Interference Modalities for Interaction and Performance Design

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ABSTRACT

While interactive media and its interfaces are susceptible to interference on technical and human dimensions, this is rarely considered by theoretical models found in the literature for describing or designing interactive settings and interfaces. This research explores modalities of interference as it affects agency in interactive and performative settings, by analysing a selection of artworks where this phenomenon becomes evident. As observed through the works discussed, modalities of interference redefine successful interaction as discovery of new potential, providing wider latitude for creative expression and collaborative engagement. Paths towards an aesthetics of interference are found on practical and conceptual levels. Challenges are identified, such as the difficulty in mastering highly variable interference, its cumulative increase, and the impossibility of anticipating the full spectrum of possible interference. As an agent for increased affordance generation and wider operational ability, on technical and cognitive levels, interference is demonstrated to be a factor of required consideration for a more informed observation and configuration of interactive and performative experiences.

KEYWORDS

Interference, design, interaction, interface, aesthetics.

ARTICLE INFO

Received: 13 November 2017
Accepted: 14 November 2017
Published: 22 December 2017

https://dx.doi.org/10.7559/citarj.v9i3.431

1 | INTRODUCTION

As interference is not limited to the technical domain, it is conceptually employed in various fields, such as psychology and cognitive science, while also being related to different dimensions and modalities of interaction. A brief clarification of these relationships is necessary before we provide context and establish their relevance.

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 takes place when two overlapping waves combine to produce a new wave pattern (Young, 1802; Feynman, 1977). This phenomenon, in more specific fields such as optics and electronics, explains the creation of unique outputs by combining different signals, or variations of the same signal. Two major types of interference are defined by the superposition of equal waves. When they are in phase, their plot appears superimposed, as they follow the same path at the same time. This produces constructive interference, since the new wave is the direct sum of its constituents. When phase is offset in such a way that its pattern is symmetrical, destructive interference occurs, since each wave cancels the other. Intermediate states are triggered for multiple applications, such as audio synthesis. Shifting the relative phases of oscillators produces new waveforms, harmonics, and other sound effects. Similarly, psychology uses interference to describe interactions between newly acquired and previously learned knowledge. Proactive interference describes the loss of new information by effect of prior knowledge, and retroactive interference refers to the inability to regain prior knowledge due to the focus on new information. Both cases describe a destructive effect, but this can be used to an advantage, when dealing with short-term memory requirements in designing user interfaces where high cognitive load is likely. Interference also affects communication when something reconfigures, interrupts, or modifies a message in its course. In linguistics, this happens when a newly learned language is contaminated by aspects of a subject's native language (grammar, pronunciation, lexicon). Also in the context of communication, eye contact is known to affect processes of cognitive control (Kajimura & Nomura, 2016), disturbing verb generation during conversations. In cinematic and theatrical works, actors directly addressing the audience or looking at the camera are a classic example of breaking the fourth wall: this technique tends to produce more cognitively enveloping experiences in the audience (Auter & Davis, 1991). Interface usability analysts have observed an aesthetic usability effect on users, who display greater tolerance to minor usability flaws in more aesthetically pleasing interfaces (Meyer, 2017). Interference is therefore present and of relevance in several areas, directly related to interaction in arts and design. As demonstrated in the following sections, the main interaction models found in literature, and commonly employed for practical development of design and artistic practice, include dimensions and modalities susceptible to operational interference.

It should be noted that interference is not synonymous with noise, nor is noise a type of interference. Noise is technically a source of interference and, cognitively, a low value attribute given to specific interference results. In communication, noise is the part of a signal that carries no meaning (semantics) or information (electronics, media). However, noise as an aesthetic element plays a role in shaping how a message is ultimately perceived. Here we must distinguish between intrinsic and extrinsic noise types, as they provide a useful reference for types of interference discussed in further sections. Intrinsic noise emerges from within systems, and is generally associated with properties of that system. As an example, pausing a videotape generally adds to the resulting image various types of visible noise, such as visual gaps and distortions. This is due to the characteristics of the machine, designed to slide a movable tape along rotating magnetic sensors: disrupting the standard operation induces a magnetic disturbance to the image reading and rendering process. Component degradation or sub-optimal ambient conditions (heat or intense humidity) can produce very similar results. Extrinsic noise is caused by external signals: this can be easily demonstrated, keeping to the same technical example, by moving a strong magnet close to a television's cathode-ray tube, distorting the image and eventually degrading it beyond recognition. Another classic example is moving a radio antenna to reduce noise and improve signal clarity, avoiding interference from physical barriers and electromagnetic fields.

