The Light That Entangles: An Enacted Posthuman Instrument For Three Players.

STEVE SYMONS, University of Sussex, UK

Additional Key Words and Phrases: Collaborative, Posthuman, Participatory Sensemaking, Entanglement

1 Program Notes

Fig. 1. The Light That Entangles at an Open Studio weekend event.

The Light That Entangles (TLTE) is a musical instrument-based installation for up to three players where participants are encouraged to immerse themselves in the experience of being together, rather than focusing on their individual musical expression. Unlike many NIMEs, this work does not sense individual players actions and map them to control functions. Rather, the interface itself is a physical sound synthesis system that suggests its own emergent interactions. Handheld objects constantly send and receive multiple sources of audio-encoded light that is shared when the objects are brought into proximity (see figure 1). It is here, where the emerging shared light field is de-coded and the audio transmitted to a mixer for amplification, that the installation creates sound. Rotating an object, or changing its relative position to the others, changes the nature of the light-broadcast information that is both sent and received to nearby interfaces. Thus any action reforms both the potential for all subsequent players' actions as well as the listening experience. In this way, the interface-synthesis integration creates a field of entanglement within which the players constantly co-constitute the materiality of the shared audio-encoded light and the agency of their co-players. The participants are quite literally playing and listening to the light that entangles them.

Participants with light sensitivity should be aware that this installation uses bright LED's that sometimes visibly pulse up to 2 times a second. Sunglasses are readily available at the installation.

Author's Contact Information: Steve Symons, University of Sussex, Brighton, UK.

This work is licensed under a Creative Commons Attribution 4.0 International License.
NIME '26, June 23–26, 2026, London, UK
© 2026 Copyright held by the owner/author(s).

2 Project Description

2.1 Introduction

The Light That Entangles (TLTE[1]) is an interactional sound and music [5] instrument based installation for up to three players. Uniquely, however, players' actions are not individually sensed with the resulting data used and combined through a prescribed synthesis control mapping strategy; but the interface, sound synthesis and player engagement are all co-contextualised as a mutual entanglement.

This installation marks the concluding element of a period of practice research investigating the application of post-human (or more-than-human) design practice [23] [16], alongside more established human-centred, embodied, approaches to social multiplayer Digital Musical Instruments (DMI). This research has sought to gain an understanding of how different conceptual frameworks impact design outcomes and, once implemented, the resulting affect on player experience and behaviour. One focus has explored ideas of centring; the manner in which the technical implementation balances individual and mutual agencies. Very few projects have explored technically manifesting posthuman ideas of entanglement into multi-player musical experiences, fewer have read the resulting experiences through a lens of tangible and embodied interaction (or visa-versa). One research outcome is presented here as an installation; with the intention that community members can reflect on how the implemented technical model and playing experience can influence their own practical designs.

2.2 Functionality

The Light That Entangles interface integrates, audio-modulated light, broadcast and receiver elements into a single unit. Each of the objects[2]', 18 square and 8 triangular sides are studded with LEDs that broadcast simple tones as pulse-width modulated (PWM) light; each face broadcasts a different frequency along a pentatonic scale with a Pythagorean temperament. Internally the tones are generated on two RP2040 microcontrollers using a mix of the internal PWM circuitry and the programmable input/output (PIO) hardware. At twenty-three cm in diameter the interface is designed to be held in to two hands. Initially all three objects broadcast the same frequencies without any additional modulation.

The square sides also have solar cells which that turn fluctuations of light level into electrical signals; all 18 of which are mixed equally to create a single channel audio signal that is then broadcast to a receiver using a 1/4" jack guitar radio link. An audio mixer combines the signals from all three interfaces into a balanced mono signal, before being played in the public space.

