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GROUPTHINK

Telepresence and agency during live performance

Live performers often describe “playing to the audience” as shifts in emphasis, timing and even content according to perceived audience reactions. Traditional staging allows the transmission of physiological signals through the audience's eyes, skin, odor, breathing, vocalizations and motions such as dancing, stamping and clapping, some of which are audible. The Internet and other mass media broaden access to live performance, but they efface traditional channels for “liveness,” which we specify as physiological feedback loops that bind performers and audience through shared agency. During online events, contemporary performers enjoy text and icon-based feedback, but current technology limits expression of physiological reactions by remote audiences. Looking to a future Internet of Neurons where humans and AI co-create via neurophysiological interfaces, this paper examines the possibility of reestablishing audience agency during live performance by using hemodynamic sensors while exploring the potential of AI as a creative collaborator.

CCS CONCEPTS • Interaction design • Collaborative and social computing • Accessibility

Additional Keywords and Phrases: artificial intelligence, human interaction/interface, music, performance

1 INTRODUCTION

GROUPTHINK is a participatory artwork that anticipates the Internet of Neurons - an era when humans and computers interact through sensory prostheses.¹ The project aims to:

- Develop new methods of remote interaction between performers and live audiences
- Examine the psychological states associated with mass connectivity via human-machine interface (HMI)
- Recruit AI as a creative partner in an HMI-integrated network
- Cultivate a role for traditional museums in contemporary art production

As a thematic core, the artists chose to portray entanglement: the emergence of collective agency through a network of metabolic exchanges.² While graphs of neurons, markets and ecologies often resemble one another, increasing evidence implies this is not coincidence.³ Brains, economies and nature may coordinate activities through similar principles, notably structural coupling which facilitates shared agency among individual components.

GROUPTHINK provided an opportunity for an entangled network to emerge during a live performance. Staged at National Gallery X, a next-generation arts studio, and live-streamed to a remote audience during Ars Electronica Festival 2022, the performance included a sitarist, a guitarist, visual artists, AI-generated animations and a visual score generated by the audience's collective heartrate. A triptych of monitors immersed the stage in video which responded to these parameters. Hence, the project's tagline, “Make art with your hearts.” The artwork's success was judged by the level of

interdependence - or physiological entanglement - attained by the performers and audience. GROUPTHINK explores collaborative agency, AI-based creativity and the growing possibility of an Internet of Neurons co-inhabited by AI and humans who interact via neurophysiological interfaces.

2 THE ARTIST IS PRESENT (REMOTELY)

Participatory art emphasizes audience agency, that is, active collaboration between artists and audiences, and biosensory art uses physiological interfaces as creative tools.⁴ A prime example of the former is Marina Abramović's *Measuring the Magic of Mutual Gaze* (2011) which engaged visitors with direct, natural interaction. In 1965 Alvin Lucier pioneered biosensory art in *Music for a Solo Performer*,⁵ and for decades Stelarc has explored shared agency through neural implants, notably in *RE-WIRED / RE-MIXED: Event for Dismembered Body*.⁶ Biosensory artworks have historically been performed by artists, for instance, Janine Antoni's *Slumber* (1993) and Lisa Park's *Eunoia* (2013), or they have facilitated individual experiences such as Mariko Mori's *Wave UFO* (2007) and Oliver Gingrich's *Aura* (2015).

Improvements in technology and costs have enabled art which is both biosensory and participatory to emerge. Recent examples include Yui Kawaguchi's *MatchAtria* (2015), Shama Rahman's *Rhythms of the Heart* (2015), Oliver Gingrich and Shama Rahman's *Zeitgeist* (2019) and Ali Hossaini's *Kosmograpf* (2020). *Zeitgeist* invited audiences to co-create by providing real-time flow state classification. Deep learning algorithms generated video representations of Möbius strips which entwined as participants reached higher levels of togetherness. *Rhythms of the Heart* (2015) explored synchronization of heartbeats, also known as entrainment, based on research that indicates: "Those who sing together, sync together," and "Synchrony is the mechanic of group empathy."⁷ Its musicians encouraged synchronicity and psychological entrainment by using the audience's pulse to set their tempo.

