glowing strings and dancing puppets: designing multisensory nightclub experiences with the ventriloquism illusion

master's thesis by **sem allush**
faculty of industrial design engineering
delft university of technology
supervised by **dr. maarten wijntjes** and **prof. dr. sylvia pont**

0.1 abstract

This project explores the application of the ventriloquism effect in the context of the nightclub, to assess its potential for enhancing audience immersion. The ventriloquism effect is a cross-modal illusion in which a sound is perceived as originating from the location of a simultaneous visual stimulus rather than its actual source. This illusion was integrated into an audio-reactive electroluminescent wire installation that generates visual cues based on live audio produced by DJs during a nightclub event. The installation was evaluated through a controlled user test, supplemented by a questionnaire distributed among event attendees and interviews with user test participants. The user test revealed a statistically significant increase in self-reported immersion during audio-reactive light modes, compared to non-reactive light modes. Additionally, an increase in self-reported spatial specificity in the perceived localisation of auditory cues was observed during audio-reactive light modes, though this effect was not statistically significant. This increased spatial specificity would indicate ventriloquism, as the perceived location of auditory cues shifts to the spatially specific visual cues created by the installation. In addition to the user test, qualitative evaluation methods revealed that the light installation enhanced audience immersion. While statistical significance concerning the presence of ventriloquism was not achieved, findings indicate that cross-modal illusions hold potential for multisensory design in nightclubs, warranting further research.

0.2 glossary

Multisensory integration
The process by which the brain combines information from multiple sensory modalities to form a unified perception.

Cross-modal illusion
A perceptual phenomenon in which information from one sensory modality influences or distorts the perception of another.

Ventriloquism effect
A cross-modal illusion where a sound is perceived as originating from the location of a simultaneous visual stimulus rather than its actual source.

Immersion
A psychological state of deep engagement and absorption in an experience, often characterised by a sense of presence and diminished awareness of the external environment.

Electronic Dance Music
A broad genre of electronic music produced primarily for nightclubs, festivals, and dance events.

Research through Design
A practice-based research approach in which design processes and artefacts are used as a means to generate new knowledge.

0.3 foreword

This project began as a result of my ongoing ambition to involve my particular interest in the nightclub environment in my design studies. Though prior attempts were less successful, the freedom afforded by this graduation project finally allowed me to bridge these two worlds. Initial conversations with my supervisors directed me towards investigating cross-modal illusions, which I aimed to somehow apply within this context. However, at the start of the project, there was no clear design case, and the beginning of the project primarily focused on finding one. While this was challenging, it provided me with the unique opportunity to familiarise myself with the breadth of fascinating literature on both cross-modal perception and the nightclub experience. Additional research methods enabled me to learn from audiovisual experts and nightclub attendees, and I even got the chance to experimentally reproduce the ventriloquism effect in a lab setting. Ultimately, the challenge of having no clear design problem definitely proved beneficial, as it forced me to acquire a lot of valuable knowledge and experience in a short amount of time. Luckily, this exploratory research led to a promising case, which was developed into a functioning audio-reactive light installation.

At the beginning of this project, my understanding of the functioning of multisensory integration, cross-modal illusions and the ventriloquism effect was limited. However, over the past six months, through complete immersion in the subject matter, I have gained some insights about these topics and how they relate to the nightclub. These insights will be shared with you in the following pages. I hope you find it as fascinating as I have.

0.4 acknowledgements

Before discussing the project in detail, I would like to express my gratitude towards those who supported me along the way. First, I would like to thank the organisations of Los Angles and Garage Noord for being open to this strange, experimental project and providing me with the opportunity to evaluate it in context. Next, I would like to thank the organisation of .WEST, for helping with the production and installation of the design. I also want to express thanks to both of my supervisors, Maarten Wijntjes and Sylvia Pont, for being critical when it was necessary, and supportive when I was unsure of what I was doing. Lastly, I would like to thank my friends and family for their immense support and for putting up with me constantly talking about cross-modal illusions.

0.5 table of contents

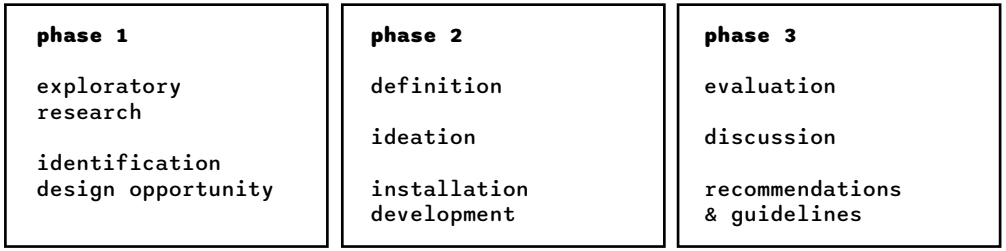
0.6 introduction

The world is a complex, dynamic, and ambiguous place. Our senses are continuously exposed to vast amounts of information, yet we are remarkably adept at making sense of it. Gestalt psychology provides a possible framework for understanding how this complexity is navigated through pattern recognition. It suggests that we do not perceive isolated sensory stimuli that are later assembled into meaningful objects. Instead, we perceive information structured into wholes according to principles such as proximity, similarity, and figure-ground organisation. While Gestalt theory is most famously used in visual perception, the notion of gestalts can be applied to cross-modal perception as well (Trujillo & Holler, 2023). In most real-world scenarios, information is integrated across multiple senses to form a holistic representation of our environment. For instance, when a ball is dropped onto the floor, we do not experience the visual input of seeing the ball land separately from the auditory input of hearing the impact. Rather, we experience both stimuli as a singular perceptual event. This process, by which information from different sensory modalities is combined into a unitary percept, is known as multisensory integration.

Although multisensory integration is generally beneficial, it can sometimes lead to cross-modal illusions when conflicting sensory inputs are combined. One such illusion, the *ventriloquism effect*, occurs when an observer perceives a sound as originating from the location of a simultaneous visual stimulus, rather than its actual location. This project investigates whether the ventriloquism effect can be used in multisensory design. Specifically, it explores how the application of the ventriloquism effect in an audiovisual installation for the nightclub can lead to enhanced levels of audience immersion. The nightclub was chosen as a context due to its inherently multisensory nature. Music, lighting, and bodily movement create a rich perceptual landscape. Interestingly, little research has explored multisensory perception in nightclub environments. The research on potential real-life applications of cross-modal illusions has been similarly limited. Thus, this project contributes both to the understanding of cross-modal illusions and to research on perception in nightlife settings.

Phase 1 of this thesis centers on exploratory research aimed at understanding the two key domains: cross-modal illusions and the nightclub experience. This led to the identification of the ventriloquism effect as the most promising illusion for a design in the chosen context, as it may enhance audience immersion. Phase 2 focuses on the development of the installation, from the initial design definition, to the final exhibition of a working audiovisual installation in Garage Noord, a nightclub in Amsterdam. Phase 3 describes the evaluation of this installation in context and draws conclusions about the efficacy of the design, and the application of the ventriloquism illusion. The full report structure is depicted in Figure 1.

Figure 1
Report Structure



0.7 research through design

Conducting research as part of a design project is a common practice, as theoretical knowledge is often necessary to understand a given context and develop an informed design strategy. This approach is referred to as *research for design*, wherein abstract, general principles are applied within a specific design context (Stappers & Giaccardi, 2014). In this project, research for design played an important role, with the initial exploratory research (Phase 1) informing and shaping the design process. Various research activities led to the identification of relevant design opportunities, ultimately leading to the development of a design aimed at enhancing audience experiences in nightclubs using the ventriloquism illusion.

However, the intended aim of this project was not to develop a commercial product. Rather, the design process was used as a method for generating knowledge. This approach, in which design itself is employed as a method of inquiry, is commonly referred to as *research through design*. In this project, the creation and evaluation of an audio-reactive light installation aimed to contribute to a better understanding concerning the effects of the ventriloquism illusion in the nightclub. While traditional scientific research is concerned with abstracting empirical findings to come to general truths, research through design focuses on better understanding real, specific situations. As will become clear in Chapter 1.1, the body of research into the ventriloquism effect in lab settings in broad. What is absent, however, is research looking into if and how this illusion can be applied in real-life settings. This is where research through design can be of value. To that end, both the design struggles encountered during the development of the final installation and the experimental and qualitative research activities conducted during the evaluation phase contributed to expanding knowledge in the field of multisensory nightclub design.

phase 1: exploratory research

This phase consists of a literature review on cross-modal effects and the nightclub experience is reviewed, a questionnaire with clubbers, interviews with light artists and designers, and a ventriloquism effect experiment. The primary goal was to identify research gaps within these domains and identify the design opportunities emerging at their intersection. Results from this phase provided the foundation for the design phase that followed.

1.1 literature review

Since the approach of this project was quite exploratory, this initial literature review casts a wide net, covering both the research into the different cross-modal effects that exist, as well as the research into the context of the nightclub and electronic dance music performance. The following topics are addressed:

1. Existing research on the experience of electronic dance music and the nightclub.
2. Which cross-modal effects exist and how they function.
3. Potential applications of these cross-modal effects in the nightclub.

Finally, a concise argument is provided in favor of the ventriloquism effect as it showed the most promise for further development.

1.1.1 The Nightclub Experience

Rietveld (2022) defines the nightclub as an urban environment that offers its guests music and the ability to dance all night. A place centred around escapism, expression and experimentation of any kind. A cultural hub for creatives of all disciplines. Today, the music offered to guests is often electronic dance music (EDM), which is investigated in the following subsections.

Electronic Music and Electronic Dance Music

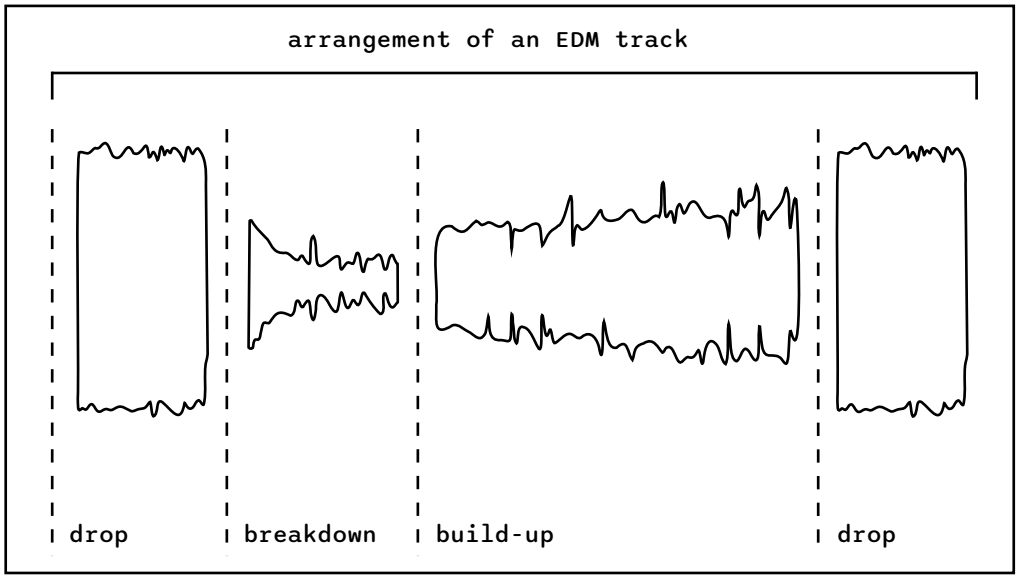
In 1956, during the early years of electronic music, Herbert Eimert described the genre as the "final chapter" of music (Eimert, 1956, p. 1). The introduction of electronic instruments revolutionised music-making, enabling the creation and amplification of audio signals through electrical components, resulting in entirely new sounds. At that time, the distinction between electronic and non-electronic music was clear, as it was defined by the process through which the music was created: acoustically or electronically. Nowadays, this definition has shifted, as most music we listen to is created through electronic means. Despite this, not all music is categorised as electronic music, raising the question: what defines electronic music today? While a clear, universally agreed upon definition might not exist, the term *electronic music* is used here to refer to music that is created primarily with the use of electronic or digital instruments and technologies (e.g., digital or analog synthesisers, software instruments and effects). Music that uses these tools, but still mainly relies on traditional electroacoustical instruments will not be considered electronic music (e.g., contemporary pop, rock). In addition to the term electronic music, the term *electronic dance music* (EDM) is often used to describe genres that are played in the club. However, confusingly, EDM also signifies a specific subgenre of commercial electronic music. To avoid confusion, in this project the term electronic dance music will be used to describe genres of electronic music that are commonly played in nightclubs. These genres include house, techno, trance, drum and bass, jungle, breakbeat, and dubstep, among others.

Experiencing Electronic Dance Music

EDM is often experienced in a nightclub, where audiences dance to music being played by a DJ for hours on end. Instead of watching a musician create music live, clubbers dance to pre-recorded music being played and mixed skillfully to facilitate an uninterrupted musical journey that lasts the whole night. The embodied element of the EDM experience seems to be quite crucial to the overall experience. While looking into the experience of EDM, Solberg and Jensenius (2016) found an association between the amount of movement participants produced through dancing, and the level of pleasure they experienced. They also found an association between the level of pleasure experienced and certain aspects of the arrangement of the music. Solberg and Jensenius describe the arrangement of EDM using three properties: the *breakdown*, the *build-up*, and the *drop*. The breakdown often consists of a

lower-intensity musical section. During the build-up tension and anticipation is raised through an increase in musical elements and effects. During the drop this tension is released and the climax is reached. One of the songs mentioned by Solberg and Jensenius containing these properties is "Ladykiller" by Vanilla Ace (2014).

Figure 2
Breakdown, Build-up and Drop



Note. This diagram depicts the waveform of an EDM track divided into three sections: breakdown, build-up and drop.

In their experimental study, Solberg and Jensenius found that pleasure is associated with the transition from one of these sections to another, especially from the build-up to the drop. While the concept of tension and release is present in most musical genres, in EDM this concept is taken to the extreme, using build-ups and drops to maximise pleasure. In a study by Solberg and Dibben (2019), participants listened to 4 electronic dance music tracks and were asked to rate them. They found that the keywords associated with these tracks tended to be embodied and spatial in nature (uplifting, light, driving, enthusiastic, flying, rising). This demonstrates that our perception of music is inherently cross-modal, where we often draw on analogies from other sensory modalities to describe how we experience the music.

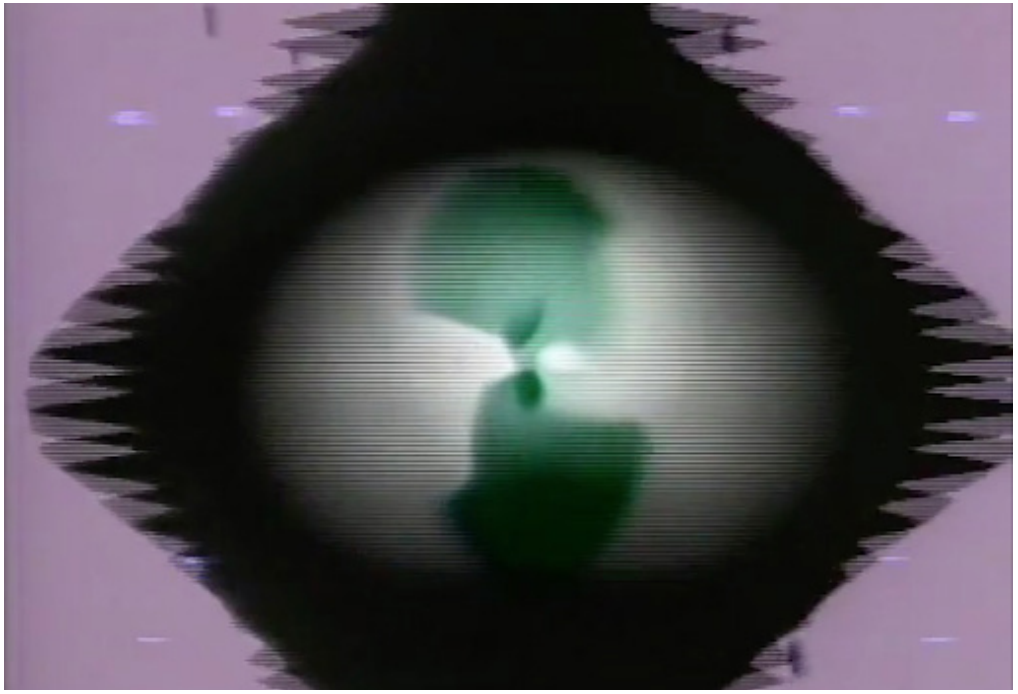
The claim that embodiment is essential to EDM is supported by an experimental study by Burger and Toiviainen (2020), who compared the movements of participants dancing to various genres. They found that the intensity of movements was higher in participants listening to EDM, and found similar differences in intensity between sections (breakdown, drop) to those that Solberg and Jensenius found. EDM's embodied nature is further explained in an essay by Garcia (2016), who argues that the sonic characteristics of the genre often have a tactile quality, where *feeling* and the senses take the foreground. In EDM, percussive elements usually play an important role. These elements often have the most impact, due to their transients and low frequency content. Since music is often played loudly in the club, these rhythmic elements are felt throughout the entire body. The importance of low frequency content (or bass) is substantiated by an experimental study by Lustig and Tan (2020), who subjected participants to music with certain frequency ranges missing. The results showed that music without low frequency content is liked less and considered less "groovy" than music with other frequency ranges missing. Apart from these experimental studies, several ethnographic studies describe how connectedness and embodiment is essential to the EDM experience (Olaveson, 2004; Malbon 2002). Olaveson mentions that one of the most important qualities of EDM experiences (specifically raves) is the fact that it is a non-rational affair. The appreciation of such events happens on a sensory level. This focus on embodiment and the senses can often lead to highly meaningful spiritual experiences, as reported in an ethnographic study by Takahashi and Olavason (2003).

Seeing Electronic Dance Music

In addition to embodiment, vision also plays an important role in the context of the nightclub, with music and visuals often being paired to create alluring audiovisual experiences. These visuals can be simple, using lights, stroboscopes

or lasers. However, they can also be far more complex, using projections or screens in combination with graphics software like TouchDesigner. The term *visuals* is used here to refer to any visual stimulus created to accompany or enhance the musical experience. The combination of music and visuals has a long history, but the connection to electronic music specifically, started in '60s and '70s, when availability of both audio and video synthesisers allowed for the creation of electronic audiovisual works (Novello, 2021). Ever since then, visuals have been an integral part of electronic music performance that enhance the overall experience. Despite their importance, little research has been done into how these visuals are perceived, and how they should be designed to enhance the experience of audiences.

Figure 3
Video synthesis



Note. Screenshot from Illuminated Music 2 & 3 (Beck, 1973).

What has been studied intensely, however, is the importance of visually observing musicians during a performance. In a meta-analysis across multiple genres, Platz and Kopiez (2012) found that seeing the musician perform while listening significantly enhanced the experience compared to listening alone. In EDM performance, it is often more difficult for the audience to understand what the performer is doing, which reduces the cross-modal effects typically present during other types of musical performances. When an audience member sees a guitarist perform a complicated solo, it is quite obvious to them what the guitarist is doing and how that action is producing the sound. This makes integration of what they are seeing and what they are hearing easier. In the case of electronic dance music, this relation is often less transparent. EDM musicians use DJ-equipment, laptops or synthesisers with many buttons and knobs and there often is not enough visual feedback for the audience to understand what the performer is doing. In order to find ways of improving audience understanding, Correira et al. (2017) conducted a study in which they compared different ways of using visuals to communicate what the performer is doing. They identify a couple of properties that are important for audience understanding: visibility of the interface, and legibility of performer's cursor. However, the main takeaway is that audience understanding is highest when the performer's actions are clearly visible and understandable. The authors conclude by noting the necessity for more research in this domain to better understand the relation between live visuals and EDM.

Apart from this research focussing on the performer, little research has been done examining the interplay between EDM and visuals in the nightclub. However, there are a few studies that look into the perception of music and visuals in other contexts. One of those studies was conducted by Boltz et al. (2009) and entailed having participants listen to music while showing them video content at the same time. The results showed that the visuals impacted melody perception in a mood congruent manner. Hammerschmidt and Wöllner (2017) reached the same conclusion when studying the audiovisual qualities of music videos: visuals influence the perception of music. One of the few sources that might actually provide an insight into how visuals are perceived in the

context of a nightclub, is an article written by Annet Dekker (2005) in which she interviews several VJs. In this article, the VJs report how they can influence the mood of the audience by presenting different visual content. An example was given of how somber imagery and slow movements had noticeable effects on the audience. They also note how important it is to surprise them. This may give us an idea of the power of visuals in the nightclub, but is far from robust scientific evidence explaining how these visuals are perceived.

Research Gap

As we have seen, some research has explored cross-modal interactions within the context of EDM and nightclub environments. First, the embodied aspects of EDM are well-established. Second, a substantial body of research examines the effect of seeing music performances, with some focusing on visualising EDM performances. However, none of this research addresses the specific visuals common in nightclubs that accompany the music and contribute to the unique multisensory experience. This provides us with a strong reason to investigate nightclub visuals and the cross-modal effects they create.

1.1.2 Cross-Modal Effects

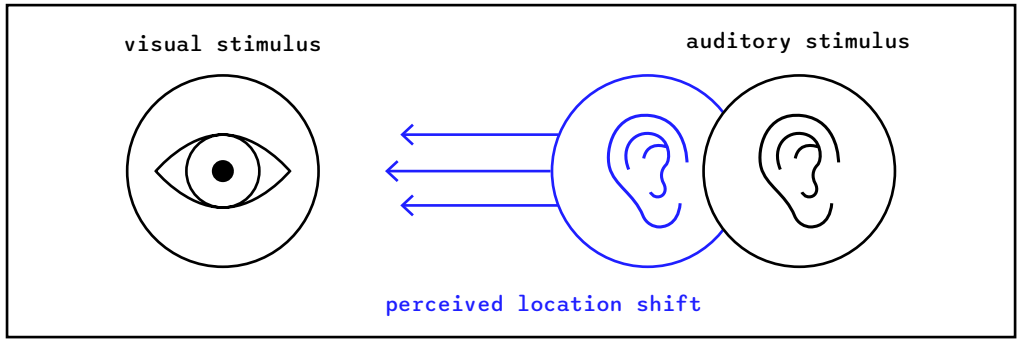
Having established the limited research on cross-modal interactions between visuals and music in the nightclub setting, we are now in a position to examine cross-modal effects explored in more controlled settings to assess their potential application in the nightclub. While the term *multisensory integration* refers more generally to the process in which the brain combines sense data from different modalities to form our perception, the term *cross-modal effect* or *cross-modal illusion* is used here to refer to perceptual phenomena where one sensory modality influences the perception in the other. While cross-modal effects will be discussed separately in the following subsections, it is important to note that most of them are governed by the same mechanisms. During perception, when the brain receives correlating signals from multiple modalities, it attempts to combine them into a singular percept. Sense data are generally incomplete and often contain noise. When sense data from different modalities are combined, the signal that is least noisy is generally dominant, and will play a larger role in determining what is perceived (Ernst & Banks, 2002). As a result, the non-dominant modality will align with the dominant modality to form a unitary percept, even when this alignment does not accurately reflect reality. Thus, the dominant modality influences the perception in the non-dominant modality. This is the primary principle causing most of the discussed cross-modal effects. These effects differ mainly in the type of correlation between modalities that leads to integration.

Ventriloquism Effect

Perhaps the oldest known cross-modal effect is the ventriloquism effect (VE), also called spatial ventriloquism. The effect derives its name from the ventriloquist's performance, where sound is perceived as emanating from the puppet's mouth rather than the puppeteer. More specifically, the visual stimulus (the puppet's mouth movement) attracts the auditory stimulus, shifting the perceived location of the sound. This occurs because the simultaneous occurrence of the auditory and visual cue creates a correlation between the two signals. The location of the visual cue is less noisy, causing vision to be the dominant modality here. Thus, the auditory cue is integrated with the visual cue and its perceived position shifts towards the visual cue. Over the last century, this illusion has been taken from the puppeteer's stage to the psychologist lab, where it has been frequently replicated in experimental studies. In these experiments, the effect is often recreated with much simpler stimuli. In a study by Bertelson and Radeau (1981), for example, loudspeakers playing 300 Hz beeps and simple flashing LED lamps were used to recreate the effect successfully. Several other studies employed similar methods (Alais & Burr, 2004; Vroomen et. al., 2001), but Jack and Thurlow (1973) took a different approach: they secured undergraduate students in dental chairs, had them watch a video of a puppet, and played the corresponding audio from various hidden locations. From this diversity in experiment design, it can be concluded that this illusion can be recreated with many different kinds of stimuli. Chen and Vroomen (2013) provide an extensive overview of representative experimental studies looking into the VE and summarise the conclusions they have reached. They note that the VE is relatively strong, but that it is important to remember that the visual stimulus attracts the auditory stimulus, and does not capture it wholly. This means that the perceived location of the sound moves toward the position of the visual stimulus, but is not identical to it. Predictably, the effect is stronger when the auditory stimulus is difficult to localise, as increased uncertainty in the auditory signal makes the visual modality more dominant (Ernst & Banks, 2002). Additionally, they discuss the range of temporal congruence required for

optimal results, noting that the auditory cue can occur anywhere from 100 ms before the visual cue to 300 ms after it. They also note that the visual stimulus should occur within a spatial window of approximately 15°, based on a study by Slutsky and Recanzone (2001). However, other studies have reported using larger spatial windows (Jack & Thurlow, 1973), indicating that this result might be influenced by the specific methodology of the study. While the effect may diminish as the spatial separation between auditory and visual cues increases, Godfroy et al. (2003) demonstrated that fusion between the two stimuli was preserved over longer distances vertically rather than horizontally.

Figure 4
Ventriloquism Effect



Ventriloquism Aftereffect and Temporal Ventriloquism

Another phenomenon that is related to the spatial VE is the spatial ventriloquism *aftereffect*. It occurs after a person has been exposed to the ventriloquism illusion for a prolonged period of time and the brain adapts to the perceived location of the sound source. After the illusion has passed, a person may still experience a shift towards a prior visual cue when an auditory cue occurs (Recanzone, 1998). Again, several representative studies have been compared and summarised by Chen and Vroomen (2013). One of the main conclusions is that the strength of the aftereffect is dependent on the length of the exposure to the VE. Whether or not the aftereffect is dependent on the consistency of the pitch of the auditory stimulus during and after exposure to the illusion is unclear, with some studies reporting that frequency changes negatively impact the aftereffect (Recanzone, 1998; Lewald, 2002), while others report the opposite (Frissen et al., 2003).

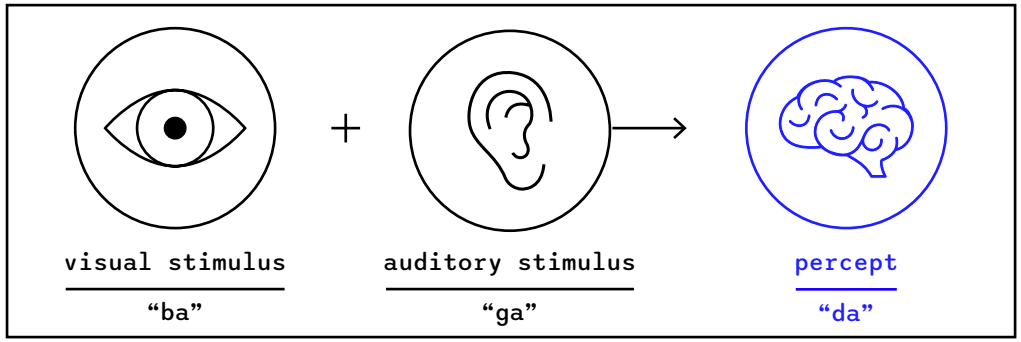
Finally, there are two interesting temporal phenomena related to ventriloquism: the *temporal ventriloquism effect* and *temporal ventriloquism aftereffect*. Much like the spatial VE, an illusion is created where a stimulus in one modality is shifted towards a stimulus in another modality. In the case of the temporal VE, this shift occurs in time rather than space (Chen & Vroomen, 2013). Additionally, in the temporal VE, the auditory stimulus is dominant, attracting the perceived timing of the visual stimulus toward it. The temporal ventriloquism aftereffect (or lag adaptation) is similar to the spatial ventriloquism aftereffect in that it involves an adaptation process, leading to a shift in temporal perception that persists even after exposure to the temporal ventriloquism illusion has ended. Specifically, after being exposed to a series of auditory and visual stimuli with a consistent lag, individuals will judge simultaneous audiovisual events differently. This difference is rather small, however, with a resulting shift of -32 ms and +27 ms for an initial “training” lag of -235 ms and +235 ms (Fujisaki et al., 2004).

McGurk Effect

First described by McGurk and MacDonald (1976), the *McGurk effect* challenges the notion that speech perception is a solely auditory affair. In their experiment, McGurk and MacDonald showed that when participants were presented with a video of a woman’s lips uttering the syllable “ba”, while at the same time listening to an audio recording of a woman saying the syllable “ga”, many of them perceived the syllable “da”. Similar to the ventriloquism effect, the McGurk effect demonstrates visual dominance. However, they differ in that the ventriloquism effect alters the perceived location of the auditory stimulus, while the McGurk effect influences the perceived meaning of the auditory stimulus. Over forty years after the initial experiment, Alsius et al. (2017) discussed the state of the research on this effect and identified a number of problems. They attempted to do a meta-analysis of McGurk literature in order to determine the strength and variability of the effect, but were not able to do so because only 2 experimental studies out of 4901 citations provided tables with the necessary data. Later they note that there is quite some variance in experiment design and methodology, making it more difficult

to draw general conclusions. Despite this difficulty, they go on to describe a number of interesting findings. One of these findings is the difference in effect strength depending on the type of vowel used in the uttered phrase (Green et al., 1988). Another interesting finding is the high variability in effect strength between subjects. While in the original study by McGurk and Macdonald, most participants perceived the effect, in a study by Gentilluci and Cattaneo (2005), for example, 67.7% did not perceive the McGurk effect. This raises questions about the conditions required to create this effect, and what specifically causes this variance in perception. Alsius et al. continue to hypothesise about what might cause this, and emphasise the need for further investigation.

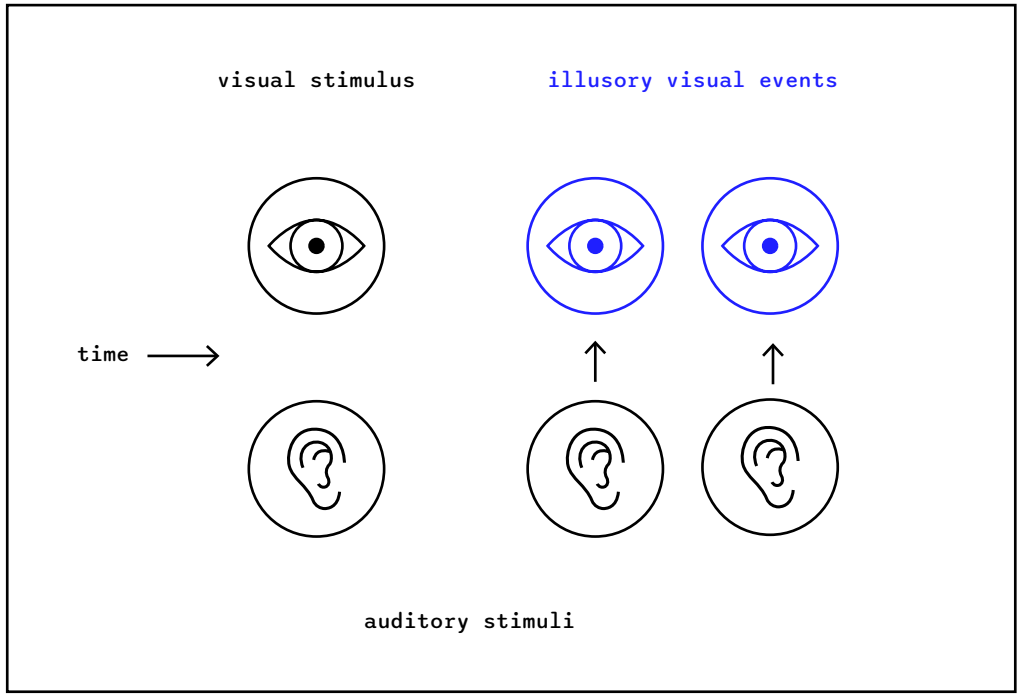
Figure 5
McGurk Effect



Sound Induced Flash Illusion

The next effect involves the potential for auditory stimuli to influence the number of visual events perceived. The *sound-induced flash illusion* (SIFI), first described by Shams et al. (2000), is typically induced by the simultaneous presentation of a single flash and a rapid sequence of beeps. In this illusion, the auditory modality dominates, leading the observer to perceive the number of flashes as matching the number of beeps. In a sense, this effect is the inverse of the McGurk effect, with sound influencing the meaning of visual events rather than the visual stimulus altering the perception of sound. One of the most important conclusions drawn from the existence of this illusion is the fact that vision is not always dominant. We saw earlier that audition can be dominant in temporal cross-modal events, but the SIFI proves that auditory stimuli can also affect the perceived quantity of events. According to Shams et al. (2002), variation in the shape, duration and source of the auditory stimulus do not change the strength of the effect. The most important known parameter that can negatively impact the strength of the effect is the stimulus-onset asynchrony: the time between the first beep and flash pair and the second beep. According to Hirst et al. (2020), who conducted a review of over 100 studies on the SIFI, the effect starts to diminish at a stimulus-onset asynchrony of over 70 ms and is non-existent at 200 ms. Apart from this parameter, the effect is rather robust and has been used effectively in multisensory processing research.

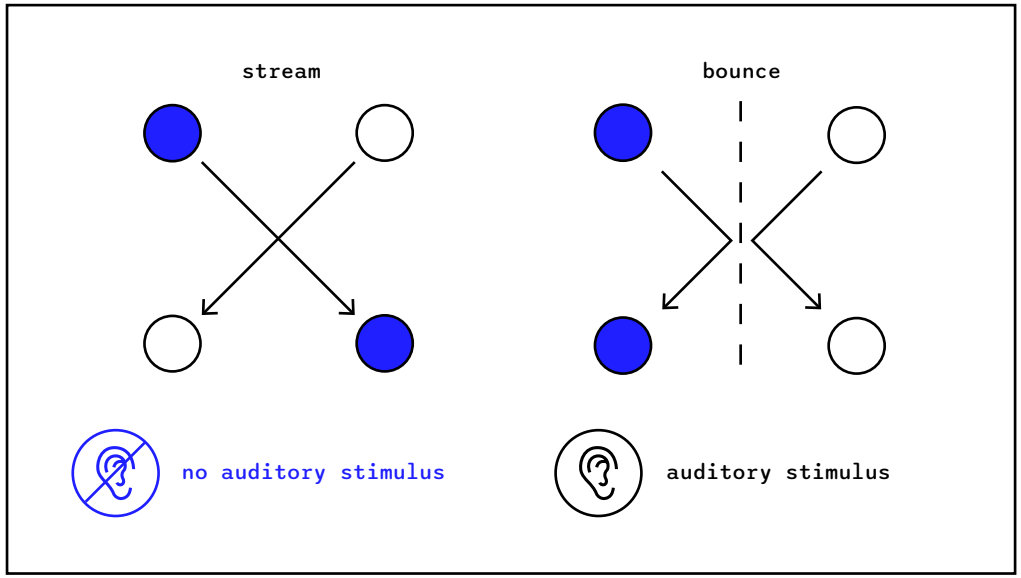
Figure 6
Sound Induced Flash Illusion



Stream-Bounce Illusion

Another effect in which the auditory modality seems to be dominant is the *stream-bounce illusion*. When an observer is presented with a visual stimulus consisting of two linearly moving discs that cross along their trajectory, an auditory stimulus can cause it to appear as though they are in fact bouncing off each other (Sekuler et al., 1997). Again, this effect shows that the meaning of a visual event can be influenced by an auditory cue. Importantly, the auditory cue needs to occur within a temporal window of -100 ms to 100 ms relative to the collision of the two discs (Remijn et al., 2004).