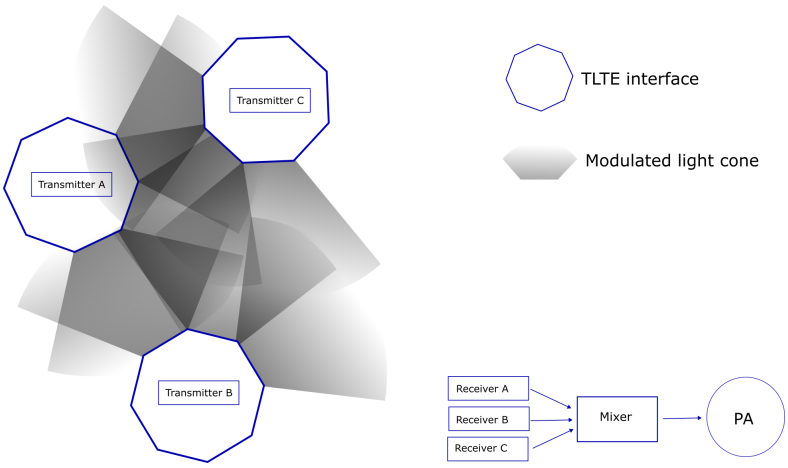

Fig. 2. The Light That Entangles system, showing overlapping of 4 from 26 light cones per interface.

The audio-encoded light from one TLTE interface is rendered audible when it shines into any receiver solar cell, whether by weaker reflection of its' own light or, directly shining onto another interface. Thus players are mutually dependant in sending and receiving audio-light. The illumination angle of the LEDS and the angles between adjacent sides of the object create areas where single or multiple sources of encoded-light can be received, depending on the players' relative movements and positioning. Ambient sunlight is not rendered audible as it has no modulation, some artificial lighting, however, can produce a background hum.

[1]Reading or pronouncing this as 'tilt' is helpful.
[2]Called a rhombicuboctahedron.

2.3 Exhibition history

Prototypes for The Light That Entangles have been shown as 'solo instrument moving to audience participation' performances at several events; notably during a residency where the initial prototypes were built at the Intelligent Instrument Lab (Reykjavik, Iceland, November 2024) and at regular improvisation evenings held by Emute Lab at the University of Sussex (Brighton, UK, 2025). The final three interfaces were exhibited at a three day open studio event (Bristol, UK, 2025) that was attended by several thousand members of the public from a wide demographic. TLTE has also been the focus of academic studies exploring player centring, shifting from individualised interface behaviour to a de-centred mode where the interfaces act uniformly.

2.4 Participant Experience

When an individual picks up, or is presented with, a TLTE interface during a study or demonstration, for example, they have often been seen to hold it in two hands then to rotate the object and move it around gesturally in relation to themselves. Experienced NIME practitioners have also been heard to start talking about wireless MIDI, accelerometers or related technologies; they might also start looking for a central laptop or synthesis system. However, experience of setting up a large number of playing entanglements has also shown that the majority of participants are readily able to explore the potential of *The Light That Entangles* as soon as they see and hear the effect of two interfaces being brought close together[3]. At which point their exploratory, physical, actions immediately become in reference to the other interfaces rather than to themselves. Once mutually entangled, players have been seen to generate audio through moving in relative positions and rotations to each other; joining and distancing themselves from the performative engagement, or simplifying and constraining the group agency by holding a specific position to gift a period of free play to their co-players.

The greatest obstacles to unsupervised participant uptake, therefore, are the initial discovery of necessary proximity, and of a disruptive handover [36] when departing players leave interface objects in an unhelpful configuration. Again, field experience has shown that a mixture of good promotional imagery showing three people playing together and a table or clear location to return the interfaces after use, alongside participants' natural curiosity and playful will to engage with each other, is enough to overcome most situations without invigilator intervention.

