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INTERACTION UNDER INTERFERENCE

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Abstract

Across numerous theoretical models employed to describe interaction, interference is seldom accounted for, even though it manifests itself on technical and cognitve levels. Practical and conceptual paths towards an aesthetics of interference suggest the need for its inclusion in a more complete model. Our research surveys the potential roles of interference within interaction, attempting to ascertain its actionable properties and variables. These can hypothetically redefine successful interaction as discovery of latent potential, and inform experience design towards increased latitude for creativity and collaborative engagement. This requires addressing challenges such as cumulative effects, difficulty in mastering highly variable interference, and the impossibility of foreseeing every type of interference a system may become exposed to. As an agent for increased affordance generation and wider operational ability, on technical and cognitive levels, interference is hoped to contribute towards a framework for a more informed observation and configuration of interaction experiences.

Keywords
Aesthetics
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1. INTRODUCTION

Interference is a familiar phenomenon to physicists and engineers working to counter its nefarious effects. The general concept of interference is also employed in economics, biology, psychology and cognitive science. Oddly enough, it has seldom made an explicit appearance in media art and design studies, despite its presence on theoretical and practical levels. As an uncredited actor in a significant role, interference is free to follow its own whimsical script, adding texture to the media landscape. When recognized, it is mostly considered a nemesis of sorts, a detrimental agent with desirably minimal impact to established goals.

When designing interactions of various kinds, one must consider relevant human, environmental and technological variables, such as: age ranges; literacy; group dynamics; processing limitations; variable input data; available area, light or time. From a functionalist standpoint, interactive systems must accommodate foreseeable inputs and actions associated with such variables, while preventing breakdown, in accordance with the given purpose of an installation or interface.

What happens when an unforeseen input enters such a prepared system? In some cases, such input can simply go unnoticed or be disregarded, as when swiping a credit card in the wrong direction. In other instances, unpredicted input can challenge the nature and integrity of the system itself. Some theatre plays may welcome audience participation, while others demand a silent audience to create immersion. A carefully planned musical performance may be spoiled by technical equipment problems, while other performers may welcome spurious glitches as valid contributions to a spontaneous sonic output. The previous examples point out a few important traits of interference: it is not limited in origin to technological artefacts, it can embed itself in a prepared program of action, and its impact, even if damaging by some standards, is not always undesirable. These features are of course independent of each other. In any case, increased technological mediation affords a wider latitude for interference, as the layers and modalities available to extraneous unpredicted input are multiplied. A fitting example of this is found in the events surrounding Wolfgang Staehle's *2001* exhibition at the Postmasters Gallery in New York, as described by Charlie Gere (2008). The exhibition featured live video feeds of three different remote locations, one of them being a view of lower Manhattan. On September 11th 2001, this video stream of a still urban landscape extended the stage for the attack on the World Trade Center, capturing the entire event. Technology was an enabling partner at both ends of this bizarre meeting of human tragedy and media art. Airplanes and airlines enabled the attack,[1] and the live stream made the art piece permeable to interference from the event. But this instance of interference brutally surpasses the humble glitch or malfunction, extending the exhibition's impact and significance far beyond the author's intended scope. Issues of live video versus photographic images were crushed by the unfortunate coincidence of broadcasting the attack. Interference is thus capable of operating through technological media to radically affect the impact and significance of a previously established program, by means of extraneous unpredicted input. A photograph or still image of the same lower Manhattan view would be immune to such interference, as it would have far fewer layers susceptible to interference.[2] Although Staehle's work is of a more contemplative nature, the issues here presented are equally applicable to interactive settings: one can easily envision the impact of such a transformative coincidence on Kit Galloway and Sherrie Rabinowitz's *Hole*

1
Alluding to Latour's (1994) non-dualist sense of technical mediation: "Purposeful action and intentionality may not be properties of objects, but they are not properties of humans either. They are the properties of institutions, dispositifs. Only corporate bodies are able to absorb the proliferation of mediators, to regulate their expression, to redistribute skills, to require boxes to blacken and close. Boeing-747's do not fly, airlines fly." (Latour 1994).

2
Though arguably such an image would also be symbolically contaminated by the September 11 events, as were countless other images of the twin towers.

in space (Durland 2016). Interference is thus not limited to technical mishaps, as it can stem from human actions and hybrid man-machine agency, intentional or accidental.

