From Natural to Non-Natural Interaction: Embracing Interaction Design Beyond the Accepted Convention of Natural

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ABSTRACT

Natural interactions feel intuitive, familiar, and a good match to the task, user's abilities, and context. Consequently, a wealth of scientific research has been conducted on natural interaction with computer systems. Contrary to conventional mainstream, we advocate for "non-natural interaction design" as a transformative, creative process that results in highly usable and effective interactions by *deliberately* deviating from users' expectations and experience of engaging with the physical world. The non-natural approach to interaction design provokes a departure from the established notion of the "natural," all the while prioritizing usability—albeit amidst the backdrop of the unconventional, unexpected, and intriguing.

CCS CONCEPTS

• **Human-centered computing** → **Interaction paradigms**; **Interaction techniques**; **HCI theory, concepts and models**.

KEYWORDS

Natural interaction, natural user interfaces, augmented reality, mixed reality, multimodal interaction, smart environments

ACM Reference Format:
Radu-Daniel Vatavu. 2023. From Natural to Non-Natural Interaction: Embracing Interaction Design Beyond the Accepted Convention of Natural. In *INTERNATIONAL CONFERENCE ON MULTIMODAL INTERACTION (ICMI '23), October 9–13, 2023, Paris, France.* ACM, New York, NY, USA, 5 pages. https://doi.org/10.1145/3577190.3616122

1 INTRODUCTION

Research on natural interaction modalities for computer systems, including gesture, voice, eye gaze, and others, has been largely motivated by the naturalness of humans' capabilities to interact and communicate effectively in physical environments, e.g., by combining and synchronizing gesture and speech [17]. In this context, technologies such as pointing [2], touch [35], gesture [12], speech [27], and emotion [3] recognition have enabled the transfer and reuse of natural human capabilities from physical to digital environments. Due to the tight interconnection between these modalities, natural interaction has been largely embraced for scientific investigation in the ICMI community from its very beginnings. For example, the ICMI 2003 call for papers[1] specified: "These new interfaces are especially well suited for interpreting *natural* communication and activity patterns in real-world environments. Their emergence represents a radical departure from previous computing, and is rapidly transforming the nature of human-computer interaction by creating more *natural*, expressively powerful, flexible and robust means of interacting with computers" (emphasis ours). Fifteen years later, James Crowley's keynote at ICMI 2018 [5] about the research advances in the field highlighted that "Multimodal interaction seeks to fully exploit these parallel channels for perception and action to provide robust, *natural* interaction" (p. 4, emphasis ours).

Numerous examples of natural interaction design span the landscape of contributions relevant to the ICMI community. This outcome is well-justified since natural interactions are intuitive, easy to perform, and easily accessible—in one word, "natural." When properly designed [23], natural interaction brings many benefits to users and, consequently, a wealth of design guidelines have been offered in the community [10,36]. *But should natural interaction design always be the favored option? Is "natural" the sole synonym for usability, efficiency, or a great user experience in digital environments? Should we exclusively value, emphasize, and prioritize natural design for multimodal interactive computer systems?* The vision outlined in this position paper is to inspire the scientific community to *move beyond the prevailing paradigm of natural design and embark on an active exploration of interaction modalities and techniques that defy convention.* Specifically, interactions that are, by design, unconventional, unexpected, surprising and, overall, challenge the notion of what is "natural." It is important to note that this does not imply that these interactions are inherently unusable. Rather, their usability emerges from the very non-naturalness of the experience itself—a unique, thought-provoking experience offered to users, rather than relying solely on naturalness. In this paper, we argue about the benefits of embracing "non-natural interaction design."

1.1 Terminology: Non-Natural, not Unnatural

It is important to clarify the terminology adopted in this paper. While the proper antonym of "natural" is "unnatural," the word "unnatural" carries negative connotations, suggesting something that goes against or deviates from the normal order or state of things, as in the artificiality, abnormality, or aberration of a given situation.[2] Also, this word may easily suggest bad or poorly designed UIs.[3]

ICMI '23, October 9–13, 2023, Paris, France

ACM ISBN 979-8-4007-0055-2/23/10…$15.00
https://doi.org/10.1145/3577190.3616122

[1] https://icmi.cs.ucsb.edu
[2] https://www.merriam-webster.com/dictionary/unnatural
[3] In Gord Kurtenbach's words [36, p. 155], "I often give a lecture entitled 'un-natural user interfaces.' This particular title is a setup to make people think I'm going to speak about examples of bad, 'unnatural' user interfaces and how we need to design them to be more natural and intuitive. However, the surprise and hopefully entertaining twist

Instead, we prefer the term "non-natural," created through prefixation, to describe phenomena—specifically, interactions within the scope of this work—that fall outside the realm of what is commonly considered natural. The prefix "non" suggests an *evolving alternative* to the commonly perceived notion of naturalness, just like natural interactions were proposed as an alternative and complement to GUIs and conventional computer interfaces before them [13,36].