2.5 From Modulated Light As Multi-player Interface Surface to Mutual Entanglement

Several projects use mechanical or physical means to modulate a light source that is then sensed by a photo-receiver for use in audio synthesis; examples being the *Oramics Machine* [25], *Sound Modulated Light* [34] and *Shadow Puppet?* [11] . These principles have, in fact, been widely applied; for example to spinning disks [20], or to generate audio for and control analog synthesis [28], as well as in the 'cut paper and camera as sensor system' the *Pattern Organ* [8]. This final example can also be considered as an multi-person entanglement; here Jasmine Butt creates a shared workspace where participants place, move, cut new and re-cut existing cardboard shapes on a camera viewed tabletop. Software scans areas of the resulting image to extract data for synthesis control. Players create both cultural and knowledge based entanglements [24] whilst observing and learning; as well as performing agential cuts [4] [3] as they reform the interface for themselves and their co-players [7].

The multi-player system, *Orb3* [21], also includes light sensors within its exploration of socially mediated composition. Here the light sensors are intended for ambient environmental detection and were used to control specific synthesis parameters; however the researchers report that players "many participants could not resist the temptation to explore further" (p 66). It is such behaviour that highlights the alignment between a light source-receive pair and [1] who describes an embodied activity being an emergent, multi-modal, phenomena that is contextual and timely.

It is precisely this immediacy of control that makes modern bike lights an interesting performance tool. Rather than dimming a LED using a varying direct voltage, modern LED based bike lights use PWM to create different brightnesses in a way that maximises battery power. The light, literally, transmits a series of ON-OFF levels through physical space that can be turned into an audible tone when sensed and amplified. With different lights and brightnesses broadcasting different tones and pulse-widths, sometimes with the addition of a brightness envelope, a performer can easily combine two light-audio sources by pointing them at the same sensor, mixing the two sounds by angling or moving one further away from the sensor. Bike lights and flashing Christmas baubles or children's toys can all make a dramatic on-stage instrument [26].

Driving an LED directly from an audio source such as a mp3 player or laptop, requires amplifying electronics [9]. However this is not required if the audio is being generated in digital PWM form at source, from say a simple microcontroller. Typically such digital PWM audio signals are converted to analog using a low pass filter before amplification; however the

[3]The inverse is also true. A number of TLTE interfaces sitting on a table or the floor next to each other will generate audio. A new participant picking one up will notice the removal of that object from the mix.

microcontroller output is also suitable for directly driving a bright LED. The resulting output is often brighter than the analogue driven LED and so provides a greater transmission range.

Fig. 3. Logpile, areas of audio modulated light turned into audio using an iLog (courtesy of Owl Project)

The Owl Project *Logpile*[4] [27] inverts the moving bike-light and solar panel combination, to create a musical co-experience based around the concept of sitting around a camp fire. This instrument installation is comprised of a pile of logs (see figure 3) each studded with super bright white LED's, with an Arduino NANO based synthesiser embedded inside. Each log represents a different sound source that vary from filtered white noise to tones (different related pitches along a log) to slower beats. The physical construction of *Logpile* causes the LEDs to create overlapping areas of audio-modulated light which can be picked up, and rendered audible using a simple sensor. Players create a soundscape by moving the sensor log above the *Logpile*, creating their own mix and composition as they explore. The installation has 3 sensor units (termed *iLogs*) each of which is connected to a dedicated speaker, so individuals can easily perceive what heard sounds are their responsibility. They can explore the audio further (and individualise their own voice) using the sensor logs' inbuilt resonant filter using a large wooden knob on the interface. The atmosphere of sitting around a shared campfire is emphasised through the strategic placement of the sensing log cables and small stools to sit or rest the *iLog* on after use.

Logpile and *Orb3* use light in different ways to create a play space where players can be seen to add their own voice to an emerging soundscape with a view to opening musical dialogue. The individuality of the instrument interface is, necessarily, at the heart of this player centric process. The *Pattern Organ*, however, when used as a multi-person experience (as opposed to a solo performance) centres the cutting/re-cutting of the musical interface itself rather than individuals taking part; effectively creating an entanglement where participants inherit, influence and re-form their own and others' interface agency as they work. *Shadow Puppet?* also entangles the players involved by creating two specific roles (static broadcaster and mobile receiver) both of whom are mutually dependant within the instrument but with different modes of engagement. *The Light That Entangles* takes this a stage further by placing the de-centring process in the space where participants engage with each other directly, ensuring that players' are co-dependant for their own agency.