Improvements in telecommunications, AI and biosensing offer artists the capacity to collaborate with remote audiences. The convergence of these factors provided the practical context for GROUPTHINK's development. At the same time, thanks to steadfast pioneers, participatory and biosensory works are now accepted as art. Joining these trends is a new emphasis on giving everyone access to culture, including individuals who cannot physically visit venues. Finally, there is a growing sense that AI may become an artistic partner as well as a creative tool. In keeping with its era, GROUPTHINK sets the stage for creating accessible, participatory art with HMI, AI and telematics.

3 TECHNICAL OVERVIEW

GROUPTHINK required a raised platform surrounded by an immersive video triptych. Performers faced a single camera for streaming video, and they tracked visual cues on two reference monitors. Separate mixing boards managed the video triptych and audio streams. GROUPTHINK incorporated the following visual elements:

- Custom applications for hemodynamic monitoring and autonomous video selection
- Digitized versions of pre-modern paintings
- AI-generated video sequences
- A web page for audience participation

The audience participation webpage was served by Heroku. An opt-in button triggered a custom JavaScript application which detected the participant's heartbeat via local webcam. Page responsiveness impacted data quality, so content was optimized to simplify the main runtime routine. The local client transmitted heartrate data via websockets to an AirTable database which forwarded anonymized compilations to the venue. Data were processed in studio by a MaxMSP patch which filtered anomalies, e.g., detection of random movement and light by the webcam. The patch sent the mean and

standard deviation of the data via OSC (OpenSoundControl) to a visual generator built in TouchDesigner. The video generator composited four visual elements on the video triptych:

1. A visual score which displayed the audience's collective heart rate in real time.
2. Animation sequences triggered by values of the mean audience heartbeat.
3. Manually controlled effects such as pixel sorting, fades and dissolves.
4. Paintings from the National Gallery's collection (UK)

The generator included manual controls for operators to smooth transitions and insert selected images. The patch's functionality allowed the media artists to integrate themselves into the performance as desired while allowing key workflow to be determined autonomously by the system. (Figure 1)