2 CONTEXT: NATURAL INTERACTION DESIGN FOR COMPUTER SYSTEMS

Natural interaction is one part of the *natural design* approach to interactive computer systems, alongside natural user interfaces (NUIs) and computation [10]. The main goal of natural design in HCI is to increase the usability of computer systems with more intuitive UIs and better system understandability; see Hirsch et al. [10] for an overview of definitions, intentions, properties, and modalities of natural design for interaction. Over time, the term "natural" has been used in the scientific literature to denote interactions that feel familiar [1], intuitive [7], ergonomic and easy to perform [21], easy to recall [20], and easy to access [36] by computer users. It has also been used to denote the alternative situation to conventional computer interfaces that use devices whose operation needs learning, while NUIs capitalize on humans' natural abilities to employ touch, gesture, motion, eye gaze, voice, and speech for interaction and communication [13]. In this context, NUIs follow GUIs with the promise to reduce accessibility barriers to computing technology still further by taking better advantage of the user's bandwidth [36]. By design, natural interaction can be achieved by observing users' unconstrained behavior with interactive systems [21,37].

Within the realm of natural design, NUIs emerge as the mediators enabling natural interaction between humans and computers. It is important to note that naturalness is not a property of the NUI, but rather external to it, and emerges from the actual interaction where users act and feel naturally [36]. From this perspective, Wigdor and Wixon [36] consider the meaning of "natural" as referring to "a design philosophy and a source for metrics enabling an iterative process to create a product" (p. 9). The focus on careful design for effective natural interaction has also been highlighted by others [14, 23], e.g., "Natural interaction is achieved through clever designs that constrain the problem in ways that are transparent to the user but fall within the capabilities of technology" [14, p. 12]. In the context of ubiquitous computing, natural interactions are mediated by disappearing UIs [11], which are interfaces that go unnoticed by users while nevertheless working effectively and enabling digital information processing to dissolve in user behavior [8].

For multimodal interactive systems, naturalness emerges from leveraging parallel channels for perception and action [5]. However, is natural design the ultimate answer for interactive systems? We contend otherwise. Next, we present our vision meant to disrupt the established norms of natural interaction design, advocating for the exploration of interactions that deliberately deviate from the confines of what is conventionally accepted "natural."

of the lecture is that I claim there is no such thing as natural or intuitive interfaces. Effective user interface design is very carefully controlled skill transfer—we design interfaces so users can take their skills from one situation and re-apply them to a new situation." Our perspective is different from Gord Kurtenbach's by explicitly stressing the value of non-natural interaction and, moreover, actively pursuing it by design.

3 VISION: EMBRACING NON-NATURAL INTERACTION DESIGN

It is useful to begin our exploration with a working definition of non-natural interaction with computer systems and the corresponding approach to design that, through systematic application, would give rise to such interactions. At first glance, one could assume that a definition of non-natural interaction would inherently arise from merely negating the characteristics of natural interaction, as they were presented in Section 2. However, taking such an approach would be misguided and of limited value for interaction design. Instead, the vision that we propose is that non-natural interactions do possess many of the user performance benefits of natural interaction with computer systems, e.g., usability and accessibility, yet capitalize on the unexpected, unusual, and unconventional. For example, an interaction technique for accessing digital content from a physical environment without receiving any feedback does not follow natural design guidelines, but is nevertheless effective [28]. Alternating normal and whispered voice is not the natural approach to speech-based interaction, yet it enables effective discrimination between commands and text input [26]. Eyelids that open and close following a specific pattern are not natural movements, but constitute into an effective input technique for users with motor impairments [6]. Supernumerary robotic limb systems are far from natural, yet they facilitate novel, transformative forms of social interaction [39]. We provide detailed examples of non-natural interaction design in Subsection 3.2. Notably, what these examples share is a departure from the traditional notion and understanding of "natural" in terms of the interaction with a computer system. Despite this deviation, these systems are usable, effective, and accessible.