The following sections explore manifestations of interference, attempting to clarify its various dimensions and properties. Interaction models are then observed as systems susceptible to interference in their various layers and modalities, relating pragmatist and humanist approaches with the technical and human agency roles. This brief framework supports a discussion on incorporating and instrumentalizing interference in different types of interaction settings, towards an interaction design practice more apt to embrace interference as an asset rather than a pitfall, ultimately leading to the possibility of an aesthetics of interference, as first advanced by Lars Qvortrup (1998). This proposition aims to contribute pathways towards a greater acceptance of interference in interaction design practice, entertaining the hypothesis that greater permeability to interference can afford more organic and expressive interactions, and reduce conditions for perceived failure. The goal is to determine whether the formative aspects of interference can contribute to a framework for the analysis and design of experimental and interactive media.

2. INTERFERENCE MODALITIES

As noted previously, interference is not limited to the technical realm, and is conceptually employed in quite diverse areas. These also relate to different dimensions and modalities of interaction, and to clarify those relations a brief characterization is required.

In its most elementary definition, interference is a disturbance to the signal in any communication system, caused by unwanted signals (Howard 2005). In physics, interference is said to occur when two superimposed waves produce a new wave pattern (Young 1802, Feynman 1977). This phenomenon, in fields such as optics and electronics, explains the generation of unique outputs from a combination of different signals, or variations of the same signal. Two main types of interference are defined by superimposing equal waves. When they are in phase, their plot appears overlaid as they follow the same path at the same time. This produces constructive interference, as the amplitude of the new wave is the sum of the amplitudes of its constituents. When their phase is offset in such a way that their pattern is vertically symmetrical, destructive interference occurs, as each wave cancels the other. Intermediary states are used for various applications, such as electronic sound synthesis, by shifting relative oscillator phases to produce wave shapes, harmonics and other sonic effects. Somewhat similarly, psychology uses interference to describe the interaction between newly acquired and previously learned knowledge, as proactive interference (loss of new information by action of previous knowledge) and retroactive interference (inability to retrieve previous knowledge due to focus on new information). In this case both situations have a destructive effect. However, this can be used to an advantage in dealing with short-term memory requirements, in the design of user interfaces where the cognitive load is prone to increase. Interference is also present in communication, when something (of human or technological origin) reconfigures, interrupts or modifies a message along its path. In linguistics, it refers to the contamination of a newly learned language by the grammar and pronunciation of the native language. Still in the communication context, eye-contact is known to interfere with cognitive control processes (Kajimura and Nomura 2016), affecting verb generation and cognitive control in conversations. In cinematic or theatrical works, actors directly engaging the audience or looking at the camera are a classic instance of breaking the fourth wall: this narrative disruption technique tends to produce more cognitively involving experiences (Auter and Davis 1991). In interface design, usability analysts have observed an aesthetic-usability effect on interface users that demonstrate greater tolerance to minor usability flaws on more aesthetically pleasing interfaces (Meyer 2017). Interference is thus present and of relevance in various areas directly related to interaction in arts and design. As discussed in the following sections, the main interaction models used in literature and practical development of design and artistic practice, include dimensions and modalities with ample opportunity for these types of interference to operate.

On an important note, interference is not the same as noise, nor is noise a specific type of interference. Rather, noise is technically a source of interference, and cognitively a low-value attribute given to specific results of interference. In communication, noise is the part of a signal which does not carry significance (semantics) or information (electronics, media). However, noise as an aesthetic element plays a role in shaping a message it becomes part of, as it is ultimately perceived. Intrinsic noise occurs from within systems and is usually associated with properties of that system. As an example, pausing a video tape usually adds to the resulting image various types of visible noise like visual artefacts, gaps and distortions. This happens due to the characteristics of the videotape player itself, as it is designed to slide a moving tape along rotating magnetic sensors: pausing this normal operation introduces a magnetic disturbance to the image reading process. This can also be caused by component degradation or suboptimal environment conditions (intense heat or humidity). Extrinsic noise is caused by external signals, which can be easily demonstrated by approaching a strong magnet to a television cathode ray tube, distorting the image and eventually degrading it beyond recognition. Another classic example is moving a radio antenna to improve signal clarity, reducing interference from physical barriers and electromagnetic fields.

