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Grace: A gesture-controlled wake-up light

Abstract
We investigated the use of a deviceless gesture control for a wake-up light, a type of alarm clock which wakes the user through both light and sound. We explain the interaction design challenges for the wake-up light and discuss the drawbacks of deviceless gesture control. These challenges and issues were explored through an experience prototype which we call Grace. We argue that deviceless gesture controls fit the sleepy interaction associated with the wake-up light and help in realizing a calm product appearance. Our key finding is that gesture control needs continuous guidance: real-time, augmented feedforward and feedback, which helps to increase the user's confidence during interaction and to improve gesture recognition.

1 Introduction
In this project, we focused on an interaction style called deviceless gesture control. Deviceless gesture control allows users to operate devices from a distance without the need for physical remote controls, body-worn electronics or markers [1], [2].
One of our use cases was a wake-up light, a type of alarm clock which wakes the user through both light and sound. A wake-up light fades in the light over a set period of time (default 30 minutes) before the alarm time. By the time the alarm sounds, the lamp has reached full strength. This slowly increasing brightness causes the user to gently wake up. The intended experience is captured in the product's tagline of "a natural, gradual way of waking up".
In this paper, we first describe the wake-up light's interaction design challenges. Then we discuss the interaction issues with deviceless gesture control. We describe two participatory innovation events, one with developers, the other with users. We then argue the benefit of gesture control for a wake-up light. Finally, we present a concept called Grace in which we address the wake-up light's interaction challenges and discuss the interaction principles we used to mitigate the drawbacks of deviceless gesture control.

2 Wake-up Light Interaction Design Challenges
Designing the interaction for the wake-up light is challenging for four reasons: multi-functionality, programmability, sleepy users and conflicting interaction and product design requirements.

2.1 Multi-functionality
A wake-up light is a multi-functional product which combines an alarm clock, a dimmable light, a radio and a digital music player, operated through a single user interface. Many of these functionalities are intertwined. For example, the brightness of the light is controlled by the alarm time of the clock. As a result, a modal approach to the interface is not possible as many functions 'straddle' two or more modes. It would

also require users to switch back and forth between modes to access functions which experientially belong together.

2.2 Programmability

Many of the parameters are programmable, including the wake-up time, the fade-in duration, wake-up brightness and the wake-up sound. Both this programmability and the aforementioned multi-functionality stretch the interface of the current generation wake-up light which consists of an alpha-numeric display and push buttons. Such a 'display + push button' interaction style is known to put a heavy burden on users' cognitive skills and to be slow and cumbersome for adjusting analog parameters [3].

2.3 Sleepy Users

Another reason why users may have more difficulties with operating a wake-up light than with other products is simply because of sleepiness. Immediately after waking up people suffer from sleep inertia, a physiological state characterized by diminished motor dexterity and a feeling of grogginess [4], [5]. This impaired alertness may interfere with our ability to perform mental or physical tasks. Similarly, sleep homeostatis–the physiological process whereby our need for sleep increases the longer we stay awake – results in sleep pressure which leads to diminished cognitive performance [6]. Clearly, these are the very moments – just after having woken up and just before going to bed – when users interact with their wake-up light. At these moments, tasks which are trivial when fully awake suddenly require effort.

2.4 Interaction vs Product Design Requirements

A Wake-up Light has many analog parameters (e.g. brightness, volume, wake-up time) and long-list parameters (e.g. radio station presets, MP3 tracks) which in current models are operated through binary, up-down controls. This requires the user to press buttons multiple times when making large adjustments, leading to a staccato style of interaction.
From an interaction design perspective, one approach to improve the interface would be to add dedicated, analog controls so that key analog parameters may be controlled directly instead of via menus and up-down buttons, resulting in a more fluent interaction style. However, one of the starting points for the product design is that a wake-up light should have a calm appearance which fits the bedroom environment.
To create such a calm appearance, the design should avoid the overt use of control panels and displays which are likely to create visual clutter. This then is where product design and interaction design potentially clash. Product design on the one hand calls for minimizing the number of controls and for repeated use of the same type of control to realize a calm appearance which makes it difficult to realize intuitive interaction. Interaction design on the other hand calls for dedicated, differentiated and analog controls such as sliders and rotary controls, all of which results in the visual codes which typify the consumer electronics 'gadget' genre. Part of our challenge was to investigate how deviceless gesture control could contribute to solving this conflict.

3 Gesture Control Challenges

Gesture control is often perceived to offer the ultimate in interaction simplicity, a popular view which is strengthened by science-fiction movies such as Minority Report [7]. According to this view, gesture control may add cost and technical complexity but will definitely result in a superior end-user experience. Considering how quickly the cost of the required technology decreases, some even envisage a day when we may interact with all our products through gesture control.
However, for the end-user, gesture control may have drawbacks more fundamental than a higher purchase price. Here we describe two user experience issues with gesture control: the need for an initiation method and the lack of inherent feedforward and feedback.