In summary, interference in its strict sense arises from the effects of non-ideal, intentional or unintended input. It can be caused by natural phenomena, technical conditions or human intervention, it can occur in series or in parallel, and it can operate in the technical and cognitive dimensions of interaction. Interference may ultimately lead to system failure, when output becomes totally unpredictable and prepared programs of action can no longer be followed. Multimodal interactions are obviously more resilient, since interference can rarely affect multiple dimensions of interaction.

2 | CONTEXT AND RELEVANCE

Interaction and interface design must observe human, environmental and technological variables, such as: age groups, literacy, group dynamic, processing limitations, input variability, area, light, weather, time. From a functionalist point of view, interactive systems must accept predictable inputs and actions associated with such variables, while preventing perceptions of failure by users or participants (e.g. results outside expected bounds), according to the purpose of an installation or interface. What happens when a prepared system receives unexpected input? This might be unnoticed or disregarded, as when swiping a credit card the wrong way. In other cases, spurious input can challenge the system's nature and integrity. While some theatre plays welcome audience participation, others require a passive audience to create immersion. A meticulously prepared performance may be hampered by technical problems, while other performers might embrace glitches and failures as spontaneous contributions. The preceding examples uncover important traits of interference: its origin is not limited to technological artifacts, it can be integrated into a prepared action program, and its effects, even when detrimental by some standards, are not necessarily undesirable. Increasing technological mediation provides a greater latitude for interference, since the layers and modalities available for unanticipated inputs are multiplied. Events surrounding Wolfgang Staehle’s *2001* exhibition at the Postmasters Gallery in New York, provide an appropriate example of this, as described by Charlie Gere (2008).

The installation included live video feeds from three different remote locations, one being a view of the lower Manhattan landscape. On September 11, 2001, this video stream extended the stage for the attack on the World Trade Center, by providing a live transmission of the entire event. From a technical standpoint, and following Latour’s notes on technical agency (further clarification provided in note 1), airplanes and airlines arguably enabled the attack [1]. Live broadcasting made the installation permeable to the event’s interference. Technology enabled an unfortunate encounter of media art and human tragedy. However, this instance of interference brutally exceeds glitch or malfunction, extending the installation’s impact and meaning beyond its intended scope. The issues of live video versus photographic images became secondary to the unfortunate coincidence of displaying the attack. Interference can therefore emerge from technological means and still radically alter the meaning and relevance of a previously established program. A static image of the same Manhattan view would be impervious to such immediate interference, as it would present fewer layers susceptible to interference [2]. Although Staehle's work is somewhat contemplative, these issues are relevant to interactive configurations. One can easily picture the effect of such a violent coincidence on Kit Galloway and Sherrie Rabinowitz’s *Hole in space* (Durland, 2016): in this work, two remote public locations (in New York City and Los Angeles) were connected by a live video feed, each side of the connection could see and hear live video and audio of the other side. The novelty of this configuration at the time (1980) quickly spread, motivating passing people to meet strangers across the country or search for loved ones. Should this live feed have become a vehicle for broadcasting a coincidental traumatic event, the discussion about this artwork would certainly be different. Interference is therefore not limited in relevance to technological issues, as it can also emerge from human actions as well as hybrid human-machine agency, whether intentional or not.

Various manifestations of interference are explored in the following sections, to clarify its dimensions and properties, through analysis and discussion of artistic works and practices, diversified in form and nature. Relevant interaction models are observed as systems susceptible to interference in their various layers and modalities, relating pragmatist and humanist approaches to the roles of technical and human agency. This framework supports a discussion on the incorporation and instrumentalization of interference when configuring interfaces and interactions, embracing interference as a resource within design practice, towards an aesthetics of interference as first advanced by Lars Qvortrup (1998). This proposition supports the acceptance of interference as a resource for interaction design, exploring the hypothesis that greater permeability to interference can foster more organic and expressive interactions, while also reducing conditions for perceived failure. In other words, a system designed to respond in some way to unstructured or inadequate input, is arguably less prone to be perceived by users as dysfunctional, inoperative or broken. By providing variable response to such input, instead of a binary “working / not working” outcome, subjects can be motivated to direct their actions in a certain way according to the feedback received, stimulating creative explorations (as in examples discussed ahead), or even guiding users towards a desired action. The aim is to determine if the formative aspects of the interference can provide a framework for analyzing and designing experimental interactive media.