Figure 7
Stream-Bounce Illusion



Colavita Effect

The *Colavita effect* occurs when a visual and auditory event happen simultaneously, and the observer responds only to the visual effect, indicating visual dominance. The first experimental studies were done by Colavita (1974) fifty years ago, and involved, yet again, a series of beeps and flashes. The original study consisted of 4 experiments, the first of which involved participants being presented with a simultaneous auditory and visual stimulus and having to choose by pressing a key, whether they heard a tone or saw a light. A significant majority of these trials ended with the participant favouring the visual stimulus, indicating a strong visual dominance. The second and third experiment in this study served to eliminate the possibility of other variables causing this apparent visual dominance (ambient light level, tone volume). During the fourth experiment the participants were explicitly instructed to press the tone key whenever they were presented with a "conflict trial" (a tone and light occurring simultaneously), and still they pressed the light key more than half of the trials. These experiments strongly suggest that in the case of a simultaneous audiovisual event, the visual sensory modality is dominant. In a meta-analysis of 14 studies, Hirst et al. (2018) provide some caveats to this conclusion. For example, the type of instructions given to participants seems to influence the strength of the effect. Another finding was that in experiments with children (under the age of 9) there was no Colavita effect found. This seems to indicate that visual dominance develops over the years and is not present from birth. The Colavita effect contrasts with the other effects discussed, as it does not involve multisensory integration. Instead, one sensory modality (audition) is effectively ignored, with only the other (vision) being perceived. A potential contributing factor to this phenomenon is endogenous attention (Wang et al., 2021). This suggests that when designing for multisensory experiences, the visual component should not dominate attention entirely, as it may diminish the perception of other sensory modalities.

Figure 8
Colavita Effect

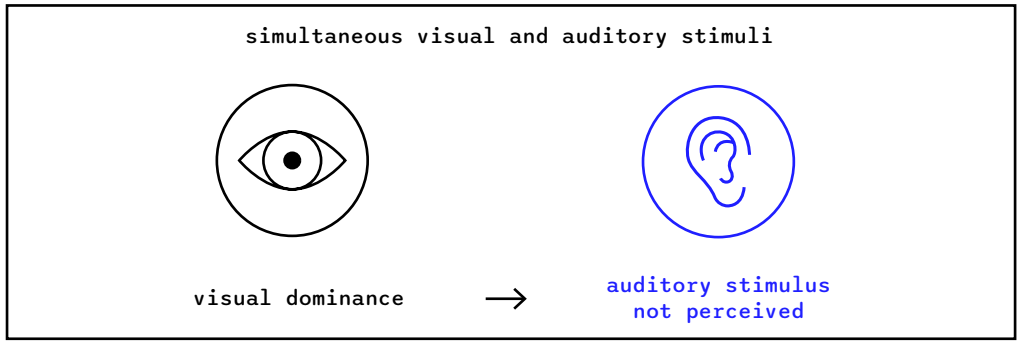
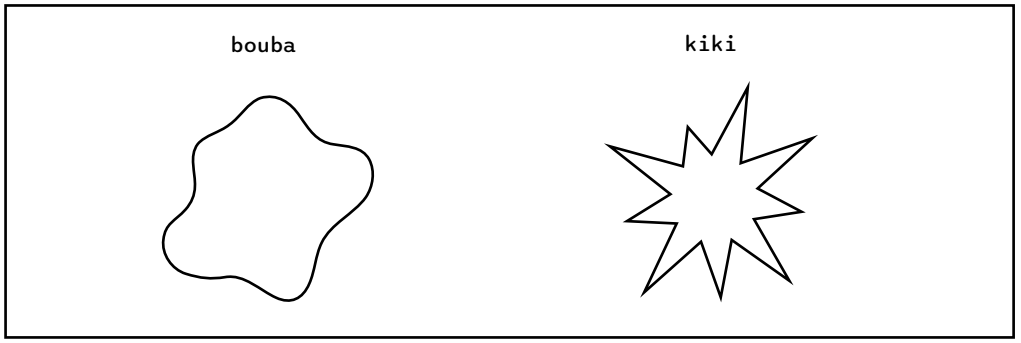


Figure 9
Bouba and Kiki



Cross-Modal Correspondences

While perhaps not being an exhaustive review of all literature on cross-modal effects, most well-established effects and illusions have been discussed above. A comprehensive overview of all effects discussed can be found in Table 1. In addition to these cross-modal effects, several cross-modal correspondences are worth addressing. A classic example of such a correspondence is the *Bouba-Kiki effect*, where the word "bouba" is associated with a round shape and the word "kiki" is associated with an angular shape (see Figure 9). This association seems to be true across different cultures (Ćwiek et al., 2022). There are correspondences within the domain of music as well. For example, a study by Adeli et al. (2014) found associations between soft timbres and round shapes, and hard timbres and angular shapes, as well as some colour related associations. Additionally, there are well-established correspondences between loudness and brightness, pitch and brightness, pitch and size and pitch and height (Zeljko et al., 2019). These cross-modal correspondences could be included in the design process in combination with one of the cross-modal illusions to increase audiovisual binding, as there is evidence that these correspondences affect integration (Spence, 2011).

Table 1
Cross-Modal Effects

name	effect	dominance	perceptual domain
ventriloquism effect	visual cue attracts spatial perception of auditory cue	visual	spatial
ventriloquism aftereffect	auditory cue shifts towards prior visual cue after adaptation	visual	spatial
temporal ventriloquism effect	auditory cue attracts temporal perception of visual cue	auditory	temporal
temporal ventriloquism aftereffect	audiovisual events are perceived differently after adaptation to asynchronous audiovisual events	auditory	temporal
McGurk effect	speech perception is altered by modulating visual cue.	visual	semantic
sound induced flash illusion	auditory cues affect the quantity of perceived visual cues.	auditory	semantic
stream-bounce illusion	auditory cue affects the perceived motion of visual events	auditory	motion
Colavita effect	during simultaneous visual and auditory events, visual events are dominant	visual	semantic

1.1.3 An Argument for Ventriloquism

Out of all the effects discussed, the ventriloquism effect and the ventriloquism aftereffect yield the most interesting and exciting potential applications within the context of the nightclub and electronic dance music. At the same time, other effects still provide important lessons to take into account when designing audiovisual experiences. The argument for the ventriloquism effect and aftereffect will be made by first eliminating the other effects before highlighting the qualities of the selected illusions.

Let us start with the temporal ventriloquism effect and temporal ventriloquism aftereffect, where the perceived timing of visual events shifts toward asynchronous auditory stimuli. This phenomenon could help align slightly mismatched visuals and music, making them appear synchronized. While the existence of this effect could be useful in those situations where technical difficulties occur and there is a slight delay between visuals and music, in most cases modern technology renders this effect useless. The stream-bounce illusion changes the meaning of the movement in a visual event by using specific auditory stimuli. Since the music is the main event in the nightclub, it is unlikely that it would sacrifice its quality by playing specific auditory cues that facilitate this illusion. Perhaps visuals could be created in such a way that the illusion could still occur without changing the music, by synchronising it with existing percussive elements. However, it remains unclear how the introduction of this illusion could enhance audience experiences. A similar argument can be used against the sound induced flash illusion. While it is possible that a rapid sequence of auditory events would occur naturally in music (during a build-up, for example), and it is also true that those auditory events might influence

the perceived quantity of simultaneous visual events, there is no immediate reason to believe that this illusion would improve audience experiences. The McGurk effect could be applied in very specific situations where the meaning of the lyrics of a song could be influenced through visuals. This might result in an interesting effect if both variations of the lyrics are meaningful in some way. However, implementing this illusion seems inefficient compared to directly recording alternate lyrics. Furthermore, as nightclub music is often instrumental (or contains minor vocal elements that are functionally instrumental), the practical application of the McGurk effect is minimal. While it may be possible to create a compelling audiovisual experience using this effect, achieving high congruence between music and visuals would be essential. Given that DJs decide on the music they play (often on the spot), this congruence is challenging to achieve. Lastly, we have the Colavita effect. This effect should not be discounted entirely, as it will play a role in any situation where audio and visuals occur simultaneously, including the nightclub. However, while visual dominance might have been established in controlled lab settings with short discrete stimuli, it might be less prevalent in the context of a nightclub, where attention is directed primarily to the music.

The reason why the spatial ventriloquism effect (and aftereffect) may yield interesting design opportunities is because it may allow existing music to be experienced in a more immersive and spatial way by introducing visual events to alter the perceived sound source of musical elements. A study by Hirway et al. (2024) found that spatial audio resulted in better self-reported experiences and heightened attention. Similarly, an experimental study by Hyodo et al. (2021) found that spatial audio enhances the emotional experience when compared to stereo audio. By binding the perceived source of auditory stimuli to locations around the listener using visual cues, the ventriloquism effect could be leveraged to create an illusory spatial audio experience. Being enveloped in the music may increase the sense of immersion the audience will experience.

Immersion is a rather nebulous term, with different definitions depending on the context in which it is used. For the purposes of this project, the following definition is used:

> Immersion is a phenomenon experienced by an individual when they are in a state of deep mental involvement in which their cognitive processes (with or without sensory stimulation) cause a shift in their attentional state such that one may experience disassociation from the awareness of the physical world. (Agrawal et al., 2019, p. 407).

This definition is chosen because it maps closely to the nightclub experience and the desires of clubbers. As described by Malbon (2002), one of the main allures of clubbing is the sense of escape, both from daily life and from the self. Creating an enveloping audiovisual experience might facilitate this sense of escape and thereby enhance overall audience experiences. In addition to possibly improving the nightclub experience by increasing immersion, another reason for focusing on the ventriloquism effect in this project, is the lack of research studying this effect in real-life scenarios. This absence was specifically mentioned by Chen and Vroomen (2013) in the concluding remarks of their literature review.

1.1.4 Discussion

In this literature review, both the literature on electronic dance music experience and perception as well as the research on cross-modal illusions were investigated in order to find opportunities to connect these domains. While being extensively studied in controlled settings, little research has looked into possible design opportunities provided by cross-modal illusions, which provides justification for this project. The context of the nightclub was chosen because it already is a cross-modal playground. There already is a rich tradition of combining audio with visuals, but little scientific research has been done investigating how these audiovisual experiences are perceived. Thus, this project addresses knowledge gaps in both cross-modal illusions in realistic scenarios and the perception of audiovisual nightclub experiences.

In order to complete this project, a specific cross-modal illusion needed to be chosen to guide the design process. The ventriloquism effect appeared to be the most suitable for this task. It does not require any changes to the music performance, which is important, since that is an established practice that is not likely to change. Additionally it shows potential to add to the experience by

Chapter Summary
This chapter investigated the literature on the nightclub experience and cross-modal effects. The ventriloquism effect and ventriloquism aftereffect were deemed as the most promising for use in this project, since they can potentially enhance audience immersion in nightclubs.

1.2 clubber questionnaire

To gain a better understanding of the current nightclub experience, and complement the ethnographic findings discussed earlier, a questionnaire was distributed to frequent clubbers. The objective of this survey was to identify what aspects of the nightclub experience clubbers enjoy or dislike, with a particular focus on the audiovisual elements. The data were collected to uncover user preferences, which helped inform the design process. A total of 21 people responded to the survey, and the complete set of questions and results can be found in Appendix A.

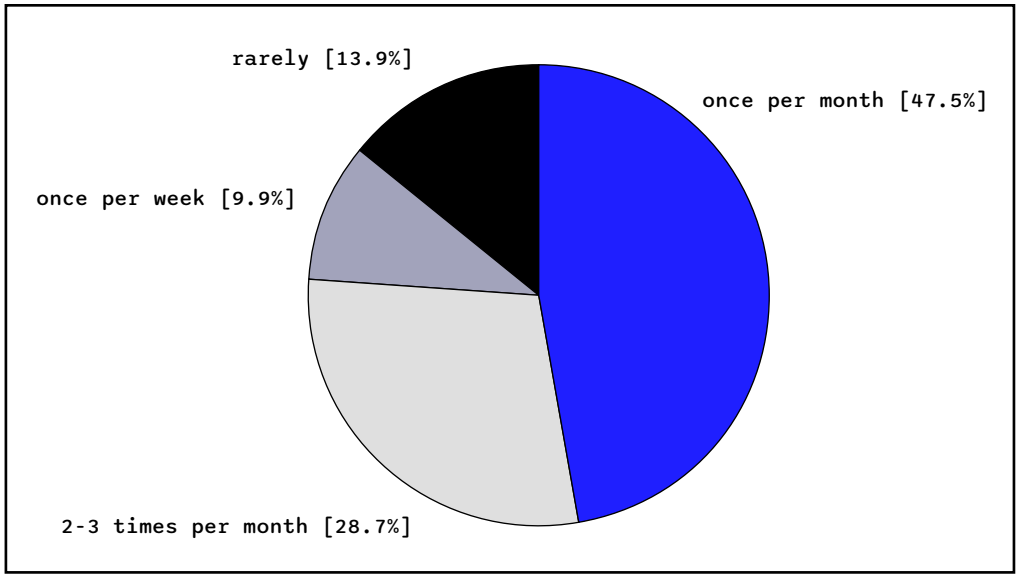
1.2.1 Results

In the following sections the relevant results are summarised and analysed. Quantitative results are given where possible, and qualitative data that is analysed by identifying the common themes found in the answers.

Demographic

Out of all respondents, 71% identified as a man and 29% identified as a woman. The age range was 18 to 31 with a mean age of 26. Club attendance was quite high, and is visualised in Figure 10.

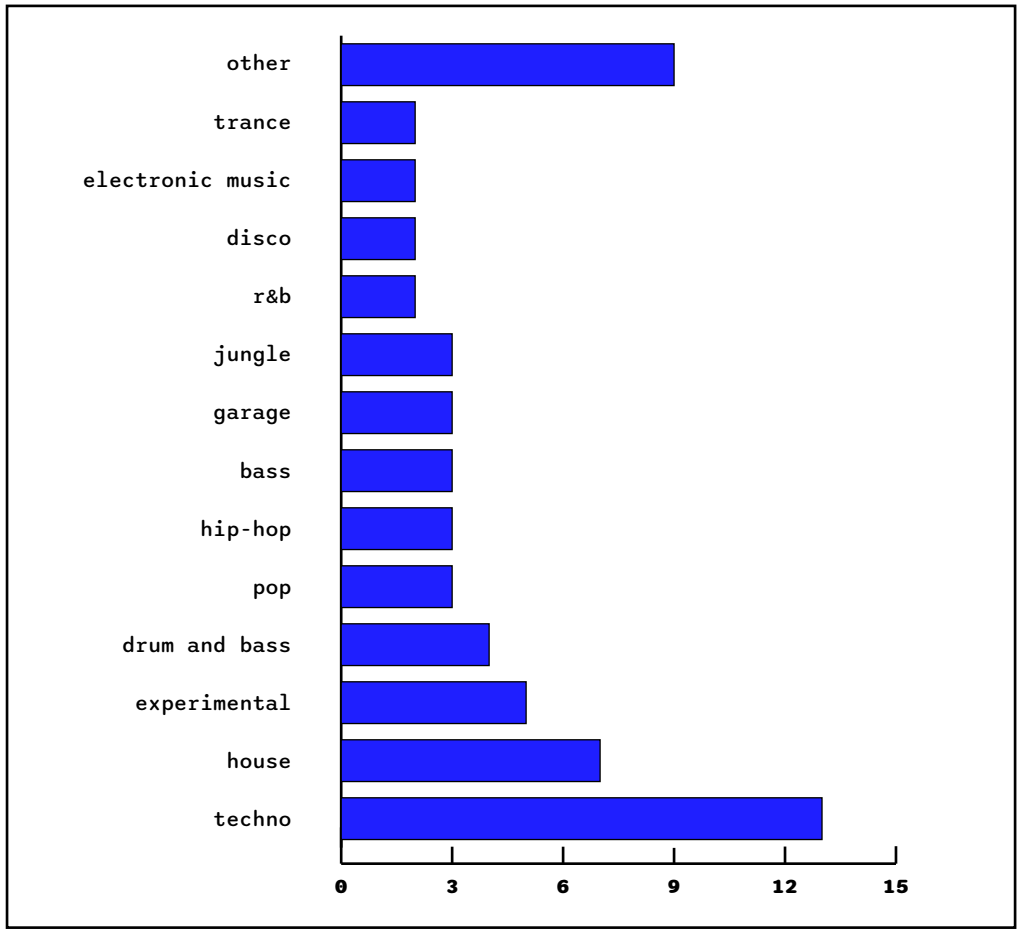
Figure 10
Club Attendance



General Questions

When asked which clubs were preferred, a wide range of answers was given, but there was a strong preference for Dutch clubs, specifically clubs in Amsterdam. This is likely due to the fact that respondents were selected through local channels. The most frequently mentioned club was “Garage Noord” in Amsterdam. When asked why respondents preferred the clubs they mentioned, most respondents said it had to do with the music curation and the atmosphere of the club. Some of them also mentioned the presence of good visuals and lighting. The respondents’ preferred genres are depicted in Figure 11.

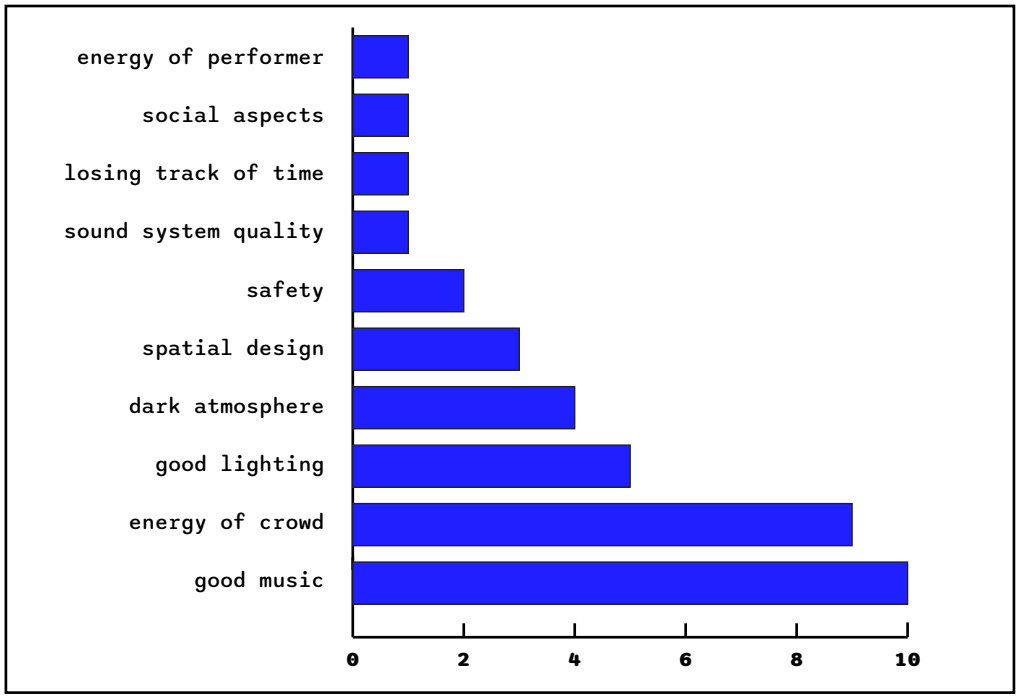
Figure 11
Popular Genres



The Nightclub Experience

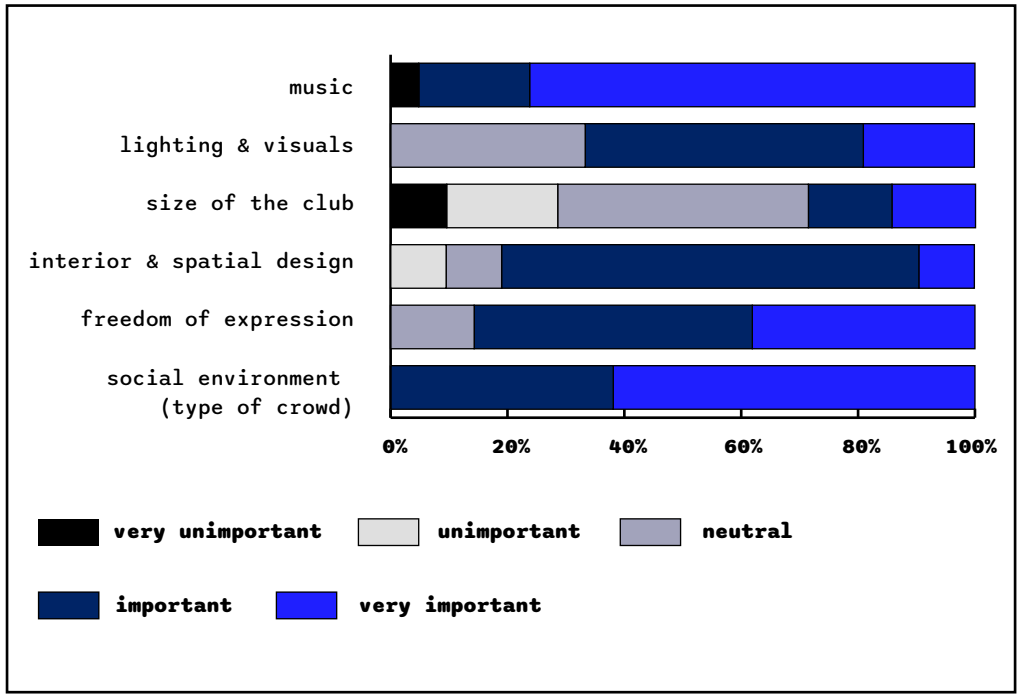
Respondents were asked to describe their best nightclub experiences. Ten themes were identified in the answers and quantified. These themes are visualised in Figure 12. The importance of good music was mentioned most, with 10 respondents emphasising its importance in their answer. Following this, the energy of the crowd, and the quality of the lighting were mentioned most often.

Figure 12
Properties Deemed Important for a Good Nightclub Experience



Following this question, 6 elements of the nightclub experience were rated using a Likert scale from very unimportant to very important. The elements were: music, lighting and visuals, the size of the club, the spatial design, the freedom of expression and the social environment. The size of the club was the most controversial element with some rating it very unimportant and some rating it very important. Additional results can be seen in Figure 13.

Figure 13
Likert Scale Rating of Six Nightclub Experience Elements

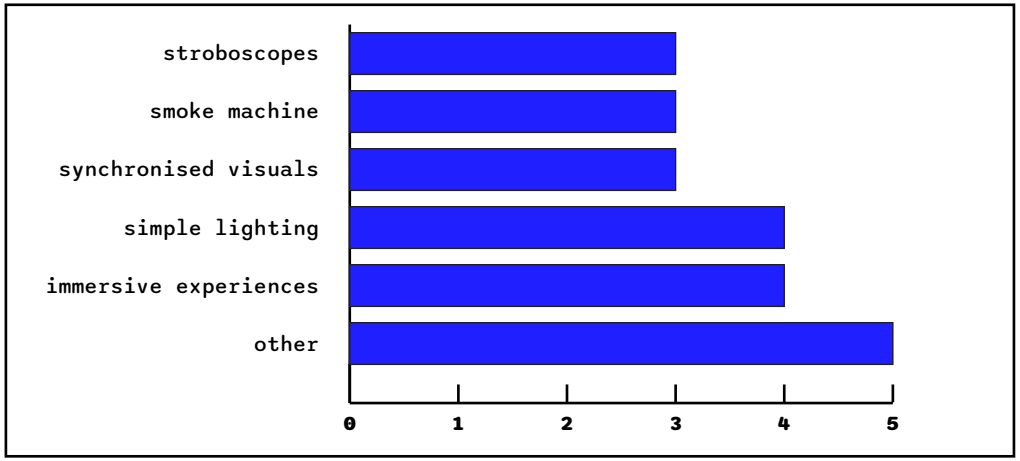


When asked how the club experience could be improved, better curation of music was mentioned 6 times, better lighting and visuals was mentioned 5 times and better door policy was mentioned 3 times. This maps well to what respondents liked in their best club experiences, where they mentioned the music, the lights and crowd as being most important. One respondent answered that a way to improve the lighting could be to spread the lights around the room more. Now, lighting is mostly focused on the performer, but they enjoy it when the audience is incorporated as well.

The Audiovisual Experience

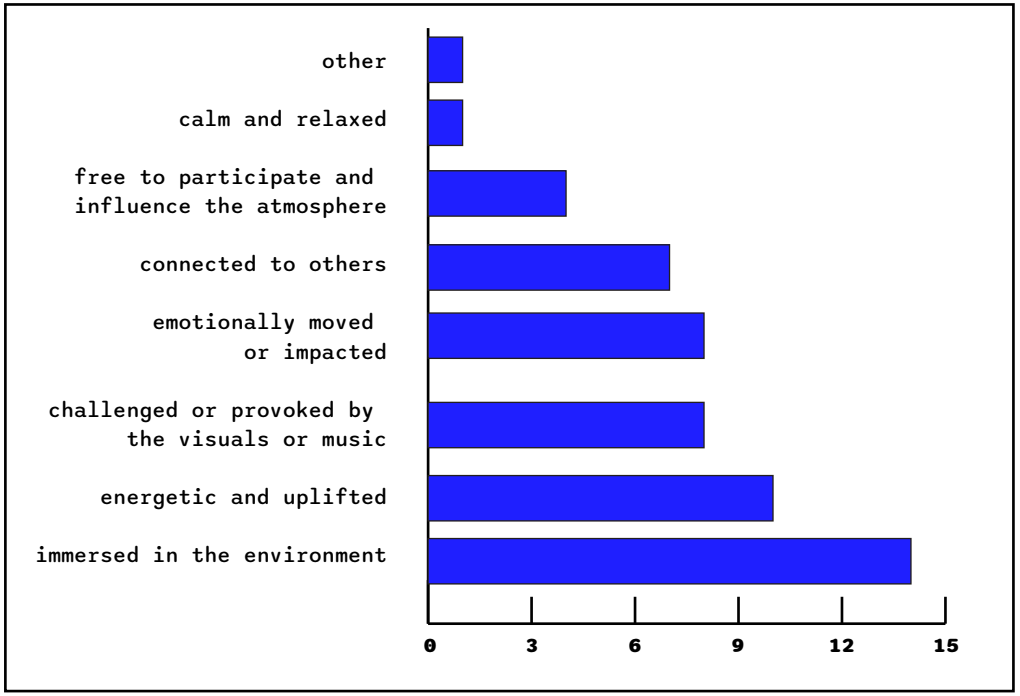
When asked to describe their best audiovisual experience, respondents diverged a bit more in their answers. Five recurring themes were identified (see Figure 14). They included feelings of immersion, use of simple lighting and synchronisation between visuals and music. Additionally, traditional club elements like use of smoke and stroboscopes were mentioned as well.

Figure 14
Recurring Elements Contributing to Preferred Audiovisual Experience



One respondent answered that they especially liked it when the visuals made them lose track of the space they were in and transported them to another place. Another respondent simply answered that they like: “The ones that make you feel like you’re tripping when you’re sober”. The majority of respondents agreed that visuals are essential to a complete club night experience, and when asked how they want to feel during such an experience, most answered with “immersed in the environment”. The remaining answers are visualised in Figure 15.

Figure 15
How Respondents Want to Feel During a Club Night



Following that, when asked if visuals or lighting affected their emotional connection to the music, 40% of respondents answered “always”, 55% of respondents answered “sometimes” and 5% of respondents answered “never”. When asked how the audiovisual experience could be improved, answers diverged a lot. There were only three common themes: minimal lighting (4), synchronisation between music and visuals (3) and more immersive experiences (3).

1.2.2 Discussion

As mentioned before, this sample is perhaps not representative of the more general club audience. Since local networks in Amsterdam and Delft were used to contact respondents, most of them are active in night scenes surrounding these locations (Amsterdam, Den Haag, Rotterdam). Additionally, the number of respondents would ideally be higher to achieve more robust statistical significance. However, since much of the data gathered is qualitative, noticing an overlap in answers to some of the questions (for example with the theme of immersion) is already quite useful. Throughout the questionnaire there seemed to be a number of themes that were quite prevalent in the respondents’ answers. Firstly, it seemed that most respondents agreed that lighting and visuals are very important to the overall experience. Social factors like the type of crowd and freedom of expression seemed to be important as well. When looking specifically at the audiovisual experience, respondents value immersion as well as simplicity. Given the fact that most respondents only sometimes feel that their emotional connection to the music is influenced by the visuals, it seems that there is still room for improvement in this regard. Apart from immersion and minimalism, synchronisation between audio and visuals was listed as the most important areas for improvement. In conclusion, it seems that designs that improve immersion and synchronisation without being visually complex would be welcomed by the club audience.

Chapter Summary
This chapter described a questionnaire conducted with frequent clubbers. Results show that clubbers find visuals essential to the overall nightclub experience. The note immersion, simple lighting and synchronisation as important elements of an engaging audiovisual nightclub experience.

1.3 expert interviews

In addition to understanding the experience of club audiences, the process of audiovisual experts was examined by conducting 4 interviews. This helped to reveal how visuals and music are already combined in practice and to assess whether this project's approach could be of value. The main takeaways from each interview are discussed below.

1.3.1 Interview #1 (New Media Art)
This expert is a new media artist who primarily uses dated analog equipment to create audiovisual works.

The work of the expert relies heavily on a scientific approach to art. The expert uses analog equipment that allows for the direct link between the visual and the auditory, since the same signal is used for both. There is no translation between sensory modalities. The expert distinguishes between arbitrary and non-arbitrary visual music, where arbitrary visual music is the pairing of any visual and auditory content that do not share the same signal source, and non-arbitrary visual music is the combination of visuals and audio that result from the same signal, thereby being representations of the same thing in different modalities. They claim that audiences *hear* more by *looking* at the visual. The visual accentuates certain properties of the sound. The expert's practice consists of using old tools to create new aesthetics. Due to the use of analog equipment, audio and visuals are synchronised extremely well. Audiences respond very well to this synchronisation. The expert switches between synchronised and unsynchronised parts during their performance, as they believe that the contrast creates an interesting experience. They refer to the different sections in techno music that contrast each other to keep the crowd engaged as an example.

.

1.3.2 Interview #2 (Lighting Design, Light Shows)
This expert primarily creates light designs and live visuals for music performances.

The expert started their work in scenography (stage design). They use light as the main storyteller in their work and music plays a supporting role. The expert's unique approach to lighting design results from the fact that they are not trained as a light technician. The expert views the whole space as their playground and uses contrast between darkness and brightness to overwhelm audiences. Their approach to lighting design is quite experimental. They are not concerned with temporal synchronisation between audio and visuals, as long as there are climactic moments where both come together. The expert describes their live work with DJs as a dialogue, where both artists need to trust each other and let the other take the lead at times. The expert notes that when sound is used in combination with light, it allows the light artist to use darkness as well, because the sound fills up the emptiness.

1.3.3 Interview #3 (Club Music, New Media Art)
This expert primarily produces electronic dance music, but also creates audiovisual works.

The expert works mostly in club music and installation art. They expressed that they dislike when music containing cultural references (melody, harmony, rhythm) is paired with an abstract visual work that does not contain those references. Instead, when working together with a visual artist in the past, they used audio recordings made during the creation of the visual work as the sound source for the music, so there is a literal connection between the music and the visual. In other works, the soundscape contained clues about the scenery in which the visuals took place, so the audience could feel as

though they were there. In describing the importance of synchronisation between audio and visuals, the artist highlighted a work involving dancers who needed musical cues to determine how far along they were in the piece. The synchronisation is not only important for the audience, but also for the performer. While describing the ideal lighting to go with their music in a club context, the expert mentioned the use of stroboscopes and a lot of smoke. They want the audience to lose track of their surroundings so they can be as present as possible and experience only the performance. They mention the role of visuals and other environmental factors (spatial design of club, smoke) in recontextualising commercial music in a non-commercial setting. Through this recontextualisation the aesthetics of a track can be altered so it can become quite interesting in a club setting. The expert is also interested in working on audiovisual installations that make audiences experience rhythm through vision. By pairing auditory and visual elements that produce the same rhythm one after the other, audiences could experience rhythm in multiple sensory modalities.

1.3.4 Interview #4 (Club Music, New Media Art)
This expert primarily produces electronic dance music, but also creates audiovisual works.

The expert describes how the visuals they create often attempt to describe the feeling they try to express with their music. The works made by the expert tend to be interpretive, abstract expressions of their emotions, where the music often inspires the visual work. When discussing club nights, the expert describes how they enjoy multiple senses being stimulated at once, resulting in a "full experience". The expert ascribes a feeling of euphoria to this sensory (over)stimulation that occurs when combining stroboscopes, dynamic visuals and club music. They also note that synchronisation between audio and visuals is not essential to them, as the brain is good at interpreting different kinds of patterns, so connections will be found even if there is no perfect synchronisation.

1.3.5 Discussion
One thing that is immediately obvious is the variety of approaches taken when creating audiovisual work. What is shared by all experts, however, is their belief that there needs to be a clear relation between audio and visuals. In interview 1, this relation is extremely direct, with the exact same signal being used to create both the sound and the visuals. In interview 2 and 4, this is the opposite, with the experts interpreting the audio and expressing themselves through visuals based on that. In interview 3, the expert describes the need for conceptual alignment between audio and visuals.

Synchronisation is a topic that came up in multiple interviews, with some valuing precise synchronisation between audio and visuals and others valuing ambiguity in this regard. An interesting point was made in interview 1, where the expert noted the parallel between synchronised and unsynchronised visuals and the different sections present in a techno track: the contrast keeps the audience interested and engaged. This inspired the mode-switching functionality in the final design described in Chapter 2.6. In addition, descriptions of ideal club nights given in both interview 3 and 4 emphasise experiential elements over conceptual elements. To these experts, a good club night is about feeling, sensory stimulation and being present. This aligns well with the ethnographic findings discussed in Chapter 1.1. Finally, while these experts incorporate auditory and visual elements in their work, none explicitly utilise cross-modal illusions in their projects. This suggests that research in this area could provide valuable insights. While these experts possess extensive tacit knowledge about creating engaging audiovisual experiences, this project could serve to synthesise and democratise this knowledge.

Chapter Summary
This chapter described a series of interviews conducted with audiovisual experts. Results show that while approaches differ, both audiovisual synchronisation and contrast between different sections are important to the audience experience.

1.4 ventriloquism effect experiment

Following the desk research on cross-modal illusions, it was important to assess how feasible it was to incorporate the ventriloquism effect in the final design. To that end, a small-scale experiment was conducted with 7 participants to test the illusion. In this experiment, the effect was created using simple stimuli
.

1.4.1 Method

To confirm the presence of the ventriloquism effect, it is necessary to demonstrate that the perceived location of a sound shifts toward the position of a simultaneous visual cue. In this experiment, a large TV was used to display visual cues and a small bluetooth speaker was used to create the auditory cues. The perceived location shift was measured by asking participants to indicate the perceived source of the sound after each trial (left, centre, or right).