To summarize, interference emerges from the effects of non-ideal input, intentional or not. It can be caused by natural phenomena, technical conditions or human intervention, occur in series or in parallel, and operate on the technical and cognitive fields of interaction. Interference can ultimately lead to system failure, when planned modes of interaction can no longer take place. Multimodal interactions are of course more resilient, as interference is rarely able to affect the multiple dimensions of interaction, as described by the models discussed in the following section.

3. INTERACTION MODELS

In absence of a comprehensive unified theory for the observation and explanation of interaction, various positions must be considered. At its core, communication systems later employed for human-computer interactions are outlined by Claude Shannon (1948) in linear fashion when describing an optimal communication process. Particularly relevant to this discussion is Shannon's central concern with noise, despite disregarding semantic issues as "irrelevant to the engineering problem" (1948, 379).

This concern, albeit purely technical, addresses the near-impossibility of a communication channel or system impervious to effects from extraneous sources. Keeping with the technical nature of the approach, an algorithmic solution is offered to the preservation and retrieval of any given message's integrity, as it is carried through the main components of the outlined communication system: message, source, transmitter, signal, receiver, and destination. This structure establishes a baseline shared by most linguistic and cognitive models related to information science. Interference is here represented as noise, a decrease in the signal's fidelity to the source. Noise is further described as randomly variable modulation, as opposed to a stable and possibly reversible modulation, which would be distortion.

As new media introduced symmetry to this model, enabling feedback in the communication process, the linear process became cyclical, and cognitive dimensions could no longer be dismissed. To address this, Norman (1984) suggested a set of four stages in human-machine interaction: forming intent, selecting an action, executing the action, and evaluating the outcome.[3] The issue of intent is of special importance, as it introduces semantic and cognitive variables to the translation of actions and messages along the interaction cycle. Interpretation (evaluating the outcome) is also of great importance, as it must be performed by both human and machine: the latter must be able to interpret human input, while the former must interpret the machine's output to evaluate the outcome. For this purpose, machines must be able to clearly communicate their change of state, in a way that's adequate to the operator's expectations. Formulation of intent and successful interpretation are then necessary conditions for perception and control, as described in the acutely detailed taxonomy of multimodal interaction by Schomaker et al. (1995), where a clear symmetry of Shannon's model is still present, but is extruded from Norman's circumference to a sphere of interaction.

3
Norman supports this description of the course from goal to action with the example of a user editing text on a computer. Aware that this is a very specific and utilitarian scenario, the author is quick to note that the four stages are approximations, not discrete sequential psychological states. Furthermore, while distinctions may be blurred by uncertainty and unconscious behaviour, we would add that not all stages are necessarily present in all interactions.

This multimodal nature of cyclical interaction is further explored by Bert Bongers (2000—2007) in the context of musical apparatus development. The human-computer system is defined as a network of sensors and actuators, which model the system's response to a subject's intent and condition the system's capability to provide feedback. Bongers is also concerned with a system's ability to properly handle the totality of human input, albeit more focused on expressive range than reproduction accuracy. The focus here is on what lies between human and machinic (procedural or otherwise) agents, on the modulation operated by the interface (sensors and actuators) upon the signal, and ultimately on the program of action embedded in any artefact's configuration.

The multidimensionality of interaction is of course also present on its conceptual level, as an aesthetic experience. Following the general theory of affordances (Gibson 1986), the dynamic properties of interaction cease to be anchored in utilitarian views and linear (if cyclical) pathways. Still, different approaches have been followed regarding the dynamic of interaction aesthetics, as enumerated by Udsen and Jørgensen (2005). These can be summarized as pragmatist and naturalist (Eustáquio 2016). The pragmatist approach remains anchored to functionalist Human Computer Interaction theories, considering aesthetics as a rationalized mechanism (Ross and Wensveen 2010) which operates through the embedded properties of artefact. The naturalist approach embraces the ungraspable (Hummels and Overbeeke 2010) and hybrid actants (Latour 1994), offering a view of aesthetics as resulting from perception within uncertainty (Xenakis and Arnellos

2014). This distinction of pragmatist and naturalist interaction models begs an important question: in any given interaction environment or system, what is the latitude for error, misinterpretation, spurious output (on any part) and unforeseen affordance generation? The functionalist may likely say none, as any shift from the preset path would result in what Xenakis and Arnellos call aesthetic pain (2013, 63). The naturalist would be more willing to embrace unexpected outcomes as adding to the potential of a given interface or interactive system.