3.1 The Need for Initiation

If gesture control were continuously enabled, users may unintentionally trigger a function. For example, if the brightness of a wake-up light is controlled through an up-down gesture, any vertical movement in the active zone such as picking up a glass of water may influence the lighting. Clearly, such false positives are frustrating as they break the user's sense of control. To prevent such unintentional triggering, users need to switch on gesture recognition before they can make a functional gesture. Our term for such an action is the initiation action. The challenge in choosing an initiation action is that if we opt for a physical movement, this initiation gesture must not occur in daily ritual and is therefore unnatural by definition. Here then lies the contradiction within gesture control: whilst gesture control is often described as offering natural interaction, the required initiation action can make it feel contrived.

3.2 Lack of Inherent Feedforward and Feedback

Physical controls such as mechanical buttons, switches and sliders have many interaction qualities, which we take for granted. For example, when using a light switch, we can see and feel the position of the switch on the wall as well as see and feel what action is required (e.g. toggling, pressing, rotating or pulling). When we switch on a light, we can see and feel the switch move and hear the click. Such inherent feedforward and feedback [8], [9] is not self-evident when it comes to gesture control. It may not be clear how to gesture or even where to gesture. In some gestural interfaces, the only feedback the user gets is when the functionality is triggered after completion of the gesture.
Though this may seem sufficient, it becomes troublesome if the system fails to recognize a gesture because it is not sufficiently well-defined, too quick or out of range. Users then seek to understand what went wrong but without feedforward and feedback it is unclear why things fail and they cannot correct their actions.
As a consequence the user can feel lost, not quite knowing what is happening in the interaction dialog. We may draw a comparison with human conversation, in which we judge from non-verbal body language cues whether we are being understood. It is this body language which is lacking from gesture-controlled products: we gesture to the product but the product fails to gesture back.

Karam [10] proposes a framework for gestural interaction with three types of feedback: reflexive, recognition and response feedback. Response feedback occurs when the user is notified that the intended task has been completed. Recognition feedback is given when the system has successfully recognized the user's gesture. These two types of feedback are known from interaction design for traditional user interfaces. For example, the light switching on in reaction to the user flicking a switch is a form of response feedback.
A beep as a reaction to a button having been pressed is a form of recognition feedback. Of particular interest to gesture control, however, is reflexive feedback which provides the user with feedback on the state of the input during performance of a gesture. Karam uses a window in a graphical user interface to provide reflexive feedback. In this reflexive window, users can see themselves performing their gestures and get feedback on what the computer sees in terms of objects being tracked.

Fig. 1. Ideation through bodystorming in context.

Fig. 2. Participant acting out gestures with WoZ experience demonstrator.

4 Participatory Innovation Events

To explore the UX we staged two events: a multi-disciplinary ideation session during a multiple stakeholder workshop with developers and a multi-cultural Wizard of Oz test in which users were confronted with an early experience prototype.

4.1 Multiple Stakeholder Ideation

Twenty developers, including technologists, marketeers and designers, ideated in multi-disciplinary teams through bodystorming in context [11], [12]. In a staged bedroom, one team member acted out the gestures to control the wake-up light, while others simulated the reaction of the product (Figure 1). A rating session at the end of the day showed that participants particularly appreciated three features: brightness control through vertical hand movement, stumble light activation – to find one's way to the bathroom at night – through a quick flick of the hand, and direct manipulation of analog clock and alarm hands through touch gestures.

Fig. 3. Vertical hand movement controls brightness.

Fig. 4. Lazy snooze. In the morning, waving in front of the Wake-up Light suffices to activate snooze.

4.2 Multi-cultural Wizard of Oz Test

We turned the preliminary concept from the multiple stakeholder workshop into a low-fi experience prototype by back-projecting an interactive animation onto the casing of an existing wake-up light (Figure 2). This experience prototype was then evaluated in Wizard of Oz style with nine users of different ethnic origin. First, we explained the functions to be offered by the wake-up light. We then asked participants to act out the gestures they would choose to control these functions and simulated the wake-up light's response from behind the scene. After having shared their own preferred gestures, we explained to them the gesture-functions combinations which had come out of the multiple stakeholder ideation session. They were then asked to also act out these gestures and again we simulated the wake-up light's response in Wizard of Oz style. Finally we asked participants to reflect upon the differences between the two sets of gestures.

