# Introspectibles: Tangible Interaction to Foster Introspection

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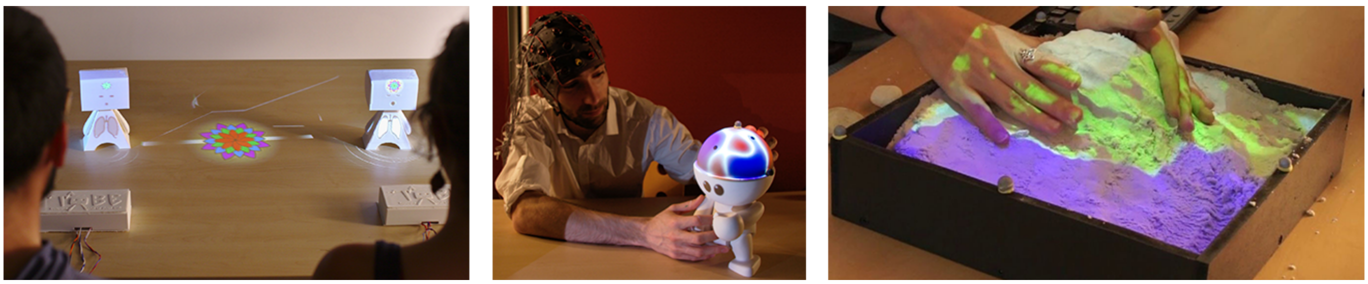


**Figure 1: (Left) Tobe is a toolkit enabling the creation of tangible augmented customized bio- and neurofeedback. Here, two users are relaxing together by using Tobe to reach cardiac coherence. (Middle) Teegi is an augmented tangible avatar that displays the user's brain activity in real time. (Right) Inner Garden is an augmented sandbox, linked to the user's inner states via physiological sensors, designed for contemplative play.**

## ABSTRACT
Digital devices are now ubiquitous and have the potential to be used to support positive changes in human lives and promote psychological well-being. This paper presents three interactive systems that we created focusing on introspection activities, leveraging tangible interaction and spatial augmented reality. More specifically, we describe anthropomorphic augmented avatars that display the users' inner states using physiological sensors. We also present a first prototype of an augmented sandbox specifically dedicated to promoting mindfulness activities.

### Author Keywords
Mindfulness; Tangible Interaction; Spatial Augmented Reality; Physiological Computing; Virtual Reality

### ACM Classification Keywords
H.5.1 Multimedia Information Systems: Artificial, augmented, and virtual realities; H.5.2 User Interfaces: Prototyping

## INTRODUCTION
Seeing the rise and ubiquitousness of the digital devices in recent years, many Human-Computer Interaction (HCI) researchers, designers and technologists have started looking at computers not merely as devices to interact with, but as a support of positive changes in their users' lives. Examples of this can be seen in the recent combination of positive psychology [19] and the fields of design [3] and HCI [1]. There are a multitude of factors that have been shown to contribute to subjective well-being and Calvo and Peters [1] have made an extensive inventory of them. In this paper, we present different interactive systems that we created to foster introspection – i.e. to reflect on our own selves. More specifically, we focused on *interoception* – the ability to sense one's internal bodily signals [4] –, *contemplation* and ultimately *mindfulness* – a broad and nonjudgmental present-moment awareness.

Traditional HCI is often focused on manipulating digital information through devices. The vision of Ubiquitous Computing, as proposed by Weiser [22], instead envisioned digital technology fused in the environment itself, only intervening when necessary. One of the underlying goal was to create *calm* experiences [23]. We present systems that are rooted in this philosophy of infusing the real world with a digital overlay so as to keep user's awareness of the environment and create such experiences. For this purpose, we are mostly leveraging tools from Spatial Augmented Reality [17] and Tangible User Interfaces [13].

Notably, for interoception, we proposed two different augmented tangible avatars (Figure 1, left and middle) representing real-time physiological measures – ElectroEncephaloGraphy (EEG), ElectroCardioGraphy (ECG), ElectroDermal Activity (EDA), breathing. Also, we developed tools to craft tailored representations of such signals. Then, based on the toolkit we created, we target contemplative and mindfulness practices. We built a first prototype of an augmented physical toy that took the form of an augmented sandbox hosting a digital world, which properties are mapped to the user's breathing and heart rate (Figure 1, right).

## EXPOSING INNER STATES

We developed tools to let people discover and learn about their inner selves. We got interested in tangible interaction, notably because of pedagogical principles; learners better become conscious of complex phenomena through self-investigation and manipulations [21, 5]. Hence, we have been using tangible augmented objects as a medium to grasp the complexity of physiological activity and human minds.