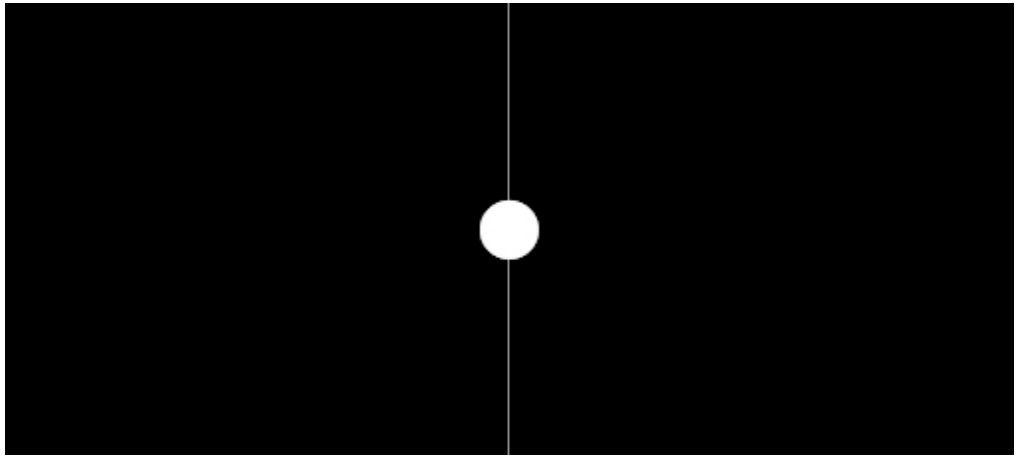
Participants

The experiment included 7 adult male participants (aged 24–30) with normal hearing.

Stimuli and Conditions

In this experiment, the position of the visual stimuli remained fixed in the centre. The auditory stimulus continuously moved to one of three positions (one 20 degrees to the left of the centre, one 20 degrees to the right). The experiment consisted of 30 trials in which participants were exposed to 2 conditions: unimodal and bimodal. The unimodal trials involved only an auditory stimulus, the bimodal trials included both auditory and visual stimuli. In both unimodal and bimodal trials, the auditory stimulus was positioned in one of the three positions (left, centre, right). If the ventriloquism effect is present, the perceived location of the auditory stimulus would move towards the centre during bimodal trials, due to the attraction from the fixed visual stimulus.

Figure 16
p5.js Sketch Containing Visual Stimulus and Horizontal Line.



Note. This is what the participant saw during the trials. When there was no visual stimulus present, there was no white circle and only a vertical line.

In addition to the 30 test trials, there were 3 practice trials to familiarise participants with the procedure. These were discarded in the analysis of the results. In total there were 18 bimodal trials and 15 unimodal trials per participant, but the order was randomised. In both unimodal and bimodal trials, the auditory positions were distributed equally. However, because the first three trials were discarded, the resulting number of unimodal and bimodal trials varies slightly per participant.

Figure 17
Experiment Setup Including TV, Chair and p5.js Sketch.

Procedure

Participants were seated and aligned with a vertical line displayed on the screen. They were informed that they would complete 33 trials (including the 3 practice trials), each involving either a single stimulus or a stimulus pair. They were instructed to verbally report whether the sound originated from the left, centre, or right of the vertical line.

1.4.2 Results

The results of the experiment can be found in Figure 18 and 19. They depict the relative results of the unimodal and bimodal trials, respectively. If the ventriloquism effect was present, a larger percentage of actual left and right auditory cues would be perceived as being in the centre during bimodal trials. This is clearly visible when comparing the unimodal and bimodal results. To determine statistical significance, a chi-square test was performed on the results. The results of the bimodal trials were considered to be the “observed” results. The “expected” results we created by taking the quantity of bimodal trials and applying the distribution of the unimodal trials. This was done due to the fact that the null hypothesis stated that there would be no difference between unimodal and bimodal trials. The resulting p-value was < 0.001, which would suggest statistical significance. One problem with this analysis is that the expected results rely on results of unimodal trials that may not even be significant themselves. Due to the limited number of participants, it cannot be said with certainty that the results of the unimodal trials are a representative baseline to which the bimodal trials can be compared. The full results and chi-square calculations can be found in Appendix B.

Figure 18
Results Unimodal Trials in Percentanges

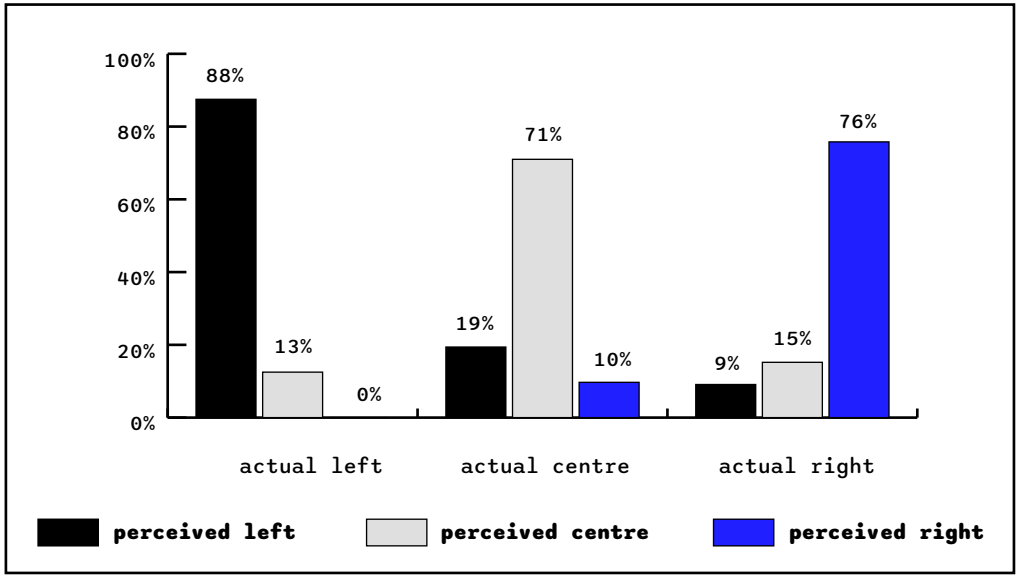
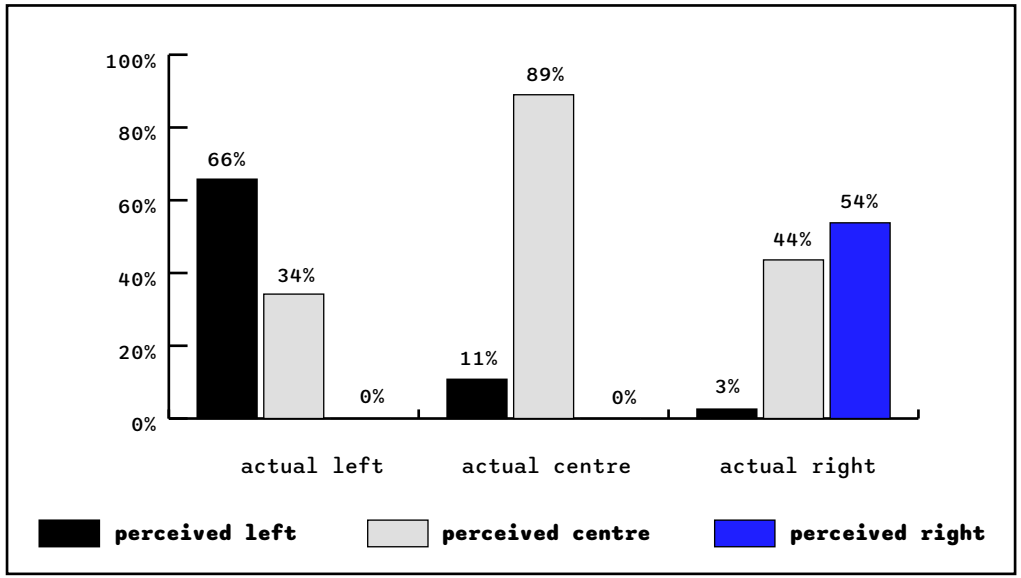


Figure 19
Results Bimodal Trials in Percentanges



1.4.3 Discussion

This experiment was successful in the sense that it provided a more tactile understanding of the ventriloquism illusion. Additionally, the results do not contradict the effect, and might even confirm it. Given the small number of participants, the difference between unimodal and bimodal trials seems promising. However, due to difficulties with proving statistical significance, it cannot be said with certainty that these results are representative of the larger population.

In this experiment, audiovisual binding was facilitated through the temporal congruence of visual and auditory stimuli. The impact of this congruence on binding could be further explored by manipulating the temporal synchronisation between the stimuli in various ways. Additionally, the effects of cross-modal correspondence on binding could be examined through different approaches, such as having stimuli in both modalities follow consistent patterns, compared to a control condition with incongruent patterns.

In conclusion, the results align with existing experimental research demonstrating the ventriloquism effect. For this project, they confirm that the effect is both achievable and worthy of further exploration through design.

Chapter Summary
This chapter described an experiment conducted to measure the ventriloquism effect. While statistical significance was difficult to prove, results indicated a presence of the effect. This showed that using the ventriloquism effect in the final design was feasible.

1.5 general discussion

The initial research phase of this project was rather exploratory, focusing on finding interesting design opportunities by combining domains. This was risky, in a sense, since it was not clear at the beginning that this exploration would yield any worthwhile results. At the end of this phase, however, it became clear that there are promising design opportunities in combining cross-modal illusions with the context of the nightclub.

The literature review was essential for gaining a thorough overview of both domains, shedding light on both the literature on both cross-modal illusions and the nightclub experience. At the same time, it highlighted the research gaps in both domains, with very few studies looking into both the application of cross-modal illusions and the perception of audiovisual experiences in nightclubs. Supported by this literature, a case was made for the ventriloquism effect and ventriloquism aftereffect. These effects affect our perception in the spatial domain, and were determined to be the most promising in the context of the nightclub.

The case for ventriloquism is further supported by the results from the questionnaire. Key themes that clubbers described as important to the experience were their sense of immersion and synchronisation between audio and visuals. They also noted that both these themes were areas for improvement. Light installations leveraging the ventriloquism effect could solve both these problems. For the ventriloquism effect to work properly, audiovisual synchronisation is required and when it works properly, sound will appear to come from multiple directions, potentially enhancing immersion. This notion of synchronisation was echoed in the expert interviews as well. However, there seemed to be differing opinions on it. Some use more strict forms of synchronisation, while others do not temporally synchronise their visuals to music at all. The feasibility of reproducing the ventriloquism effect was assessed rather successfully in the conducted experiment. While conclusive statistical significance may not have been achieved, the results implied that the ventriloquism effect did in fact occur. The fact that the effect was reproduced in a controlled setting using simple equipment, indicated that implementing the effect in the final prototype was an attainable goal.

In conclusion, during the first seven weeks of this project, a variety of research methods were applied to investigate whether an interesting connection can be made between the world of cross-modal illusions and the world of clubbing. After careful analysis of the results, the findings supported continuing this project with a focus on applying the ventriloquism effect in the nightclub context to enhance audience immersion.

1.6 research questions

The findings from the research phase led to the formulation of the following primary research question:

RQ1. *Does the ventriloquism effect applied in the nightclub lead to higher levels of audience immersion?*

In addition to investigating the ventriloquism effect's impact on immersion, a secondary research question was formulated, exploring whether consistent mapping between musical elements and corresponding visual cues influences the audience's experience. To address this, the design must incorporate two operational modes: one with consistent mapping (e.g., the snare drum consistently triggers a specific light) and another with randomised mapping (e.g., the snare drum triggers different lights each time). By comparing these modes, the influence of consistent visual-auditory cue pairing on binding can be assessed.

RQ2. *Does consistent mapping between visual and auditory cues affect binding?*

If consistency has no significant impact on immersion or the ventriloquism effect, it would simplify the design of audio-reactive systems, reducing their complexity. Conversely, if consistency significantly enhances the audience experience, it would highlight a powerful strategy for light designers and artists to create more engaging and impactful audiovisual designs.

phase 2: design

This phase starts with the design definition, ideation and idea selection. Next, the selected idea is developed into a functioning audio-reactive installation. After thorough testing, the design was installed in the nightclub, in preparation for exhibition and evaluation.

2.1 definition

Following the exploratory research and the formulation of research questions, the design phase commenced. This chapter outlines how the findings from the research phase led to a concrete design goal, interaction vision and list of design requirements. The purpose of design within this project is to function as a research tool to generate knowledge about cross-modal design in nightclub environments.

2.1.1 Design Insights from Research Phase

During the research phase several methods were employed to better understand the context. Findings from these activities that were used for guiding the design process are listed in Figure 20. One key finding is that while synchronisation is necessary (to create the VE), audiences respond best to visuals that alternate between synchronised and unsynchronised sections. This makes intuitive sense, as it is quite easy to imagine how looking at the same type of visual for a prolonged period of time might become uninteresting. Another finding is the fact that audiences both value immersion and simplicity when it comes to visuals. Thus, the final design needs to be able to create a sense of immersion without relying on visual complexity. Lastly, to increase binding, cross-modal correspondences need to be included in the design as well.

2.1.2 Design Goal

To address the answer the research questions, the final design must induce the ventriloquism effect within the nightclub environment by creating visual cues that are synchronised with the music produced by the DJ. The design can then be evaluated to determine whether the ventriloquism effect enhances audience immersion. To achieve this, the following design goal was established:

To increase the sense of immersion for clubbers in nightclubs by leveraging the ventriloquism illusion.

Figure 20
Insights from Research Phase

insight	research acitivity
cross-modal correspondences may increase binding	literature review
audiences prefer immersive audiovisual experiences	questionnaire
audiences prefer simple light installations	questionnaire
audiences respond well to synchronisation with minimal delay	expert interview
audiences respond well to contrast between synchronised and unsynchronised sections	expert interview

2.1.3 Interaction Vision

To guide the design process in terms of form and interaction qualities, an interaction vision was developed. To create a fitting vision, a brainstorm was performed focusing on scenarios that embodied the envisioned emotional experience. The outcomes of this brainstorm are visualized in Figure 21. The interaction vision that best captured the desired experience can be summarized as follows:

Interactions with my design should feel like exploring a butterfly house.

Figure 22 visually represents this interaction vision, illustrating the intended atmosphere and emotional qualities. Apart from capturing the desired feeling,

this interaction vision also reflects the multisensory nature of this design. A butterfly garden offers a multisensory experience, characterized by the dynamic movement of butterflies, which provides continuous visual stimulation.
The subtle rustling of leaves and the soft sound of fluttering wings add an auditory dimension to the environment. Additionally, the presence of flowers and plants introduces an olfactory component, enhancing the sensory richness of the space.

Figure 21
Interaction Vision Brainstorm

a blanket fort	a cocoon	a bath house	coral reef
a butterfly house	a fire in a cave	a field of wildflowers	bio luminescent algae in a cave
being in a train overlooking beautiful landscape	a tent overlooking a starry night	beautiful stained glass church	kitchen
standing underneath a waterfall	surfing in the barrel of a wave	fragrant spice store	fragrant food market
going on a date	walking into fragrant bakery	tasting menu/ fine dining experience	

Figure 22
Interaction Vision of a Butterfly House

Note. Image generated using DALL-E 3 (OpenAI, 2023).

2.1.4 Interaction Qualities

Upon analysis, the interaction vision revealed several key interaction qualities to incorporate into the design. The three most useful qualities are outlined below:

Intimate

A butterfly house, with its small scale and abundance of flowers, plants, and butterflies, creates an intimate environment that feels immersive and personal. Similarly, the nightclub is an intimate setting where individuals can freely

express themselves and form connections with others. The design should emphasize and enhance this sense of intimacy, creating an environment that supports personal expression and shared experiences.

Unfamiliar
The presence of exotic butterflies, free to fly around and approach closely, introduces a sense of unfamiliarity and intrigue within the intimate space of the butterfly house. This interplay between intimacy and unfamiliarity is similarly fitting for the nightclub. A defining characteristic of the club is its experimental and boundary-pushing nature, where clubbers often explore new aspects of fashion, dance, sexuality, and self-expression. The design should embrace and reflect this sense of unfamiliarity, creating moments of perceptual intrigue that resonate with the club's exploratory atmosphere.

Welcoming
The visual appeal of the butterfly house, with its vibrant atmosphere, draws visitors in, making it a welcoming space. While the environment may be unfamiliar, visitors should still feel comfortable and secure. Similarly, to encourage vulnerability and self-discovery, the club must provide a safe and inviting space. The design should captivate clubbers, drawing them into the experience and encouraging active engagement, while ensuring the atmosphere remains inclusive and free of intimidation.
These interaction qualities capture the desired experience. The combination of being welcoming yet unfamiliar should evoke curiosity and encourage engagement. The intimacy of the space must be maintained and further enhanced through the design. As ethnographic studies have shown (Chapter 1.1), human connection is a fundamental element of nightclub culture. In addition to these qualities, the multisensory aspects of the interaction vision would need to guide the design process as well. While the design is inherently multisensory, integrating both auditory and visual elements, it also needs to incorporate the constant movement found in butterfly houses.

2.1.5 Exhibition
To effectively evaluate the design, it was important to be able to test in context. To that end, an exhibition opportunity was arranged to show the installation at Garage Noord (a nightclub in Amsterdam) during a club event on the 15th and 16th of February 2025. The constraints created by this event (e.g. time, budget) were taken into account in the design requirements.

2.1.6 Design Requirements
Following the definition of research questions, design goal and interaction qualities, concrete design requirements could be formulated:

Function
The design must be synchronised to the audio (max. delay: 30 ms)
Synchronisation is required for the ventriloquism effect. Too much delay between audio and visuals might inhibit the effect from occurring, as well as create frustration in the audience.

The design must create visual cues that are distributed throughout the space
The distribution of visual cues is essential for the ventriloquism effect to enhance immersion. If all cues were confined to one location, the audio would seem tied to that spot, preventing the creation of a spatial audio illusion.

The design must be able to create consistent and randomised visual cues.
To answer the second research question, the design must be capable of both synchronisation modes.

The design must incorporate one or more cross-modal correspondences.
To increase binding, one or more of the cross-modal correspondences discussed in chapter 1.1 should be incorporated in the design.

The design must alternate between synchronised and unsynchronised modes.
As discussed in chapter 1.2, audiences prefer contrast between synchronised and unsynchronised sections. The design should alternate between different modes to meet this audience preference.

The design must be able to function automatically without the need of a VJ.
There will not be a VJ available during the event at Garage Noord. The limited budget cannot accommodate the additional expense of hiring a VJ.

Form

The form of the design must fit the exhibition space.
The exhibition space frames the design. Its affordances and limitations need to be taken into account and the form must harmonise with it, rather than fight it.

The form of the design must be simple.
As mentioned in chapter 1.2, audiences prefer simplicity over complexity in lighting and visuals, so the form must balance visual interest with simplicity.

Feasibility

The production cost must remain affordable.
No additional budget has been provided by the event organisers, so it is crucial to keep costs minimal, as the majority of expenses will be covered independently.

The design must be easily transportable in a single car.
Renting a van would significantly increase the cost. The budget is better spent on the design, not transportation.

The design must be designed in such a way that it can be installed in 5 hours.
There are only two days available for installation at Garage Noord (starting at 3 pm), one of which is needed for evaluation.

Reliability and Safety

The design must be able to withstand vibrations.
Club sound systems can reach up to 110 dB(A) and produce significant vibrations. If components are not properly mounted or installed, these vibrations could lead to damage or failure, creating potential safety hazards.

The design must be able to withstand or avoid guests touching it.
The nightclub is not a conventional exhibition space where respectful behaviour can be expected of its visitors. Some guests may intentionally or unintentionally touch the design, and it would need to be able to withstand that.

Chapter Summary
This chapter defined the objectives for the design phase, consisting of a design goal, interaction vision and design requirements. To answer the research questions, an audiovisual installation needed to be designed that created spatially distributed audio-reactive visual cues in the nightclub.

2.2 ideation

After defining the design parameters and requirements, the ideation process began. This involved both idea generation, discussed in Section 2.2.2, and material exploration, which will be detailed in the following section. These processes occurred simultaneously, as working directly with materials provided a tactile understanding that informed the idea generation.

2.2.1 Material Exploration

The relatively complex functionality of the design, requiring electronics for audio-reactivity, ruled out low-fidelity prototyping as a practical option. Evaluating ideas effectively would demand high-fidelity prototypes. Fortunately, all ideas required the same core functionality: producing distributed audio-reactive visual cues within the exhibition space. The primary differences between ideas were in their *form* and *materiality*. Thus, the approach settled on involved experimentation with as many materials as possible, to assess if they could be used in the design, rather than to make functioning prototypes with only a small selection of them. An overview of all tested materials can be found in Figure 23.

Figure 23
Tested Material

category	material
lights	addressable LED strips (SK6812)
lights	LED filaments (300mm)
lights	electroluminescent wire (5m)
lights	LED bars (TL)
lights	LED matrix (64x32)
displays	screens (HP monitors)
displays	projector (Topvision)
light diffusors	3D-printed transparent PLA

Addressable LED Strips

The LED strips are easy to use and program with a microcontroller. Each LED is individually addressable, offering significant flexibility. However, without proper diffusion, individual LEDs are visible, contributing to an uninteresting, typical LED strip aesthetic.

LED Filaments

LED filaments were also simple to use, requiring only 3V and easily powered by a coin cell battery. They offer an interesting form, but their short length limits flexibility, and longer versions are harder to source and more expensive.

EL Wire

The electroluminescent wire showed great potential. While not very bright, it emits a pleasant glow and is cost-effective, with longer wires readily available. Its aesthetic is more unique than LED strips due to its thin, continuous form. The main drawback is that it requires 100V AC to operate, necessitating an inverter for use with a DC power supply.

Figure 24
El Wire Experiment

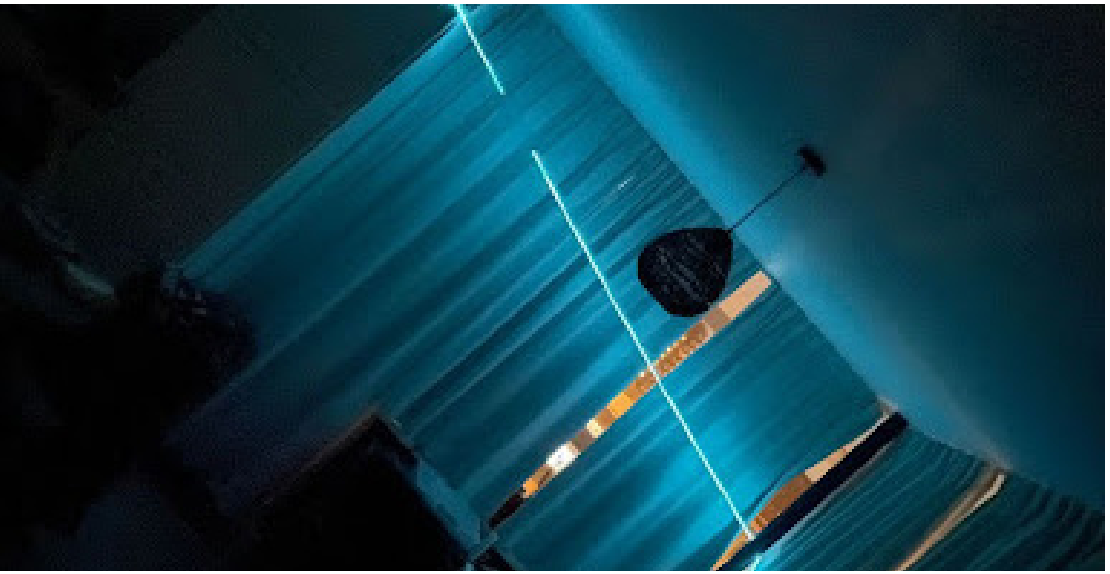
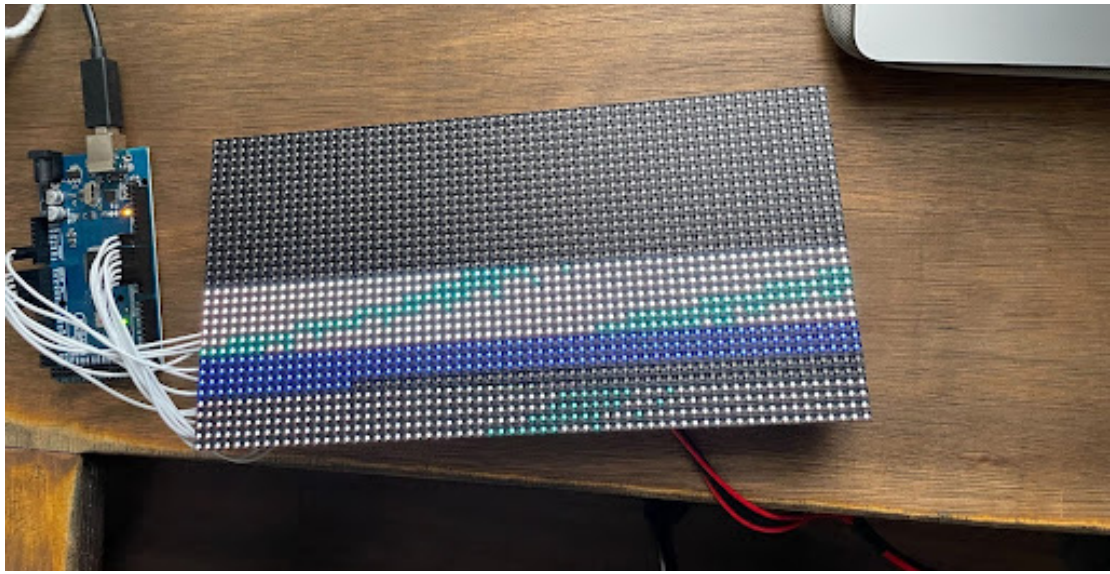


Figure 25
LED Matrix Experiment



LED Bars
LED Bars provide a classic industrial look. Controlling them is easiest with a DMX dimmer (which is rather expensive). They are quite bright, which means fewer of them would be needed in the nightclub to reach the desired light level. At the same time, having fewer lights also limits the amount of expressive power available for the design.

LED Matrix
The LED matrix tested proved challenging to use, despite numerous attempts. While it offered greater expressive potential than LED strips due to its two-dimensional nature, its small size and high cost rendered it impractical for large-scale installations within the project's budget.

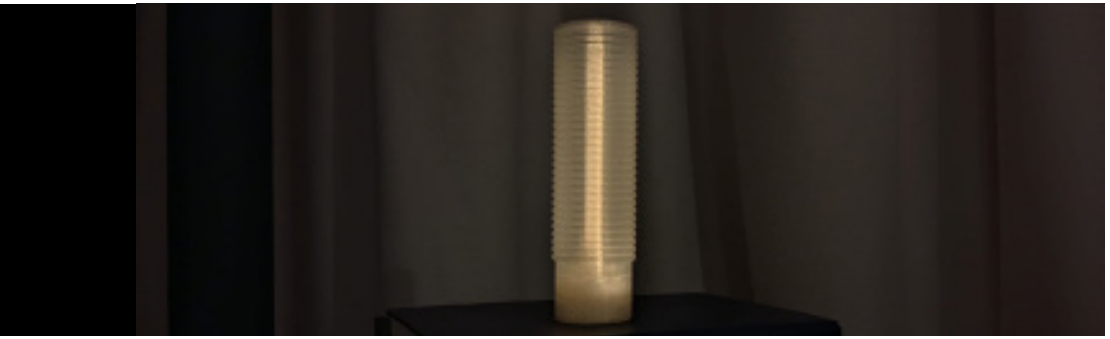
Screens
The screens were straightforward to use. However, they are quite old, so a DVI to HDMI adapter was needed to be able to connect them to a computer. The fact that they were so old did provide an interesting low-resolution look, which fits the rugged nightclub aesthetic.

Projector
The projector was the simplest display option, functioning via standard HDMI output. To create engaging visuals, it could be used for projection mapping onto angled surfaces. However, both display options (projector and screens) require a computer with a powerful graphics card to generate real-time audio-reactive visuals, which exceeds the budget.

3D-Printing for Light Diffusion

Lastly, 3D-printed transparent PLA was tested as a light diffuser. When combined with an LED filament, a simple, small lamp was created with pleasing light diffusion. However, a downside is the time-consuming nature of creating custom lamps. Designing just this small lamp took a week, making it a labour-intensive process.

Figure 26
LED Matrix Experiment



Discussion

Among the materials tested, EL wire and LED filaments proved the most promising. EL wire is simple to use and offers a unique aesthetic, while LED strips and matrices are more common and less visually engaging. LED bars are easy to implement but lack creative flexibility. Screens and monitors offer more possibilities but require a powerful computer that exceeds the project's budget. Additionally, creating audio-reactive visuals with software like TouchDesigner requires expertise, making it unfeasible within the project's time frame. LED filaments, when paired with 3D-printed lamp shades, have potential, but the time required for development could provide a challenge.

2.2.2 Idea Generation

Alongside material exploration, the idea generation process began. The constraints defined by the design goal, interaction qualities, and design requirements established a clear framework. Each idea needed to align with these parameters. As mentioned before, the goal was to develop an automatic, audio-reactive installation capable of generating visual cues that are both spatially distributed and synchronised with the music.

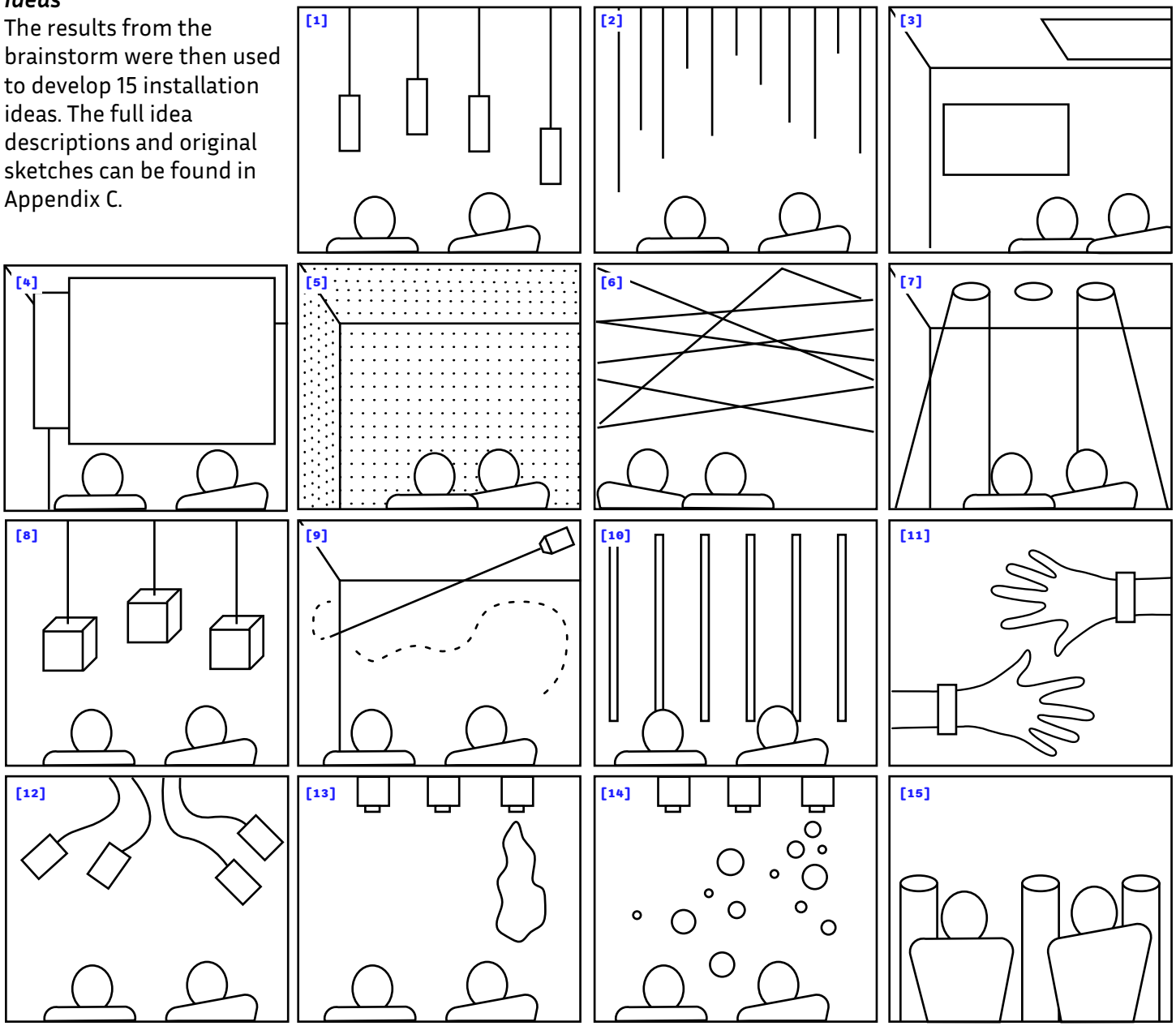
Initial Brainstorm

To start off the ideation process, a brainstorm was performed around the question: *How can (spatially distributed) visual cues be created?* The results are visualised in Figure 27.

Figure 27
Initial Brainstorm

kinetic sculpture	glass that can be transparent and opaque	mechanical displays (flip dot)	audience participation (gestures)
confetti	tiny drones	smoke machines	led matrix
flying insects	paper planes	spotlights	foam machine
screens	lasers	pepper's ghost	lava lamp
old lamps	marble machine	led strips	projections
el wire	led filaments	reflectors	dancers
led bars	strobes	oscilloscope	gobos
uv paint + uv light	persistence of visuon display	model train track	floating bubbles
ar/vr goggles			

Ideas
The results from the brainstorm were then used to develop 15 installation ideas. The full idea descriptions and original sketches can be found in Appendix C.



[1] lanterns
Custom 3D-printed lanterns attached to ceiling.

[2] strings
EL-Wire string attached to the ceiling.

[3] windows
Screens mounted to different surfaces (walls and ceiling).

[4] curtains
Textile suspended from the ceiling acting as projection surface.

[5] matrix
Matrix of LEDS covering the walls and ceiling.

[6] web
Web of EL-Wire covering parts of the ceiling and walls.

[7] beams
Ceiling mounted spots that create downward facing beams of light.

[8] cubes
Cubes acting as projection surfaces suspended from the ceiling.

[9] uv laser
All surfaces are covered in UV reactive paint. Lasers draw on these surfaces.

[10] bars
Surfaces are covered in LED bars.

[11] wristbands
All guests are given remote controlled glowing wristbands.

[12] canopy
A tree-like canopy made from EL-panels.

[13] smoke
Ceiling mounted smoke machines that create visual cues in different locations. based on auditory cues.

[14] bubbles
Ceiling mounted bubbles machines that create visual cues in different locations. locationsbased on auditory cues.

[15] pillars
Cylindrical pillars that can light up are placed on the ground throughout the space. locationsbased on auditory cues.

2.2.3 Idea Selection

Each idea was rated on a scale from -2 to 2 based on design requirements (see Figure 28) and interaction qualities (see Figure 29). The *web* idea scored highest for design requirements (20 points), followed by the *bars* (19 points), and the *strings* and *lanterns* (17 and 16 points, respectively). Most ideas had similar functionality scores, as they differed primarily in form. Feasibility varied most, with some ideas being too expensive or time-consuming. For interaction qualities, both the *strings* and *web* ideas scored 5 points, while the *lanterns*, *curtains*, and *canopy* scored 4 points. The *web* idea, offering more freedom and playfulness in its form, stood out over the *strings* idea, which was more static.

When combining the results from evaluations based on the design requirements and interaction qualities, the *web* idea emerged as the highest-scoring option with a total of 25 points. It was followed by the strings idea with 22 points and the lanterns idea in third place with 20 points. Based on these results, the *web* idea was chosen for further development. The specific form of the web still needed further development and depended heavily on the exhibition space.