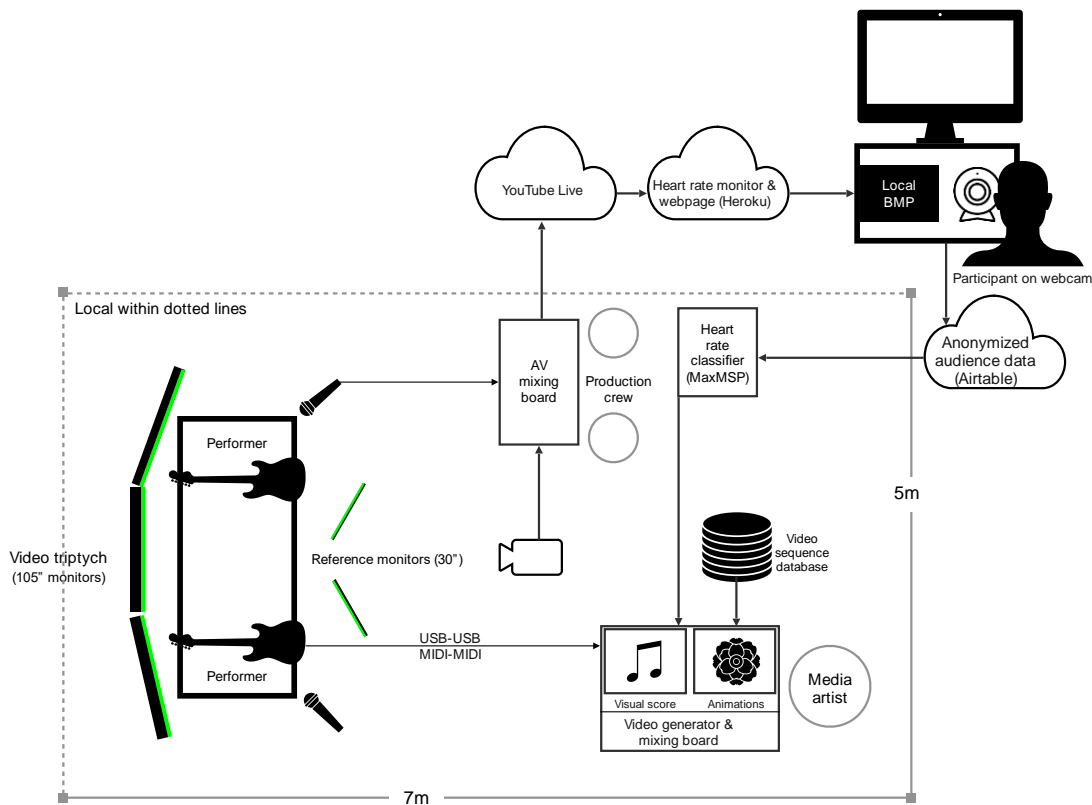


Figure 1: GROUPTHINK system design

4 REPRESENTING THE AUDIENCE

Audience members participated via remote monitoring of their heartbeat. During the performance, heartbeats were averaged in real time then represented as a visual score whose form evolved with heartrate measurements. Performers responded to the visual score by changing the musical mood and tempo. This feedback loop aimed to replicate the dynamics of a traditional performance by using heartrate as a proxy for excitement. GROUPTHINK's visual score offered its audience

direct representations of their input and introduced new visual themes. The score took the form of rhizomes which pulsed, grew, and elaborated over time. (Figure 2)



Figure 2: Examples of the visual score

The visual score served practical, theoretic and aesthetic purposes. When composited in the video environment, it could be intuitively processed by performers and audience. Its quasi-organic structure provided a pleasing intervention within the plant-inspired animations described below. Although this proposition was not tested, studies demonstrate that the brain synchronizes with pulsing visual stimuli by producing steady-state visual evoked potentials (SSVEPs)⁸, and we speculated that this may reinforce musical entrainment. Although *sui generis*, GROUPTHINK's visual score developed in the atmosphere created by generations of innovators such as John Cage, Anthony Braxton and Iannis Xenakis, and its double-duty as musical guide and a work of visual art resonates with Craig Vear's description of digital scores which "bring to mind a map of the harmonic shape of ... [a] song and also a tempo, a feel, a groove of how to interpret it."⁹

Figure 3 shows the audience participation webpage. The hemodynamic monitoring application calculated participant heart rates by assessing color changes in the forehead, a process which required participants to hold their face inside a target region.¹⁰ (Lower left corner of Figure 3.) GROUPTHINK's software incorporated Eulerian Video Magnification.¹¹ It recorded a mean color value for each frame, and a Fast-Fourier Transform analyzed the most recent 256 frame values. Given that 1 Hz is 60 beats per minute, this frequency could be converted to heartrate easily.

Audience reactions were categorized into three energy levels: low, medium and high. These levels were keyed to 80 - 100 bpm (heartbeats per minute), 101 - 120 bpm and above 120 bpm. These bands presumably conveyed the audience's level of excitement with the performance. To encourage entrainment, the performers asked participants to hum with the music. Musicians responded with tempos that both led and followed the visual score, and one of the visual artists presented animations that corresponded with low, high and medium energy. Every attempt was made to engineer a system which

functioned in close to real time. Although the lag between performance, measurements and the score often approached 2,000 milliseconds, the evolution of the music through loops and slowly evolving variations created an impression of convergence between the performance and audience response.