4. INTERACTION AND INTERFERENCE

This section identifies modalities of technical and human interference, which can become instrumental within interaction models. Different systems and environments naturally foster a variety of configurations, with variable permeability to interference. Such configurations not only define the layers available to interference (sensors, actuators, physics, semantics) and the degree to which they are open to disturbance (within operational ability), but also the qualities ascribed to the results of interference, as detrimental or beneficial dimensions to the total experience. As previously mentioned, interference can occur in series or in parallel, stemming from natural, technical or human origins.

4.1. Technical interference

In the technical realm, interference is in series when the disturbance intercepts and reshapes the signal during interaction. This is represented in Shannons's model (1948) by noise entering the signal path. In this case, it is conceivably impossible to isolate the original signal from its disturbance, as both share the same delivery channel. Parallel interference, on the other hand, affects perception without directly altering the significant signal source. Such is the case of spatial acoustics: while the same sound can be played in different spaces, unadulterated in origin, variable room dynamics prevent listeners from enjoying identical auditory experiences. Both types of interference would be present if the sound was played through a malfunctioning equipment. One type worthy of mention is the feedback loop: though it can be caused both by technical malfunction or human error in equipment setup, feedback can occur without needing to piggyback on a preexisting signal, since feedback can emerge as signal by itself, which puts into question whether it can qualify as a modality of interference. Beyond these modalities, there are several specific types, normally grouped under physical, biological, electromagnetic and radio frequency interference, with their own ramifications. The extent of this classification is outside the scope and purpose of this discussion.

Natural origins for interference on the technical level are fairly common. Atmospherical and electromagnetic conditions have well-known effects on the operation of machines and electronics. Devices are, by themselves, inevitably affected by natural decay of their component matter: malfunctions are a prime cause for unexpected disturbance.

4.2. Human interference

Instances of human interference can be found on cognitive, sensorial, and physical levels, but many of these may be hard to place with greater emphasis on any one of these levels. Cognitive issues play a role in the disturbance of an interaction in read/write states, when decoding system feedback, during input into the system, and when composing interaction settings (Norman 1984). Cognitive dissonance (from unclear system states) and proactive interference (from frustrating interactions) can hinder one's ability to engage affordance discovery towards a rewarding result (Xenakis and Arnellos 2013). Limitations to the senses can introduce deviations to expected signal outcomes (Schaeffer 2004). Motor and haptic functions greatly affect the ability to control and master an interface that requires their involvement (Bongers 2000). Human interference can extend to the technical realm as far as devices are human creations. In this sense, interference from an electrical device could be argued to stem from human invention. This becomes a matter of how far back the cause of any given event is traced.

Interference can happen directly at the human endpoint of an interaction or communication, irrespective of technological involvement. A wandering mind, a traumatic event or a sudden heavy cognitive load can lead to a disconnect in sensory channels, even if temporary. An ill disposition can induce biased interpretations of discourse. Much like malfunctioning technical equipment, human can also find themselves in suboptimal conditions at any time.

Hybrid types of interference can also occur, usually formed by a sequence of natural and / or human causes. Wet hands can cause short-circuits. Static energy accumulated in the body can produce damaging electrical discharges. Very low temperature can affect a musician's dexterity or a singer's vocal abilities, just as it can affect the acoustic properties of sensitive instruments and amplification equipment, by altering its frequency response or even its basic operational ability. Ultimately, technological determinism could be said to support the notion that human history is under constant interference from inevitable technical developments. Inversely, it has also been argued[4] that technical advancements are instruments of planned ideological interference programs.