2.6 Affecting Player Experience Through Modulating Centring and Decentring

Some multi-player DMI systems focus on emphasising the interactive nature of the player engagement through re-enforcing direct inter-player connection [15] [2] [30]. Whilst other projects have focussed on a post-human design approach where a key approach is de-centring [23], which can equate to placing the participants within a resulting set of forces rather than focussing on individual desires and action whether multi-player or not. A feature of of de-centring instruments can been seen to lever notions of favouring influence over direct control [10]. Previous work in the field shows that de-centring can be achieved through several methods such as designing an instrument so large that multiple players are required [35], feedback [13] [22], ultrasonic distortion [29] or using machine learning to create systems of mutual control [31]. It should also be noted that under certain conditions very embodied player-centric systems can also effectively de-centre the individual through facilitating participatory sense-making [12] [32] and the emergence of shared autonomous behaviour that "constitutes an emergent autonomous organization" ([12], p493). It is this liminal space, where participants oscillate between self and group awareness, interacting and influencing, being centred and de-centred that *The Light that Entangles* is situated.

By deliberately avoiding sensing movement for subsequent mapping sound synthesis, TLTE creates a co-played musical instrument that can be used to explore the playing texture that emerges from balances of centring and de-centring without re-mapping an externalised synthesis system. As discussed earlier, each TLTE player engages through a handheld object

[4]View a short video clip here https://vimeo.com/1159299637

that constantly sends multiple sources of audio-encoded light where the frequency is controlled with a specific signal, whilst the same object also receives and decodes encoded light back into audio. This transceiving of light data creates a field of entanglement around the players as they mutually approach one another and, in doing so render the encoded light audible for others; whilst they themselves co-temporarily broadcast to and are decoded by co-players. Rotating or repositioning any individual interface object therefore re-configures the nature of the entanglement for all other immediately transceiving objects. It is through engaging with this field that players co-consitute the materiality of the shared audio and all the entangled players' agency.

Although the potential for posthuman entanglement and player de-centring is integral to the system's conceptualisation, we can also consider TLTE from a player-centred perspective. From such a viewpoint we could say that, the immediacy of the underlying functionality (as seen when considering pointing a bike light source at a solar cell) encourages individualised control based on tangible embodied interaction [1] [19]. Whilst the potential for the co-player to also move the receiving solar panel facilitates mutual engagement [6] based on instrument resistance [14].

The deliberate avoidance of clear interface orientation symbols and the creation of a central single channel of audio from equally mixed streams from each object (as opposed to each object having its own internal speaker), mean that the key reference points for an individual's agency are either their own interpretations or when one interface exhibits specific functionality that is different to the others. The latter is controlled by a looping score that triggers differing tonal shifts and the addition of pulsating rhythms to some of the LED faces that individualises interfaces. Noting that the ability to better identify ones' own voice centres the individual playing experience by highlighting awareness of their individual actions [33]; the texture of the playing agency that emerges from the interplay between a players' sense of, centred, control and of, de-centred, influence therefore depends on the nature of the entanglement that frames the experience; this in turn stems from the individuality of each interface. The TLTE looping score changes the behaviour of specific interfaces and so re-entangles individual and group agency[5]. At several points the individuality of the three interfaces becomes very hard to distinguish, and, at such times players are encouraged to immerse themselves in the group experience of being together rather than focussing on their own musical expression.

3 Technical Notes

The player experience typically lasts about 12 minutes. This installation version has a looped score of 3 minutes and 30 seconds, with a short silent period separating each cycle. Participants might stay for 2 or 3 cycles. The work requires 2m by 2m uncluttered area with ambient natural light or in semi-darkness. This is essential, there must be no dimmable or fluorescent lighting as this interferes with the system. The interfaces sit on a low table (e.g. 80cm x 60cm) in between use and this covers a WiFi router and a small mixer. The installation requires a set of speakers.