Figure 28
Idea Rating Based on Design Requirements

design requirements	ideas [1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]
The design must be synchronised to the audio (max. delay: 30 ms)	2	2	1	1	2	2	2	1	-1	2	-2	2	-2	-2	2
The design must create spatially distributed visual cues	2	2	1	1	1	1	0	1	0	0	2	2	1	1	2
The design must create consistent and randomised visual cues	2	2	2	2	2	2	2	2	2	2	2	2	-1	-1	2
The design must incorporate cross-modal correspondences	1	1	2	2	2	1	1	2	1	1	1	1	-1	-1	1
The design must alternate between synced and unsynced modes	2	2	2	2	2	2	2	2	0	2	2	2	0	0	2
The design must be able to function automatically	2	2	1	1	2	2	2	1	2	2	2	2	1	1	2
The form of the design must fit the exhibition space	1	1	0	1	0	2	1	0	-1	1	0	1	2	-1	-2
The form of the design must be simple	0	1	0	-1	0	1	2	0	0	2	1	0	1	0	0
The production cost must remain affordable	1	2	-2	-1	-1	2	0	0	-1	2	-2	0	-2	-2	-1
The design must be easily transportable in a single car	2	2	0	1	1	2	0	0	1	2	2	1	-1	-1	-1
The design must able to be installed in 5 hours.	1	0	1	0	-2	1	0	-2	-2	1	2	0	-1	-1	0
The design must be able to withstand vibrations	1	1	1	1	0	1	0	-1	0	1	2	-1	-1	-1	1
The design must be able to withstand or avoid guests touching it	-1	-1	1	-1	-1	1	2	-1	-1	1	-1	1	2	2	-2
total	**16**	**17**	**10**	**9**	**8**	**20**	**14**	**5**	**2**	**19**	**11**	**13**	**-2**	**-6**	**6**

ideas

[1] lanterns [2] strings [3] windows [4] curtains [5] matrix
[6] web [7] beams [8] cubes [9] uv laser [10] bars
[11] wristbands [12] canopy [13] smoke [14] bubbles [15] pillars

scoring

-2 -1 0 1 2

Figure 29
Idea Rating Based on Interaction Qualities

interaction qualities	ideas														
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]
intimate	2	2	-1	2	-1	1	-1	-1	-1	-1	1	1	1	0	0
welcoming	0	1	1	0	0	2	0	2	2	-1	0	2	-1	1	2
unfamiliar	2	2	1	2	-1	2	0	0	-2	0	1	1	0	2	1
total	4	5	1	4	-2	5	-1	1	-1	-2	2	4	0	3	3

ideas

[1] lanterns
[2] strings
[3] windows
[4] curtains
[5] matrix
[6] web
[7] beams
[8] cubes
[9] uv laser
[10] bars
[11] wristbands
[12] canopy
[13] smoke
[14] bubbles
[15] pillars

scoring

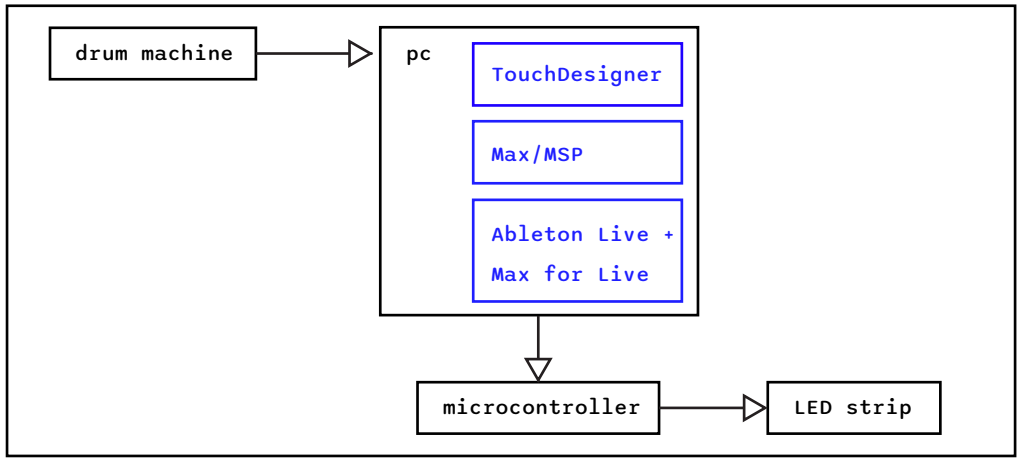
-2 -1 0 1 2

Chapter Summary
This chapter consisted of material exploration, idea generation and idea selection. In the end, the *web* idea was selected, as it best satisfied both the design requirements and the interaction qualities.

2.3 audio-reactive prototyping

One of the primary requirements of this design is audio-reactivity. Without visual cues synchronised to live audio, the ventriloquism effect cannot be achieved. Given the critical role of this feature, various tools for creating audio-reactive visuals were tested early in the process. Due to budget constraints, DMX-based systems were avoided, and alternative methods for controlling the lights were explored. Microcontrollers were chosen as a cost-effective solution, as they can easily interface with a computer via serial over USB. The design could then function by capturing audio from the DJ mixer, analysing it on a computer, and sending trigger commands to the microcontroller, which in turn controlled the lights. Three software platforms were explored that could perform the audio-analysis and generate the triggers: TouchDesigner, Max/MSP, and Ableton Live with a custom Max for Live plugin. To test these tools, a simple hardware setup was devised that emulated the signal flow that would be found in a nightclub. This setup is depicted in Figure 30.

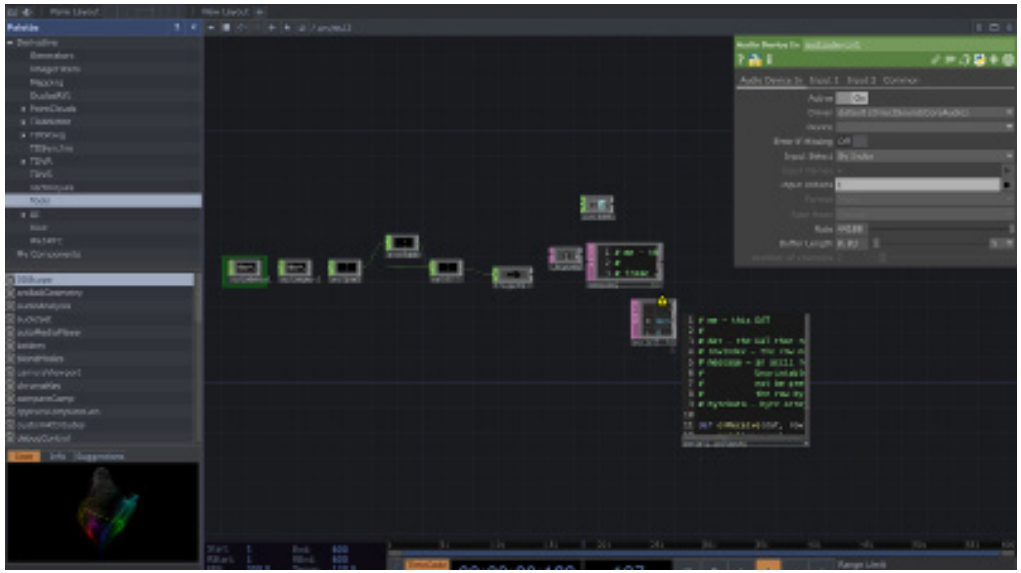
Figure 30
Hardware Setup for Audio Reactive Prototyping



2.3.1 TouchDesigner

TouchDesigner, a visual programming language for graphics, can process audio and communicate over serial. During the test, TouchDesigner analysed audio input with a simple gate. If the volume exceeded a threshold, the software generated a trigger. While functional, the computer's CPU struggled with live audio processing, causing significant delays and rendering TouchDesigner unsuitable for this project.

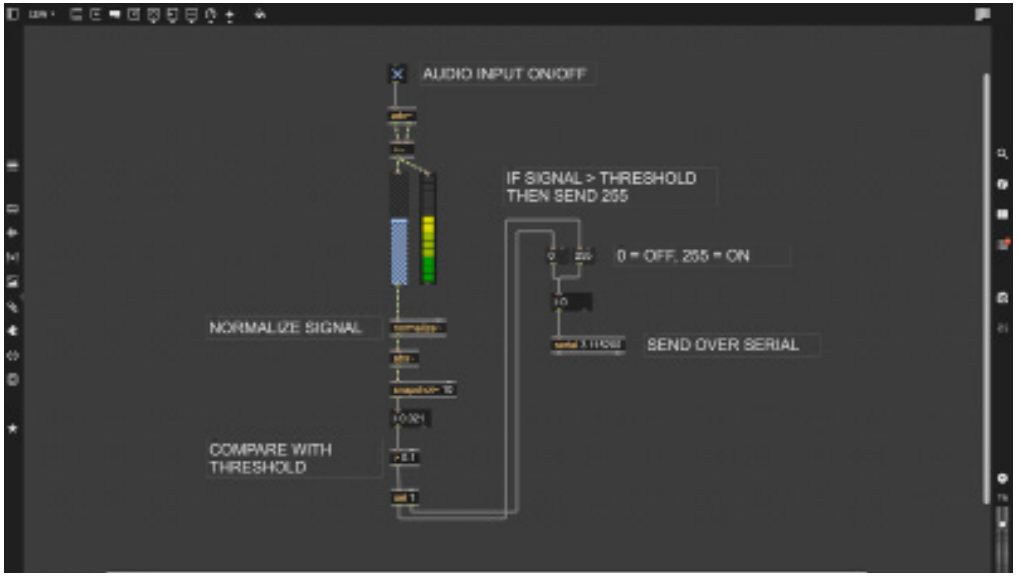
Figure 31
TouchDesigner Experiment



2.3.2 Max/MSP

Like TouchDesigner, Max/MSP is a visual programming language, but it is better suited for audio processing. The same signal flow was recreated in Max, without the delays or performance issues.

Figure 32
Max/MSP Experiment with Binary Triggers



Note. Audio signal is normalised, then compared with a threshold of 0.1. If it exceeds the threshold a value of 255 is sent to the microcontroller over serial.

2.3.3 Ableton Live + Max for Live

Max is also available within Ableton Live, allowing integration with Ableton's audio tools for preprocessing before serial communication in Max. However, running Max within Ableton introduces some performance limitations due to added computational overhead. The same signal flow from the standalone experiment was implemented in Ableton, and it functioned similarly. Combining the Max for Live plugin with Ableton's Gate audio effect enabled more precise audio refinement, resulting in improved triggers.

Figure 33
Ableton Experiment

Note. Audio is pre-processed in the "Gate" plugin before entering the "mfltest" custom Max for Live plugin. This plugin functions the same as the patch depicted in Figure 25, but it also incorporates some user interface elements.

Discussion

TouchDesigner quickly proved unsuitable for this project due to significant delays and performance issues. In contrast, Max/MSP provided the right tools with minimal latency. It can be used in both standalone mode and its integrated form within Ableton Live, each offering distinct advantages. The standalone version ensures optimal performance with minimal risk of desynchronization, delays, or other errors. On the other hand, Ableton's built-in audio effects simplify signal fine-tuning before further processing in the Max for Live plugin. While both approaches are viable, performance and reliability is the priority, which makes the standalone version the better option. The same processing achieved in Ableton with the Gate audio effect can also be replicated in Max/MSP, albeit with a bit more effort.

2.4 exhibition space and stakeholders

After having chosen the idea that was best suitable for further development, next steps were taken to turn this idea into a functioning installation. The prototype would be exhibited during a weekend long club night, so apart from evaluating the design and answering research questions, it would need to function adequately and provide the right atmosphere for the club. This chapter will outline the context of this exhibition and provide an overview of the stakeholders.

2.4.1 Exhibition Stakeholder Map

The exhibition was held at Garage Noord, a popular nightclub in Amsterdam. The installation was part of an event hosted by Los Angles that lasted from Saturday the 15th of February until Sunday the 16th (2025). The lighting design for this event was curated by .WEST, an organisation focused on exhibiting art in nightclubs. The production costs were split among myself and .WEST. Figure 34 provides an overview of all stakeholders involved in this exhibition:

Figure 34
Stakeholder Map

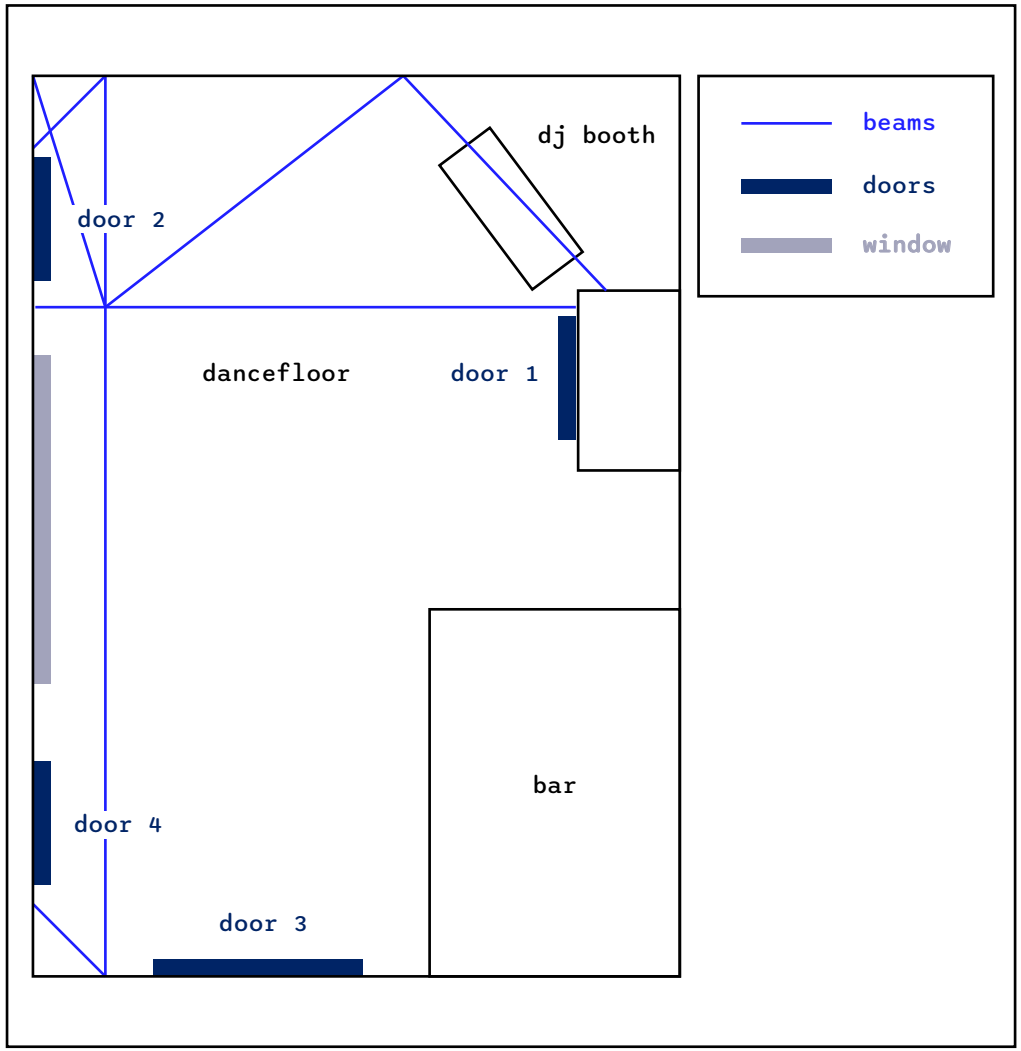
venue	event organisers	light curation	installation design
garage noord	los angles	.WEST	sem allush

2.4.2 Site Visit

Before designing the final form, a clearer understanding of the exhibition space's layout and constraints was needed. The nightclub was visited to take photographs and measurements, focusing on potential mounting locations for the EL wire and identifying any spatial limitations. Garage Noord has two main rooms, one large and one small. The small room was requested for the exhibition as it aligned best with the *intimate* interaction quality. An overview of the space is given in Figure 35 and a simplified plan view is shown in Figure 36.

Figure 35
Overview of bar40, the Small Room at Garage Noord.

Figure 36
Plan View of Exhibition Space



Note. This plan is not to scale

The ideal mounting locations for the installation are on the beams highlighted in blue in Figure 36. These beams are made of steel, attached to the ceiling, and can easily support the weight of the EL wire. As shown in Figures 37 and 38, the walls of the exhibition space are predominantly covered in tiles, with concrete bricks behind them. This combination makes drilling into the walls less practical, though still feasible. Door 1 (Figure 37), which leads to a maintenance closet, can accommodate drilled holes; however, it could not be guaranteed that this door would remain closed during the event. In contrast, Door 2 (Figure 38) is never opened and could be reliably used for mounting.

The dance floor is located in front of the DJ-booth, while guests will move around more in the area around the bar and the back of the room (as seen in Figure 40). The installation needed to be centred around the dancefloor, as this is the heart of the club experience. Visual cues needed to be distributed around this centre point to create the ideal experience. Additionally, the bar lights needed to remain on at all times for staff, making it preferable to minimise the installation's presence in that area. Since EL wires are relatively dim, they would be most effective in darker sections of the space.

The area to the right of the DJ booth, shown in Figure 39, presents challenges for placing parts of the installation. As previously mentioned, there was a chance that this door would need to be opened during the event, so it was best to avoid obstructing it with EL wire. However, the steel structure above the bar could serve as a suitable mounting point for the EL wire, which could then be connected to Beam 3 or Beam 1.

The back of the room (see Figure 40) features two additional beams suitable for mounting. However, as previously mentioned, the installation's primary focus needed to be centred around the dancefloor. That said, having some installation elements in this section could help spark curiosity in passers-by and enhance the *welcoming* interaction quality. A possible approach was to use the frosted windows between Door 2 and Door 4, which overlook the hallway to the bathrooms. Positioning lights behind these windows could generate visual interest and attract attention from those walking past.

Figure 37
Photo of the DJ-Booth

Note. Room appears larger due to lens distortion.

Figure 38
Photo of the Area to the Left of the DJ-Booth

Note. Room appears larger due to lens distortion.

Figure 39
Photo of the Area to the Right of the DJ-Booth

Note. Room appears larger due to lens distortion.

Figure 40
Photo of the Area to the Left of the DJ-Booth

Note. Room appears larger due to lens distortion.

The site visit provided valuable insights into the space's opportunities and limitations, helping me to develop the form further with the space in mind.

The key conclusions are as follows:

1. The ideal mounting locations were the steel beams on the ceiling, offering both support and accessibility.

2. Wall-mounting would be challenging due to the tiles and concrete, making it less practical.

3. The installation needed to focus on the centre of the dancefloor, in front of the DJ-booth, as this is the heart of the club experience.

4. The bar area needed to be avoided to maintain visibility of the installation.

5. The frosted window overlooking the hallway presented an opportunity to create visual interest.

6. Door 2 offered a practical mounting location without disrupting the space's flow.

Chapter Summary
This chapter described the constraints created by the exhibition space. The installation's focus area was identified, as well as ideal mounting locations.

2.5 form development

With a clear understanding of the exhibition space, the form could be developed. This form plays a crucial role in achieving the interaction qualities and producing the ventriloquism effect. To ensure it is effective, compelling, and appropriate for the space, 5 iterations were conducted, refining the design to balance feasibility, aesthetics, and its ability to create spatially distributed visual cues.

Iteration 1: Web

Building on the initial idea, two refined sketches were produced to explore the web idea further. These were overlaid onto a traced photograph of the exhibition space to assess their spatial feasibility. To mitigate safety risks, most EL wires were positioned along the walls and ceiling, so they would not form a tripping danger. However, it was concluded that these forms were unsuitable, as the chaotic distribution of EL wires introduced ambiguity, making it difficult to generate distinct visual cues. Sketches from this iteration are provided in Appendix D.

Iteration 2: Exploration

To generate alternative forms, reference images were compiled into a mood board to explore alternative ways of using EL wire (see Figure 41). Following this, several sketches were produced, diverging from the web concept. One approach, illustrated in Figure 42, outlined objects in the exhibition space. While this created an interesting visual effect, the outlined objects had no relation to music. This lack of connection made this approach difficult to justify. Next, the material's inherent flexibility was explored, leading to the development of the forms shown in Figures 43 and 44. While these successfully integrated the material's affordances, their overall appearance was chaotic and lacked clear direction.

Figure 41
Moodboard

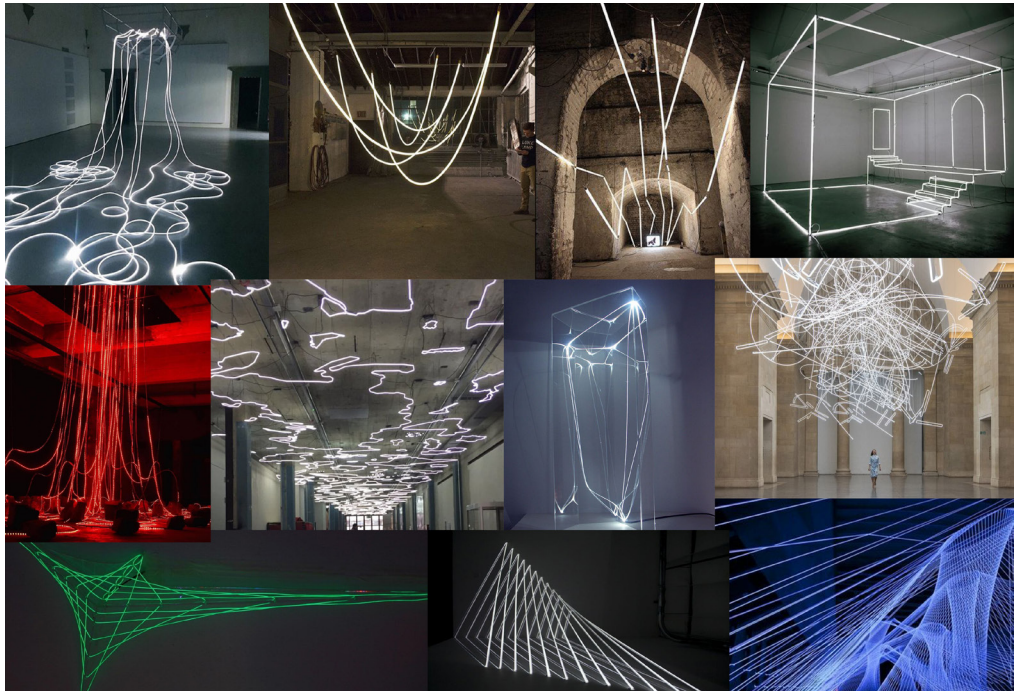


Figure 42
Form Iteration: Outlines

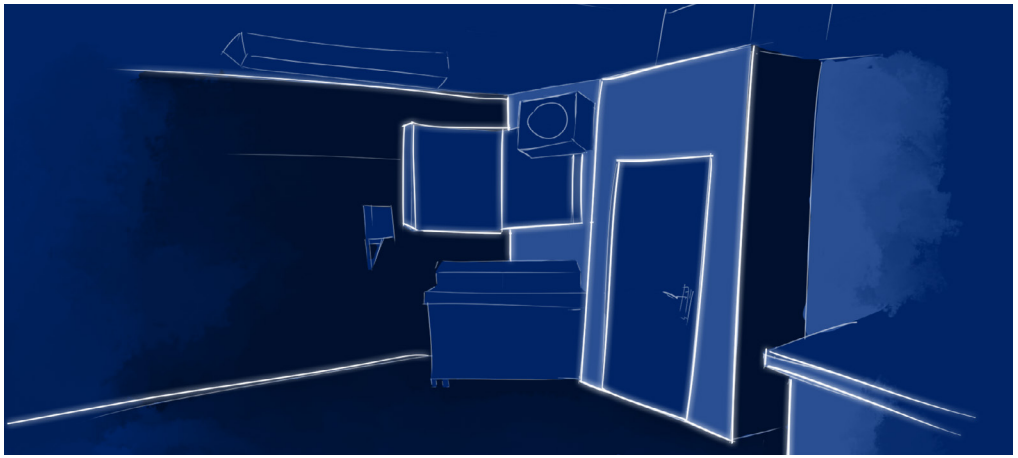


Figure 43
Form Iteration: Liquid

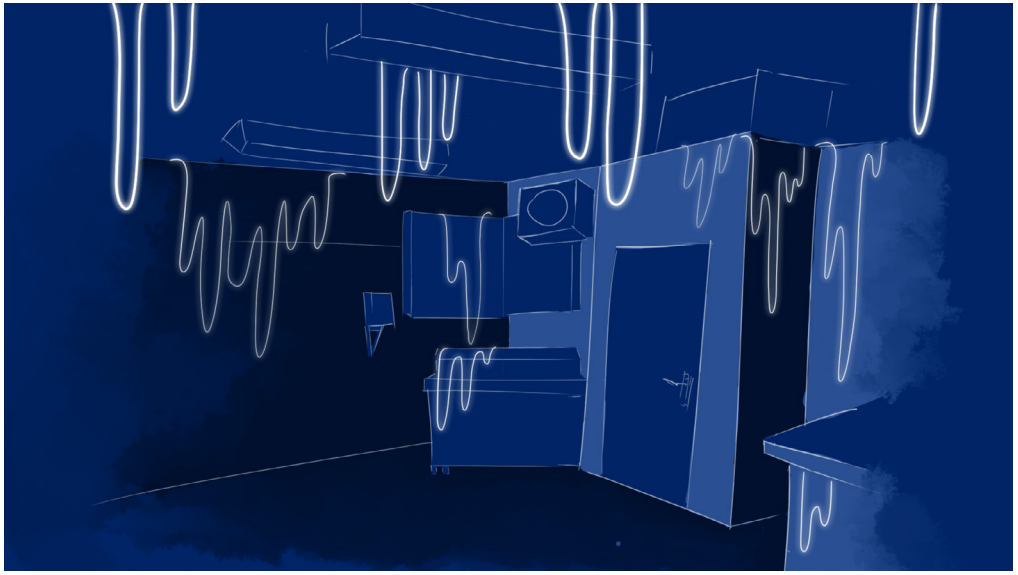
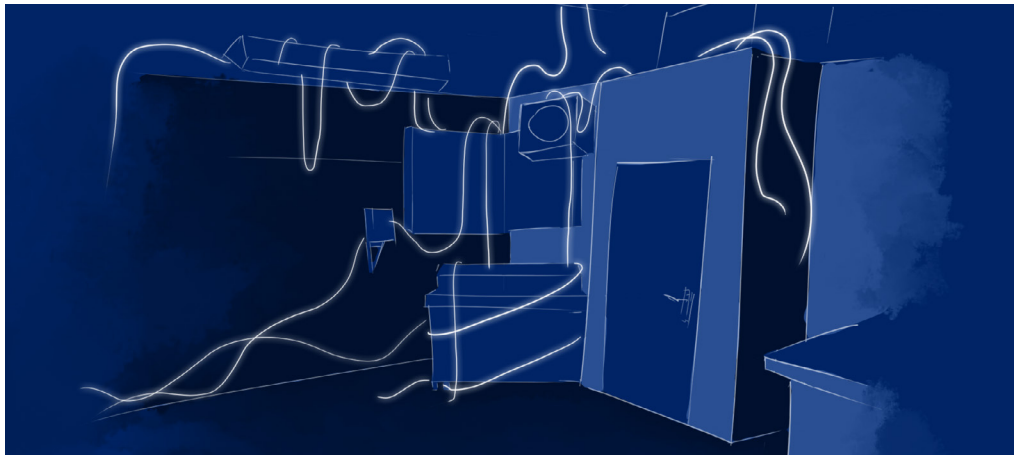


Figure 44
Form Iteration: Tendrils



Iteration 3: Regions

To address the issue of ambiguity in the visual cues identified in the first iteration, forms with distinct regions were developed to facilitate clear, spatially distributed cues. Grouping EL wire enhanced its visibility, compensating for its low brightness. The form in Figure 45 consists of three regions: one on the ceiling and two on the walls beside the DJ booth. However, the use of straight lines limited playfulness and failed to utilise the material's flexibility. In contrast, the curved EL wire arrangement in Figure 46 created a more dynamic, immersive canopy above the audience. This iteration confirmed that separate EL wire regions were effective, but greater playfulness was needed.

Figure 45
Form Iteration: Three Regions

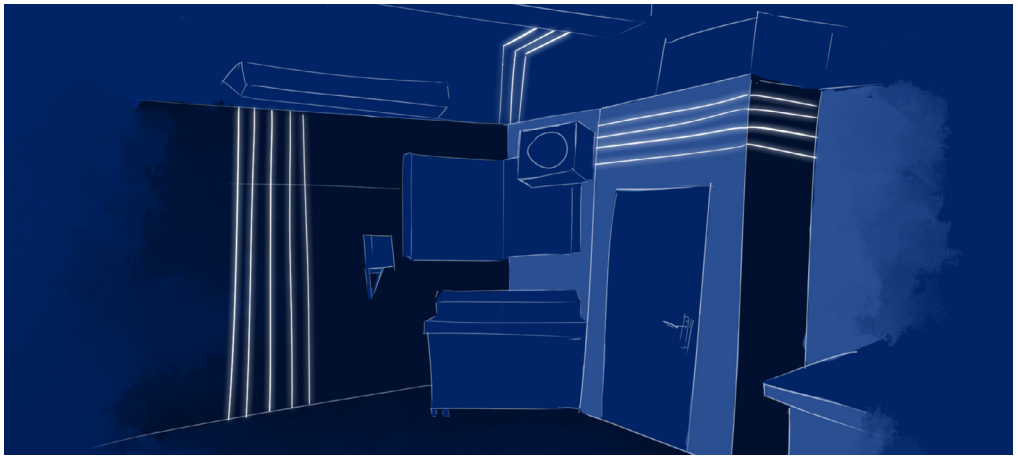
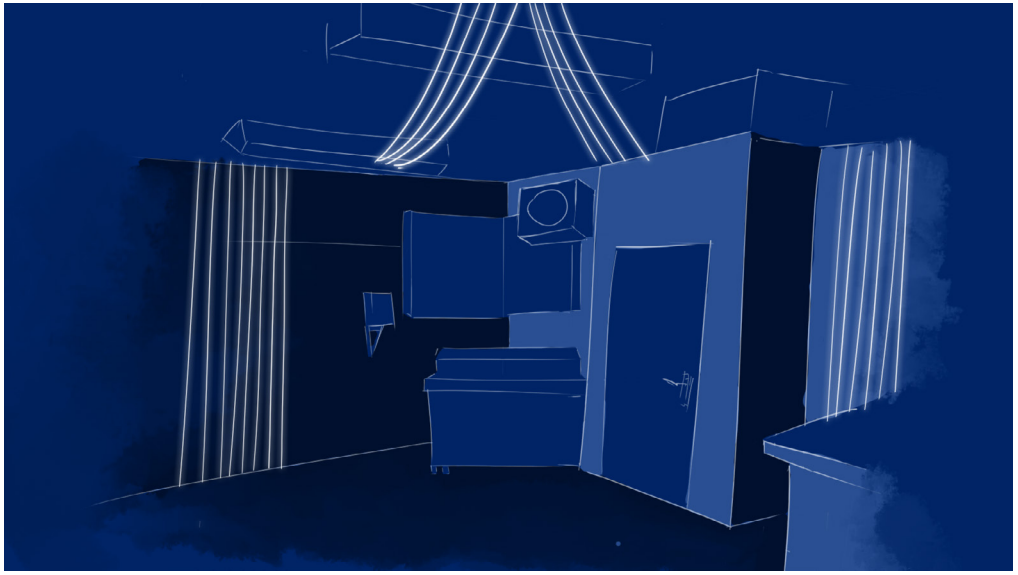


Figure 46
Form Iteration: Curved Regions

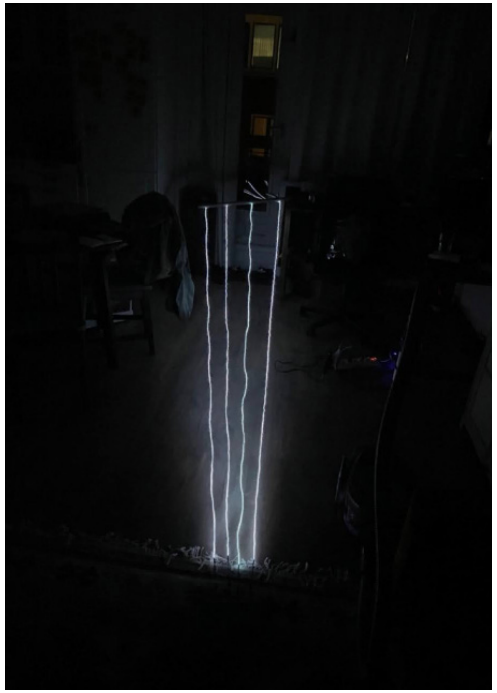


Iteration 4: Physical Experimentation

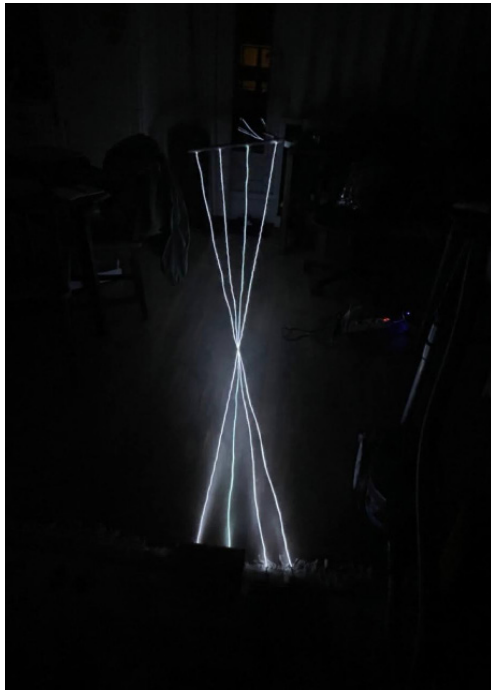
Although sketching proved valuable in the early design stages, direct physical experimentation was required to fully understand the material's behaviour. After acquiring the EL wire, a series of experiments was conducted to explore its potential and limitations.

An initial attempt was made to recreate the straight lines from earlier sketches. As shown in Figure 47, the wires exhibited slight wobbliness due to being coiled during shipping. Various methods aimed at reducing these irregularities were tested, but none proved particularly effective. Eventually, larger curls were

Figure 47
Form experiment: Straight lines



(a) Parallel



(b) Intersecting

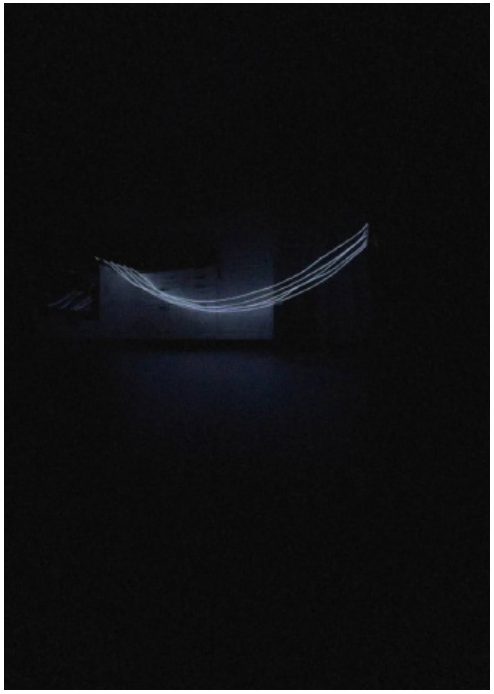
reduced, although minor irregularities persisted. This unexpected material property also affected the appearance of curved parallel EL wires (see Figure 48), which, instead of forming smooth, elegant curves, appeared crooked and disorganised. As a result, the form direction from the previous iteration was reconsidered.