4 Famously by Langdon Winner (1980).

5. EMBEDDED INTERFERENCE

Similarly to intrinsic noise, interference can be caused by internal elements to the system, as discussed previously (component degradation, processing error). However, when triggered from within or otherwise becoming part of that system, such interference falls outside what is commonly defined as disturbance caused by external signals, while most likely occurring in series with any output signal (or producing signal all by itself, as in the case of spontaneous feedback). When a system remains operational under these conditions, interference becomes embedded in the interaction, or in any of its successive operational stages (when distinguishable, as in discernible modular systems). This implies a constructive interference, in the sense that a usable and operative signal is generated: something new is added to the original design and contributes to more diverse output, regardless of whether the changes to the system are permanent. Alvin Lucier's seminal *Sitting in a room* (Burns 2002) presents a clear example of embedded interference by using the acoustic properties of spaces and recorders to produce a cumulative effect on the original signal (spoken words). A derived work by Patrick Liddell (known as The Ontologist),[5] aptly entitled *I Am Sitting in a video room*,[6] pays homage to Lucier's work by translating the process to video recording: here, instead of a room's acoustic properties, digital automated compression algorithms produce a cumulative degradation on successive downloads and

5 http://www.ontologistmusic.com/bio

6 Video by Patrick Liddell, known as The Ontologist, 2010. Available at https://youtu.be/icruGcSsPp0. Accessed: 2017-02-05.

uploads of a video recording. While apparently similar, the two works differ in a fundamental aspect: while Lucier works with intrinsic and extrinsic interference (the recorder and the acoustics of the room), Liddell solely explores the intrinsic noise produced by cumulative video compression, therefore not embedding external interference to the system put in place. One could argue that Lucier's room is part of the system; however, the "any room" part of the artwork's process keeps its core integrity independent from the location where external interference is harvested.

John Cage's prepared piano (1938) beautifully explores interference both in series and in parallel, by adding elements over the strings which can be disabled at will, thus modulating the effects. Interference can also be drawn from the environment, exploring natural elements such as moisture, light and biological activity, as is the case in Martin Howse's *Sketches for an earth computer.*[7] Golan Levin presented an interesting conundrum with his *Augmented hands series:*[8] in this work, a camera captures video of a subject's hand, and a screen presents various real-time dynamic transformations of that hand. These transformations alter one's perception of the physical self (a wobbly hand, a hand with six fingers), inducing a sensorial dissonance. While there is a kind of simulated interference on the technical level (the distortions are deliberate, stylistically calculated and procedurally generated), a cognitive interference is induced on the subject: rather than accepting and embedding interference, the system induces it by design.

Context can also provide a source of interference: for *Salle des départs,*[9] Robin Rimbaud (known as Scanner) composed a soundscape to be used in the morgue room of the Raymond Poincare Hospital, as part of an intentional strategy to provide comfort to those parting with loved ones. This work configures a cycle of mutual interference: as the music tries to induce a peaceful state of mind, it is permanently associated with the nature of the location and the memories it houses.

Between embedded and parallel modalities, Pierre Schaeffer (2004) also describes various modes of interference in the acousmatic field: vision impedes pure listening (musical conditioning: much of what was thought to be heard was in reality only seen), subjective variations in listening, variations in recording and / or playback (deliberate or not). For Schaeffer, sound objects as ultimate autonomous entities can be described and analyzed regardless of these factors. However, as they emerge in our perceptive consciousness, sound objects are also permeated by interference from previous sensorial conditioning, embedded interference in the recording process, and variable dynamic interference in the listening experience.

Among the cases briefly presented here, most are from exhibitions or performative settings, where interaction is somewhat limited. Contained interactions make it easier to drive experiences towards an interesting result: as seen in previous works cited, the cumulative effects of interference can be harder to manage if significance lies mostly in signals prior to the effects of interference, and herein lies a challenge to embedding interference in cyclical interactions. The piece by Levin is a notable exception to this, despite (or because of) reversing the flow of interference. In using both the technical and the human to produce something not exclusive to either side, interference becomes a manifestation of symbiosis instead of a cause for worry, or a sign of failure. A system that reacts gracefully to a broad spectrum of interference is one with potential for a richer, more tolerant experience. Especially when interference can potentially drive a system

7
Project documentation available at http://www.1010.co.uk/org/sketches.html. Accessed: 2017-02-05.

8
Project documentation with video demonstrations available at http://www.flong.com/projects/augmented-hand-series/. Accessed: 2017-02-05.