4 Media Links

Project Link: https://entangled-instruments.xyz/the-light-that-entangles
Direct video documentation: https://vimeo.com/1054465606

5 Acknowledgements

This project has been realised through the kind support of the Leverhulme Trust, though the be.AI (biomimetic embodied AI) Centre, Sussex AI, University of Sussex, UK. The author would also like to acknowledge and thank the on-going support of their supervisors Chris Kiefer, Alice Eldridge and Thor Magnusson. User study testing was conducted through the support of the Pervasive Media Studio, Bristol UK.

6 Ethical Standards

The authors do not believe there are any potential conflicts of interest, whether financial or non-financial. The research for this project was conducted following ethical review at the University of Sussex. The project does not collect any data. The pulsing of the LEDs is kept below the 4 Hz, UK statutory requirement for bike lights [18] [17], whilst the lowest frequency broadcast of 75 Hz is above the UK mains frequency.

References

[1] Newton Armstrong. 2006. An Enactive Approach to Digital Musical Instrument Design. (2006).
[2] Tauba Auerback. 2009. Tauba Auerbach - Auerglass Organ (Collaboration with Cameron Mesirow a.k.a Glasser).
[3] Karen Barad. 2003. Posthumanist Performativity: Toward an Understanding of How Matter Comes to Matter. (2003).

[5]At time of writing this score is a series of open sound control (OSC) commands sent over a local WiFi. A Raspberry Pi runs a Python script (OSCPlayer) that uses a CSV formatted file (editable in a spreadsheet application) to co-ordinate compatible multi-client multimedia devices. https://github.com/stevemuio/oscPlayer

[4] Karen Michelle Barad. 2007. *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning.* Duke University Press, Durham.

[5] N Bryan-Kinns, R Fencott, O Metatla, and S Nabavian. 2010. Interactional Sound and Music: Listening to CSCW, Sonification, and Sound Art. (2010), 4.

[6] Nick Bryan-Kinns, Patrick GT Healey, and Joe Leach. 2007. Exploring Mutual Engagement in Creative Collaborations. In *Proceedings of the 6th ACM SIGCHI Conference on Creativity & Cognition.* ACM, 223–232.

[7] Jasmine Butt, Benedict Gaster, Nathan Renney, and Maisie Palmer. 2025. Entangling with Light and Shadow: Layers of Interaction with the Pattern Organ. (2025).

[8] Jasmine Maria Butt. [n. d.]. Patterns in Space and Time - Optical Sound and Its Material Entanglements. ([n. d.]).

[9] Nicolas Collins and Simon Lonergan. 2020. *Handmade Electronic Music: The Art of Hardware Hacking* (third edition ed.). Routledge, Taylor & Francis Group, New York London.

[10] Alberto de Campo. 2014. Lose Control, Gain Influence - Concepts for Metacontrol. (2014).

[11] Mariska De Groot and Dieter Vandoren. 2013. SHADOW PUPPET?

[12] Hanne De Jaegher and Ezequiel Di Paolo. 2007. Participatory Sense-Making: An Enactive Approach to Social Cognition. *Phenomenology and the Cognitive Sciences* 6, 4 (Dec. 2007), 485–507. https://doi.org/10.1007/s11097-007-9076-9

[13] Alice Eldridge, Chris Kiefer, Dan Overholt, and Halldor Ulfarsson. 2021. Self-Resonating Vibrotactile Feedback Instruments ||: Making, Playing, Conceptualising :||. In *NIME 2021.* PubPub, Shanghai, China. https://doi.org/10.21428/92fbeb44.1f29a09e

[14] Aden Evens. 2005. *Sound Ideas: Music, Machines, and Experience.* University of Minnesota Press, Minneapolis.

[15] Sidney Fels, Linda Kaastra, Sachiyo Takahashi, and Graeme McCaig. 2004. Evolving Tooka: From Experiment to Instrument. (2004).