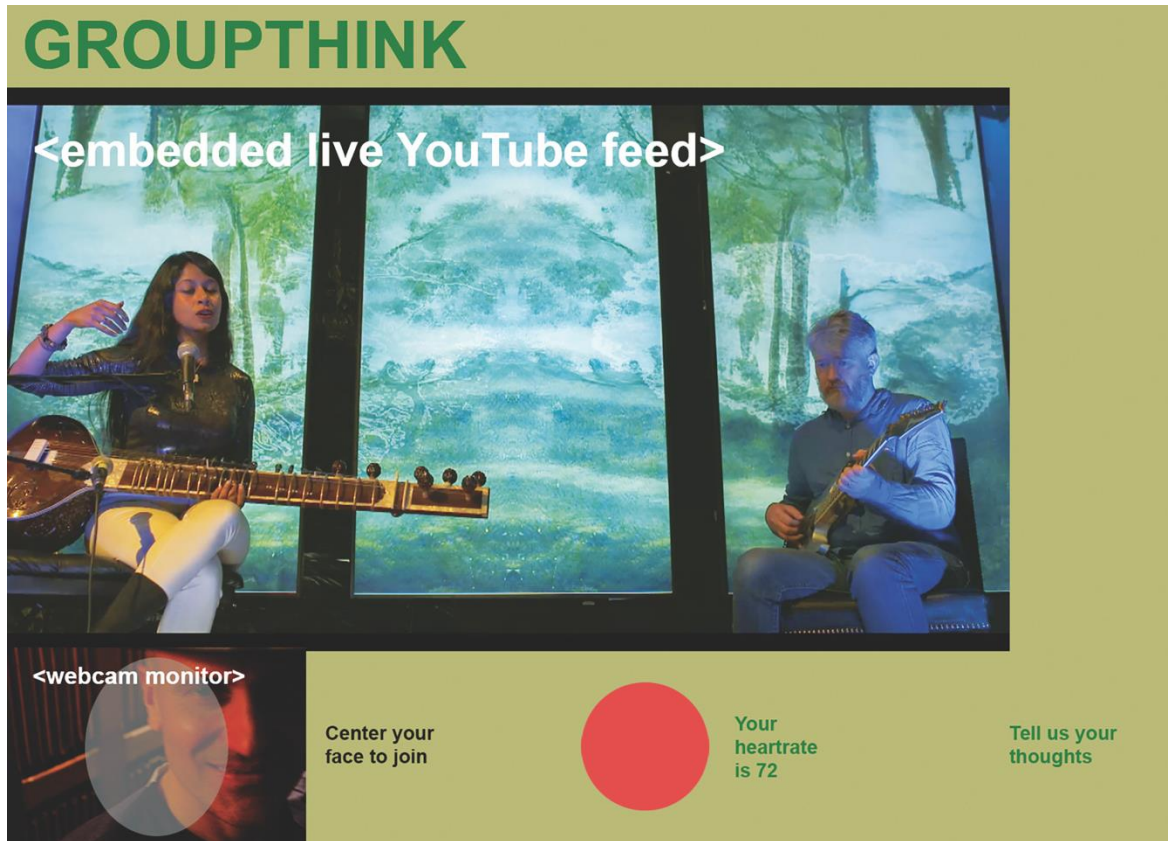


Figure 3: Webpage for audience participation

5 REPRESENTING NATURE

The base video contained two distinct but developmentally related elements. The first element was ten landscape paintings from the National Gallery. These were representative of the artistic corpus described below. Entanglement provided the conceptual bridge between the National Gallery's collection of organic imagery, and the biosensory apparatus of GROUPTHINK. AI / ML translated the visual dynamics of landscape paintings into surprising, spontaneous animations. Paintings of nature contain inherent forms of organic growth, and, when interpolated into video via latent vectors, they produce animations which evoke the spontaneous formations of entangled life. Digitized images of canonical paintings from the National Gallery segmented the performance when musical moods changed.

Three generative adversarial networks produced the second element. (StyleGAN2 on Runway ML and Google Collab) Initially pre-trained botanical models were used to interpret 200 hundred landscape paintings . The results did not meet the

project's ambition: to generate animations that combined the texture of canonical painting with the sinuous motion of organic growth.

The desired results were achieved by using data-centric techniques championed by Andrew Ng.¹² The models were retrained on custom datasets: 3,000 images of plants excerpted from a broader selection of National Gallery paintings (anything with a plant) and 2,000 photographs of tree branches taken by the director. The StyleGANs produced still images categorized into three energy levels: low, medium and high. (Figure 4) From these base images, latent space transversal sequences produced over 200 animations. The retrained models created exciting animations - visual poems - that stretched the artists' imaginations and creative capacity.