3.1 Vision

We propose the concept of "non-natural interaction design" as a transformative, creative process that leads to highly usable and effective interactive computer systems by *deliberately* deviating from users' expectations and experience of engaging with the physical world. In this context, non-natural interaction design challenges established norms of accessing and consuming digital content to pave the way towards surprising, unexpected, and thought-provoking user experiences. Non-natural interactions are, by design, not natural. However, it is important to note that non-natural does not imply a lack of usability, accessibility, or efficiency. In fact, by considering the characteristics of Norman's [22] three levels of design, non-natural interactions challenge the *visceral* level, fulfill performance expectations at the *behavioral* level, and engage users at the *reflective* level via the novel, unconventional experience they offer.

3.2 Examples

We illustrate non-natural interaction design with a selected set of examples of interactive computer systems [4,28,31,34] spanning mobile and wearable computing, augmented reality, and ambient intelligence; see Figure 1 for an overview.

3.2.1 Digital vibrons. Digital vibrons [34] represent manifestation of digital content in the physical world in the form of vibrations. When a digital file is picked up from its native container, e.g., a smartphone, and brought into the physical world, it changes its

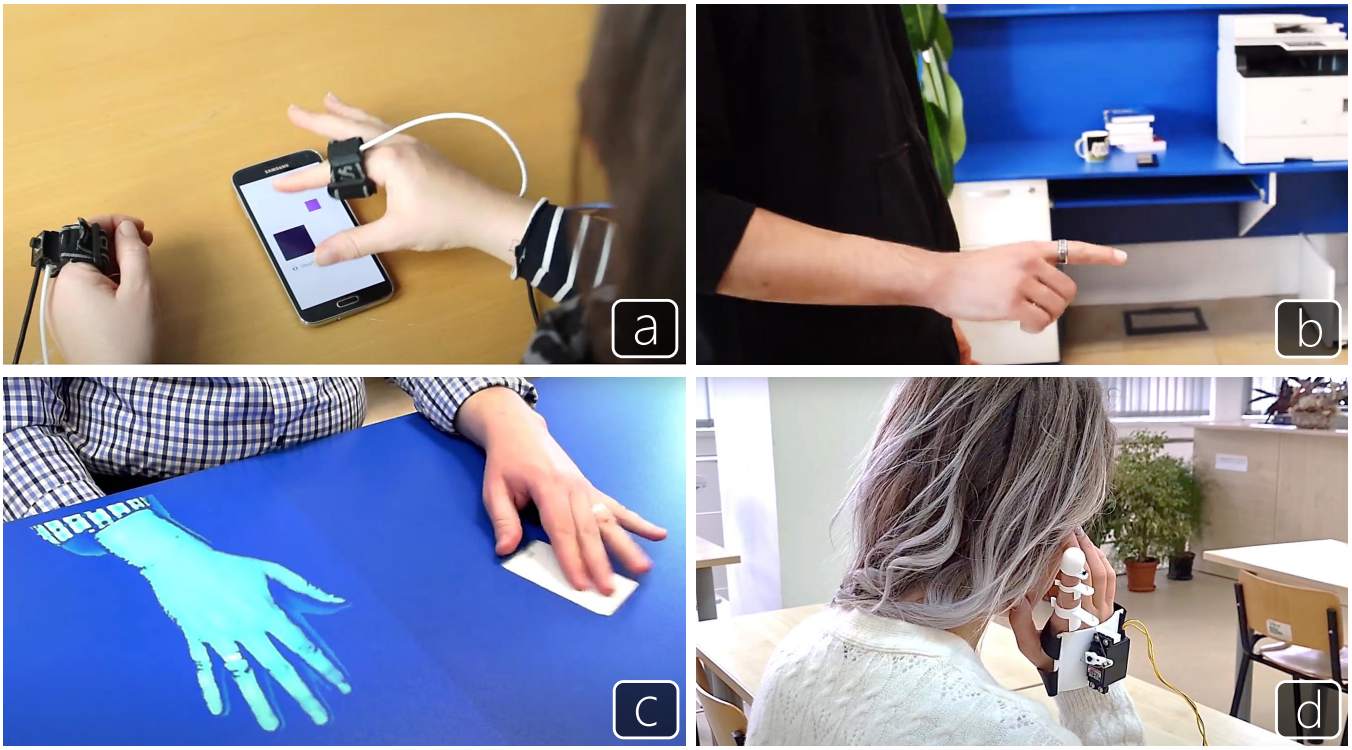

Figure 1: Examples of non-natural interaction by design: (a) after picking up a digital object from the smartphone, the consistency of the output modality breaks and the object manifests its presence with vibrations on the user's finger [34]; (b) digital files can be anchored in mid-air and retrieved effectively at a later time without any sensory feedback [28]; (c) the experience of watching a virtual hand, aligned with the user's body, taking part in a bimanual action [31]; (d) compromising the sense of agency to a hand-augmentation device that controls the user's finger [4]. From (a) to (d), the interactions challenge, by design, users' expectancy for feedback, body ownership, and agency, without compromising system usability; see the text for details.

manifestation. By means of an analogy with particle physics implemented with a finger-augmentation device that delivers vibrations, the user feels holding the digital file between their fingers (Figure 1a), although the original visual representation of that file is no longer available on the smartphone. In the authors' words: "when in the physical world, digital objects are *invisible* to the eye, have *zero weight*, but manifest their presence with localized *vibrations*, until they reach again their container device" (p. 217). The behavior of digital vibrons challenges user's perception of the materiality of the interaction with digital objects, but also the expectancy for a consistent output modality when the file transcends the boundary between the digital and physical worlds. Although this experience deviates from the commonly accepted concept of natural manipulation of physical or digital objects, digital vibrons were described by the twenty participants of the user study reported in [34] as attractive, fun, creative, and the system was perceived easy to use.