Teegi [6] is a "puppet" that displays the users' brain activity in real time – recorded by the mean of EEG. Teegi proved to be an appealing form factor, that favored the understanding of how the brain works, even for novices with little or no prior knowledge. The fact that Teegi is anthropomorphic encourages users to "connect" with their avatars, as the combination of anthropomorphism and tangibility foster social presence and likability [18, 12, 11]. Moreover, this bond helps them comprehend rather abstract information – i.e. brain activity – that they could not directly sense otherwise. Indeed, cognitive processes are difficult to assimilate [15].

Teegi was a dedicated support for visualizing brain activity but did not propose any high-level constructs such as workload or attention. We went beyond this interface with the Tobe project [9], which gave access to mental states alongside low level signals (e.g. heartbeats, breathing). Moreover, we designed wearable sensors, that could be equipped easily (Figure 2).

Because the dynamic representation of physiological signals is still an open question at the moment [2], we conducted surveys during a pilot study to gain more insight about the knowledge and the representation people had. In particular, we asked participants to express with drawings and text how they would represent various metrics. We were surprised by how creative people were; we found little resemblance between participants for a given signal, even where we would have expected a consensus to emerge – e.g. some people drew a physiologically accurate heart instead of a simple sketch. Therefore, the toolkit we built around Tobe also enables people to tailor their own dynamic feedback, animated using their real-time physiological measurements.

Not only does customized bio- and neurofeedbacks create meaningful representations, but the very act of taking part in the creation of the avatar, through 3D printing, increases the involvement of users in the process. But far from gaining simple knowledge, such emphasis on the body has immediate benefits. For instance, improving interoception could suffice to favor a better health [4]. Since interoception is also associated with empathy, it could affect how we feel toward others [8]. By exposing overtly inner states – as we propose to do with the tools we present – we sharpen human senses toward themselves and others, for the better good of both.

## SUPPORTING MINDFULNESS

One of our overarching goals was to eventually go beyond "simple" feedback and interoception, and also directly support mindfulness activities.

As a first step in this direction, we put into practice the Tobe system to create a multiuser relaxation experience, where pairs of users had to synchronize their heart rates through breathing exercises (Figure 1, left). From there, it encouraged us to go further and to build a dedicated application and form factor for mindful practices.

Inner Garden [20] is an augmented sandbox: a world in miniature that slowly evolves according to the users' inner state. The system is inspired by both the reflective and metaphoric nature of zen gardens as well as the playful and experimental nature of sandboxes. Zen gardens are all about careful placement of elements and are often used for contemplative and meditative purposes. On the other hand, sandboxes call for interaction and experimentation. Our main goal was to create an ambient and meditative toy that could both include playful physical creation and contemplation.

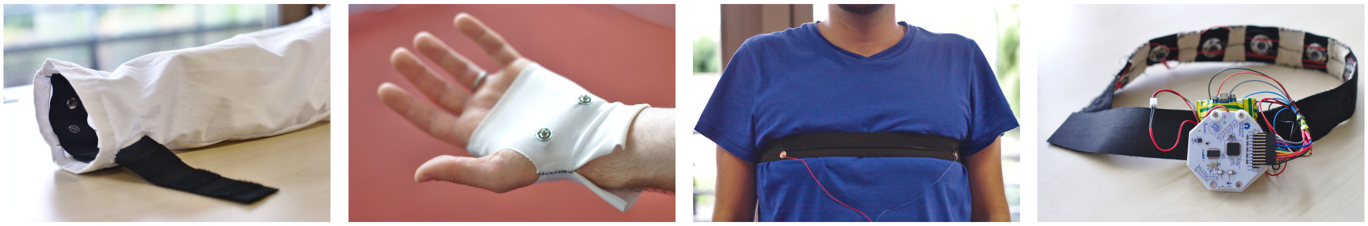
We designed Inner Garden as a toy: it can be played with, without any inherent goal or rules. Since our objective was to create a self-reflective and slow experience, mainly driven by self-motivation and curiosity, a toy seemed the best support. Using this approach, Paulos et al. [16] created toys to encourage children to explore their physical environment. Another example is the work of Karlesky et al. [14] who created seemingly meaningless tangible toys in order to explore the interaction that happens in the margins of creative work. The sandbox itself can be made of any size. We built one that is small enough to live on the side of the desk, acting as an ambient display during the user's daily activities, while the user can also decide to interact directly. Alternatively, a bigger one could support more users in a shared environment, such as a living room at home or a break area at work.