Thus, exploration continued to determine what else was possible with this material. Rather than resisting the wire's natural curves, forms were created that allowed it to flow more freely (see Figure 49). However, achieving aesthetically pleasing results still required careful arrangement to highlight the wire's qualities without introducing excessive visual chaos. Translating this concept into a larger installation proved challenging, leading to the development of another form with several EL wire "arms" radiating from a single point (see Figure 50). This structure created a cohesive, immersive installation with distinct visual cues across different areas. Additionally, it reinterpreted the original web-like concept to fit within project constraints. Combining these "arms" with the organic shapes, seemed like the most promising way forward.

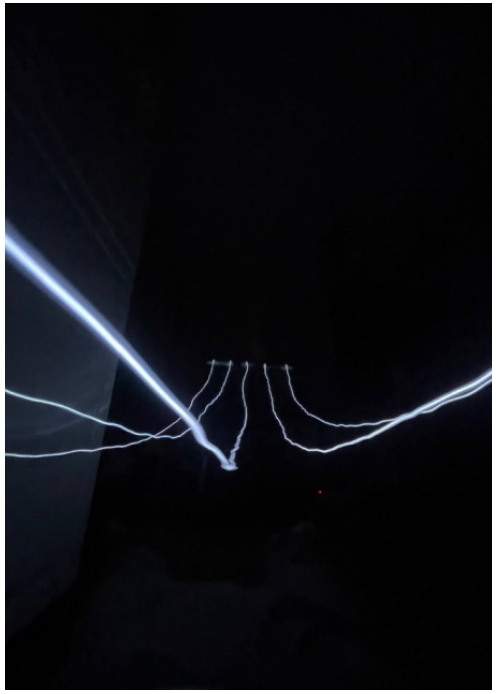
Iteration 5: Final Design

Having established that the installation should feature separate organically shaped arms emanating from a single point, the final form could be developed.

Figure 48
Form experiment: Curved lines



(a) Side



(b) Front

Figure 49
Form experiment: Organic Shapes

(a) Valley

(b) Peak

Figure 50
Form experiment: Web Revisited

(a) Close-up

(b) Total

The chosen arrangement included two arms on the ceiling, one on the left wall, and one behind the DJ. This introduced variation in all dimensions while avoiding the bar area. Figure 51 integrates organic shapes with this arrangement, by using multiple curved threads per arm, creating a dynamic form. However, this approach distributed light evenly along the arm rather than producing distinct focal points. To refine this, further physical experiments were conducted (Figures 52 and 53), shifting the focal point to the ends where individual wires diverge. These experiments also highlighted that arms with subtle width variations created more visual interest. The “fork” experiments felt too rigid, while the “curl” experiments were overly exaggerated; the final form needed to balance these extremes. Additionally, more diverging branches along the arms needed to be incorporated to cover a larger area of the exhibition space.

The form of these experiments reminds of the structure of dendrites. Interestingly, dendrites, along with firing neurons, align well with the concept

Figure 51
Form experiment: Threads

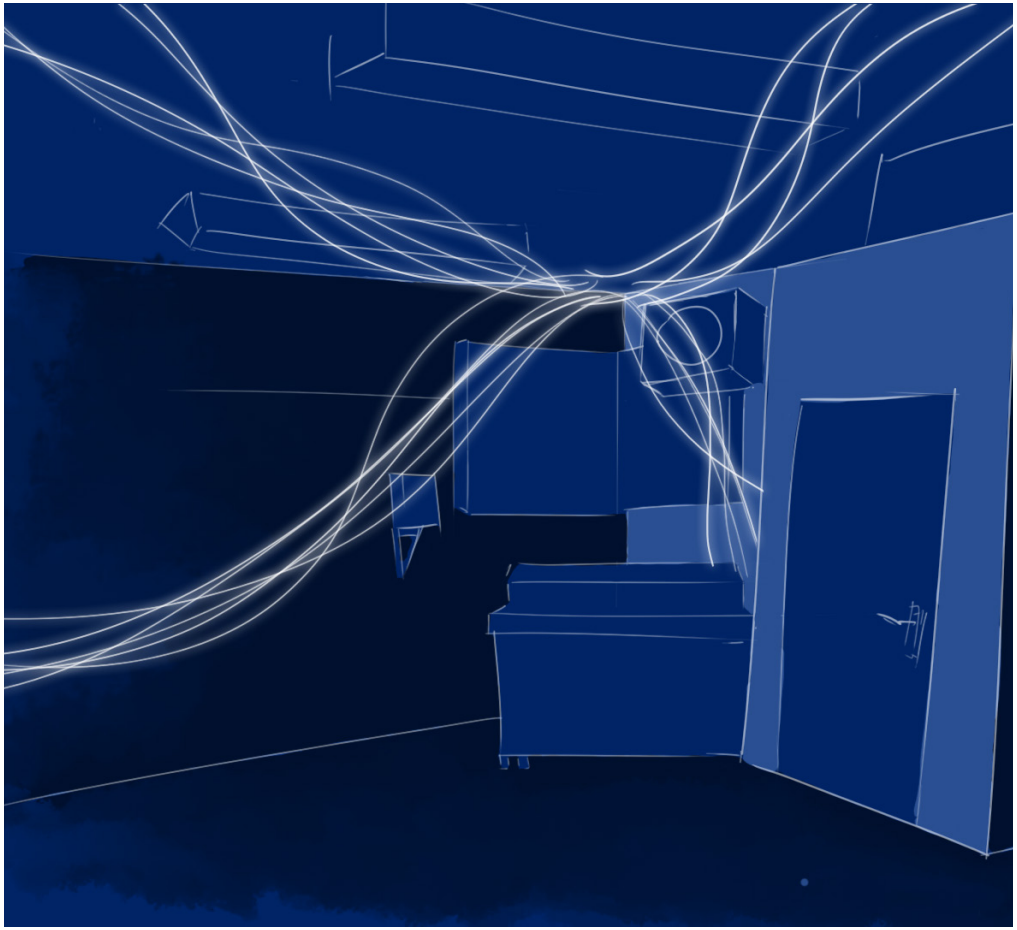
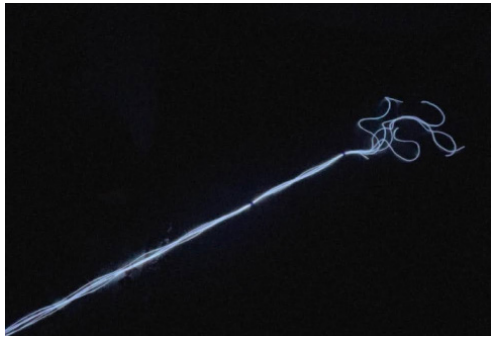


Figure 52
Form experiment: Forks

(a) Angular

(b) Curved

Figure 53
Form experiment: Forks



(a) Straight Arm

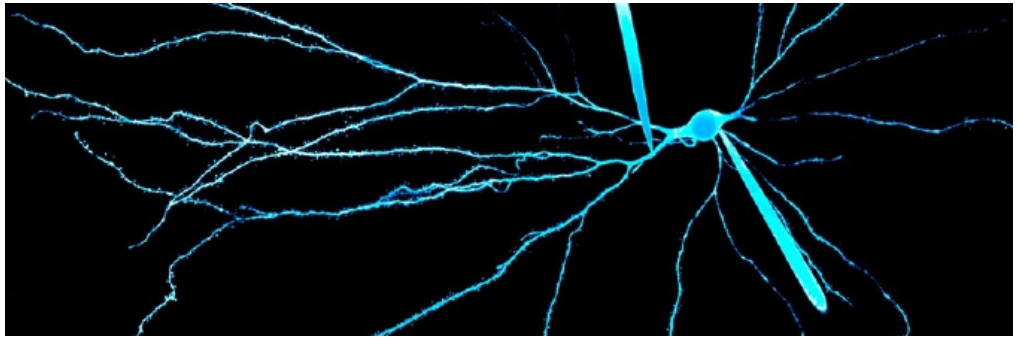
(b) Irregular Arm

of the installation. The arms light up when triggered by music, much like how neurons fire when triggered by a stimulus. Additionally, since the installation explores multisensory perception, an aesthetic inspired by the brain seems fitting. An example of dendrites can be seen in Figure 54.
The final design, shown in Figure 55, incorporates insights from previous iterations and takes inspiration from these dendritic structures. Additionally, it meets the form-related design requirements:

1. It enables visual cues distributed throughout the space.
2. It works within the constraints of the exhibition space.
3. It is not overly complex.

The design also successfully embodies the intended interaction qualities. The all-encompassing arms create both a welcoming and intimate atmosphere, surrounding visitors with light from all directions. The organic form introduces a sense of unfamiliarity and "aliveness." Several additional elements from the interaction vision are also present: the dynamic form evokes the movement of butterflies in a butterfly house, the organic shapes resemble the curves of plants and flowers, and the overall multisensory, immersive experience aligns with the essence of a butterfly house.

Figure 54
Dendrites



Note. Visualisation of Dendrites (Beaulieu-Laroche & Harnett, 2018).

Figure 55
Final Design Sketch

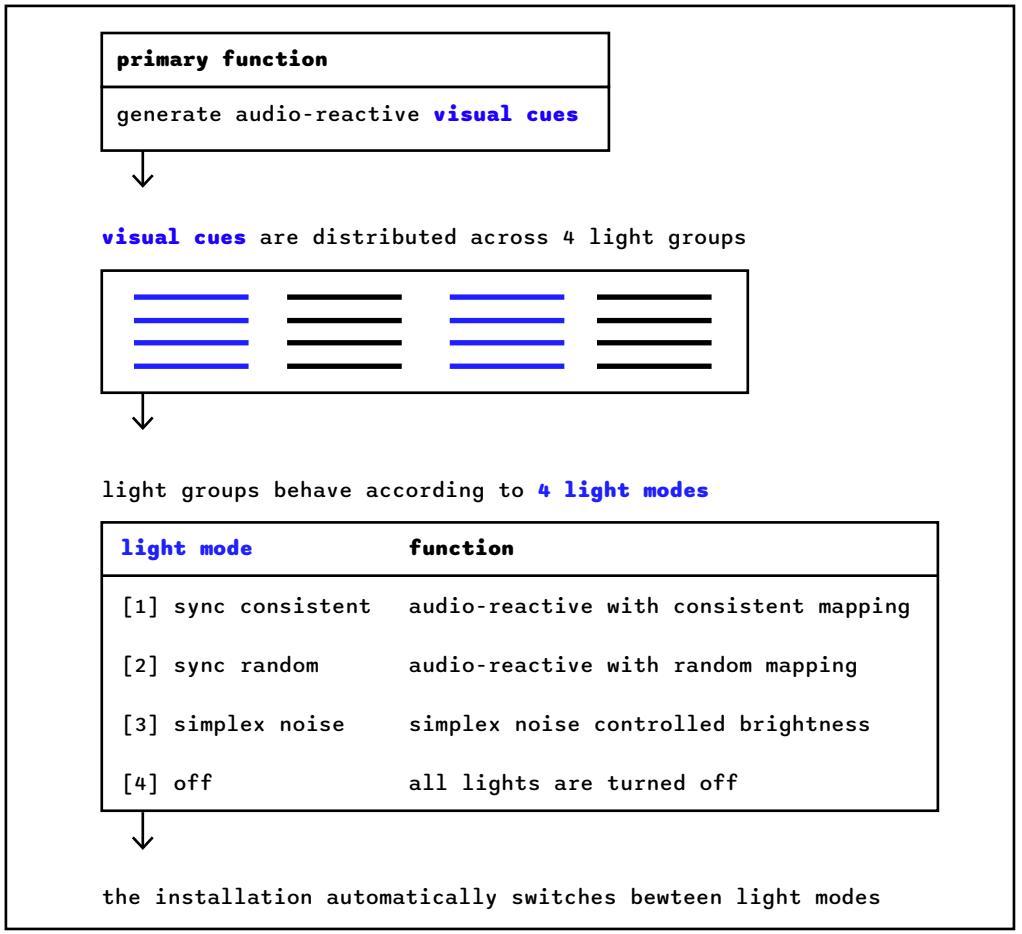
2.6 function development

Having determined the form, the focus could shift to the details of the functionality. This chapter discusses the development of both the hardware and software needed to achieve this functionality. But first, a brief explanation is given about what this functionality entails.

2.6.1 Functionality Overview

The general function of this installation is to generate synchronised, audio-reactive visual cues. As determined during the form iterations, these cues are created by EL wire and are distributed across 4 distinct light groups. To align with the interaction vision, the installation needs to incorporate a dynamic range of light animation modes, and switching between these modes needs to occur automatically. To assess the effect of consistent mapping on binding, two audio-reactive modes are needed: one with consistency and one without. To create contrast with the audio-reactive modes, non-reactive modes are needed as well. Two were developed: one controlled by Simplex noise, and one where all the lights were off. Finally, loudness-brightness correspondence is included in the design by relating the loudness of auditory cues to the brightness of the different light groups. An overview of the functionality is provided in Figure 56.

Figure 56
Overview of Modes



2.6.2 Hardware

To facilitate the functionality described above, a system consisting of custom hardware and software needed to be developed. The primary objective of the system is to convert audio signals from the DJ mixer into triggers for the light groups. The following solution was implemented:

1. The audio from the DJ is digitally analysed using Max/MSP on a PC, which receives the input through an audio interface.

2. This analysis generates triggers for the audio-reactive modes, which are sent to a microcontroller.

3. The microcontroller, which also manages the simplex noise and off modes, controls the light groups using MOSFETs (controllable switches).

4. DC inverters are used to power the EL wire, as it requires AC power.

A comprehensive diagram of the electronics system is provided in Figure 57.

Figure 57
AV Diagram

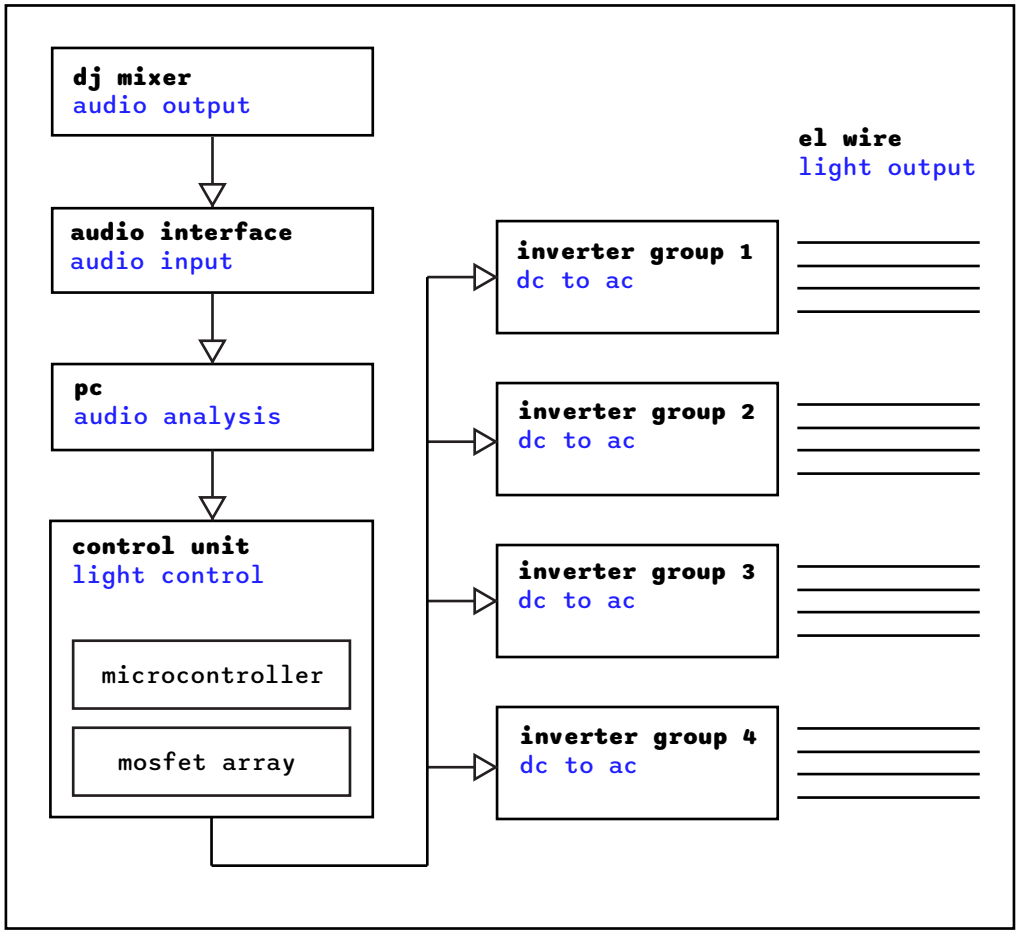


Table 2
Hardware Components / Cost Overview

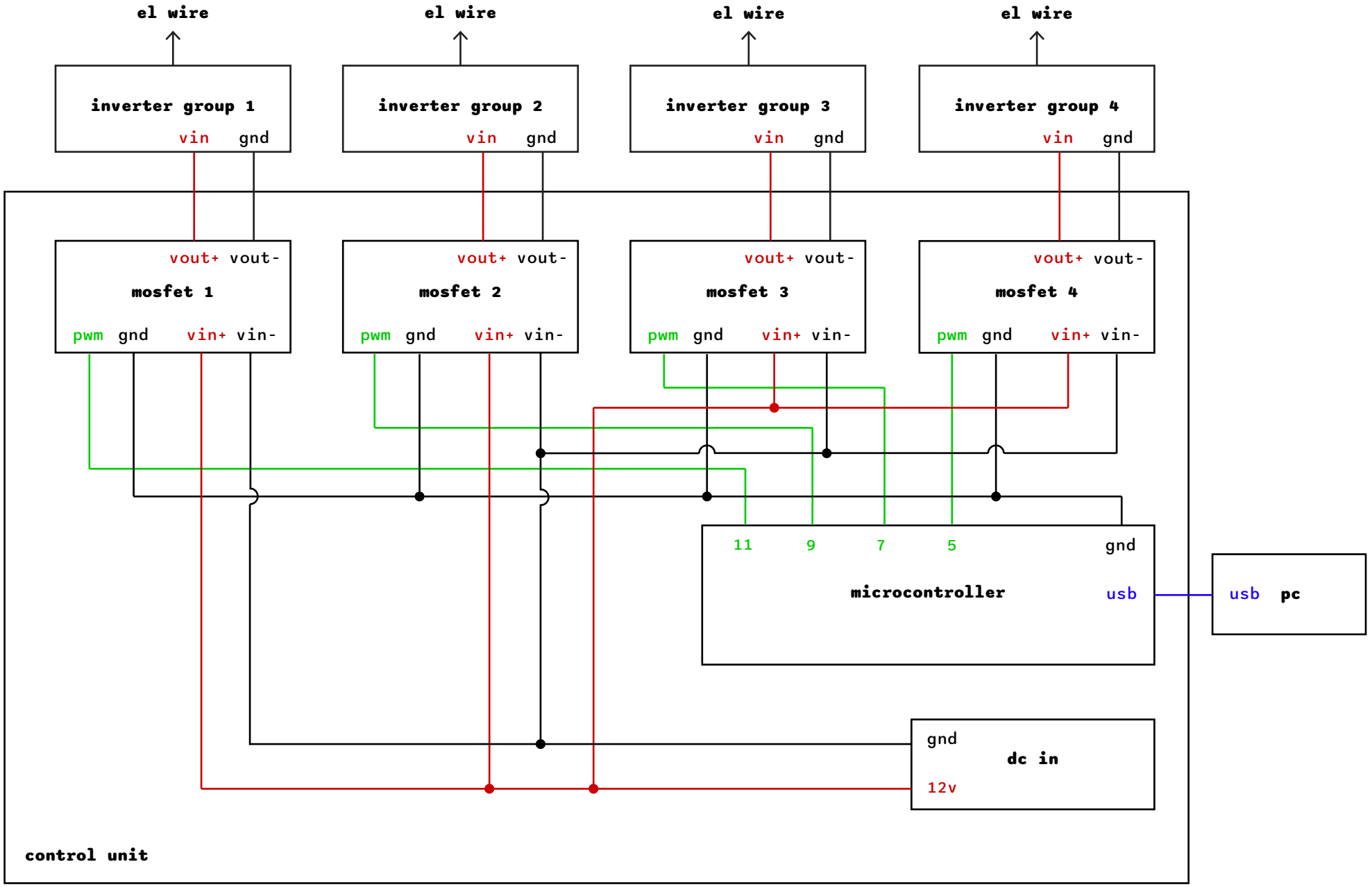
component	quantity	total cost (excl. BTW)
el-wire	48 units	€ 210.14
12v dc inverter	48 units	n/a
insulated dual-core wire	30 meters	€ 36.27
n-channel mosfet	4 units	€ 4.30
power supply (12v 20a)	1 unit	€ 66.07
teensy 4.0 microcontroller	1 unit	€ 23.55
usb a to micro-usb cable	1 unit	€ 2.27
12v dc connector	4 units	€ 3.63
perforated board	1 unit	€ 0.46
audio interface (focusrite 2i2)	1 unit	n/a
pc (dell)	1 unit	n/a
	total:	**€ 346.69**

The hardware components required to build this system, along with their costs, are depicted in Table 2. The Teensy 4.0 microcontroller was selected for its affordability and high clock speed (600 MHz), ensuring faster processing and more reliable control of the lights.

Electronics Configuration

Since each light group needs to be controlled separately, 4 MOSFET modules were required in total. Each MOSFET controls multiple DC inverters, with each inverter powering a single EL wire. Before assembly, the wiring was mapped out in a diagram, as shown in Figure 58. Power from the DC input is split across 4 MOSFETs. PWM and ground signals are connected to the microcontroller's data and ground pins, allowing the microcontroller to control the MOSFETs. Each MOSFET output connects to an inverter group, with the inverters connected to multiple EL wires.

Figure 58
Diagram Full Electronics Configuration



Electronics Housing

The electronics were housed in a 3D-printed enclosure, designed with screw mounting points for the MOSFETs and microcontroller. The DC input connector was friction-fit into a custom mount, and female DC connectors were used to allow easy connection and disconnection of inverter groups. The enclosure design is shown in Figures 59–61.

Figure 59
Electronics Housing (Open, Axonometric View)

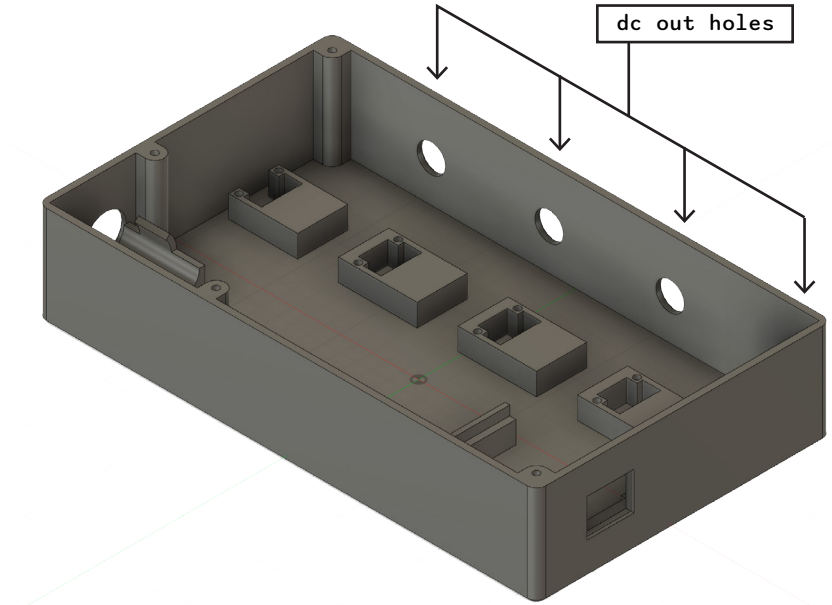


Figure 60
Electronics Housing (Closed, Axonometric View)

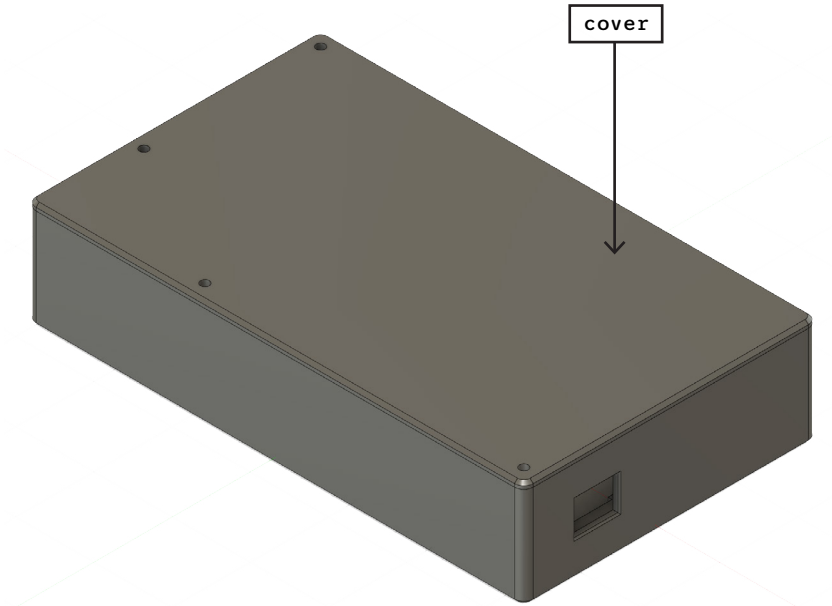
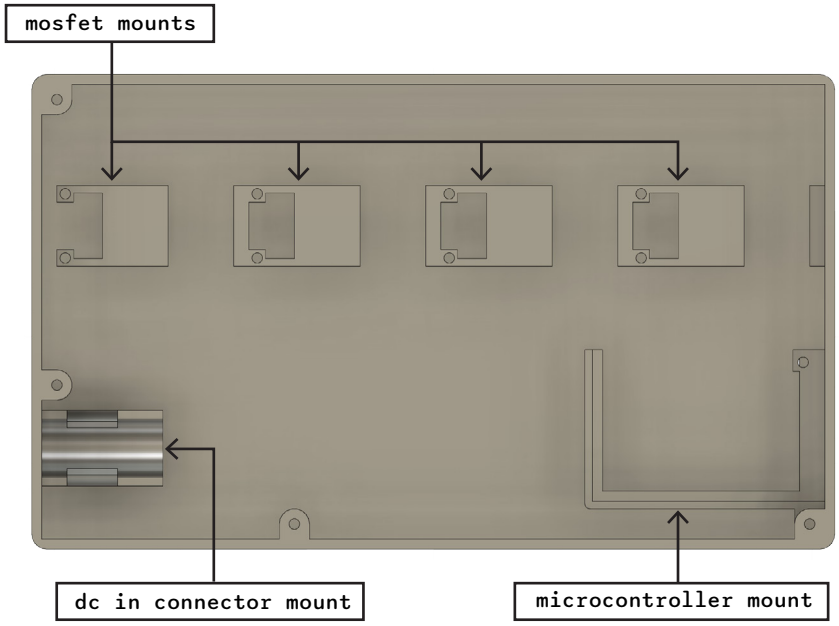


Figure 61
Electronics Housing (Open, Top View)



Assembly and Wiring

After 3D-printing the housing, all the components were assembled. A perforated board was used to create solder connections between the microcontroller and the MOSFETs. Additional connections were made according to the diagram depicted in Figure X. The fully assembled electronics box is shown in Figure 62.

Figure 62
Electronics Housing (Open, Top View)

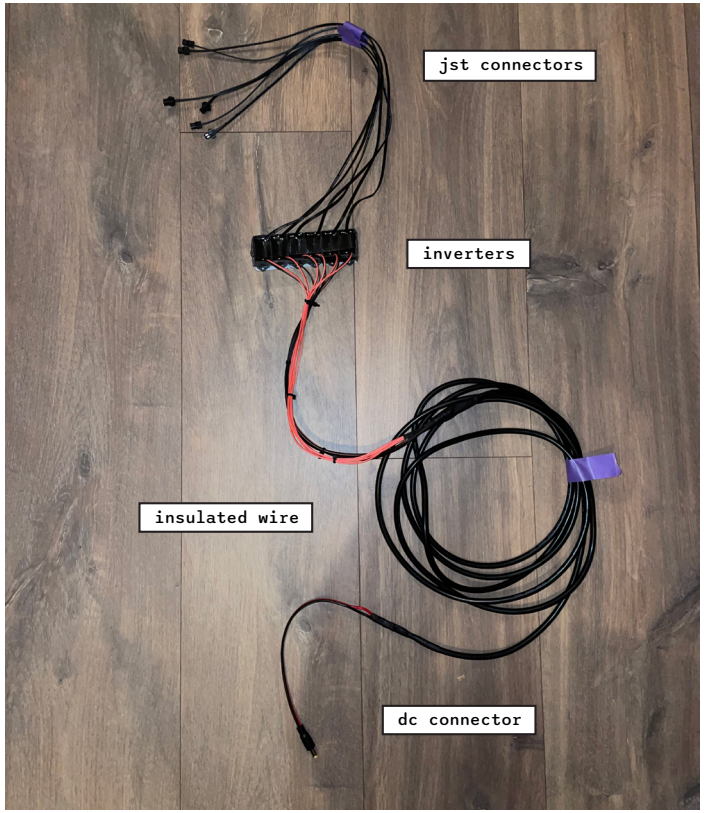
(a) Open

(b) Closed

Inverter Groups

As mentioned above, each MOSFET was connected to a group of inverters, which powered a corresponding set of EL wires. To achieve this, 12 inverters were soldered together and connected to a single 5-meter insulated dual-core cable. A male DC power connector was attached to the opposite end of the cable, allowing the inverter groups to be plugged into the electronics box. A completed inverter group is shown in Figure 63.

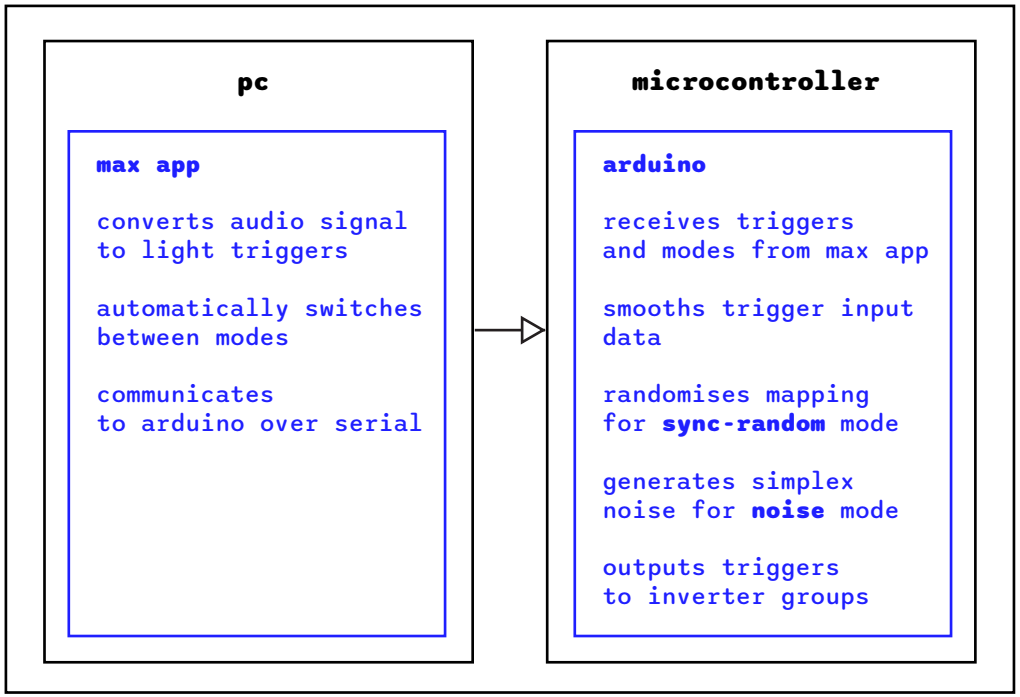
Figure 63
Finished Inverter Group



2.6.2 Software

Alongside the electronics, the software was developed using Max/MSP for audio analysis, following the conclusions outlined in Chapter 2.3. Triggers generated by Max/MSP were sent to a microcontroller running Arduino code, which controlled the light groups. Figure 64 describes the division of tasks between the microcontroller and the PC.

Figure 64
Software Division of Tasks



Max/MSP

To implement the audio-reactive modes, the audio signal is segmented into 4 frequency bands (see Figure 66) corresponding to key instrument groups in electronic dance music: bass, drums, vocals and melodic content, and cymbals and noise. This was achieved using band-pass filters applied at specific

frequency ranges. The filter cutoff frequencies were adjustable within the software, allowing fine-tuning to optimise the effect.
Once filtered, the signals were routed through noise gates (see Figure 65), which functioned as thresholds. A signal only passed through if it exceeded a predefined threshold, effectively filtering out quieter sounds that were not intended to trigger the lights. The threshold level could be adjusted to control the number of light triggers, preventing excessive or insufficient activation.
Using this two-part approach, individual instruments could generate distinct visual cues. The analysis continuously generated 4 triggers, one for each frequency band. The mapping (either consistent or random) between these 4 triggers and the 4 light groups is handled by the microcontroller.
Instead of a binary on/off response, the output triggers are continuous values between 0 and 255, where louder sounds result in higher values. For example, a loud bass hit could produce a value near 250, while a softer sound just above the threshold might yield a value around 100. This output value is mapped to the brightness of the light group, enabling loudness-brightness correspondence.