9
Project documentation available at http://www.scannerdot.com/art/2002/salles.html. Accessed: 2017-02-05.

outside the bounds of its operational ability (towards disintegration or failure), options should be considered for dealing with its impact in a constructive manner.

6. INSTRUMENTALIZED INTERFERENCE

Perhaps one of the most interesting strategies for embedding interference is its instrumentalization, as it can be used to modulate an appropriate channel, and add to or subtract from a given signal. Instrumentalization can take various meanings, the most literal being the transformation into an instrument, musical or otherwise. However, interference can be instrumental in other ways, also not limited to technical layers.

A typical example of a device built around a modality of (electromagnetic) interference is the cracklebox (Ghazala 2005, Collins 2009): an electronic circuit employed to produce sounds when touched, normally remaining mute when idle. Interference is here embedded by design, and the device is sonically uninteresting until actuated upon. The system depends on interference as input to become relevant and provide feedback. The cracklebox is somewhat lacking as an instrument: as it returns erratic feedback, control and mastery of its behaviour is quite challenging. However, this also makes it playful, approachable, less intimidating. The theremin[10] implements the same principle on another level. Similarly to the cracklebox, it requires human interference to produce output, by exploring electrical properties of the human body (in this case, capacitance) to modulate amplitude and frequency of its oscillators (Bongers 2000). Without this technical interference, the theremin disguises itself as a writing desk with curious appendages. Contrary to the cracklebox, however, proficient engineering produced in the theremin a reliable and expressive instrument, easy to control, if still quite difficult to master.

Embedded interference can be instrumentalized not just on a technical layer. Steve Reich's *Pendulum music* (1974) is a case of formal (procedural) employment, timing feedback through simple physics—or, to apply the features listed before, using environmental properties to sequence intrinsic noise: gravity and kinetic energy produce a progressively decreasing destructive interference in feedback generation, and the procedure as written by Reich progressively oscillates the system between stability states, materializing an instrumentalization of interference in the process itself.[11]

Other sorts of instrumentalization can operate on different layers. When recording or broadcasting a debate, different microphones can be placed in different configurations, producing notable differences in the rendition of the speakers' voices, thus skewing the listener's attention and empathy. Physical configuration of technical elements thus affects the impact of each speaker's discourse, potentially contributing to a shift in the perceived outcome regarding who provided better arguments. Embedded technical interference affects the perception of the debate and of the speakers themselves. Interference is here an instrument that plays on cognitive bias.

Instrumentalization can thus occur on different levels and serve various purposes, benign or nefarious to the system itself and to perceptions of the system (depending on preset goals), or rather, to the technical and human layers of interactions. The results are most useful and pleasing when interference is instrumentalized to the benefit of interactors, towards the production of meaning and meaningful interactions. A simple but effective final example can be found when connecting

10
Famously designed by Lev Thermen (2016) circa 1920, the eponymous instrument consists of an electric circuit purposefully designed to accept interference: antennas connected to the capacitors in LC oscillators affect output frequency and amplitude, according to human proximity. Although notably difficult to master, the instrument's design is explicitly intended for musical applications.

11
For the purpose of this discussion, while the system is initially triggered by human operators, it is pointless to consider whether they are musicians and the piece's setup constitutes an instrument, as the result would be indiscernible from one where the process was started by nonhuman devices. It should be noted, however, that Reich specifically calls for "performers" in the original described procedure.

two mouse pointing devices to a computer: the system becomes disoriented and frantically alternates the cursor position between both pointing devices, following the last one to move. If, instead, it produced a smooth movement following the median of both positions, a new type of operational input could be explored, and two subjects would be able to use the computer in a joint effort, be it a collaborative or a competitive one.