Figure 4: Representative StyleGAN output for latent space animations (a: high energy, b, c: medium energy, d: low energy)

6 A REAL-TIME, COLLABORATIVE PERFORMANCE BETWEEN AUDIENCE, ARTISTS, AND AI

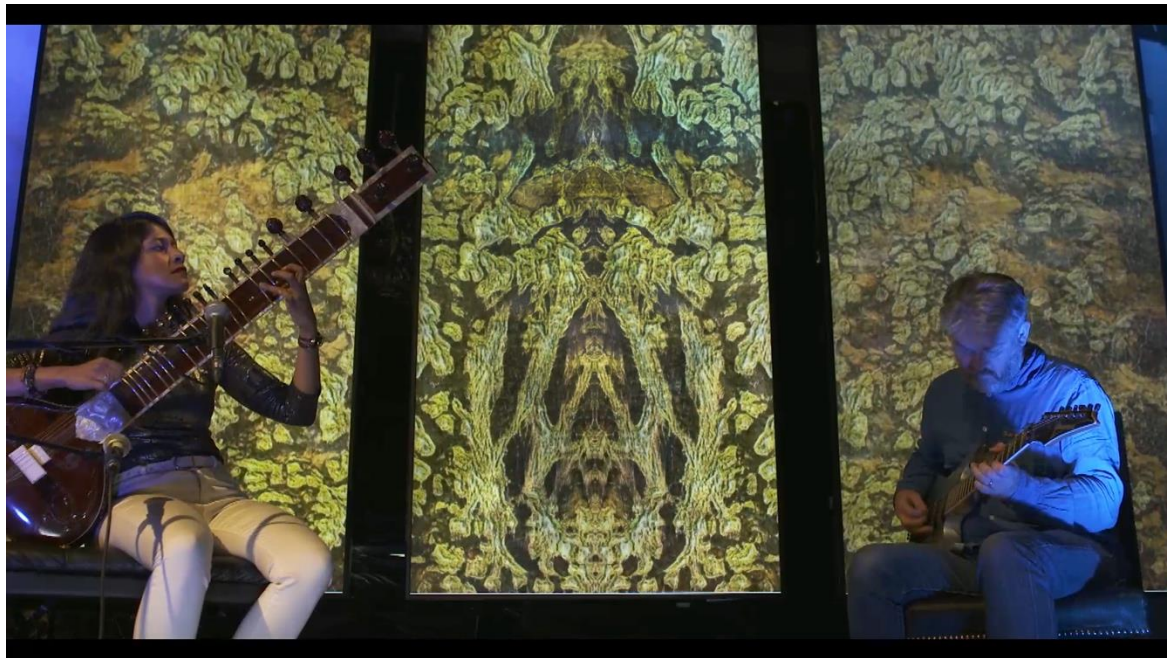


Figure 5: GROUPTHINK performance

Two one-hour performances of GROUPTHINK were staged in September 2021. (Figure 5) The artists opened by explaining how viewers could simply observe streaming video or participate by launching the page which contained the hemodynamic monitoring application. The performance began with slow, inviting melodies accompanied by low-energy animations. When the visual score indicated more or less excitement, the musicians played music that ranged from ambient loops to bright, rhythmic grooves to frenzied percussives.

During the performance, the visual generator selected animations - autonomous visual poetry - by matching energy level to audience heart rates. One of the artists manually smoothed the visual generator's transitions, and they live-mixed selections in response to the music and visual score. They also inserted full-frame paintings into the triptych to segment the event when they sensed a change in mood. The artist thus served as a third performer who provided a poetic visual counterpart and closure to the musical experience.

7 ART FROM THE HEART

Performance 1 begins at 475 seconds in Figure 6. From this time, there is a steady increase in average heart rate which starts at 80 bpm and climaxes at 120 bpm. Performance 2 begins at 800 seconds. Average heart rate increases from 100 bpm to 115 bpm. It displays more variance and a higher standard deviation, and thus synchronicity is not as pronounced as the first session.