Figure 65
Diagram Depicting Noise Gate

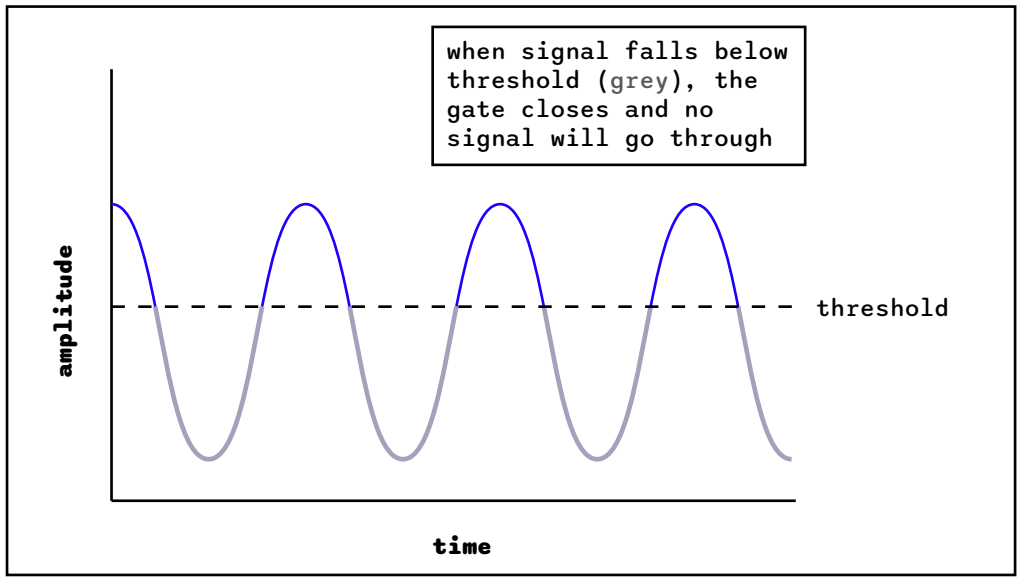
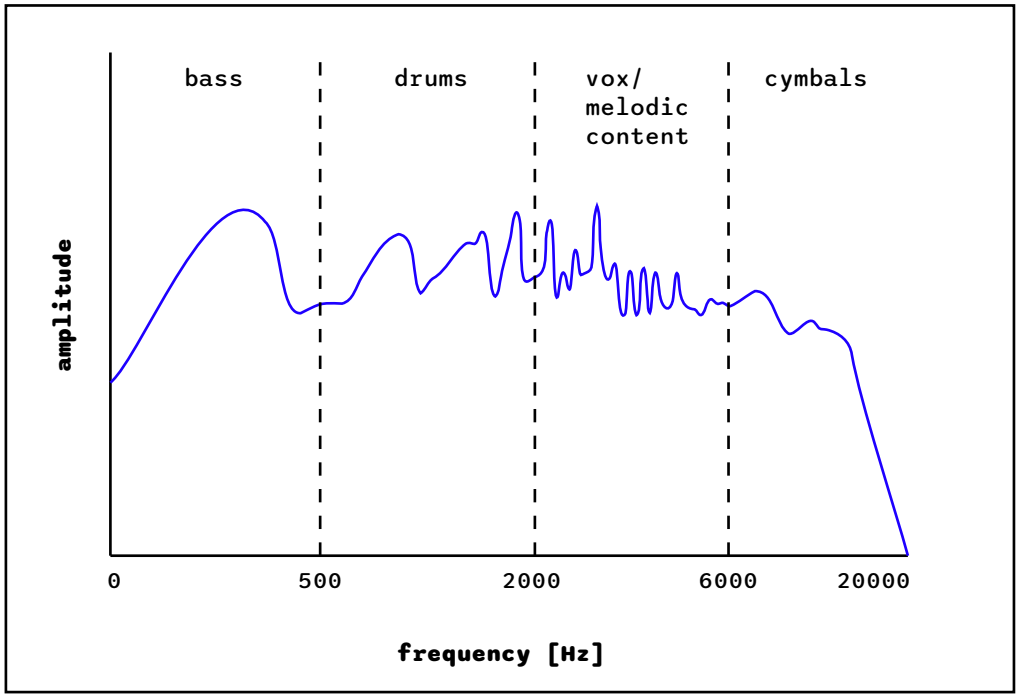


Figure 66
Diagram Depicting Division of Frequency Bands



Since the installation needed to run automatically throughout the whole event, an algorithm was developed to manage switching between modes as well. As discussed in Chapter 1.3, audience engagement can be increased when using audio-reactive modes for the “drops” of the music played, while reserving unsynchronised modes for the “breakdowns”. Since breakdowns typically feature reduced low-frequency content, a threshold is applied to the bass frequency band to determine the current musical section. If the low-frequency level drops below the threshold, the lighting system transitions to an unsynchronised mode; when bass levels rise again, it switches back to an audio-reactive mode.

The complete Max/MSP system is shown in Figure 67. A user interface and preset-saving system were included to improve usability. Figure 67 depicts the Max app in presentation mode, which hides internal connections to create a more user-friendly interface. Detailed patches and subpatches illustrating signal routing and processing are provided in Appendix E.

Figure 67
Max App (Presentation Mode)

Note. Audio input (left), four frequency bands (top), four gates (bottom), presets & serial communication (right).

Arduino

An overview of the tasks performed by the microcontroller is given in Figure 64. For the *sync consistent* mode, triggers from the same frequency bands always trigger the same light group. For the *sync random* mode, mapping is randomised at a random time interval. To reduce flickering in the lights, a custom smoothing algorithm was implemented, as standard smoothing functions introduced a delay when controlling EL wire. The algorithm operates similarly to a leaking bucket that is intermittently refilled. Here, the "bucket" represents the brightness value (ranging from 0 to 255) assigned to the EL wire. This value continuously decreases over time, ensuring a gradual fade-out effect. When the microcontroller receives a new trigger from Max/MSP, the corresponding brightness value is added to the existing level, allowing for immediate updates while maintaining smooth transitions. This algorithm preserves responsiveness while preventing flickering. The full Arduino code, with detailed comments, is available in Appendix F.

Chapter Summary
This chapter described the development of the hardware and software required to make the installation work. This included custom 3D-printed electronics housing, a Max/MSP app for audio-reactivity and Arduino code that implements a custom smoothing algorithm for the lights.

2.7 final exhibition

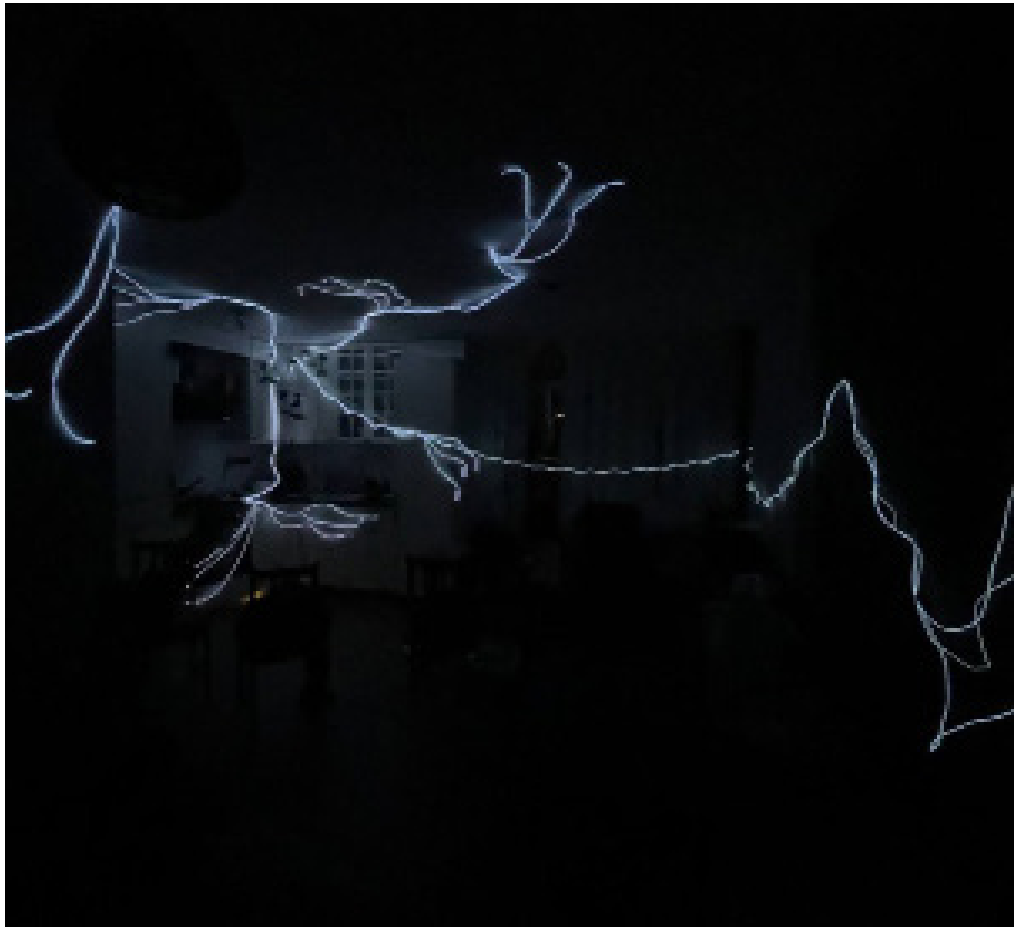
2.7.1 Integrated Prototype

Once the form was designed and all the components for the installation were developed, an integrated prototype test was conducted before installing the lights in the exhibition space. This step was crucial to fully judge the form and ensure that everything functioned as intended. The EL wire was set up in a manner similar to the final installation. After connecting all the electronics, the system was tested thoroughly with music similar to what would be played at the event. After making a few minor tweaks to the software, the installation performed excellently. The form looked even better in real life than in the sketches. Standing beneath it felt truly immersive. The arms reached out in all directions, creating a sense of being fully surrounded.

Videos were made of the three tested modes:

1. Synchronised Consistent
2. Synchronised Random
3. Simplex Noise

Figure 68
Integrated Prototype Test



2.7.2 Installation

The installation was carried out the day before the event and required approximately 10 hours to complete. All equipment was transported to the nightclub by taxi, and upon arrival, the installation process commenced following the unpacking of materials. To facilitate assembly, all light and inverter groups were colour-coded for easy matching (see Figure 68).
The inverter groups were first installed near the ceiling above the DJ booth (see Figure 69), serving as the central point where all light groups converged. The inverters were then connected to the electronics housing and PC to verify functionality. Once confirmed, the lighting remained on to aid in shaping the installation. The light groups were then attached to the walls and ceiling according to the layout depicted in Chapter 2.5, using custom 3D-printed cable guides and double-sided adhesive pads (see Figure 70). This attachment method had been tested beforehand to ensure stability throughout the event. The benefit of this method is that it did not require drilling in the walls, which was determined to be difficult during the site visit. Following the installation of all the EL wire, the overall form was assessed, and minor adjustments were made. Finally, the system's functionality was tested using the club's DJ equipment. Upon confirming that all elements operated as intended, the installation was finalised and ready for the event.

Figure 69
Color Coded Lights and Inverter Groups

Figure 70
Installation of Inverter Groups

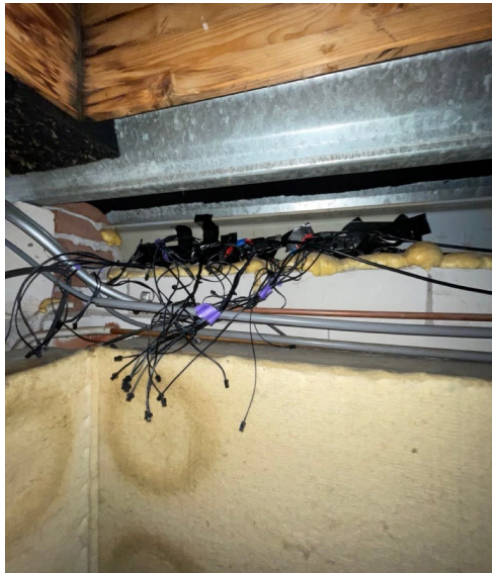
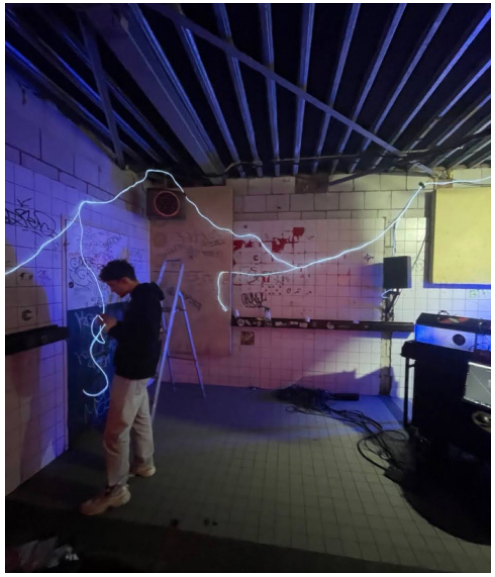


Figure 71
3D-printed Cable Guides

Figure 72
Installation in Progress



2.7.3 Exhibition

After installation, the design was prepared for the exhibition. Evaluation took place before and during the exhibition and is discussed in the following chapters. The event, a club night hosted by the Los Angeles collective, ran from 23:30 on Saturday, 15 February, to 00:00 on Sunday, 16 February. The room containing the installation was open from 02:00 to 20:00 on Sunday, during which the installation operated continuously. Several DJs performed throughout this period, and on Sunday evening, live performances featuring vocalists took place. As a result, the installation was active alongside a diverse range of musical genres. The event proceeded with minimal issues. The only technical difficulty involved occasional freezing of the audio input, which was resolved by remotely accessing the PC running the installation and restarting the software. Figures 72-76 (see following pages) present images of the final installation, while videos showcasing the final installation are accessible via the following links.

1. Demo in Exhibition Space Before Event

2. Demo in Exhibition Space During Event

3. Showcase Video

Figure 73
Final Installation 1/4

Figure 74
Final Installation 2/4

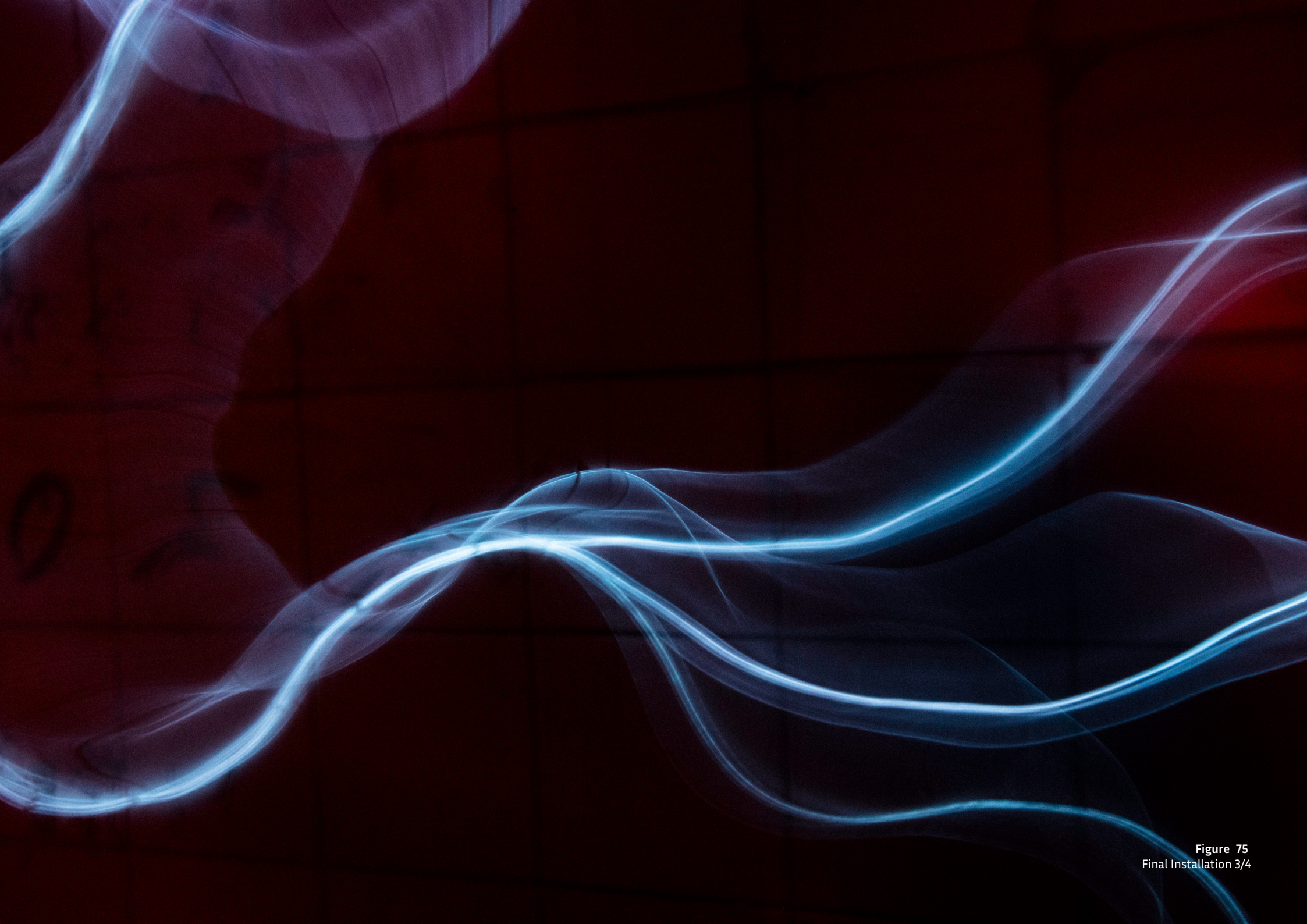


Figure 75
Final Installation 3/4

Figure 76
Final Installation 4/4

phase 3: evaluation

During this phase, the final design was evaluated during a weekend-long club event. Results from this evaluation led to the formulation of recommendations and guidelines for multisensory design in the nightclub.

3.1 evaluation plan

To address the research questions and assess whether the objectives outlined in Chapter 2.1 were achieved, a three-part evaluation plan was developed.
First, a controlled user test was conducted in the nightclub prior to the event to examine the presence of the ventriloquism effect, the importance of consistent mapping between auditory and visual cues and to assess audience immersion. This test also contributed to evaluating the presence of the intended interaction qualities. Both qualitative and quantitative data were collected during this phase.

To supplement the user test with additional qualitative insights, 4 follow-up interviews were conducted with participants in the week following the event. This approach provided further context on how the ventriloquism illusion was perceived and the extent to which the audience felt immersed.
A key challenge of the controlled user test was that its conditions did not fully replicate those of an actual club night. In a typical club setting, the venue is crowded, and attendees engage in dynamic activities such as dancing and social interaction. To address this limitation, an additional questionnaire was distributed to 15 attendees during the club night itself. This questionnaire further investigated audience immersion, interaction qualities, and overall impressions of the experience.

Finally, findings from all three evaluation methods were synthesised to draw general conclusions regarding the effectiveness of the design. As this is a research-through-design project, insights from the design process were incorporated as well. These conclusions informed the formulation of recommendations and design guidelines for multisensory design in nightclub environments.

3.2 user test

The user test was conducted on the day of the event in the same space where the event would occur. As stated in the evaluation plan, the goal was to answer both research questions and to evaluate the interaction qualities. Both quantitative and qualitative data was gathered during this evaluation activity.

3.2.1 Method

Two groups of participants were exposed to three audiovisual conditions, one for three of the light modes discussed in Chapter 2.6. The simplex noise mode acted as the control condition, with no audio-reactivity, while the other two were audio-reactive and served to measure the differences between consistent and randomised mapping of visual cues. After each condition, participants were asked to rate their experience based on immersion and the perceived localisation of sounds. If ventriloquism is present, this perceived localisation is hypothesised to be more spatially specific, as auditory cues are bound to distributed visual cues within the space. Participants were also asked to rate each condition based on the interaction qualities. After exposure to all conditions, qualitative data was gathered concerning the installation as a whole. A detailed explanation of the stimuli and conditions as well as the exact procedure is given below.

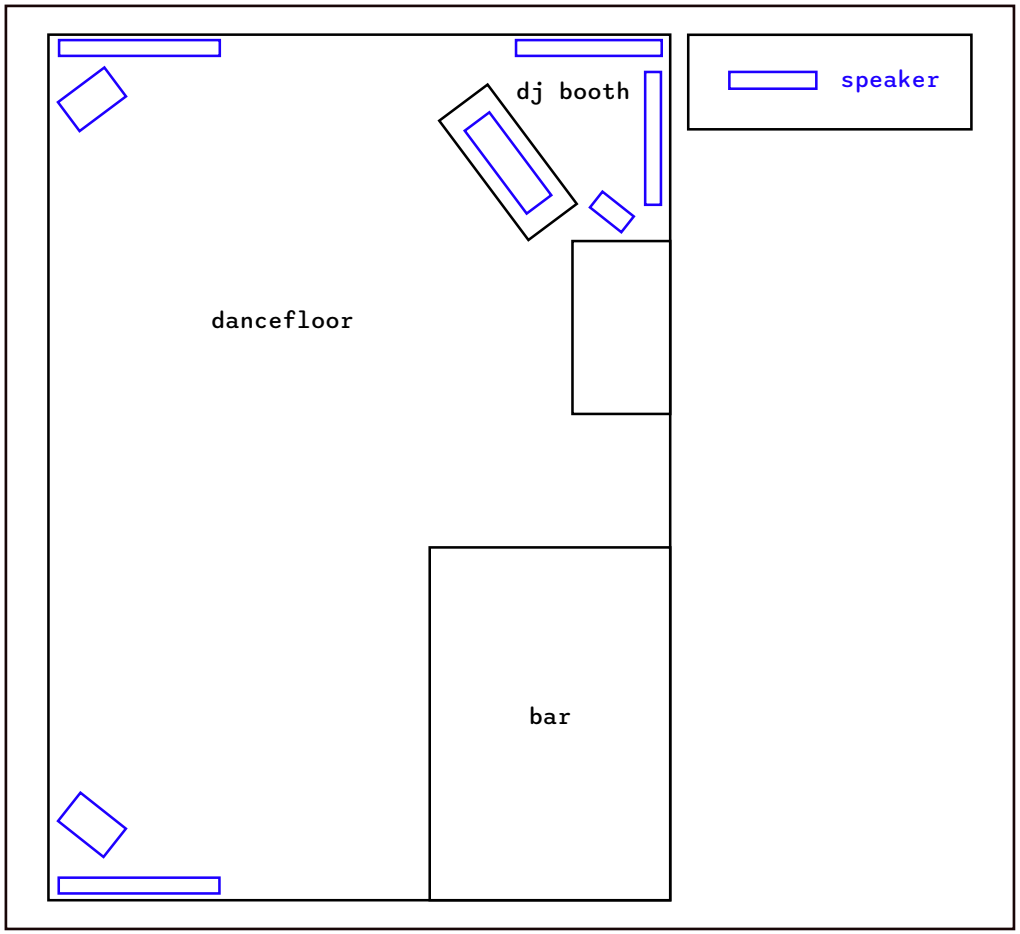
Participants

Thirteen participants took part in the test, with 6 in group 1 and 7 in group 2.

Stimuli & Conditions

Visual stimuli were provided by the designed installation, while auditory stimuli consisted of the same EDM track for all conditions: "Big Up The Ladies" by Fracture (2019). The track was played on the custom club sound system in the room, with speaker placements shown in Figure 77.

Figure 77
Speaker Placement



Three conditions were tested: two experimental and one control. All conditions were bimodal, consisting of audiovisual pairs. Condition A involved synchronised visual stimuli that were consistently mapped to the same light groups (*sync consistent* mode). Condition B involved visual stimuli with randomised mapping to the light groups (*sync random* mode). Condition C, the control, featured visual stimuli controlled by noise (*simplex noise* mode). Differences between Condition A and B would indicate an effect of consistent mapping on perceived localisation and immersion.

Table 3
Overview of Conditions

condition	visual stimulus	auditory stimulus
A	sync consistent	“Big Up The Ladies” by Fracture
B	sync random	“Big Up The Ladies” by Fracture
C	simplex noise	“Big Up The Ladies” by Fracture

Procedure

Participants were divided into two groups (group 1: 6 participants; group 2: 7 participants). Each group entered the exhibition space separately and participated in a distinct test session. Before testing, both groups briefly experienced all conditions to ensure they were familiar with the setup and could accurately rate their experiences. Each test consisted of exposure to stimuli pairs from all conditions, with participants completing Questionnaire 1 after each condition. Upon completing the test, participants filled out Questionnaire 2, resulting in a total of 4 questionnaires per participant. Both questionnaires are depicted in Table 4. Participants were free to move around the room and interact naturally, similar to a club environment, though they were instructed not to discuss their experiences during the test. Exposure to each condition lasted for two minutes, and the order of conditions was randomised between groups.

Table 4
Questionnaires

questionnaire 1	questionnaire 2
please rate your sense of immersion during this light mode. [10 point scale]	did you notice differences in immersion between the different light modes? please explain why.
please rate the perceived localisation of the audio (i.e. where the sounds come from) during this light mode. [10 point scale]	did you notice differences in perceived localisation of the audio between the different conditions? lease explain why.
please rate the following statement: I found this installation “intimate”. [Likert scale]	
please rate the following statement: I found this installation “unfamiliar”. [Likert scale]	
please rate the following statement: I found this installation “wecloming”. [Likert scale]	

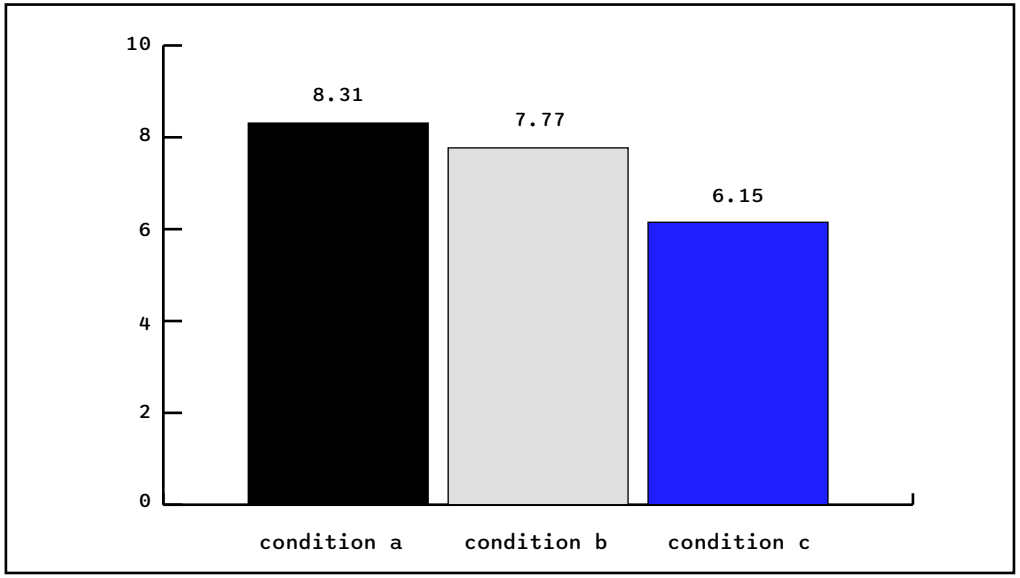
3.2.2 Results

This section summarises the results of the user test, both quantitative and qualitative. Raw data can be found in Appendix G.

Quantitative Results: Questionnaire 1

Results from Questionnaire 1, conducted after each condition (three times per participant), were all quantitative in nature. The mean immersion scores (on a scale from 0 to 10) for each condition are presented in Figure 78. A one-way ANOVA revealed a statistically significant difference between the three conditions ($p < 0.05$). Post-hoc T-tests, adjusted using a Bonferroni correction ($p < 0.0167$), indicated statistical significance only between Condition A and Condition C ($p = 0.014$). No significant differences were found between Condition A and Condition B ($p = 0.37$) or between Condition B and Condition C ($p = 0.058$). Effect size analysis, using Cohen’s d, revealed a small effect size of 0.36 for the comparison between Condition A and Condition B, a large effect size of 1.05 for Condition A and Condition C, and a moderate effect size of 0.79 for

Figure 78
Mean Immersion Scores



Condition B and Condition C.
The mean perceived localisation scores (also on a 0-10 scale) for each condition are presented in Figure 79. A one-way ANOVA revealed a statistically significant difference between conditions ($p < 0.05$). However, after applying the Bonferroni correction ($p < 0.0167$), post-hoc T-tests revealed that none of the comparisons reached statistical significance. The p-values for the comparisons were as follows: Condition A vs. Condition B ($p = 0.71$), Condition A vs. Condition C ($p = 0.028$), and Condition B vs. Condition C ($p = 0.055$). Effect size analysis revealed a small effect size of 0.14 for Condition A and Condition B, a large effect size of 0.94 for Condition A and Condition C, and a moderate to large effect size of 0.80 for Condition B and Condition C.

The interaction qualities were assessed in Questionnaire 1 using a 5-point Likert scale (strongly disagree, disagree, neutral, agree, strongly agree). Responses were quantified by assigning numerical values from 1 to 5, with 1 representing strongly disagree. The mean ratings for each interaction quality across all conditions are shown in Figure 80. A one-way ANOVA found no statistically significant differences between conditions for any interaction quality ($p > 0.05$), suggesting that the ratings were consistent across conditions. However, when comparing interaction qualities irrespective of condition, a separate ANOVA revealed a statistically significant difference ($p < 0.001$). Post-hoc t-tests indicated that both *intimate* vs. *unfamiliar* and *welcoming* vs. *unfamiliar* comparisons were statistically significant ($p < 0.0167$, Bonferroni-corrected),

Figure 79
Mean Perceived Localisation Scores

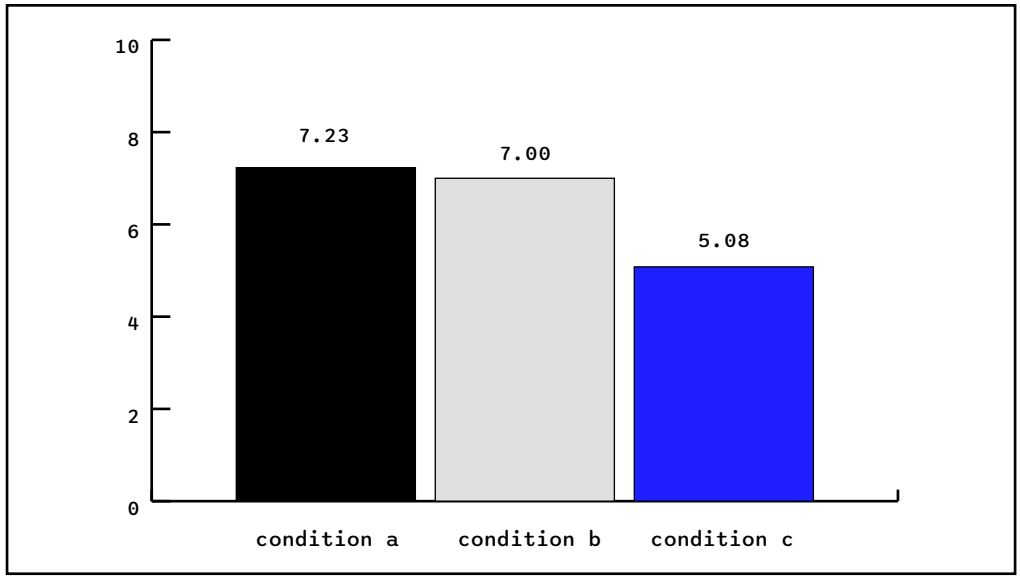
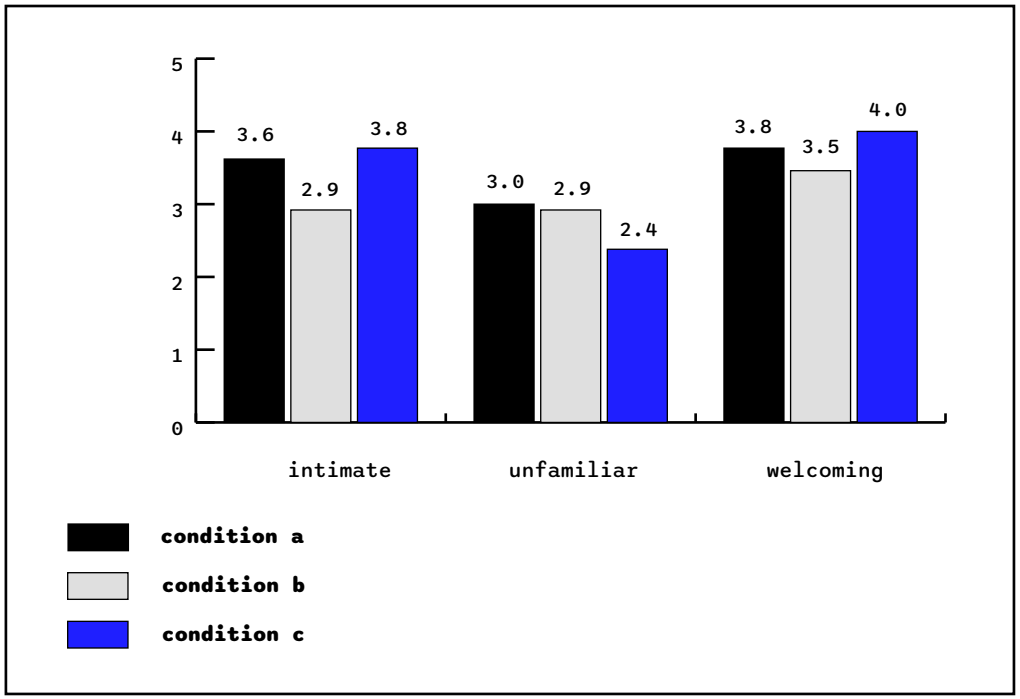
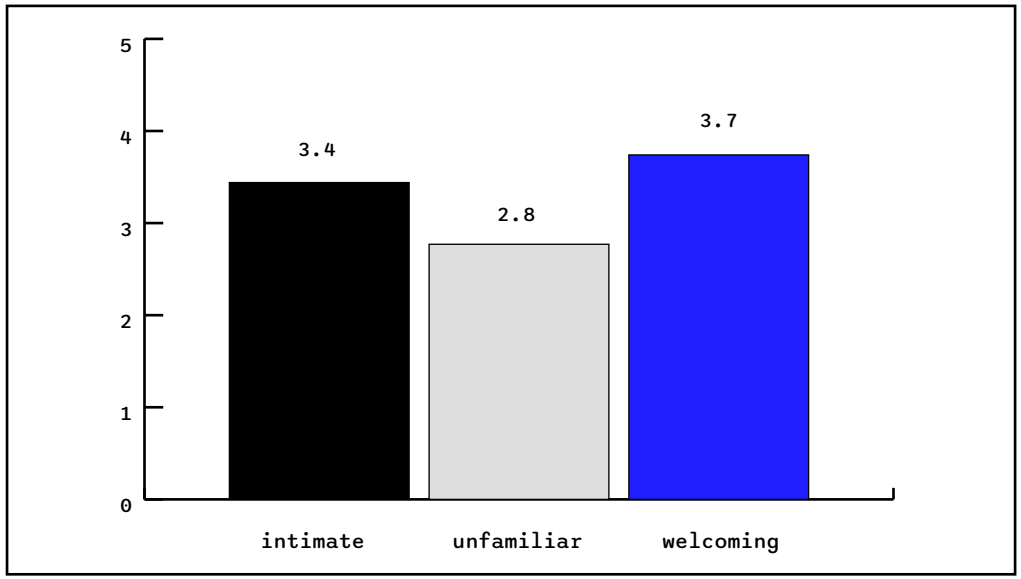


Figure 80
Mean Interaction Quality Ratings (Per Condition)



while *intimate* vs. *welcoming* did not show a significant difference (p = 0.192). The mean quality ratings irrespective of condition can be found in Figure 81. The *intimate* quality was rated 3.4, the *welcoming* quality received a higher rating of 3.7, and the *unfamiliar* quality was rated 2.8. These findings suggest that the experience was perceived as more welcoming and intimate than unfamiliar.

Figure 81
Mean Interaction Quality Ratings (Combined)



Qualitative Results: Questionnaire 2
Questionnaire 2, conducted after exposure to all conditions, collected qualitative data on participants' experiences of immersion and perceived localisation of auditory cues.

All participants reported differences in immersion between conditions, though their preferences varied. Some appreciated the calmness of Condition C, while others preferred the intensity of the audio-reactive conditions. The majority found the audio-reactive conditions more immersive, particularly Condition A. One participant noted: "The difference in immersion was caused most of all by the alignment between certain parts of the light display and specific musical cues. As a side effect, this drew my attention to different parts of the space." Experiences of localisation were mixed. While most participants did not strongly associate the audio with specific locations, some did report a spatial connection between sound and light. One participant described: "Mostly when the kick lined up with the long arm gripping around me, it felt like the sound was also filling the room more." Another reported an increased sense of localisation over time: "In the third round, I stopped thinking and could actually feel and hear the audio coming from different places." This suggests that ventriloquism may strengthen with extended exposure.
Participants also shared additional insights. One noted that the contrast between light modes could mirror the contrast between sections in music. This was, to some extent, implemented during the event. Additionally, one participant commented on the form of the installation, stating that attaching the organically shaped EL wire to the grid of bathroom tiles grounded the installation within the physical space, enhancing immersion.