Whenever the user alters the terrain, the modified section of the simulation is restarted, living on its own. Grass grows, trees starts appearing and water flows. However, this process takes place slowly. The growth speed and overall health of the world, in combination with atmospheric effects (day-night time-lapse, clouds and sea) are linked to the user's inner state, measured with EEG and a breathing belt.

The main objective of the system is to foster contemplative and reflective activities. The small living world is a peaceful, slow display, while also motivating the users to practice relaxing breathing exercises whenever they want to take a moment for themselves.

## DISCUSSION

In our undergoing Inner Garden project, we are interested both in social interactions and in individual user experience. We would like to install the Inner Garden in shared spaces, such



(a) (b) (c) (d)

**Figure 2: Wearables. a: coat embedding ECG sensors; b: fingerless glove measuring EDA; c: breathing belt; d: EEG headband.**

as break rooms or living rooms. Different colleagues or family members could work together onto shaping the world, and then the world would evolve according to their states – monitored using wearable sensors such as smartwatches – e.g. Empatica's E4[1]. This could lead to interpersonal interactions, both in working together to improve the garden and cultivating empathy between participants.

We envision the inclusion of Virtual Reality (VR) using a Head Mounted Display (HMD) – such as the Oculus Rift[2] – enabling a user to have a private session *inside* the garden. While immersed, the world evolution would be slowed down, and the user could experience the biofeedback directly (e.g. his or her breath controlling the sea waves or the wind). Another advantage of the use of VR is that, since the user is already being equipped with the HMD, the addition of physiological sensors could be done seamlessly, such as EEG electrodes embedded in the HMD's elastic strap – see also [10] for an example on how to use head mounted devices to measure breathing and heart rate.

### What we want to measure

As we propose to make available a shared space that people could interact with and contemplate, we want to learn how such ambient system could alter how we relate to one another. We believe that, by itself, an augmented sandbox left at disposal in a working environment or at home could prompt direct interactions between passersby, improving connectedness – e.g. "team building". We envision to test the system for a prolonged period of time (several weeks), so we could measure potential changes in interpersonal relationships. Notably, it will be important to assess if these changes are due to a novelty effect and if they eventually will settle back to the previous dynamics.

We also plan to use the Inner Garden to propose mindfulness experiences and familiarize people with introspection. We will let users immerse themselves in the Inner Garden using a HMD, and we will augment their sensing capabilities by the mean of physiological sensors. Hence, we are curious to know if people will seize these technologies as an opportunity for self-empowerment and we wonder how much the system could guide them toward healthier habits.

The technology we developed is a mean, not an end. The Inner Garden is a stand for raising awareness toward others and our own selves. We seek to measure how the beneficial effects, such as a mindful routine, induced by the Inner Garden (if any) echoes beyond its direct usage. Ultimately, it would be desirable that these effects persist months after the system is removed.

### How to Measure

Inquiries shall be the principal evaluation method to gather insights about how people welcome the system. Beside surveys, we plan to conduct regular interviews; freely discussing with several users will notably help to assess the social impact of the system and gauge which aspects of the Inner Garden should be refined.

However, the very hardware that we employ to run the system is an opportunity to also collect exocentric measures, as defined in [7]. Indeed, the cameras that we use for augmenting the sandbox can also record how users interact with the system and in the surrounding space. Such video feed could then be processed to observe peoples' behavior – e.g. number and duration of the interactions, if they rather play with the sandbox or use the virtual reality modality, to what or whom they look at, how much they move, and so on.

Moreover, the physiological signals that are used to give an online biofeedback to users could be recorded and further analyzed offline. Features such as breathing patterns, heart rate variability or synchronization between brain areas could give metrics about relaxation or meditative state – see [9]. Such metrics could be investigated over weeks to sense how users evolve.

Finally, being able to bring altogether inquiries, behavioral data and physiological sensors – varying from qualitative to quantitative measures – will help to contextualize our findings so we could iterate over our system, aiming to support mindfulness practices, especially mindfulness meditation sessions.

## CONCLUSION

We have presented three different interactive systems based on tangible interaction to foster introspection. More specifically, we described how anthropomorphic avatars could raise awareness on the inner working of our bodies and minds and support interoception. We also presented a first prototype of another form factor of our toolkit, an augmented sandbox specifically dedicated to promoting mindfulness activities. We believe that tangible ambient installations, as opposed to regular displays, have great potential for these purposes since they are anchored in reality, which mindfulness is all about.

[1] https://www.empatica.com/

[2] https://www.oculus.com/

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