5 Benefits of Gesture Control for Wake-up Light

Our experiences with the multiple stakeholder workshop and the Wizard of Oz user test sharpened our understanding of how gesture control can be of benefit for the wake-up light. Gesture control may help realise the wake-up light's promise of 'a natural gradual way of waking up', by complementing the functional light effect with a low cognitive load interaction style which fits the user's sleepy physiological state. Gestures can offer control over the wake-up light's key functions without the user having to interpret labels, icons or displays and without having to reach and fumble for buttons. Finally, gestures allow the user to stay snug and comfortable while operating the device from a distance. We chose the following gesture-function combinations:

• Brightness - vertical hand movement
• Volume - horizontal hand movement
• Snooze - wave on alarm
• Show the time left to sleep - wave during the night
• Stumble light - wave until active

The gesture vocabulary was intentionally kept small with only three gestures (horizontal, vertical and wave) to avoid it becoming like a modern day DOS language which requires users to learn and remember a large collection of arbitrary gesture-function combinations [13].

6 Concept Design

We designed and built an experience demonstrator of a gesture controlled wake-up light which we call Grace. Our aim was to address both the aforementioned wake-up light interaction design challenges and issues with gestural interaction.

6.1 A Sleepy Interaction Style

We designed Grace to allow sleepy, low cognitive load interaction.

6.2 Adjust Brightness/Volume Whilst Staying Comfortable

When reading in bed or listening to music, the user can simply adjust the light level through a vertical hand movement or sound volume with a horizontal hand movement without having to reach. Whilst adjusting the light level, the light ring reacts with a 'peacock' effect: the line between the dark and light part of the ring follows the user's hand movement (Figure 3).

6.3 Lazy Snooze

In the morning, waving in front of the Wake-up Light suffices to activate snooze (Figure 4).

6.4 Ambient Sleep Time Indication

A wave during the night suffices to make the Wake-up Light show the "time left to sleep". It will light up an arc from the current time to the wake up time. The length of the arc will give the user an approximate indication of the time left to sleep without having to interpret the hour and alarm hands (Figure 5).

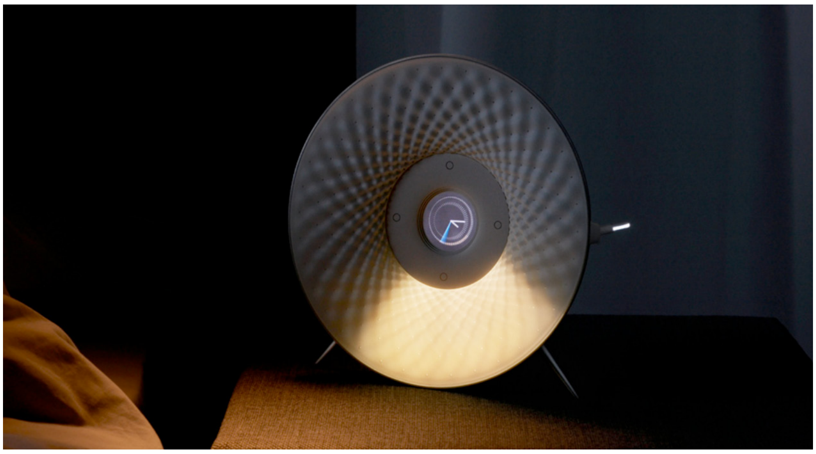

Fig. 5. Ambient sleep time indication.

Fig. 6. A touchwheel is used to enter detailed settings.

6.5 Calm Appearance

Grace uses a combination of deviceless gesture control for the key functions (Figures 3-5) and a touchwheel for detailed settings (Figure 6). The touch wheel allows easy adjustment of analog parameters such as the wake-up time and the dusk duration. It also allows easy selection from long-lists such as radio stations and MP3 playlists. The combination of deviceless and touch-based gesture control allowed us to eliminate all but one physical control and to keep the product's appearance very clean and restrained. The final design is based on a round form factor with three concentric circles (Figure 7), the semantics of which suit an analogue clock, support the sun metaphor and refer to the traditional alarm clock product category. The inner circle is formed by a circular colour OLED display, the middle ring is formed by a touchwheel and the outer ring is formed by the light surface. To further strengthen the reference to traditional wind-up alarm clocks, the product stands on three legs, two in front and one at the back (Figures 8 and 9).

6.6 Initiation by Delay

One way to make initiation faster, less convoluted and less contrived is to use a multi-modal approach. For example, a physical movement can be combined with sound (e.g. handclap, finger snap) or voice [14]. However, when interacting with the wake-up light the user's partner may be asleep and initiation must be silent. Therefore we opted for initiation by delay: the user needs to hold her hand still for 1.5 seconds within the active zone before gesture control becomes active.

6.7 Continuous Guidance

As previously mentioned, inherent feedback is missing from deviceless gesture control. We therefore need to add augmented feedforward and feedback to provide users with information on what is going on [9]. With gesture control this augmented feedforward and feed-back needs to change in real-time in response to users' gestures so that they may adjust their actions while gesturing. For this we use the term continuous guidance (Figure 10).