[16] Christopher Frauenberger. 2020. Entanglement HCI The Next Wave? *ACM Transactions on Computer-Human Interaction* 27, 1 (Feb. 2020), 1–27. https://doi.org/10.1145/3364998

[17] UK Government. 1989. The Road Vehicles Lighting Regulations 1989. https://www.legislation.gov.uk/uksi/1989/1796/contents.

[18] UK Government. 2005. Pedal Cycles - Lighting. https://www.gov.uk/government/publications/pedal-cycles-lighting/pedal-cycles-lighting.

[19] Simon Holland, Tom Mudd, Katie Wilkie-McKenna, Andrew McPherson, and Marcelo M. Wanderley (Eds.). 2019. *New Directions in Music and Human-Computer Interaction.* Springer International Publishing, Cham. https://doi.org/10.1007/978-3-319-92069-6

[20] Derek Holzer. 2007. Macumbista.Net » Tonewheels Live.

[21] Dan Livingstone and Eduardo Miranda. 2005. Orb3 – Adaptive Interface Design for Real Time Sound Synthesis & Diffusion within Socially Mediated Spaces. (2005).

[22] Tom Mudd. 2023. Playing with Feedback: Unpredictability, Immediacy, and Entangled Agency in the No-input Mixing Desk. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems (CHI '23).* Association for Computing Machinery, New York, NY, USA, 1–11. https://doi.org/10.1145/3544548.3580662

[23] Iohanna Nicenboim, Doenja Oogjes, Heidi Biggs, and Seowoo Nam. 2025. Decentering Through Design: Bridging Posthuman Theory with More-than-Human Design Practices. *Human–Computer Interaction* 40, 1-4 (July 2025), 195–220. https://doi.org/10.1080/07370024.2023.2283535

[24] Alva Noë. 2023. *The Entanglement: How Art and Philosophy Make Us What We Are.* Princeton University Press, Princeton Oxford. https://doi.org/10.1515/9780691239293

[25] Daphne Oram. 1962. The Oramics Machine.

[26] Owl Project. 2007. Musikprotokoll, Graz | Owlproject.Com.

[27] Owl Project. 2014. Log Pile | Owlproject.Com.

[28] Owl Project. 2014. Optikit | Owlproject.Com.

[29] Nicole Robson, Andrew McPherson, and Nick Bryan-Kinns. 2025. Negotiating Entanglements in the Composition and Curation of an Ultrasonic Art Installation. (2025).

[30] Steve Symons. 2023. The Stickatron and the Elastiphone: Two Entangled Musical Instruments.

[31] Steve Symons. 2024. The Perceptron: A Multi-player Entangled Instrument Based on Interpretive Mapping and Intra-action.. In *Audio Mostly 2024 - Explorations in Sonic Cultures.* ACM, Milan Italy, 385–391. https://doi.org/10.1145/3678299.3678338

[32] Koray Tahiroğlu. 2024. Musical Intra-Actions with Digital Musical Instruments. *Journal of New Music Research* 53, 1-2 (March 2024), 126–138. https://doi.org/10.1080/09298215.2024.2442350

[33] Atau Tanaka. 2006. Interaction, Experience and the Future of Music. In *Consuming Music Together*, Kenton O'Hara and Barry Brown (Eds.). Vol. 35. Springer-Verlag, Berlin/Heidelberg, 267–288. https://doi.org/10.1007/1-4020-4097-0_13

[34] Edwin van der Heide. [n. d.]. Edwin van Der Heide - Sound Modulated Light.

[35] Gil Weinberg. 2005. Interconnected Musical Networks: Toward a Theoretical Framework. *Computer Music Journal* 29, 2 (June 2005), 23–39. https://doi.org/10.1162/0148926054094350

[36] Anna Xambó, Eva Hornecker, Paul Marshall, Sergi Jordà, Chris Dobbyn, and Robin Laney. 2016. Exploring Social Interaction With a Tangible Music Interface. *Interacting with Computers* (June 2016), iwc;iww019v1. https://doi.org/10.1093/iwc/iww019