3 | UNPACKING INTERACTION MODELS

When lacking a comprehensive unified theory for observing and explaining interaction, various perspectives must be drawn. Machine-mediated communication systems are fundamentally outlined by Claude Shannon (1948), describing an optimal communication process in linear fashion. Especially important to this discussion is Shannon's concern with noise, despite a disregard of semantics as "irrelevant to the engineering problem" (p. 379). This concern, though mainly technical, focuses on the near impossibility of a channel or communication system immune to external disturbance. Maintaining the technical approach, an algorithmic solution is described for protection and recovery of the integrity in any message, as it travels the components of the communication system: source, transmitter, signal, receiver and destination. This structure provided a foundation to support most linguistic and cognitive models concerned with information science. However, interference here is represented by noise, or a diminished fidelity to an original signal. Noise is described as random variable modulation, as a stable and possibly reversible modulation would constitute distortion.

By allowing feedback in the communication process, new media added symmetry to this model. The linear process evolved to a cycle, and cognitive dimensions could no longer be discarded, as they were by Shannon (1948), who as focused solely on the technical aspects of information displacement. To address this, Norman (1984) suggested a set of four steps in human-machine interaction: forming intent, selecting an action, performing the action, and evaluating the outcome [2]. The question of intent is particularly important, as it brings semantic and cognitive variables into play in the interpretation of actions and messages throughout the interaction cycle. Outcome evaluation is of dual importance as it needs to be executed by both humans and machines: the latter must convert human input to intent, while the former needs clear feedback from the machine to properly evaluate the result. Machines must clearly communicate their change of state, meeting expectations, countering doubt and frustration. Formulated intent and successful interpretation are then necessary conditions for perception and control, as minutely described in the multimodal interaction taxonomy by Schomaker et al. (1995), where a clear symmetry of Shannon's model is still present, but extrudes a sphere of interaction from Norman's cycle.

This multimodal nature of cyclic interaction is discussed by Bert Bongers (2000; 2007) in the context of developing musical instruments. A network of sensors and actuators, as an analogy to the human-computer system, explains a system's adaptability to a subject's intent, and the conditioning of a system's ability to return feedback. Bongers is also concerned about a system’s ability to properly handle the entire possible spectrum of human input, although with more interest in expressive range than accuracy. The focus here is on what connects human and mechanical agents (procedural or other), the modulation effected by the interface (sensors and actuators) on the signal, and finally, on the program of action incorporated in the configuration of any artefact.

Interaction multidimensionality is also present at its conceptual level, as aesthetic experience. Following the general theory of affordances (Gibson, 1986), the dynamic properties of interaction are no longer anchored in utilitarian views and linear (if cyclic) paths. Different views have been expressed on the dynamics of interaction aesthetics, as enumerated by Udsen & Jørgensen (2005). These can be summarized as pragmatist and naturalist (Eustáquio, 2016). The pragmatist approach retains the functionalist theories of Human Computer Interaction, describing aesthetics as a rational mechanism (Ross & Wensveen, 2010), which operates through the built-in properties of artifacts. The naturalist approach considers the intangible (Hummels & Overbeeke, 2010) and hybrid agents (Latour, 1994), viewing aesthetics as resulting from perception within uncertainty (Xenakis and Arnellos, 2014).

This division of pragmatic and naturalistic approaches leads to an important question: in any given environment or interaction, what latitude is there for error, misinterpretation, spurious output, and affordance generation? The functionalist would say none, since any change of the predefined program would result in what Xenakis and Arnellos call aesthetic pain (2013, p. 63). The naturalist would more willingly interpret unexpected results as representation of increased potential in a system.

4 | INTERFERENCE ORIGIN AND AGENCY

This section describes types 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.

In the technical realm, interference is in series when the disturbance intercepts and reshapes the signal during interaction. This is represented in Shannon'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 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 a 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 unfortunately common. Atmospheric 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.

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 & 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 receivers 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 (Winner, 1980) that technical advancements are instruments of planned ideological interference programs.

5 | OPERATIONAL INTERFERENCE IN ACTION

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 *I Am Sitting in a Room* (Burns, 2002; Lucier, 1969) 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, aptly entitled *I Am Sitting in a Video Room* (Liddell, 2010), pays homage to Lucier's work with a translation of 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 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 (Howse, 2014). Golan Levin (2014) presented an interesting conundrum with his *Augmented Hands series*: 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*, Robin Rimbaud (2002) (known by the stage alias Scanner) composed a soundscape to be used in the morgue room of the Raymond Poincaré 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. Levin's (2014) piece 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 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 [3] 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 [4].