7. TOWARDS AN AESTHETICS OF INTERFERENCE

The Shannon-Weaver (Weaver 1949) pipeline model of communication was criticized by Marshall McLuhan for its left-brain lineal bias (McLuhan and McLuhan 1992), at a time when transformations in the media landscape had long been in demand of a right-brain oriented model. Weaver's contribution to Shannon's original theory already attempts to demonstrate applicability beyond the purely technical level, going as far as calling it a "theory of meaning" (1949, 12) with near-universal validity, and countering Shannon's original dismissal of the semantic layer of communication. But for all its merit, this model could not account for the totality of multidimensional and multimodal communication, or the ramifications of interactive communication. Hardly any model could, for that matter, particularly when concepts such as accuracy, precision and effectiveness become a barrier to expression, rather than a prerequisite condition. While noise is approached by Shannon as a negative influence over a signal, it is heralded by Luigi Russolo as a resource to "enlarge and enrich the field of sound", urging artists and musicians to explore in noise "the means of expanding and renewing itself" (2004). This evolutionary shift of musical art towards noise-sound is perceived as a natural consequence of increasing man-machine collaboration,[12] and technical developments continually renew opportunities for this type of exploration, with important new differences. While the Futurist approach suggests the construction of devices for instrumentalization of noise, by applying expressive control of their pitch and timbre (moving the noise source to the starting point of the Shannon-Weaver model), the noise-sound dualism fades under new strategies of interference in technological media. These strategies range from conceptual approaches and subversive manipulations to the harvesting and incorporation of spontaneous sonic artefacts, ultimately giving rise to a glitch culture (Menkman 2011). John Cage,[13] Christian Marclay[14] and Thomas Brinkmann[15] have produced diverse works from similar techniques, manipulating and modifying vinyl records and turntables to invite noise, glitches and usually undesired effects into musical composition.

This strategy combines human interference (by means of strategic misuse of artefacts and deliberate alteration of their physical properties) with its consequential technical interference (tone arms skipping and sliding). Yasunao Tone (2004) translates this practice to Compact Disc players, using punctured tape to circumvent the digital error-correction embedded in the playing devices, forcing them to perform with erratic behaviour. This practice becomes symbolic of a need to overcome preset programs of action in media devices, in the search for an extended creative and expressive range. The Negativland[16] collective extends this to cultural and political levels by ostensive sampling of copyrighted material, in a deliberate intent to interfere with the generalized acceptance of commercial authorship and protectionism. Masami Akita, under the moniker of Merzbow, returns to a more futuristic and extreme approach, by drilling aggressive textures

12 In the original: "This evolution of music is comparable to the multiplication of machines, which everywhere collaborate with man" (Russolo 2004, 11). This formulation curiously suggests a kind of autonomous agency in technical artefacts, as they are understood to work with humans, rather than by humans.

13 John Cage, "Imaginary Landscape N° 1", 1937. http://www.medienkunstnetz.de/works/imaginary-landscape-1/audio/1/. Accessed: 2017-02-05.

14 Christian Marclay interview with Jonathan Seliger, Journal of Contemporary art, undated. http://www.jca-online.com/marclay.html. Accessed: 2017-02-05. An example of Marclay's turntable use can be viewed at https://youtu.be/IIFH4XHU228. Accessed: 2017-02-05.

15 Thomas Brinkmann, "LIVE @ TAICO CLUB camps", 2010. Video available at https://youtu.be/eNEEjbBbdqo. Accessed: 2017-02-05.

16 Negativland: http://www.negativland.com/news/?page_id=250. Accessed: 2017-02-05.

from non-instrumental devices, modelling electricity through effects devices and mixing desks (Cox and Warner 2004). In all these practices, there is an incorporation of signal disturbance and failure into composition process, and / or sonic vocabulary. This is especially evident in computer-generated music.

After computers became massively available and reasonably capable of emulating analog equipment (oscillators, synthesizers, and even classic instruments to a certain degree), they became almost invisible, an ideally neutral conduit. Countering this, instead of struggling for perfect virtual emulation, many turned to a practical enquiry on the specific potential of general-computing capable devices. Their ability to inspect themselves allowed musicians and artists to embed program errors, compression artefacts, interference manifestations and various types of noise (static, clipping, digital noise floor) into their works (Cascone 2004). Through these practices, interference emerges as a key resource for dissolving the noise-sound dualism under a cohesive strategy to develop new sound objects, through human and technical agency, on technical and conceptual levels.