3.2.2 Invisible, inaudible, impalpable. By drawing from the concept of imaginary UIs [9], Schipor and Vatavu [28] explored users' preferences for placing digital objects, e.g., files, emails, music, etc., in the physical environment, including at locations in mid-air; see Figure 1b. The goal of the exploration was interactive system design that "enable[s] users to access digital content pinned 'in thin air' in the digital layer of the smart environment" (p. 77). The distinctive nature of the exploration was that absolutely no type of feedback was provided to users. UIs such as these, where the mapping between physical locations and digital content exists solely in the user's mind and imagination, challenge the perception of a natural response when interacting with physical or digital objects. Nevertheless, recall performance results [28] revealed an average offset of just 16 cm from the invisible, inaudible, and impalpable regions of the physical environment where digital content was anchored.

3.2.3 Possi(A)bilities. Possi(A)bilities [31] is an augmented reality system that extends the human body with a virtual hand physically aligned with the user's arm; see Figure 1c. The virtual hand performs gestures from a database of recorded hand movements, e.g., grasps, finger and hand poses, and can move on the table surface. The combination of physical-virtual and live-recorded action makes Possi(A)bilities "a medium for exploring, examining, and reflecting on the motor abilities of the human hand enabled by possibilities for human action beyond the physical world and the individual's capacity to act independently" (p. 827). Bimanual gestures performed with a real and virtual hand, enabling action at the boundary between the physical and virtual, deviate from the accepted notion of natural interaction in several ways. First, the combination of a

virtual and physical hand is uncommon, unexpected, surprising. Second, the virtual hand is not under the user's control although it seems physically linked to their body. Third, the non-natural design of bimanual gesture input challenges the commonly accepted notion of motor skill: who owns the motor skill of the virtual hand?

3.2.4 Fingerhints. By drawing from the area of on-body and proprioceptive interaction [15], Fingerhints [4] is a finger-augmentation device that delivers notifications through hyper-extensions of the index finger; see Figure 1d. Fingerhints challenge the user's sense of agency and, thus, create a state of tension between the user and the computer, both demanding control over the same body part. In the authors' words: "On-body output affects user agency, instrumental for interacting in the real-world, which becomes shared with a computer in the new paradigm" (p. 518:1). Nevertheless, despite the unusual experience that fingerhints create, which deviates from the accepted norm of natural interaction where the user is in control of their body and action, empirical evaluation results [4] revealed an overall good level of usability, low perceived creepiness, and moderate to high acceptability to use fingerhints in various public settings, including in front of public audiences.

