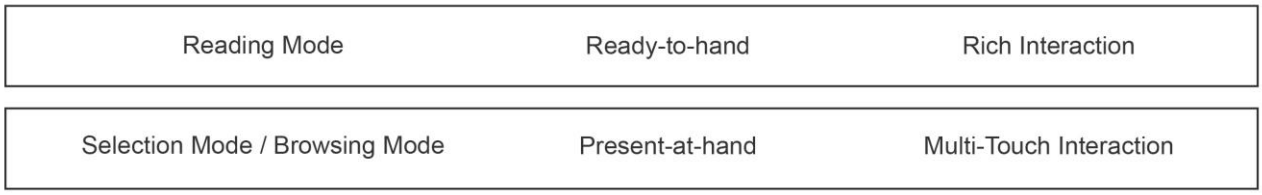


Fig. 31 An overview of the different modes in our e-book

Since reading a book involves a repeated switch between both mental states, we believe that both

interaction styles will alternate each other frequently and naturally, and will be experienced as one integrated interaction. Dourish [9] speaks of *variable coupling*. He claims that "a continual process of engagement, separation and reengagement" is crucial for an effective use of each tool or product. By building on the concept of variable coupling, our e-book, more than the Pay-Key Concept, integrates both interaction styles up to a mature level.

5 Resume

Before reflecting on the third stand and its significance with respect to the multi-touch display, we would like to recapitulate the rationale that we followed up to now. We claimed that the multi-touch display, being a dematerialized product, suppresses the richness of the physical world and raises a standardized interaction for a multitude of tasks. We proposed the third stand as our framework to guide dematerialization. A research through design project, our alarm clock, illustrated the strong specific character of the third stand, which opens the gate to the physical world. The Pay-Key Concept, a student project, triggered us to apply the third stand on the multi-touch display, and to combine two interaction styles: multi-touch interaction on a display and rich interaction. We elaborated this combination in yet another research through design project: our e-book. We will now discuss the benefits and limitations of this e-book, and of our third stand.

6 General Discussion

Our e-book applies the third stand, and integrates multi-touch interaction on a display and rich interaction. The benefit of this approach lies in the resulting interaction, which aims at offering the richness of the physical world. But there is a significant cost: the multi-touch display becomes function-specific, and loses its versatility. How do we cope with this? We want to stress that we do not have the intention for third stand products to replace second stand products, i.e. smart phones and tablets. Both product types can exist next to each other: function-specific as well as generic. When we position the third stand like that, we can focus on its benefits, rather than regret its loss of flexibility. Then what exactly are these benefits, and how must we frame them? Or else: Why do we need to re-materialise? We try to answer this question in the following discussion.

6.1 Familiarity

In the context of embodied interaction, Dourish [7] mentions the concept of *familiarity*. We humans are familiar with the physical world and its residents, its artefacts and processes. If we can build upon this familiarity when we design digital products and systems, the latter will be more "fit" to us and our environment. Our interaction with digital products and systems will be more natural. Let us look at this concept in the context of our e-book.

As we discussed before, interaction with today's multi-touch display in smart phones and tablets *actually is* more natural and intuitive than interaction with a traditional desktop PC. In our opinion, in this generation of digital products, the concept of familiarity is applied *in a pragmatic way*, to

make these products more efficient and easy-to-use. And it works. If you compare our e-book with today's multi-touch e-readers or tablets, our e-book does not make book-reading more efficient. On the contrary, in terms of physical effort, our e-book places a higher burden on the user than a commercial e-reader does, since the latter involves less physical handling. Still, we feel that people would appreciate our e-book. Why? Since it offers other values than effectiveness or efficiency [18, 27]. We designed this e-book simply because we felt that the slow, static nature of a physical book is somewhat at odds with the dynamic character and flexibility of the multi-touch display, as it is used in today's e-reader. In other words, today's e-reader is a single-purpose product, but not a strong specific one. When we designed our e-book, we considered the familiarity concept more broadly. We see humans as cognitive, perceptual-motor and emotional creatures [26], and we consider book-reading as an all too human activity. By reflecting on the act of reading a physical book, and on its meaning for us in our personal life, we came to the distinction of the two different mental states, which lead to two different interaction styles, as we discussed before. In other words, we designed the reading interaction, *before* we started to design the hardware [32]. We let this interaction drive our design process, and ended up with a concept that offers a composite, differentiated interaction pattern [5], as compared to interaction with a tablet computer. We think this composite interaction style feels more fit to the human body, which is capable of an enormous amount of different, meaningful actions [1, 4]. Moreover, we think this composite interaction style offers *a different reading experience*. The continuous switching between acting *through* and acting *on* the e-book, resonates with the recurring periods of immersion that one experiences when reading a physical book.

To conclude, in the context of our e-book, re-materialization and the third stand provided us with handles to create a specific reading interaction that is potentially more diverse and fit to the user, than the standardized multi-touch interaction with the current e-reader or tablet computer. In general, re-materialization and the third stand urge the designer to question the multi-touch display, and to design a specific interaction *before* he designs the hardware that sets the stage for it.

6.2 A new Set of Values

There is another reason why we advocate the third stand. The aim of the third stand is not simply to make the digital less computer-like. We do not necessarily consider the digital as something incomplete, which becomes better when combined with the physical. We value the rich action potential and inherent meaningfulness of the physical but are also attracted to the dynamism and fluency of the dematerialized digital [30]. We feel that, when the two of them are integrated in the right way, new values emerge, which are uniquely present in this specific physical–digital space, i.e. *on the border between* the two worlds, not *inside* either one of them. In our e-book, these new values must be sought in the coupling between physical and on-screen movements. When the user goes to browsing mode, by simultaneously pushing both sliders towards each other (Fig. 28), both green LED bars jump from the sliders on the screen. The physical control elements literally dematerialize in front of the user's eyes, which exposes the tension between *the persistent* of the

physical and *the ephemeral* of the digital world. We believe this tension is a vital characteristic of the third stand, and, if consciously worked out by the designer, leads to products that are highly fascinating, stimulating and engaging. For now, we place these values in the area of aesthetics of interaction, and come back to them in further research.

7 Conclusion

We started by stating that the current generation of digital products, with the smart phone and the tablet computer as exponents, do not entirely match the principles of embodied interaction. From our viewpoint of dematerialization, we argued that these products are dematerialized, multi-purpose products, centred round a very flexible multi-touch display. They propagate a standardized interaction style, which leads to a homogenization of different tasks, and a narrowing of interaction. In this matter, we established the multi-touch computing paradigm as a contemporary version of the desktop computing paradigm.

Next, we discussed our own third stand, which we established in order to guide dematerialization. Through the design of an alarm clock, we explored further its single-purpose character, and extended it with the idea of strong specificity. We wondered whether this third stand could open new ways of thinking about the multi-touch display and the interaction that comes with it.

A student project, the Pay-Key Concept, inspired us to think that our third stand could lead to a fruitful combination of rich interaction and the multi-touch display. We further explored this idea in a research through design project of a digital book-reading device, where we first designed the reading interaction, and after that the actual product. We concluded that re-materialization leads to products that offer a specific user interaction, and a more adapted experience. We shortly touched upon a new kind of aesthetics of interaction, that comes along with the third stand.

Djajadiningrat [5] implicitly asks *why* the current generation of strong specific digital products feels so “computeresque”, in other words, *why* the interaction that they imply is reduced to button pushing or multi-touch gestures. We believe the answer is that today’s industrial designers are trained to think about form and function, but lack training to bring this skill to the act of designing for interaction. We hope this paper can inspire them to think differently.

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