Going a few steps further, Lars Qvortrup (1998) uses interference to describe the complexities of polycentric media landscapes. Arguing that artistic media practice is an exercise in critical observation, Qvortrup describes the production of aesthetic experience as a process of interference within complex systems, challenging the nature and locus of agency. Resorting to Husserl's essential phenomenology, the aesthetic experience is placed between object and conscience, parallel to the notion of interference as mediator within the human-computer interaction model. While this proposition hasn't established itself as an influential paradigm shift, it still provides intriguing clues to the role of interference between technological and human actants, beyond mere unpredictability as a front for complexity.

8. CONCLUSION

The United States Federal Code of Regulations stipulates that radio frequency devices "may not cause harmful interference, and […] must accept any interference received, including interference that may cause undesired operation".[17] This stipulation is mainly designed to ensure a functional operational environment in a saturated electronic ecosystem, but also configures a control bias in consumer devices: they must not be able to disturb the behaviour of others, and must be susceptible to external control, by naturally occurring phenomena but also, presumably, by devices other than those commonly available.

This configures a practical but limiting scenario, which has been circumvented in many ways, mainly by interfering with devices themselves (deconstruction and recombination) and with their intended purpose (shifting programs of action).

In any case, the potential impact of interference is such that it demands legal governance. This becomes particularly relevant as technology is taken for granted and embedded in our life, an invisible part of our ecosystem (Gere 2008), and its interference becomes intrinsic to the mediation of our interactions.

As relayed human agency (Latour 1994), technological media embeds interference as an instrument of disturbance and control, not only over media artefacts and mediated content manifestations, but also over communication and interaction modalities. This makes it necessary to take interference into account when exa-mining or designing interactions. Instead of a descriptor for an undesired result, interference can help reframe observations on the stability of interaction systems and performative settings. It is here argued that interference must not beconsid-

17
E-CFR: Title 47: Telecommunication PART 15—RADIO FREQUENCY DEVICES Subpart A—General. 2017. Electronic Code of Federal Regulations. Accessed: 2017-02-05.

ered solely on a defensive standpoint, as something to exclude and quarantine. Instead, there are constructive benefits to be found by embedding interference in interaction, and that it can be instrumentalized for the creation of meaning. Observing the communication channels (or data paths) of an interaction model as sensitive to technical interference, enables new possibilities for the modulation of information flowing through those channels, by means not necessarily predicted in the system. By embedding interference, we can then consider such channels as a process of interference, enabling radical shifts in programs of action and extending interference to cognitive functions. This can be achieved during interaction experience (by producing interference) and interaction design (by embedding interference). A videotape can be paused to explore the stylistic effects of magnetic interference, and this visual effect can be programmed as a filter to be applied onto digital video, as an evocative, nostalgic layer. Instagram famously em-ployed digital filters simulating the visual output of film cameras and aged paper photos, allowing users to embed interference for cognitive impact. Audio mastering software programs often include simulations of old amplifiers, for similar effect. Admittedly, these are instances of "preset interference", where users have limited access to a few parameters. For all their convenience, digital devices are also noticeably harder to unbox, as they are composed of fewer and more multifunctional components, making it harder to tap channels of interference (this is done mostly by electromagnetic waves, sensor actuation and simulation in software). Analog devices include discrete components and more single-purpose parts, making it easier to tap communication channels at various stages and embed interference at the lowest operational level. For this reason they are extremely popular with the DIY community, and this is also why they better illustrate the potential of interference in interaction, in contrast with digital devices.

Technical interference can be employed to modulate the output of a device, altering its intrinsic properties. Human interference can take place on cognitive, sensorial and physical levels, as humans exchange actions and information with a given system. Effects of these types of interference can become embedded in the interaction system or be applied parallel to the exchanges taking place. Previously discussed cases demonstrate how these types of interference can be instrumentalized for the benefit of wider operational and expressive range, expanding the richness of interactions and performative settings.

Challenges are also pointed out, such as the cumulative effects of interference in cyclical interaction, the difficulty in mastering the outcome of highly variable interference, and the impossibility of foreseeing every type of interference a system may become exposed to. Interference, in the context of interaction, can thus be mobilized as an agent for increased affordance generation and wider operational ability, as previous conditions of failure can be recontextualized towards significant output. Interference emerges within interaction models as organic part of a framework for a more informed observation and configuration of interaction experiences. This is the desirable role of interference in interaction: that of meaningful contribution, rather than dysfunctional intrusion.

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