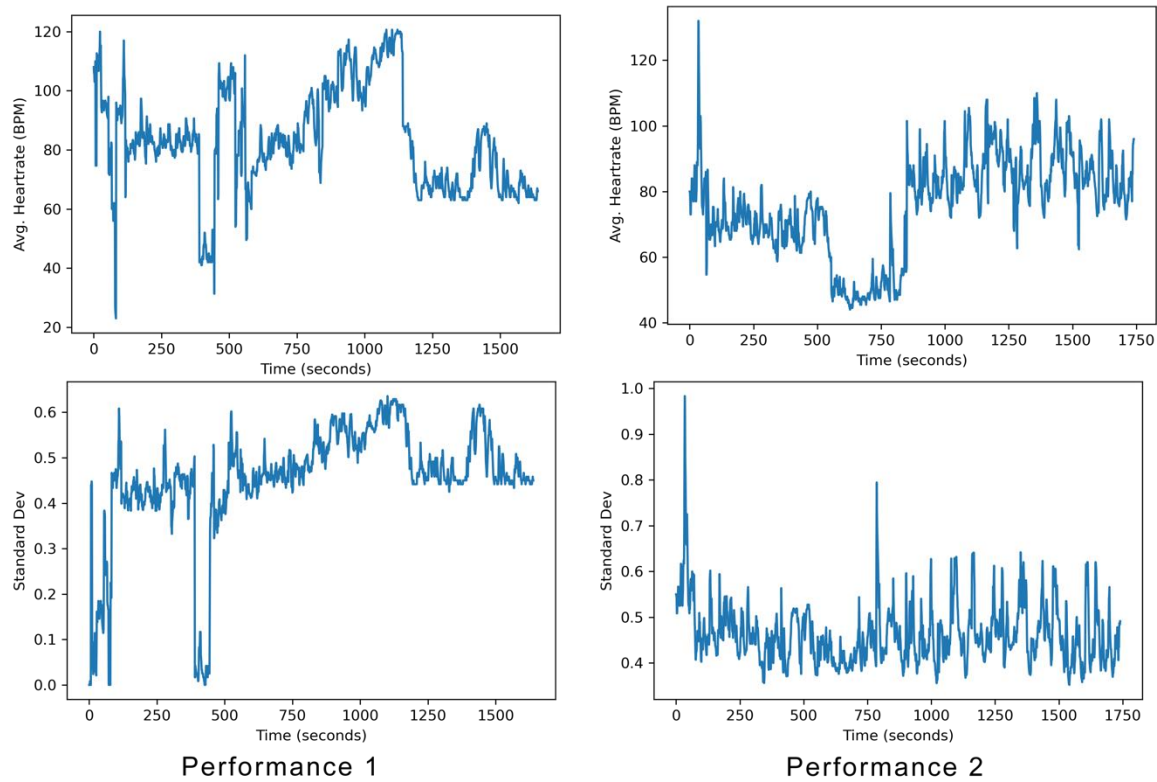


Figure 6: Audience data plots

Performance 1 influenced data more than Performance 2, but heart rates in both sessions reflected the music's amplitude and spectral intensity. The second session may have included participants from the first, and differences in synchronization might be explained by foreknowledge of the performance. These results are consistent with similar experiments including Iwanaga et al (2005),¹³ where "...excitatory music decreased perceived tension and increased perceived relaxation as the number of sessions increased," but straightforward intensity continued to have an overall impact on tension. Recent studies in exercise, health and fitness indicate possibly similar relationships between tempo and heart rate, although potential confounds can complicate attempts to measure such relationships.¹⁴

Taking this analog social experiment to the digital realm, GROUPTHINK connected over 100 audience/participants remotely and even improved on the findings of a paradigmatic experiment by Vickhoff et al because we varied tempo in three rather than two modalities.¹⁵ Inspired by entanglement, GROUPTHINK's process utilized the dynamics of entrainment to influence the audience's perception of painting masterpieces while engaging in a prosocial, telematic bonding experience.

8 CREATING A SENSE OF "LIVENESS"

Debates about the nature of liveness often gravitate to the poles of Peggy Phelan and Philip Auslander.¹⁶ While the ontology of media pertains to our artwork, we sidestep earlier conceptions of liveness by focusing on the phenomenology of

performance. One of the limitations of media is embedded in the word: it mediates (and restricts) the richness of live interaction. Humans interact via multiple physiological channels, and events where performers and audiences share space facilitate psychophysiological feedback loops. Performers adapt to audience reactions such as movement, dilated eyes, sweat and non-verbal vocalizations; audiences encourage or discourage new directions in the performance. Changes in heartrate accompany emotional range, and, in GROUPTHINK, hemodynamic monitoring approximated direct physiological channels of co-adaptation. The experience of GROUPTHINK was jointly produced by a physiological collective. The project sought to measure sensations of shared agency between performers and audience, and, according to a post-performance survey, a majority of participants (57.1%) felt their hearts influenced the performance. If we venture into ontology, GROUPTHINK explores whether telematic performance could become a self-generating or autopoietic organization that generates unanticipated collective experiences.