3.2.3 Discussion
The results indicate that immersion varied significantly between conditions, with Condition A receiving the highest mean score (8.3), followed by Condition B (7.8) and Condition C (6.2). The significant difference found between Condition A and Condition C suggests that audio-reactive lighting enhanced immersion compared to the Simplex noise-controlled lighting. However, the lack of a significant difference between Conditions A and B in the quantitative results suggests that variations in audio reactivity did not substantially impact immersion levels. The effect size analysis supports this interpretation, with a large effect (d = 1.05) between Conditions A and C and only a small effect (d = 0.36) between Conditions A and B. These findings align with qualitative responses, where most participants found audio-reactive conditions more immersive, particularly Condition A.
Perceived localisation followed a similar trend, with Condition A again receiving the highest mean score (7.23), followed closely by Condition B (7.00), while Condition C had a substantially lower mean score (5.08). Although ANOVA indicated a significant difference, none of the post-hoc comparisons survived

Bonferroni correction. However, effect size analysis suggests meaningful differences, with a large effect size (d = 0.94) between Conditions A and C and a moderate to large effect size (d = 0.80) between Conditions B and C. Qualitative responses provide further insight, with some participants reporting that synchronisation between light and sound positively affected how they experienced the music. Additionally, one participant noted increased audiovisual binding over time, suggesting that prolonged exposure could strengthen the effect.

While a definitive conclusion on the presence of the ventriloquism effect is difficult, quantitative results do suggest (though not statistically significant) that spatial specificity of auditory cues was higher in audio-reactive modes. Perceived differences between Condition A and B were small during this test, providing no evidence that consistent mapping affects localisation or immersion. The results strongly indicate that the light installation positively influenced immersion, with audio-reactive light modes resulting in significantly higher immersion compared to non-audio-reactive modes.

Interaction quality ratings showed no significant differences between conditions, indicating that the perceived interaction qualities were stable regardless of light mode. However, when comparing qualities irrespective of condition, the experience was generally rated as more welcoming (M = 3.74) and intimate (M = 3.44) than unfamiliar (M = 2.77). These results indicate that the installation was positively received as welcoming and intimate, while participants found it less unfamiliar. This means that in this user test, 2 out of 3 interaction qualities were satisfied.

Chapter Summary

This chapter described the user test that evaluated the final design. It indicated statistically significant higher levels of immersion during audio-reactive light modes. Ventriloquism also seemed to be present, although the effect was not statistically significant.

3.3 user test interviews

In addition to the user test, follow-up interviews were conducted with user test participants in the week following the exhibition, to collect further qualitative data to supplement the results from the user test.

3.3.1 Method

Participants

4 participants were interviewed.

Procedure

The following interview questions were used as a guideline for the interview process. Interviews were conducted and transcribed using Microsoft Teams.

Questions

1. What were your general impressions of the installation?
2. Did you experience the sound differently because of the lights?
3. Do you think the light installation affected your sense of immersion?
4. Did you notice a difference in experience between different light modes?

3.3.2 Results: Participant 1

Participant 1 responded positively to the installation's form, describing it as unconventional and surprising. They noted that the softness of the lighting, and the organic shape contributed to a warmer, more intimate atmosphere. The spatial configuration, with lights positioned on the walls and ceiling, enhanced their immersion, further aided by the presence of smoke. They preferred the audio-reactive modes over the noise mode, favouring Condition A, where the synchronisation of sound and light was most consistent. While they did not perceive the sounds as originating from the same location as the lights, they did experience strong audio-visual binding during Condition A.

3.3.3 Results: Participant 2

Participant 2 appreciated the small, intimate space, noting that the installation integrated well within it. They particularly enjoyed the nature-inspired form, describing the tree-like structures as reminiscent of fractals. They valued the variety of light modes, which introduced unpredictability and intrigue. During the audio-reactive modes, the lights captured their attention rather than the sound due to rapid movements. Nevertheless, they experienced the lights and sounds as a unified whole. Audio-reactive modes enhanced immersion, with Condition A reported to feel more natural, whereas Condition B was perceived to lack a clear pattern.

3.3.4 Results: Participant 3

Participant 3 appreciated the installation's unique form, particularly how the lights "wrapped around them". They also enjoyed the thinness of the EL wire, which appeared to glow in the smoke. Regarding audio-reactivity, they found Condition A to produce the strongest audiovisual binding, especially when the long "arm" of light spanning multiple walls aligned with the kick drum. Condition A corresponded more closely with musical cues than Condition B, making it more satisfying, while Condition B felt more ambiguous, leading to weaker binding. They noted that this dissonance in Condition B could serve as a contrast to the more consonant Condition A. They reported feeling most immersed during audio-reactive modes, stating that "everything clicked". Finally, they remarked that they had never encountered an audio-reactive light installation where visual and auditory cues aligned so clearly.

3.3.5 Results: Participant 4

Participant 4 highlighted how the spatial configuration of the installation enhanced immersion, with the distribution of lights making it clear which sound triggered each light. They preferred Condition A, stating that Condition

C felt disconnected from the music. Condition B seemed random at times, making it difficult to follow the pattern. During Condition A, the participant had a primarily sensory experience, which they found enjoyable and allowed them to disengage from their thoughts. They also observed that, at times, the sounds seemed to move slightly toward the light source. Finally, they mentioned that the audio-reactive modes made them eager to dance.

3.3.6 Discussion

Overall, the installation was well-received, with participants describing it as engaging and intriguing. The results highlight the importance of both audio-visual synchronisation and spatial configuration in creating immersion. Participants responded positively to the installation's unique form, appreciating the organic shape, which is uncommon in this context. The addition of smoke further enhanced the immersive experience.

In contrast to the user test results, interview participants expressed a preference for Condition A, indicating that consistent mapping between visual and auditory cues does influence the experience. Condition B was perceived as random or confusing. While no strong evidence of the ventriloquism effect was found in these interviews, one participant did note that the sounds seemed to move slightly towards the light sources. This effect may be improved with further refinement of the audio-reactivity.

Chapter Summary

This chapter described follow-up interviews with user-test participants. Findings confirm that the installation was engaging and immersive. They also indicate a strong preference for consistent mapping over randomised mapping of visual cues.

3.4 club night questionnaire

To understand how well the installation design achieves its goals in a realistic scenario, a questionnaire was completed by several attendees of the club night where the work was exhibited. The primary goal of this questionnaire was to assess the levels of audience immersion and the presence of the interaction qualities.

3.4.1 Method

15 event attendees completed the questionnaire. Participants were recruited both during the event and the days following the event. The questionnaire consisted of 9 questions and is depicted in Table 5.

3.4.2 Results

The questionnaire yielded both quantitative and qualitative results, which will be discussed separately in the following subsections. Raw data can be found in Appendix H.

Quantitative Results

Questions 2 and 4 assessed immersion in the exhibition space, both using a 0-10 scale. Question 2 results indicated a high sense of immersion in the event space, with a mean score of 8.5 (SD = 1.30). Question 4 results showed that the light installation specifically contributed to that immersion, with a mean score of 8.6 (SD = 1.24).

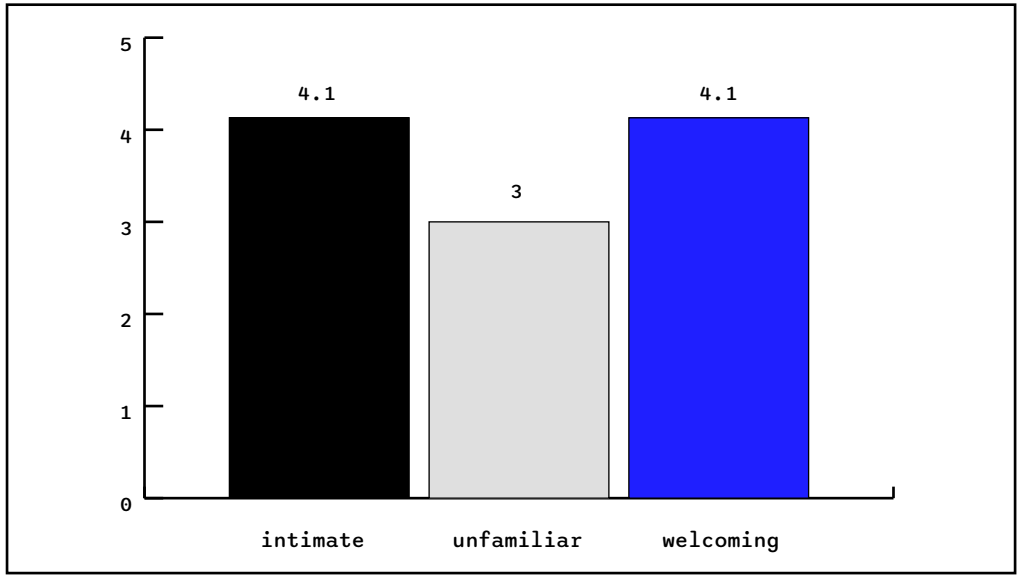
Questions 6, 7, and 8 examined interaction qualities using a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree). Mean ratings for each interaction quality are presented in Figure 82. A one-way ANOVA confirmed significant differences between interaction qualities ($p < 0.05$). Post-hoc t-tests revealed significant differences between the intimate-unfamiliar and welcoming-unfamiliar pairs ($p < 0.0167$, Bonferroni-corrected), but no significant difference

Table 5
Club Night Questionnaire

questionnaire
how often do you attend a nightclub?
how would you rate the sense of immersion you experienced in bar40 (room upstairs) during the Los Angles weekender compared to other club nights you have experienced? [10 point scale]
please explain why.
to what extent did the light installation in bar40 enhance the sense of immersion you experienced? [10 point scale]
please explain why.
rate the following statement: I found the audiovisual experience in bar40 intimate. [Likert scale]
rate the following statement: I found the audiovisual experience in bar40 welcoming. [Likert scale]
rate the following statement: I found the audiovisual experience in bar40 unfamiliar. [Likert scale]
did you notice something special or unique about the interplay between lights and music?

between intimate and welcoming, which had identical mean scores. These results suggest that participants experienced the installation as more intimate and welcoming than unfamiliar.

Figure 82
Mean Interaction Quality Ratings

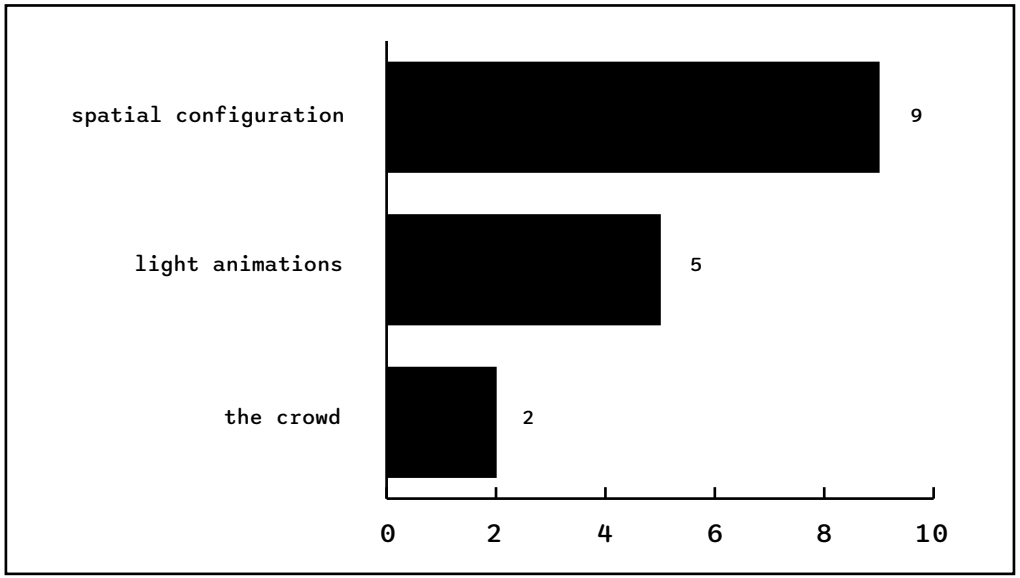


Qualitative Results
Questions 3 and 5 allowed respondents to elaborate on factors influencing their sense of immersion during the event. Three key contributing themes emerged from the responses:

1. The spatial configuration of the installation
2. The dynamic light modes
3. The dancing crowd

Mentions of these themes were quantified and are presented in Figure 83.

Figure 83
Factors Contributing To Immersion



The spatial configuration had the strongest impact on immersion, with multiple participants highlighting the unique form of the installation, particularly its arms extending across the walls and ceiling. One participant described the experience as: “The light installation made me feel as if I had stepped into a cocoon—a protected, intimate space.” Another participant noted how the installation integrated with the environment:

> The light installation had ‘tentacles’ all around the room, meaning the light was all around me (especially standing in the front). Compared to other light installations I’ve seen, this one felt more like part of the environment, rather than just being in the room.

The light modes were also frequently mentioned. One participant emphasised their engaging quality: “The light immediately drew my attention. The way in which it interacts with the sound makes it very captivating”. Another described

the transportive effect of the installation: “The lights moving to the beats and the harmonic spectrum made it feel like you were in a kind of strange other world”. Lastly, two respondents highlighted the role of the crowd in enhancing immersion. Due to the high attendance, simply being within the audience was described as an immersive experience in itself.

Questions 9 and 10 explored the interaction between music and lighting and allowed respondents to share any additional thoughts. Nine respondents commented on the audiovisual synchronisation, with two specifically stating that the lights enhanced the experience. One participant noted: “The lights played along with the music; even when I wasn’t paying attention, they amplified the music’s rhythm”. However, despite the positive reception of audiovisual synchronisation, no respondents explicitly mentioned perceiving the audio as coming from the lights. One participant did describe experiencing audiovisual binding: “When the musical cues aligned with different arms of the light installation, it felt as if light and sound had the same source, which was nice”.

3.4.4 Discussion

The quantitative results demonstrated a high level of immersion experienced during the event, largely attributed to the light installation. This already satisfies part of the design goal. Interaction quality ratings further revealed a strong presence of *intimate* and *welcoming*, alongside a mild presence of *unfamiliar*. These findings are supported by qualitative responses, where intimacy was frequently cited in descriptions of the installation. The configuration of the lights, extending across multiple walls and the ceiling, emerged as a key contributor to immersion. Audio-reactivity was also positively referenced, with one participant specifically describing a sense of audiovisual binding. Despite this, no participant mentioned localisation of sound. In conclusion, while the questionnaire confirmed that the light installation enhanced immersion, it did not provide evidence supporting the presence of the ventriloquism illusion.

A note on the method: Recruitment for the questionnaire proved challenging. QR codes were placed throughout the venue to passively attract respondents, but this approach yielded no responses. Active recruitment was more effective, but only a few attendees completed the questionnaire during the event. Consequently, the majority of responses were collected the following days.

Chapter Summary
This chapter described the questionnaire conducted with attendees of the event. It confirmed again that the installation was immersive and that the interaction qualities were present.

3.5 general discussion

The three-part approach revealed several key insights about the reception and perception of the installation. In this chapter, those findings will be used to answer the research questions and to evaluate whether the design satisfied the design goal, interaction vision and design requirements. Additional findings from the design phase will be summarised here as well, to conclude the research-through-design process.

3.5.1 Research Questions

Research Question 1

The first research question, as formulated in Chapter 1.6, is:

Does the ventriloquism effect applied in the nightclub lead to higher levels of audience immersion?

To answer this question, it first needs to be established if the ventriloquism effect was present when participants were exposed to the installation. Then, it needs to be proven that the presence of this illusion leads to higher levels of immersion. The results from the user test did not provide statistically significant evidence that the ventriloquism effect was present. However, when testing for perceived localisation of auditory cues, there was a large effect size when comparing either audio-reactive condition (A and B) with the non-reactive condition (C). This means that while lacking statistical significance, an indication is there that the audio-reactivity of the lights affected the spatial perception of the music. The qualitative results from both the user test and the interviews provide a more nuanced view. While a minority claims to have experienced the sound moving towards the lights during audio-reactive conditions, most participants did not share this experience. However, several participants noted a sense of binding between visual and auditory cues. One participant observed that binding appeared to strengthen over time, suggesting that future experiments could benefit from longer exposure durations. This may be related to the ventriloquism aftereffect, which was described in Chapter 1.1.

While there is no conclusive evidence that the ventriloquism illusion was experienced during the user test, it can be stated with greater confidence that the installation induced high levels of audience immersion. Mean immersion scores resulting from the user test were high across all conditions, with Condition A receiving the highest mean score, followed by Condition B and Condition C. Statistical analysis indicated that the difference between Condition A and C was significant, suggesting that audio-reactivity leads to more immersion. The immersion scores resulting from the club night questionnaire were high as well, supporting the notion that high immersion was not limited to the controlled user test, but was also present in realistic conditions. One additional factor that could explain the high immersion scores, is the spatial configuration of the installation. Participants in both the interviews and the club night questionnaire reported that the fact that the lights extended across multiple walls and the ceiling significantly enhanced their sense of immersion. They felt as though they were surrounded by lights from all sides, fostering a sense of oneness with the audiovisual experience. Some participants that completed the club night questionnaire also noted how the presence of a crowd added to their sense of immersion.

In summary, the presence of the ventriloquism effect cannot be confirmed due to the lack of statistical significance. However, quantitative results indicate that perceived localisation of auditory cues was higher in audio-reactive modes, albeit not to a statistically significant degree. What can be stated with confidence is that the installation was immersive, as both quantitative and qualitative findings from both controlled and realistic settings consistently

demonstrated audience immersion. Further research is needed to establish a potential causal relationship between the ventriloquism effect and this sense of immersion.

Research Question 2
The second research question, as formulated in Chapter 1.6, is:

Does consistency between visual and auditory cues affect binding?

Quantitative results showed no statistically significant difference in localisation or immersion between the two conditions, offering no clear evidence that consistency influences these factors. However, qualitative results tell a different story. All participants interviewed preferred Condition A over Condition B, describing Condition B as confusing, disconnected from the music, and less satisfying. Overall, the qualitative findings suggest that audiovisual binding was perceived to be weaker in Condition B. Combining these results, it can be concluded that a small difference in binding might be present between the two conditions, but that the difference is minor, at least in the case of this installation. It should be noted that technical limitations prevented perfect audiovisual synchronisation with individual instruments, introducing ambiguity in both conditions. This ambiguity may have masked the consistency in Condition B, where there was already an element of randomness in the mapping. This may have caused Condition A to appear more audio-synchronised. Thus, it cannot be said with certainty that the less favourable perception of Condition B was entirely due to inconsistent mapping. It can be said, however, that more consistent synchronisation in general leads to more binding and higher audience satisfaction.

To summarise, definitive evidence that consistent mapping affects binding was not found. However, qualitative data suggests that it may contribute to stronger binding. Limitations in the prototype's audio-reactivity may have influenced the results, highlighting the need for further research to better understand the role of consistency in audiovisual binding.

3.5.2 Design Goal
The design goal, formulated in Chapter 2.1, is:

To increase the sense of immersion for clubbers in nightclubs by leveraging the ventriloquism illusion.

This design goal relates closely to the first research question and can be evaluated in a similar manner. While it remains unclear whether the ventriloquism effect was achieved, the installation demonstrably enhanced immersion, partially fulfilling the design goal. Future iterations with greater precision in audio-reactivity could strengthen audiovisual binding. This may improve the weak spatial perception of audio reported by some participants during audio-reactive conditions and provide more conclusive evidence for the ventriloquism effect.

3.5.3 Interaction Vision
The interaction vision, and specifically the interaction qualities found within it, were thoroughly analysed during the evaluation activities. During the user test, each condition was rated based on the three interaction qualities. And in the club night questionnaire, the experience as a whole was rated based on the qualities as well. Interaction quality ratings did not differ significantly across conditions during the user test, and remained relatively consistent between the user test and the club night questionnaire. Both intimate and welcoming were overwhelmingly present in the installation, with positive ratings in both evaluation activities. The unfamiliar quality was rated less positively, gaining a neutral score in both evaluation activities. However, a sense of unfamiliarity was found in the results from the interview, with multiple participants describing the installation as unique and unconventional.

Additional aspects found within the interaction vision were also present in the final design. The installation was inherently multisensory, with multiple participants commenting positively on the interplay between light and sound in the club night questionnaire. The dynamic movement found within a butterfly house, was mirrored in the movement of this installation as well. In all evaluation activities, participants commented on the light animations, with one participant even noting that it made them want to dance.

Ultimately, it seems that this interaction vision and the qualities within it are well-represented within the final design.

3.5.4 Design Requirements

The majority of the design requirements stipulated in Chapter 2.1 were satisfied by the final design. An overview of the achieved requirements is given in Table 6.

Audio synchronisation (1), which was a primary requirement of the design, worked well. While the system was not always able to perfectly isolate individual musical elements, the visuals were generally synchronised to the music. Loudness–brightness correspondence (4) was achieved, with brightness levels modulated by the audio intensity across different frequency bands. However, the relatively low maximum brightness of the EL wire limited the resolution of brightness variation, somewhat diminishing the impact of this effect. Automated alternation between light modes was implemented, obviating the need for a VJ (6). The form was received positively by clubbers, with some noting how it fit the intimacy of the small space well. The final form could perhaps not be described as overly simple (8), but it was not so complex that it became distracting. The only design requirement that was definitely not achieved was requirement 11. In the end, 10 hours was spent installing the design, with most of the time being spent mounting the EL wire to the various surfaces. This needed to be done carefully, to guarantee that no wire would detach during the event.

3.5.4 Findings from the design process

In addition to the insights gained from experimental and qualitative research into the degree to which the installation facilitated ventriloquism and immersion, reflection on the design process provides additional insights into how can be best designed for the ventriloquism effect, the nightclub context and multisensory installations in general.

Audio-Reactivity

Due to technological as well as time constraints, the algorithm converting audio into signals for the different light groups could not be overly complex. Consequently, there were imperfections in how this audio-reactive system

Table 6
Evaluation of Design Requirements

design requirement	evaluation
[1] the design must be synchronised to the audio (max. delay: 30 ms)	achieved
[2] the design must create visual cues that are distributed throughout the space	achieved
[3] the design must be able to create consistent and randomised visual cues.	achieved
[4] the design must incorporate one or more cross-modal correspondences.	moderate
[5] the design must alternate between synchronised and unsynchronised modes.	achieved
[6] the design must be able to function automatically without the need of a VJ.	achieved
[7] the form of the design must fit the exhibition space.	achieved
[8] The form of the design must be simple.	moderate
[9] The production cost must remain affordable.	achieved
[10] The design must be easily transportable in a single car.	achieved
[11] The design must be designed in such a way that it can be installed in 5 hours.	failed
[12] The design must be able to withstand vibrations produced by sound systems.	achieved
[13] The design must be able to withstand or avoid guests touching it.	achieved

worked. Ideally, the algorithm would be able to isolate individual instruments, to facilitate strong binding between instrument and light group. However, in reality the efficacy of this functionality seemed to be highly dependent on the music selection. Music of different genres, loudness, intensity and mix quality were played throughout the event, causing there to be variations in how the system responded. For optimised audio-reactive behaviour for use with music provided by DJs, a more advanced algorithm is required that better adjusts to variations in the music.

Tangled Wire
During the prototype development, a significant challenge arose due to the difficulty in straightening the EL wire. Despite several attempts to straighten it, small irregularities always remained. These imperfections were incorporated into the final design, where they contributed to an organic shape. Nevertheless, to achieve the desired form, the wire had to be attached to the wall at many points to prevent tangling or the formation of undesired shapes between attachment points.

Brightness Limitations
The maximum brightness of EL wire is relatively low, resulting in a limited expressive resolution in this dimension. Consequently, the cross-modal correspondence between loudness and brightness was subtle. To achieve a more pronounced loudness-brightness correspondence, an alternative light source with greater intensity may be more appropriate.

Experiential Prototyping
One of the key observations during the design process was the benefit of prototyping from an early stage. From the start of the design process, materials were experimented with to gain a multisensory understanding of their form and functionality. Then, as soon as an idea was chosen for development, the materials required were heavily experimented with again to further refine the concept. Only when the various EL wire shapes were physically prototyped, could the form truly be assessed. Only when the initial software iterations were combined with the lights, could the experience as a whole be judged, and could the software be adjusted. Particularly when designing multisensory installations, it seems extremely beneficial to move from paper sketches to physical artefacts as soon as possible.

Suboptimal Stimuli
When designing this installation, attention needed to be given to creating a form that aligned well with the aesthetics of the nightclub. Overly figurative or colorful aesthetics would clash with the industrial and rugged appearance of the exhibition space. This limited the expressive resolution of the installation to a degree, which might have affected the strength of the ventriloquism effect. It stands to reason that use of correspondences relating to color or icons (e.g., a light in the shape of a bass guitar to signify the low frequencies) may have increased binding. Thus, the insight gained is that when designing with cross-modal illusions, real-life contexts may limit the use of ideal stimuli, possibly affecting the illusion's strength.

3.5.5 Conclusion
Primarily, the goal of this project was to gather insights into whether the ventriloquism effect could yield interesting design opportunities in the context of the nightclub. The hypothesis was that by leveraging the ventriloquism effect, an illusory spatial audio experience could be created that enhances immersion. While no statistically significant evidence was found that the ventriloquism effect was present, the results from the evaluation serve as a strong indication that the application of cross-modal illusions within this context is a worthwhile avenue for further exploration.

The goal of achieving immersion was satisfied, with results from all evaluation methods indicating that the audience felt incredibly immersed, mostly during audio-reactive modes. However, it remains unclear if ventriloquism or illusory spatial audio contributed to this. The interaction vision and design requirements were also mostly achieved. In summary, the evaluation indicates that the final design successfully met the majority of the objectives established at the outset of the design phase.

3.6 recommendations & guidelines

Since this project entailed an exploration into a novel combination of domains, there are naturally opportunities for improvement. Thus, findings from the evaluation were synthesised into a set of recommendations, which will be discussed below. Each recommendation is paired with a guideline for designing multisensory nightclub experiences.

3.6.1 Audio-Reactivity

As discussed at length throughout this thesis, audio-reactivity was both incredibly important to the design and difficult to perfect. In an ideal scenario, visual cues would be linked to notes from individual instruments. This would allow the audience to attribute different lights to different instruments, which may help audiovisual binding. The fact that a live audio signal from the DJ had to be used during this project, meant there was no separation of individual instrument tracks, and no possibility to pre-analyse the music. However, the latter may be a possible avenue for future improvement. A software solution could be developed that interfaces with the mixer or CDJs and is able to identify the track once it is loaded. Then, it could use more advanced artificial intelligence aided instrument separation to be able to create more accurate light triggers.

Guideline: *When designing a synchronised audiovisual experience, link visual cues to individual instruments to maximise binding.*

3.6.2 Cross-Modal Correspondences

The design utilised loudness-brightness correspondence to some success, but the effect was quite subtle. Future iterations on this design could benefit from including more pronounced correspondences. While EL wire does not afford it, LED based lighting could easily accommodate more dynamic loudness-brightness correspondence, pitch-brightness correspondence or even pitch-colour correspondence. Additionally, the form could be adjusted in such a way that it facilitates correspondences as well (e.g., pitch-size correspondence). Implementing one or more correspondence may have a positive effect on binding.

Guideline: *To strengthen binding, use cross-modal correspondences in your design.*

3.6.3 Diversity in Light Modes

While there were no complaints that the installation became boring after long exposure, the design could benefit from a greater variety in light animation modes, so it would remain interesting club night after club night. For example, a possible additional audio-reactive mode could entail only one frequency band reacting at a time. This would isolate one instrument in the mix, allowing the audience to connect more deeply with it.

Guideline: *To keep the audience engaged in audiovisual experiences, facilitate a wide variety of both synchronised and unsynchronised modes.*

3.6.4 Improving Immersion

While the measured immersion scores were positive, there are definite avenues to explore to increase it further. For instance, the lights could take up an even larger space of the room. The design would likely have had more impact if more of the room's surface was covered in EL wire. Especially if the wire also covers the back wall, a truly 360 experience could be created that gives the audience the impression that they are "in" the music.

Guideline: *To improve immersion in audiovisual experiences, ensure that visual cues surround the audience from all sides.*

3.7 reflection

Above all, this project provided valuable insights into conducting research in hard-to-access contexts. As mentioned before, while the nightclub is an important cultural hub in modern society, little research has been done in this context. To me, this project proved how design can function as a valuable tool for doing research in contexts like these. By making a bespoke installation for a particular event, I could satisfy and even excite stakeholders within this context, while also being able to generate valuable research findings. At the same time, doing research in a chaotic context like the nightclub, also introduced challenges. Obviously, my research was not the priority of the event, so I had to take initiative and be flexible to be able to conduct my evaluation activities. Luckily, the stakeholders involved were very accommodating, and gave me a lot of freedom. However, there were several practical limitations that would simply not have occurred in a lab setting. Most of all, I had to deal with the time constraints created by the venue. Due to other events in the same week, only two days were available for installation, documentation and evaluation. In the end, this meant I had only a few hours to conduct the controlled user test. Additionally, due these time constraints, there was no real way to perform a pilot test or refine the experiment design in any meaningful way. Nonetheless, I believe the benefits of performing a test such as this in context greatly outweigh the downsides. The complex multisensory nature of a nightclub experience is extremely difficult to emulate in a lab, as it is made up of many variables (music, lights, smoke, people, drinks, drugs, exposure time, etc.). The controlled user test allowed me to get very close to the actual conditions, and the questionnaire allowed me to gain an insight into the complete experience.

The installation developed for this event challenged me to work with new materials and methods. In addition to best suiting the design requirements, the EL wire based web idea excited me as it allowed me to work with a new material. As discussed before, this was not without its challenges. The requirements of inverters and MOSFETs forced me to devise a more complex electronics system than would have been required with LED strips. As I had no prior experience with these electronic components, this served as a valuable learning experience. The same can be said for the software. While I have programming experience, this was my first venture into developing a Max/MSP application. Using this software for audio analysis has equipped me with a valuable skill applicable to future installation work. It remains true, however, that improvements can be made to the way in which this audio-reactivity functions. I intend to make those improvements in the future.

To conclude, this project has allowed me to explore a multitude of fascinating topics. I now know more about perception as it pertains to the nightclub and about the complexities of designing an audio-reactive installation. Apart from contributing to the research domains discussed, to me, this project also reaffirms the value of research-through-design and provides insights into navigating complex contexts.

references

Adeli, M., Rouat, J., & Molotchnikoff, S. (2014). *Audiovisual correspondence between musical timbre and visual shapes.* Frontiers in human neuroscience, 8, 352.

Agrawal, S., Simon, A., Bech, S., Bærentsen, K., & Forchhammer, S. (2019). *Defining immersion: Literature review and implications for research on immersive audiovisual experiences.* Journal of Audio Engineering Society, 68(6), 404-417.

Alais, D., & Burr, D. (2004). *The ventriloquist effect results from near-optimal bimodal integration.* Current biology, 14(3), 257-262.

Alsius, A., Paré, M., & Munhall, K. G. (2018). *Forty years after hearing lips and seeing voices: the McGurk effect revisited.* Multisensory Research, 31(1-2), 111-144.

Beaulieu-Laroche, L., Harnett, M. (2018). [Visualisation of Dendrites]. MIT News. https://news.mit.edu/2018/dendrites-explain-brains-computing-power-1018

Beck, S. (Director). (1973). *Illuminated Music 2 & 3* [Film].

Bertelson, P., & Radeau, M. (1981). *Cross-modal bias and perceptual fusion with auditory-visual spatial discordance*. Perception & Psychophysics, 29(6), 578-584.

Boltz, M. G., Ebendorf, B., & Field, B. (2009). *Audiovisual interactions: The impact of visual information on music perception and memory*. Music Perception, 27(1), 43-59.

Burger, B., & Toiviainen, P. (2020). *Embodiment in electronic dance music: Effects of musical content and structure on body movement.* Musicae Scientiae, 24(2), 186-205.

Chen, L., & Vroomen, J. (2013). *Intersensory binding across space and time: a tutorial review*. Attention, Perception, & Psychophysics, 75, 790-811.

Colavita, F. B. (1974). *Human sensory dominance.* Perception & Psychophysics, 16(2), 409-412.

Correia, N. N., Castro, D., & Tanaka, A. (2017, August). *The role of live visuals in audience understanding of electronic music performances.* In Proceedings of the 12th international audio mostly conference on augmented and participatory sound and music experiences (pp. 1-8).

Ćwiek, A., Fuchs, S., Draxler, C., Asu, E. L., Dediu, D., Hiovain, K., ... & Winter, B. (2022). *The bouba/kiki effect is robust across cultures and writing systems.* Philosophical Transactions of the Royal Society B, 377(1841), 20200390.

Dekker, A. (2005). *VJ Culture: A Phenomenon in History, Presentation, and Perception*. Viitattu, 21, 2024.

Eimert, H. (1956). *Electronic music (Vol. 601).* K. Stockhausen (Ed.). National Research Council of Canada.

Ernst, M. O., & Banks, M. S. (2002). *Humans integrate visual and haptic information in a statistically optimal fashion*. Nature, 415(6870), 429-433.

Fracture. (2019). *"Big Up The Ladies."* On Big Up The Ladies [Single]. UK: Astrophonica. URL: https://www.youtube.com/watch?v=0r4itlbrVtE
Frissen, I., Vroomen, J., de Gelder, B., & Bertelson, P. (2003). The aftereffects of ventriloquism: Are they sound-frequency specific? Acta Psychologica, 113, 315–327.

Fujisaki, W., Shimojo, S., Kashino, M., & Nishida, S. Y. (2004). *Recalibration of audiovisual simultaneity.* Nature Neuroscience, 7(7), 773-778.

Garcia, L. M. (2015). *Beats, flesh, and grain: sonic tactility and affect in electronic dance music*. Sound Studies, 1(1), 59-76.

Gentilucci, M., & Cattaneo, L. (2005). *Automatic audiovisual integration in speech perception.* Experimental Brain Research, 167, 66-75.

Godfroy, M., Roumes, C., & Dauchy, P. (2003). *Spatial variations of visual—auditory fusion areas.* Perception, 32(10), 1233-1245.

Green, K. P., Kuhl, P. K., & Meltzoff, A. N. (1988). *Factors affecting the integration of auditory and visual information in speech: The effect of vowel environment.* The Journal of the Acoustical Society of America, 84(S1), S155-S155.

Hammerschmidt, D., & Wöllner, C. (2017). *Audio-visual quality perception in musical performance videos.* Musikpsychologie, 1(27), 112-127.

Hirst, R. J., Cragg, L., & Allen, H. A. (2018). *Vision dominates audition in adults but not children: A meta-analysis of the Colavita effect.* Neuroscience & Biobehavioral Reviews, 94, 286-301.

Hirst, R. J., McGovern, D. P., Setti, A., Shams, L., & Newell, F. N. (2020). *What you see is what you hear: Twenty years of research using the Sound-Induced Flash Illusion.* Neuroscience & Biobehavioral Reviews, 118, 759-774.

Hirway, A., Qiao, Y., & Murray, N. (2024). *A Quality of Experience and Visual Attention Evaluation for 360 videos with non-spatial and spatial audio.* ACM Transactions on Multimedia Computing, Communications and Applications.

Hyodo, Y., Sugai, C., Suzuki, J., Takahashi, M., Koizumi, M., Tomura, A., Mitsufuji, Y., & Komoriya, Y. (2021). *Psychophysiological Effect of Immersive Spatial Audio Experience Enhanced Using Sound Field Synthesis.* 2021 9th International Conference on Affective Computing and Intelligent Interaction (ACII), 1–8. https://doi.org/10.1109/ACII52823.2021.9597435

Jack, C. E., & Thurlow, W. R. (1973). *Effects of degree of visual association and angle of displacement on the "ventriloquism" effect.* Perceptual and motor skills, 37(3), 967-979.