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 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 | INTERFERENCE-DRIVEN AESTHETICS

The Shannon-Weaver (Weaver, 1949) pipeline model of communication was criticized by Marshall McLuhan for its left-brain lineal bias (McLuhan & 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, p. 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” (Russolo, 2004). This evolutionary shift of musical art towards noise-sound is perceived as a natural consequence of increasing man-machine collaboration [5], 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 (1939), Christian Marclay (2004) and Thomas Brinkmann (2010) have produced diverse works from similar techniques (Seliger, n.d.), 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 artifacts and deliberate alteration of their physical properties) with its consequential technical interference (tone arms slipping 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 behavior. 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 collective ("Negativland", n.d.) 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 ("Merzbow", n.d.), returns to a more futuristic and extreme approach, by drilling aggressive textures from non-instrumental devices, modelling electricity through effects devices and mixing desks (Cox & 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 to an extent, classic instruments), they became almost invisible: they became 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 artifacts, 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 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 | CONCLUSIONS

For homologation purposes, electronic devices are commonly required to not cause harmful interference and to accept any interference received, including that which may cause undesired operation. This is mainly to protect a functional environment in a crowded ecosystem. It also establishes a control bias in consumer devices: they should not provide the ability to disturb others, but they must be open to external interference, presumably from naturally occurring phenomena, but also from devices exempt from observing such rules. Because this is a useful but limited setup, it has been circumvented in various ways, particularly by modifying devices (hacking) and their intended applications (programs of action). In any case, the potential impact of interference is evidently significant enough to warrant legal governance. This takes an entire new meaning as technology is increasingly accepted and integrated into our lives, becoming a figuratively invisible part of our ecosystem (Gere, 2008): its operational features become an intrinsic interference on the mediation of our interactions. As relayed human agency (Latour, 1994), technological media embodies interference, as an instrument of disturbance and control, over devices and their mediated content manifestations, but also over modes of communication and interaction. Interference must therefore be considered when studying or designing components of interaction settings. Rather than just provide an umbrella name for unwanted results, interference can reframe observations on the nature and integrity of interaction systems and performative configurations. By abandoning a defensive standpoint on interference, as something to simply avoid and quarantine, one can find constructive benefits by embedding or instrumentalizing interference for the creation of meaning in interactive or performative settings, potentially widening their expressive range.

Exploring the sensitivity of an interaction model's channels to interference, exposes unpredicted possibilities for modulating the signals travelling across those channels. Embedding interference can turn such channels into a process of interference in itself, allowing significant shifts in programs of action and extending the reach to cognitive functions, ultimately transforming the original system into something else entirely. This may be done during performance/interaction (producing interference) or in interaction design stages (incorporating interference, relayed agency). While a video tape can be paused to generate textural audio-visual effects, these can in turn be emulated by software, and applied during digital video post-production, for nostalgic effect. Audio mastering software often applies the same principle by emulating familiar modulation nuances from audio hardware equipment. Smartphone photography apps have generalized the use of image filters simulating aged photo paper or film cameras, embedding interference for cognitive impact. Under this type of "preset interference", users generally have limited access to variability through pre-ranged parameters. For all their convenience, digital devices are noticeably harder to unbox: the scale and speed at which they operate is not human, requiring translation agents and interfaces for the sensors and actuators on each side of the human-machine model. They offer fewer direct channels for interference. On the other hand, analog devices are generally simpler in construction and include more discrete single-purpose parts, allowing easier access to physical manifestations of communication processes and data transport. This is one of the main reasons why they are more popular with DIY communities, and why they often better demonstrate the effects of interference: in contrast with binary black-boxes that either work or not, analog devices can offer more entry points for interference and degrade gradually, providing more room for mastery in controlling the outcome. Technical interference can modulate the output of a device, to the point of changing its intrinsic properties. Human interference can occur at cognitive, sensory, and physical levels, as humans exchange actions and information with(in) a system. Technical and human interference can incorporate and transform the system, or act in parallel to the flow of actions and information. Previously discussed cases demonstrate how these types of interference can be instrumentalized for broader operational and expressive range. Challenges are also pointed out, such as cumulative effects in cyclical interaction, the difficulty in mastering highly variable interference, and the impossibility of predicting the full spectrum of interference a system can withstand.

Interference, in the context of interaction, can thus be mobilized for affordance generation and wider operational capacity, redirecting preconditions of failure towards meaningful results. It emerges within interaction models as organic part of a framework for a more informed analysis and design of interactive media: its formative aspects generating meaningful contribution rather than dysfunctional intrusion.

ENDNOTES

[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 can 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] 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 behavior, we would add that not all stages are necessarily present in all interactions.

[3] Famously designed by Leon Theremin (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.

[4] For 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 designates "performers" as part of the described procedure. It should be noted, however, that Reich specifically calls for "performers" in the original described procedure.

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

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