An autopoietic definition of liveness may be useful in the design of emotionally satisfying telematics. GROUPTHINK was enabled by contemporary telecommunications, inexpensive cloud services and growing acceptance of remote cultural events following Covid-19. While its assemblage is complex, GROUPTHINK's artistic objective was simple: to reprise - in mediated form - spontaneous organic connections between performers and audiences. The artwork achieved its goal of conveying physiological reactions from the audience to performers. As the post-event survey and discussions with the performers revealed, both groups felt a sense of mutual agency during the event.

9 LIMITATIONS & POSSIBILITIES

We should note the limitations of generating telematic liveness. Engineering provides one set of constraints. Bandwidth, compression, computational processing and the speed of light contribute to latency. Based on our experience, delays as short as 10 milliseconds can disrupt networked performances. To compensate, GROUPTHINK incorporated looping cycles of music and imagery which engulfed the relatively long processing delays. Most participants (55.6%) felt strongly connected to the performance while the balance felt some connection. The performers felt the audience reaction lagged their musical moods, but not to the point of inhibition. As with any medium, technics limits aesthetics while introducing new creative possibilities.

Other constraints derived from project necessities. Physiological data can be acquired through various means, notably personal fitness devices, but business, API and privacy issues made this approach impractical. We chose webcams because they are ubiquitous, and we could control the entire workflow. However, our hemodynamic monitoring application only works if the user's face remains fixed within the webcam's sensor array. The participant survey reported that 45.5% of participants found the web interface easy to use, and 54.5% rated it as average on a 5-point scale. People enjoy moving, and entrainment relies on motion as well as metabolism. We see this implementation as a proof of concept that similar effects could be generated with sensors which allow more freedom of movement.

10 CONCLUSION: AI & THE INTERNET OF NEURONS

The notion of AI as partner offers a useful metaphor for working with machine-based intelligence: autonomous systems are partners which may one day connect with our bodies. Human-machine teaming is already part of military doctrine.¹⁷ However, the metaphor is problematic if we start believing AI is sentient. ML does not create speculative representations of the world. Though given a wide degree of autonomy, and capable of surprising results, AI did not serve as a full collaborator in GROUPTHINK because it lacks agency.



Figure 7: The performance ends with Piero del Pollaiuolo's *Apollo and Daphne*. Daphne's gruesome salvation portrays the ambiguities of humanity's growing dependence - and possible merger - with the Internet.

As military planning reveals, questions remain about the stability and accountability of AI-reliant systems, especially in an unpredictable networked environment. Physiological or direct neural interface multiplies potential hazards. GROUPTHINK provides a safe context to experiment with autonomous, networked systems before they are placed into service. (Figure 7) One day we may coexist with AI on an Internet of Neurons. For now, AI / ML opens new horizons for art which parallel possibilities in disciplines ranging from banking to battle. Will our view of AI-based artwork, telematic collectives and autopoiesis become a social fixture, or will it continue evolving? Can art provide a safe space for experimenting with disruptive technologies? Consider Romanyshyn's discussion of Alberti's Window, an artistic technique which became a standard for documenting visual space.¹⁸ By creating new artistic perspectives, we can explore technological spaces before they mature. We intend GROUPTHINK to foster discussions of authorship and individuality, the liminality of human-machine agency and the invasiveness of media. Subsequent iterations will offer opportunities for artists, engineers and the public to contemplate the rewards and dangers of possible futures. As Lucian Freud stated, the artist's task is to make people uncomfortable. GROUPTHINK asks uncomfortable questions by blurring the boundaries between performance and participation, passive and active experience, virtual and physical presence, and, finally, between networked, machine-mediated collectives and organic individuals.

Ethical statement

The GROUPTHINK project complies the ACM Code of Ethics and Professional Conduct and the European Union GDPR.

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