3.3 Framing Non-Natural Interaction Design

The examples discussed in the previous subsection represent good illustrations of non-natural interactions resulting from a deliberate design process. The goal of the interaction designer is a clear departure from the commonly accepted notion of what is and feels natural by having users experience new sensations with mobile, wearable, and ambient technology. Nevertheless, the resulting systems are usable, favorably perceived, and positively appreciated. Next, we try to pinpoint this specific nuance of non-natural interaction design in the context of generic design strategies, and suggest ways for advancing research in this direction.

By deviating from the established norm of natural and, correspondingly, from the design guidelines for natural interaction [10, 36], non-natural design offers unique and distinctive experiences to users. Moreover, we contend that in the context of emerging computing environments and interactive contexts, such as mixed worlds [18], mediated reality [16], or body augmentation and human-computer integration systems [19], natural interaction may not inherently be the optimal design choice. Actually, the emotional responses generated by non-natural interactions should align with the non-natural look and feel of such new computer environments towards a cohesive and highly immersive experience. In fact, when discussing emotional design, Donald A. Norman emphasizes the value and importance of emotions in our daily lives: "Sure, utility and usability are important, but without fun and pleasure, joy and excitement, and yes, anxiety and anger, fear and range, our lives would be incomplete" [22, p. 8]. Non-natural interaction design seamlessly fits into this context as its objective is to create usable interactive systems, while evoking a distinct emotional experience that diverges from the familiar expectation of natural interaction.

Norman's [22] description of the three levels of design—*visceral*, *behavioral*, and *reflective*—represents a useful framework to position and understand the scope, impact, and value of non-natural interaction design. At the *visceral* level, the physical features of a product or experience dominate, i.e., how the product/experience looks and feels. While natural interactions evoke a sense of simplicity, low effort, and intuitiveness, non-natural design challenges the visceral level by deliberately provoking and inciting users. At this level, non-natural interaction design embraces the unfamiliar, unconventional, and, occasionally, the creepy. However, even creepiness has its merits for interactive technology as interaction design may strategically leverage it for the benefit of users [38]. At the *behavioral* level, what matters is user and system performance. In natural design, this objective is achieved when interactions are easily understandable, accurately interpreted by the computer system, and a well match to the tasks. Non-natural design also aspires to this objective since usability remains at its core, as evidenced by the examples discussed in the previous subsections. The *reflective* level of design is about the message, culture, and the meaning of the product/experience as well as the reflected self-image of the user. Non-natural interaction design aims to create unexpected, unconventional, thought-provoking experiences that reflectively engage users, of which recent advances in human augmentation [25] or human-computer integration [19] are relevant examples.

4 WHAT NEXT?

The non-natural interaction approach reframes the design and research of interactive systems by forcing a shift from the established notion of the natural, while still emphasizing usability—yet in the presence of the unfamiliar, unconventional, and unexpected. Natural interactions feel natural to use because they fit the skills and context of the user [36]. In contrast, non-natural interaction provokes the senses and the body by challenging both perception and action in new environments and contexts. Therefore, new methodologies and frameworks are needed to formalize non-natural interaction design. In the following, we mention a few potential directions. Sensorimotor Realities (SRs) [32] represent a conceptual space and technology-agnostic framework for computer-mediated perception and action. By capitalizing on the heterogeneity of human sensorimotor abilities, SRs can inform interaction design that leverages existing abilities in new contexts, including for body augmentation, imaginary worlds, mixed reality, and assistive technology [33] by leveraging the commonalities among various computing paradigms [30]. Wabi-Sabi design [29] capitalizes on themes of impermanence, incompleteness, and imperfection. The conscious use of impermanent materials and media, explicitly unfinished designs, and engagement with available resources can be effective ways to escape the confines of natural design thinking towards exploration of unique and unpredictable outcomes in the design process. Furthermore, placing interaction design within a relevant philosophical and cultural framework [24] can help deal with the bridging state between natural and non-natural in environments that become into being in the intertwining between what is human and what is computer. We look forward to such innovative research.

ACKNOWLEDGMENTS

This work was supported by a grant of the Ministry of Research, Innovation and Digitization, CNCS/CCCDI-UEFISCDI, PN-III-P4-ID-PCE-2020-0434 (PCE29/2021), within PNCDI III. The photographs in Figure 1 were taken by Annette Mossel and Christian Schönauer (1a), Ovidiu-Andrei Schipor (1b), and Adrian-Vasile Catană (1d).

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