With Grace, we provide continuous guidance by means of an animated point cloud effect on the circular OLED display to elegantly bridge the delay during initiation. There are two possibilities when the user's hand enters the active zone. The first option is that the user has no intention of operating the wake-up light and that the hand passes through the active zone incidentally, for example to pick up a glass of water, a set of keys or a mobile phone (Figure 11). In this case, the clockface which is shown in the idle state changes into a point cloud which follows the user's hand movement, to return to a clockface when the user's hand leaves the active zone. The second option is that user does intend to operate the wake-up light (Figure 12). In this case, the clockface changes into a point cloud which moves with the hand to then morph into a cross-shaped UI during the initiation delay. The cross-shaped UI indicates that horizontal (i.e. volume) and vertical (i.e. brightness) gestures are possible.

Grace's continuous guidance serves a purpose similar to Karam's [10] reflexive feedback. However, in the case of Grace the display shows an abstract representation of the user's gestures rather than a camera image.

Fig. 7. The design of Grace is based on three concentric circles.

Fig. 8. The front legs are reminiscent of traditional alarm clocks.

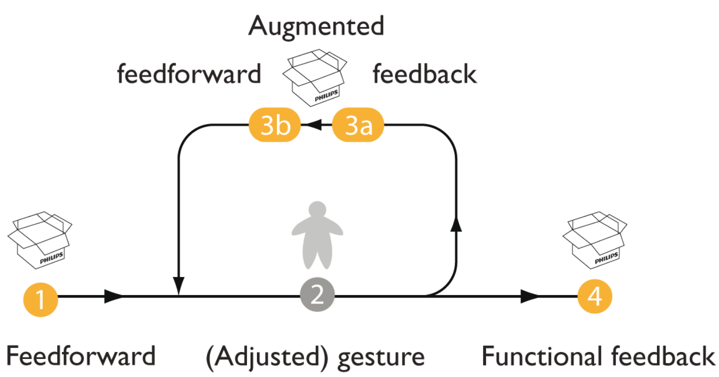

Fig. 10. Continuous guidance is about repeating steps 2 and 3 until the intended function (4) has been triggered.

7 Reflection

Gesture control's main drawbacks are the need for an initiation action and the lack of inherent feedforward and feedback. In our concept we tackled these issues together: Grace makes use of initiation by delay while an animated point cloud provides continuous guidance by mirroring the user's hand movements and bridging the delay through a morphing effect. This implementation shows that continuous guidance need not take the form of a literal camera image of the user but can also take a more abstract and impressionistic form.
Through this project, we discovered that gesture control has a number of lesser known user experience advantages. One is that gesture control requires less focus than traditional, physical controls and therefore is a comfortable form of control when the user is sleepy. Another advantage is that gesture control offers can offer direct, analog control over key functions without the need for traditional analog controls such as sliders or rotaries which clutter the product design.
In any case, gestural interaction raises many semantic issues. In contrast to physical controls, gestures can be coupled to form, feedback and function in any way desired. A gesture has no fixed meaning that is only suited to a particular function. Instead, the meaning of gestures is pliable and can be influenced through a product's form, its physical and screen based UI and light and sound. Gesture control puts much responsibility on designers to prevent these couplings from coming across as completely arbitrary.

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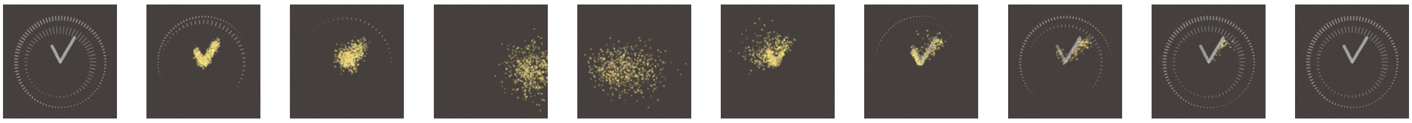

Fig. 11. Presence detected but the user does not activate gesture control.

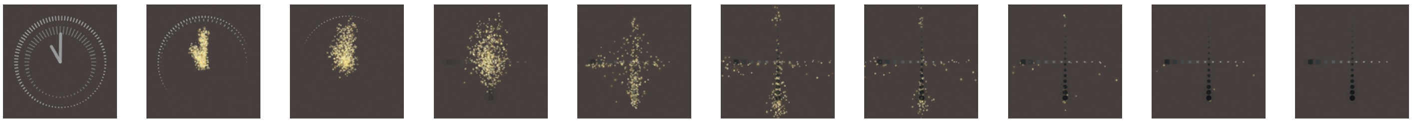

Fig. 12. User initiates gesture control.

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Fig. 9. Grace looks lighter than existing Wake-up Light models, and leaves space underneath for small objects such as mobile phones and keys.

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