Lewald, J. (2002). *Rapid adaptation to auditory-visual spatial disparity.* Learning & Memory, 9(5), 268-278.

Lustig, E., & Tan, I. (2020). *All about that bass: Audio filters on basslines determine groove and liking in electronic dance music.* Psychology of Music, 48(6), 861-875.

Malbon, B. (2002). *Clubbing: Dancing, ecstasy, vitality.* Routledge.

McGurk, H., & MacDonald, J. (1976). *Hearing lips and seeing voices.* Nature, 264(5588), 746-748.

Novello, A. (2021). *Media archaeology-based Visual Music*. Musica/Tecnologia, 15, 7–30. https://doi.org/10.36253/music_tec-13300

Olaveson, T. (2004). *'Connectedness' and the rave experience: Rave as new religious movement?*. In Rave culture and religion (pp. 85-106). Routledge.

OpenAI. (2023). DALL · E 3 [Image generation model]. https://openai.com/dall-e

Platz, F., & Kopiez, R. (2012). *When the eye listens: A meta-analysis of how audio-visual presentation enhances the appreciation of music performance.* Music Perception: An Interdisciplinary Journal, 30(1), 71-83.

Recanzone, G. H. (1998). *Rapidly induced auditory plasticity: the ventriloquism aftereffect.* Proceedings of the National Academy of Sciences, 95(3), 869-875.

Remijn, G. B., Ito, H., & Nakajima, Y. (2004). *Audiovisual integration: An investigation of the 'Streaming-bouncing' phenomenon.* Journal of physiological anthropology and applied human science, 23(6), 243-247.

Rietveld, H. C. (2022). *The nightclub.* The Bloomsbury Handbook of Popular Music, Space and Place, 139.

Sekuler, A. B., Sekuler, R. and Lau, R. (1997). *Sound alters visual motion perception*, Nature 385, 308.

Shams, L., Kamitani, Y., & Shimojo, S. (2000). *What you see is what you hear.* Nature, 408(6814), 788-788.

Shams, L., Kamitani, Y., & Shimojo, S. (2002). *Visual illusion induced by sound.* Cognitive brain research, 14(1), 147-152.

Solberg, R. T., & Jensenius, A. R. (2016). *Pleasurable and intersubjectively embodied experiences of electronic dance music.* Empirical Musicology Review, 11(3-4), 301-318.

Solberg, R. T., & Dibben, N. (2019). *Peak experiences with electronic dance music: Subjective experiences, physiological responses, and musical characteristics of the break routine.* Music Perception: An Interdisciplinary Journal, 36(4), 371-389.

Spence, C. (2011). *Crossmodal correspondences: A tutorial review.* Attention, Perception, & Psychophysics, 73, 971-995.

Stappers, P., & Giaccardi, E. (2014). 43. *Research through Design.* The encyclopedia of human-computer interaction.

Takahashi, M., & Olaveson, T. (2003). *Music, dance and raving bodies: Raving as spirituality in the central Canadian rave scene.* Journal of Ritual Studies, 72-96.

Trujillo, J. P., & Holler, J. (2023). *Interactionally Embedded Gestalt Principles of Multimodal Human Communication.* Perspectives on psychological science : a journal of the Association for Psychological Science, 18(5), 1136–1159. https://doi.org/10.1177/17456916221141422

Vanilla Ace. (2014). "*Ladykiller (Original Mix).*" On Ladykiller [Single]. UK: Erase Records. URL: https://www.youtube.com/watch?v=itaH-YrAVa8

Vroomen, J., Bertelson, P., & De Gelder, B. (2001). *The ventriloquist effect does not depend on the direction of automatic visual attention.* Perception & Psychophysics, 63(4), 651–659. https://doi.org/10.3758/BF03194427

Wang, A., Zhou, H., Hu, Y., Wu, Q., Zhang, T., Tang, X., & Zhang, M. (2021). *Endogenous Spatial Attention Modulates the Magnitude of the Colavita Visual Dominance Effect.* i-Perception, 12(4), 20416695211027186.

Zeljko, M., Kritikos, A., & Grove, P. M. (2019). *Lightness/pitch and elevation/pitch crossmodal correspondences are low-level sensory effects.* Attention, Perception, & Psychophysics, 81, 1609-1623.

appendix a: clubber questionnaire

ID	What is your age?	What is your gender?	How often do you visit a nightclub?	What are your three favourite nightclubs, and what factors (e.g., music, visuals, atmosphere) make them your favourite?
1	25	Man	Monthly	De School (RIP), Garage Noord, Radion
2	29	Man	2-3 times per month	Garage Noord; lineups, crowd, overall aesthetic and their politics. 60 Dock Road; lineups, overall aesthetics, sound Public Records; sound, lineups, crowd
3	26	Woman	Once a week	Poing Club - the atmosphere, the people, the music and curation, queer identity Griessmuehle - the outside area/terrain and atmosphere Raum - the atmosphere, sense of freedom, queer identity
4	24	Man	Monthly	Skatecafé: industrial atmosphere, freedom in activities, multiple different sized stages Radion: a bit dark (vision and atmosphere wise) Parallel: music
5	26	Man	Monthly	Not sure if I can answer this, it's mainly about what's available. But if I had to make a guess steck - because i often know people there poing - because the music is pretty nice
6	26	Man	Monthly	Poing, weelde, perron. All three focus on techno at different price ranges and sizes. But most of them are a platform for both established and up and coming artists
7	25	Woman	2-3 times per month	garage noord, lofi, worm. it depends on the clubs, but generally chill atmosphere, space to move around, music, and lighting system.
8	28	Woman	2-3 times per month	RAUM - love the design of the space and lights there, the crowd is usually also cute GARAGE - usually just good vibes, fun lineups, sound and lights are not insane quality but not bad at all either OPEN GROUND - beautifully done space and sound is sososo good
9	27	Man	Monthly	Bird, Weelde, Club Centraal. For my atmosphere is the most important thing and for music I make sure I go on evening I know the djs or music will be nice
10	26	Man	Rarely	De School, Marktkantine (when it was still open) (sorry idk a third, haven't clubbed for a while) I like them because they're old buildings (e.g. schools, warehouses) that have been repurposed as nightclubs. They are very characterful, you can tell they've been around for a while, and the layout is interesting for a club because it wasn't built to be a nightclub. It goes against convention, which is reflected by the crowds it attracts. Often the music was ear-deafening techno, with psychedelic, abstract lights and/or visuals. I hate the trend of using AI-generated video that just loops, it detracts from the experience.
				Bitterzoet / paradiso, amazing ambiance in an old building. Often nice artists

11	24	Woman	Once a week	IVY in Sydney, because you are always unsure if you are inside or outside or both and it has multiple areas and places from which you can view the dj/ different djs and a pool on the rooftop
12	24	Man	2-3 times per month	music must be good, them atmosphere(including lightings, foggy effect etc.)
13	18	Man	2-3 times per month	Charlie Colorado, Danzig en Nobel. The main reasons for Charlie Colorado are the type of music (house music) and the nice setting at the beach. The main reasons for Danzig and Nobel are the social factors.
14	29	Man	Monthly	Lofi - size, price/quality, versatility (fun in summer and winter) Shelter - always there, best enjoyed with a non-headliner (when not busy, it's a very fun club!)
15	31	Man	Rarely	Garage Noord, levenslang, ot301
16	26	Man	Monthly	Garage Noord Complex Maastricht Roxy Prague Their sound and stage-setting are good.
17	28	Man	Monthly	Blitz Munich (Soundsystem), Tresor Berlin (Soundsystem and Atmosphere), Radion Amsterdam (Atmosphere)
18	27	Woman	Rarely	What I look for when going out is type of music, I don't really have a favorite nightclub
19	27	Woman	Monthly	garagenoord AMS, club raum AMS, tritolo, avigliana (ita) in order of importance: music+atmosphere and visuals a favourite venue is that safe place were i can listen and dance to the music I love. venues usually curates the atmosphere and select people admitted so picking a venues means also shared values.
20	29	Man	2-3 times per month	the architecture of the space, the quality of the sound, the vibe and safety I feel when I'm in.
21	25	Man	Monthly	pip den haag -> spatial layout and crowd worm -> music and atmosphere garage noord -> crowd responsive visuals

Which genres of music do you like listening to in nightclubs?	Do you usually visit nightclubs alone or with others?	Can you describe one of the best experiences you had at a nightclub? What specific elements (e.g., music, visuals, crowd energy) made it great?	M
Techno, Experimental, Industrial, Classical	With one or two friends	The best was when there was a mysterious atmosphere, a sense in the crowd of important music.	V
Jungle, DnB, Techno, IDM, Garage, Bass	With one or two friends	Lineup and crowd matched, high energy from the performers and reciprocated by the crowd, amazing display of musicallity by performers and dark atmosphere	V
electro, techno, bass, trance, breakbeat, experimental, deconstructed club	It varies	I was sober and felt like I had a natural high on just the music, the flow and vibe of the crowd and lights. Really gave me goosebumps.	V
House/garage/jungle with influences of hiphop	It varies	When you resonate with others (friends or other people) in terms of energy	I
(melodic) techno	It varies	Probably did some drugs, there was happy kind of music containing live instruments, a good ambiance and a nice crowd of friends with whom I feel comfortable	V
Techno	It varies	Poing's closing night (previous ownership) was great, there was just the whole vibe of going out with a bang and enjoying it one more time. Also with the staging and the lights they made a regular sized room feel huge	I
electronic music	With one or two friends	I had a very nice experience last summer at Mono Rotterdam because the music was very good (trance techno) and the mood of the crowd was chill and respectful. The night had some nice live performances that made the whole experience more vibrant and less monotone. Another standout was the closing event at Kanaal40 in Amsterdam. I loved the variety of music across different floors and how the spatial design, like the stage on the stairs, created unique interactions within the crowd. It felt way more engaging than the typical club layout.	V
bass and related sub-genres	With one or two friends	the last great night was pre-summer at RAUM, it was also my first time there. I really enjoyed the freedom walking between different spaces, lineup was great and I felt very safe and unbothered on the dancefloor. i really like the minimalistic approach they usually take with the lights. i also made friends that night with who I am still in touch with.	V
Disco, House, Techno if it isn't to intance, trannce, hiphop, indie, old school hits	With a larger group of friends	A club which had multiple different rooms, each with their own atmosphere and style of music. You could walk around freely and switch rooms when you wanted another muisic genre or dj	V
Mostly Techno, sometimes House	With one or two friends	About two years ago I went to supposedly 'the last' party at De School before it would close. We went on a Saturday, but the party was from Friday until Monday morning. There were three rooms converted to stages, each with different music and vibes to them, so you could let your own mood decide where to go. There was also a kind of inner garden where people would smoke and chill in between dancing, which was great. The music was really nice, everyone was friendly and the diversity of vibes meant there was something for everyone. I think we left at 9 in the morning. I don't recall any visuals being there, aside from some lights -- the school classrooms themselves did add to the experience. There were some artworks on display there, idk by whom, it was kind of random but also funny to see.	V
Techno, house, pop, 2000hits, R&B	It varies	Loosing the feeling of time, finding hidden bars and bands, more festival vibe discovering hidden places and having a spot for every mood. Big open area's with smoke and lights, but also tiny cosy with plants and jazz	I
electronic, R&B	With one or two friends	Music with beats, which you can dance with. Lightings were not too blinky, which would make me nauseous. Everyone were like hype about the music and people even would interact with strangers which was really nice.	V
House/ tech-house	With a larger group of friends	The first time I went to Charlie Colorado was one of my best nights out ever. As I said I like house music very much and that combined with the setting at the beach, 20 degrees Celsius, a few beers and a nice and chill crowd made it unforgetable.	V
Deep House, Garage	With a larger group of friends	Antal & Hunee at Lofi - the music was great, the crowd was awesome and the sound system hit all the right marks despite them going from disco - afrobeat - house and anything in between. So the sound was consistent despite the multi-genre approach. That's what made it so fun - when a disco record slaps just as hard as a house one that consistency is what keeps the crowd engaged.	V
Experimental	With one or two friends	Music in garage Noord and atmosphere	V

Techno, Drum & Bass, Experimental Club Music.	With one or two friends	In Berlin I went to Tresor. The long walking road to the club itself was really cool. The cave lightning system really made it feel like you're in a cool club. It was dark, which was also really nice. Everyone could be and dance like themselves.
House and Techno	With a larger group of friends	
Hip hop, early '00s pop, '80s disco, techno	With one or two friends	
drum and bass, experimental electronic or techno	It varies	there was this club where I grew up that was in a old tnt factory, it had different rooms to dance and a beautiful terrace with grass and small cubed lights. it was a mix of music, friends and venue. and then garage noord gifted me with the best evenings, introducing me to different new artists and I really love that beautiful circular led piece in the main room, magic
techno	It varies	Berghain definitely. The chance I had to finally get in after queueing for hours, the music selection, the vibe where everything is possible and feeling like if i'm losing the perception of the time
jungle footwork dnb just like fast drum stuff	With one or two friends	i came back from a part in amsterdam with a friend around 12 and we went to pip because it was closer to home and they have one area in like a container where there was just one guy in the corner and the dj but the music was better than the other dj booths so it was the two of us dancing in the middle of the room for what felt like an hour right underneath the lights as other people gradually joined and it filled up and this is narcissistic as hell but it felt really special at the start because it was so intimate but also after because i felt some ownership over creating that vibe in a way?

Music	Lighting/Visuals	Size of the Club	Interior/Spatial Design	Freedom of Expression	Social Environment (type of crowd)	Rate your overall satisfaction with the nightclub experiences you have had over the last year.
Very Important	Important	Neutral	Important	Important	Important	Neutral
Very Important	Very Important	Very Important	Important	Very Important	Very Important	Satisfied
Very Important	Important	Neutral	Important	Very Important	Very Important	Neutral
Important	Neutral	Neutral	Important	Important	Important	Neutral
Very Important	Important	Unimportant	Unimportant	Neutral	Important	Neutral
Important	Important	Neutral	Important	Important	Very Important	Satisfied

Very Important	Very Important	Important	Important	Important	Very Important	Very Satisfied
Very Important	Very Important	Unimportant	Neutral	Very Important	Very Important	Neutral
Very Important	Important	Neutral	Important	Important	Important	Satisfied
Very Important	Important	Neutral	Very Important	Very Important	Very Important	Satisfied
Important	Very Important	Important	Neutral	Very Important	Very Important	Satisfied
Very Important	Neutral	Very Unimportant	Unimportant	Very Important	Important	Satisfied
Very Important	Neutral	Neutral	Important	Important	Important	Satisfied
Very Important	Important	Very Important	Important	Neutral	Important	Satisfied
Very Unimportant	Important	Important	Very Important	Very Important	Very Important	Neutral
Very Important	Important	Unimportant	Important	Important	Very Important	Satisfied
Very Important	Neutral	Very Unimportant	Important	Important	Very Important	Satisfied
Very Important	Neutral	Unimportant	Important	Neutral	Important	Neutral
Very Important	Neutral	Very Important	Important	Very Important	Very Important	Satisfied
Very Important	Important	Neutral	Important	Important	Very Important	Satisfied

Important	Neutral	Neutral	Important	Important	Very Important	Satisfied

In your opinion, how could the overall nightclub experience be improved?	Can you briefly describe the most memorable visuals/light shows/light installations you have experienced in a nightclub? What made them special?	To what extent do you agree with the statement: 'Good lights and visuals are essential to a complete nightclub experience.'
More focus on cutting edge music, interdisciplinary collaboration with young artists to create new experiences	One industrial techno rave I went to in 2018 had two lights. One white strobe, and one red light emminating from the dj booth. There was industrial style artwork lining the walls. The crowd went feral.	Agree
Better understanding of DJ lineups and regular visitors of the club (big name DJ doesn't mean they gotta play peak time!). Right use of space by the club, friendly and helpfull staff and correct use of light (a club is not a concert space!)	Lighting design at Laak by Joeri Woudstra, perfect understanding on how light impact the perception of the space and your surroundings, minimal use of light yet very powerful and effective 100/100. Basement at De School, ADE 2023. Minimal use of light and heavy smoke, completely changed the perception of the space, also great use of strobes in the back room behind the glass.(very sad they changed direction and started using color lights like purple (ick) in 2024. 100/100 Not club but Draaimolen 2024, getting actual artists instead of light technicians to decide the lighting of a space REALLY makes a difference, 100/100	Strongly Agree
Improve social safety	The ones that make you feel like you're tripping when you're sober	Strongly Agree
No phones, better overview of smaller venues	1: not so much of a Light show, but a dark, cloudy room where you can't see that much, the focus turned away from the whole room, you were only concerned with the 5 meters around you. Felt like a never ending room where the (lack of) crowd didn't negatively influence the experience	Disagree
More options for different kinds of music (or maybe I just don't know where to find what I like)	I think it was during ADE when Amelie lens was playing and her logo was lit up above her. But the room lighting was alternating between just showing her logo and having laser lights and light beams all around	Agree
maybe in the visuals you could experiment with where the visuals are. Because they are mostly behind or around the stage. I remember some visual elements being used in the crowd as a part for some concerts, maybe you could strive for a similar vibe in that	I always think it's really cool if the DJ is lit from below, especially if it's a warmer light. The intimate cozy lighting draws you in towards the DJ and brings focus to the artist and the music. It creates a kind of microcosm for the people dancing around the DJ and really rewards people for coming up close to the stage.	Agree
I feel that the times in which I enjoy less the experience are when the club is too crowded and I can't move and breathe properly, so checking beforehand how many tickets should be sold to let the people not suffocate inside would be nice. I also don't like it when the lighting doesn't match well with the music or if it is too static and it happens very frequently. So, I think that putting more focus on the lights could ensure a better experience.	I think that the most memorable one was two years ago at Worm for the lighting festival. The visuals were great and matched perfectly with the music, it was for sure generative but not too abstract. The visuals were changing a lot so it was not monotone but the changes were smooth, so I didn't feel disoriented. Overall it was nice because it was all designed together so the experience was totally immersive.	Strongly Agree
vibe checks or other ways of pre-selecting the crowd - people in the club can make or break the night + prohibit the strobe lights:))))	really enjoyed the floating UFO light in the Pit during Draaimolen I often find VJing and/or big screens behind the DJ too bright and disruptive	Agree
I want more focus on cozy atmosphere and music and less so on very intense techno and "beuken"	During a polo & pan concert. Behind them there was a huge screen at thee back of the stage which played animations that fit the songs they were playing the whole time. The ceiling lights were synced with the screen and would shine in the same colours. The animations were also synced with the music which made it very cohesive.	Agree
There was a guy who kept asking everyone for ketamine, he was annoying so it would've been nice if he had been removed. In terms of lighting/visuals, I think there was room for more experimentation, as there was little going on.	I saw Justice at Lowlands last summer, which wasn't really a nightclub of course, but I think elements of the lighting setup could be applied to a nightclub scene. They used lots of small lights, mirrors and spotlights to really give off this kind of 70s/80s electro-disco vibe. I don't know how to better describe it, they have some performances on YouTube though.	Agree

Have more diversity and ways to exress yourswlf and your needs		
A thing or product that would create interaction between people, making people interact with each other even if they were strangers.	Different colors, shining with music rhythm, made me feel like I am dance with beats.	Agree
Reasons clubs ussualy give less fun experiences are the people the clubs tend to attract or the setting (looks and designs) of the club or both of these reasons combined.	Danzig was I think the most special but nothing really outstanding.	Agree
Sound systems this year were lacking at Lofi, HEMkade. In my head it was always more clarity and punch than nowadays.	Justice concert (Best Kept Secret) - the light show is insane. The way it moves around and complemented the music was totally nuts. Together with a sound system that really slapped. Lighting is important, but for me in the sense that it should be serviceable to the music (justice was a bit of an exception). I dont like overbearing light shows.	Agree
More inclusivity and more freedom	Festival in Padova je t'aime . Alessandro Cortini it was very minimalistic and dark	Agree
I would tell the owner: Give the very talented but unexperienced DJ's a chance instead of the mediocre DJ's that always play there.	It was at a bigger venue, AFAS. Ben Böhmer's live set was integrated in the light system and every part of the set had it's own vibe. The lights bounced to the rhythm and it got more intense as the music got more intense.	Agree
Investing in a proper soundsystem, and better curation of artists.	When I visited Blitz Club in Munich recently, I was impressed by the installations. They were subtle yet effective—nothing overly flashy, just perfectly balanced. However, the most striking visual experience I've encountered was at Grelle Forelle in Vienna. Their ceiling installation was captivating, offering an immersive and futuristic vibe that truly stood out. Another experience that stood out was at Tresor in Berlin. Instead of elaborate light installations, the atmosphere was shaped by dense smoke and strobe lights. You could only see the silhouettes of dancers, creating a raw and hypnotic vibe.	Agree
		Agree
introducing weekly/monthly artists to showcase their work during the events would improve the atmosphere	garage noord has a beautiful ring installed on the ceiling and that is always nice. club raum has dmx spotlights in the ceiling that combined with smoke, make the room alive. also on the wall, behind the dj booth, there is a long led strip between the wall window and the ceiling that has beautiful pixel visuals, it felt like raining inside last time- beautiful. then seeing live moderat (working with pfadfinderei), massive attack (working with united visual artists) and chemical brothers (smith&lyall), were the best visuals I have experienced.	Strongly Agree
avoiding trends and homologation	I don't remember where, but I liked the fact that visuals and lights were making me losing the real dimension I was dancing in and made me feel like if I was in a trip	Strongly Agree
less boring techno	lame answer but genuinely office space. ive seen cool and creative visuals at concerts and installations but never really in nightclubs. what made it special of course the interactivity and seeing how people interacted with it (and also the tits). but ill say this with the caveat that special and innovative doesnt necessarily mean its also a good thing for the clubbing experience. i dont think weve talked about this before but maybe the most interesting part about office space was seeing how people would sometimes fixate on it trying to take their chance to broadcast a picture of just their hand which on the one hand feels like wanting to be in the spotlight which is something i think clubbing has a complicated relationship with, but also like its your hand. no ones gonna recognize that you made that image except for you but still people were like standing waiting to put their hands on the thing even when it was glitching out and kept rewinding. interactivity with the show def activates some part of the brain in like a compulsive way that im not sure yet if its participation in a collective work/experience or attention seeking. idk complicated stuff!	Disagree

How do you like to feel during a nightclub experience in terms of music and visuals?	Do you feel visuals and lights influence your emotional connection to the music?	Do you prefer to feel like an observer or an active participant in the audiovisual experience, able to influence it?
Connected to others in the crowd;Immersed in the environment;Challenged or provoked by the visuals/music;	Sometimes	Depends on mood
Emotionally moved or impacted;Challenged or provoked by the visuals/music;Distorted perception of the space and my surroundings, including other people.;	Always	Depends on mood
Emotionally moved or impacted;Free to participate and influence the atmosphere;Challenged or provoked by the visuals/music;	Always	Depends on mood

Immersed in the environment;Connected to others in the crowd;Free to participate and influence the atmosphere;	Sometimes	Depends on mood
Immersed in the environment;Energetic and uplifted;	Sometimes	Depends on mood
Immersed in the environment;Connected to others in the crowd;Free to participate and influence the atmosphere;	Always	Depends on mood
Immersed in the environment;Energetic and uplifted;Connected to others in the crowd;	Always	Depends on mood
Immersed in the environment;Emotionally moved or impacted;Challenged or provoked by the visuals/music;	Sometimes	Depends on mood
Immersed in the environment;Energetic and uplifted;Free to participate and influence the atmosphere;	Sometimes	Observer
Challenged or provoked by the visuals/music;Connected to others in the crowd;	Always	Depends on mood
Immersed in the environment;Energetic and uplifted;Connected to others in the crowd;	Sometimes	Depends on mood
Emotionally moved or impacted;	Sometimes	Depends on mood
Immersed in the environment;Emotionally moved or impacted;Energetic and uplifted;	Sometimes	Observer
Challenged or provoked by the visuals/music;Immersed in the environment;Calm and relaxed;	Sometimes	Depends on mood
Emotionally moved or impacted;Energetic and uplifted;Challenged or provoked by the visuals/music;	Sometimes	Observer

Immersed in the environment;Energetic and uplifted;	Rarely	Observer
Energetic and uplifted;	Sometimes	Depends on mood
Immersed in the environment;Emotionally moved or impacted;Energetic and uplifted;	Always	Depends on mood
Immersed in the environment;Emotionally moved or impacted;Energetic and uplifted;	Always	Depends on mood
Connected to others in the crowd;Challenged or provoked by the visuals/ music;Immersed in the environment;	Always	Depends on mood

How important is the physical sensation of music (e.g., feeling bass vibrations in your body) to your overall enjoyment of the club experience?	Please briefly explain why	What role does the environment (e.g., smoke, lighting, crowd density) play in creating a sense of physical immersion?
Very Important	Physical sound...	Important
Very Important	I really need high air pressure to fully enjoy a nightclub	Very Important
Very Important	It adds an extra dimension. I talked about it with quite some professionals in nightlife that most of us prefer to stand right in front of the speaker or subwoofer.	Very Important
Important		Important
Important	makes me feel immersed in the music	Important
Important	Technically this wasn't a club, but it was a performance in 'Brutus, the concrete cathedral' and I could feel the air kind envelop around myself through how the bass was moving, and this felt amazing	Very Important
Very Important	It enhances the feeling of being immersed in the experience.	Important
Important	it would be strange not to feel the music - it would let me feel like something is off or like music is too flat	Neutral

Important	Feeling the bass feels like an exxtra thing you can only experience in that kind of setting and not at home, making it more special	Important
Important	The music should overwhelm you a bit, making thoughts fade away so you can just be in the moment.	Very Important
Very Important	I enjoying dancing so feeling the beats are important	Important
Very Important	Sound systems and the intensity of the music is for me a very important factor when going out. Hard to explain. It just gives me more energy	Important
Very Important	thats why I go to a club. If I just want to get the emotion I can listen to the track with my headphones. The sound system is there for you to feel the bass with others	Very Important
Very Important	Because makes the experience emotionally valuable	Important
Important	low frequencies are supposed to feel 'heavy'. I think it's part of nature that you're connecting with.	Important
Important	It adds another level of immersion, but sometimes can be distracting from the music itself.	Important
Neutral		Important
Important	it makes me feel alive and bodily involved	Very Important
Very Important	feeling music makes the experience more immersive and stimulates me to move my body	Very Important
Important	speaker go brrrrrrr	Very Important

Please briefly explain why2	How can the visuals/lights or the audiovisual experience as a whole be improved in most nightclubs in your opinion?
It invites people to participate more openly.	More sparse... more mysterious...
These are the factors that influence spatial perception and mood.	Actually hiring someone who has studied how these elements are perceived by an observer!!
It contributes to the dreamy and mysterious atmosphere and creates a space that makes it different from spaces during the day. It adds to an environment for self expression and experimentation.	More smoke and more thoughful lighting plans that varies from time to time. More emphasis on the side of light art than on the technical engineering side.
Crowd density place a big role and the sweet spot of enough room to move but not uncrowded is important	
It teleports you outside of reality into a pocket dimension	embrace different kinds of experiences - strobes, ambiences, video, noise-
I think this can kind of help the music transform you from a room in a basement to something surreal	like stated before, explore more areas than just the stage and experiment with crowd involvement
All of these factors play with different senses of your body, so if they match well they can create a better experience.	I think that more focus and collaboration in the creation of the lighting according to the set that is gonna be played are important because I often feel the dissonance between them. I also feel that most of the clubs don't offer visuals supporting the set and I would like to see it more often.
crowd density is not really important unless it is too packed and uncomfortable, i also prefer smokey space with darker and minimalistic lights	less is more
It influences how you percieve the music that is played and if you are able to dance freely	Be more integrated with the music, make it a more cohesive experience
Too many people and you feel like you have no space to dance freely; too little people and you feel exposed, vulnerable (at least, I do). I love it when the crowd feels like one big breathing organism, going with the motions of the music, being directed by the DJ. Lighting can really unify the room and affect how you perceive the music, crowd, atmosphere emotionally.	I find that often only lights come from behind or above the DJ booth, and the further away you get, the less immersed you are. So somehow visuals and lights could be spread more over the club, so you feel part of the experience the moment you enter dancefloor at whatever point.
More people creates a synchronized vibe and immersion in the music	changes when people are dancing or when they are really thrilled. but also based on music rhythm
Same reason I guess	I feel like for example the lights could be played more in sync with the music sometimes. It might make the crowd feel even more energy and vibes from the already ongoing flow from the music.
Take Shelter - on sold out nights you literally cant even open the door to the main room because it's so packed. You need physical space to dance and have fun	Get minimal and creative. Play with light themes and motifs but make it subtle, only complementing the music. Pick a few (max 3) moments over the course of a night/set to take over control and then fade back into the background again.
Freedom and safety are important	More minimalistic and playing with the environment
You feel more anonymous in the crowd when the vibe is right and you feel more free to be yourself.	Most of the time there's a generic visual show. Visuals could be more 'intelligent' about how they react to the music. Maybe in the future AI could be used to program the visual show beforehand, telling the program what emotions you want to feel and how intense and quick the visuals should be.

By using the right combination of elements mentioned above, you can create a really immersive experience,	It really depends on the scenario and mood. While flashy lighting can work in certain situations, I generally prefer more subtle setups on most nights out. Each club should tailor its lighting to match the genre of music being played, the type of crowd it attracts, and the layout of the space. Sometimes, a simple combination of smoke and a strobe can create the perfect atmosphere, while other times, a more elaborate and immersive setup might be ideal. However, there isn't a single solution to improve nightclubs universally—it all depends on the context and the experience a club aims to deliver.
	Personally, I like it when the light and music are in sync, and the lights are relatively dim. It's quite annoying when they suddenly flash in your eyes
closeness with people can be unpleasant if the place is overcrowded. smoke and lighting are the best combo to "disappear" and enjoy the music.	good sound system space to experiment with artworks inviting artists and creating open calls to showcase in venues
it lets you disconnect from the dimension and gives you the sensation of "seeing" the music	less lights but more immersive, don't like chaotic and too much lit dancefloors
its literally the environment im physically immersed in	they should explore the intersection between technology and human connection more

appendix b: data ventriloquism experiment

Raw Data All Participants

participant 1

	perceived		
actual	left	center	right
left	4	1	
center		3	1
right			4

	perceived		
actual	left	center	right
left	3	3	
center		5	
right		3	3

participant 2

	perceived		
actual	left	center	right
left	3	1	
center	2	3	
right	3	1	

	perceived		
actual	left	center	right
left	4	2	
center	1	4	
right	1	3	2

participant 3

	perceived		
actual	left	center	right
left	3	1	
center		3	1
right		1	4

	perceived		
actual	left	center	right
left	5		
center		6	
right			6

participant 4

	perceived		
actual	left	center	right
left	5		
center	1	4	
right			5

	perceived		
actual	left	center	right
left	2	3	
center		5	
right		4	1

participant 5

	perceived		
actual	left	center	right
left	4		
center	1	3	1
right			5

	perceived		
actual	left	center	right
left	1	4	
center	2	4	
right		2	3

participant 6

	perceived		
actual	left	center	right
left	4	1	
center	1	3	
right		2	3

	perceived		
actual	left	center	right
left	5	1	
center	1	3	
right		2	4

participant 7

	perceived		
actual	left	center	right
left	5		
center	1	3	
right		1	4

	perceived		
actual	left	center	right
left	5		
center		6	
right		3	2

Total All Participants

total

	unimodal		
	perceived		
actual	left	center	right
left	28	4	0
center	6	22	3
right	3	5	25

	bimodal		
	perceived		
actual	left	center	right
left	25	13	0
center	4	33	0
right	1	17	21

Chi-Square Test

total unimodal

	perceived			
actual	left	center	right	total row
left	**28**	**4**	**0**	**32**
center	**6**	**22**	**3**	**31**
right	**3**	**5**	**25**	**33**
total column	**37**	**31**	**28**	**96**

total bimodal

	perceived			
actual	left	center	right	total row
left	**25**	**13**	**0**	**38**
center	**4**	**33**	**0**	**37**
right	**1**	**17**	**21**	**39**
total column	**30**	**63**	**21**	**114**

H_0: The distribution of perceived positions is the same across unimodal and bimodal conditions.

H_1: The distribution of perceived positions differs between the unimodal and bimodal conditions.

observed

	perceived			
actual	left	center	right	total row
left	**25**	**13**	**0**	**38**
center	**4**	**33**	**0**	**37**
right	**1**	**17**	**21**	**39**
total column	**30**	**63**	**21**	**114**

expected

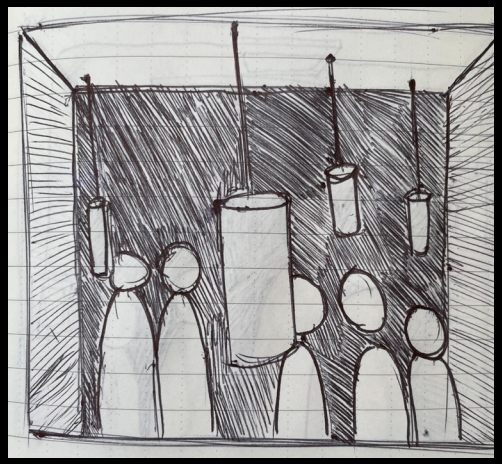
	perceived			
actual	left	center	right	total row
left	**33,25**	**4,75**	**0**	**38**
center	**7,18**	**26,27**	**3,58**	**37,03**
right	**3,55**	**5,93**	**29,55**	**39,03**
total column	**43,98**	**36,95**	**33**	**114,06**

calculations	left	center	right
left	**2,046992481**	**14,32894737**	**0,000000001**
center	**1,408412256**	**1,724130187**	**3,58**
right	**1,831690141**	**20,66524452**	**2,473857868**

chi square total	48,05927482
deg of freedom	4
p	0,000000000917

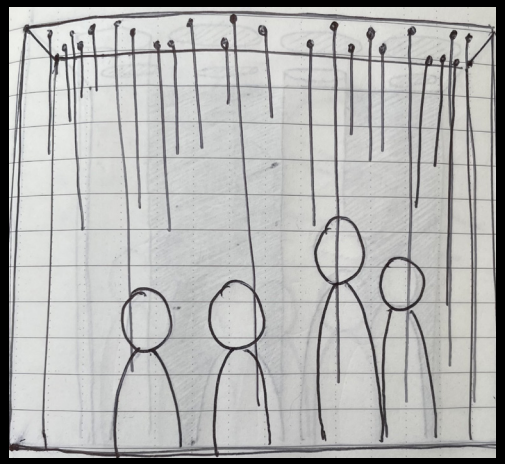
appendix c: idea sketches & descriptions

1. Lanterns



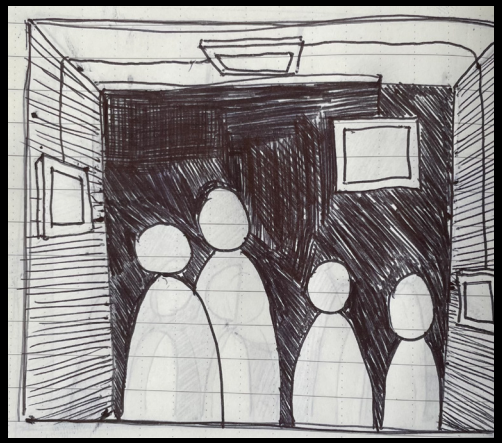
Custom 3D-printed lanterns with LED filaments, attached to ceiling. Different lanterns light up based on different audio triggers. Brightness of lamps can be mapped to parameters like pitch or loudness.

2. Strings



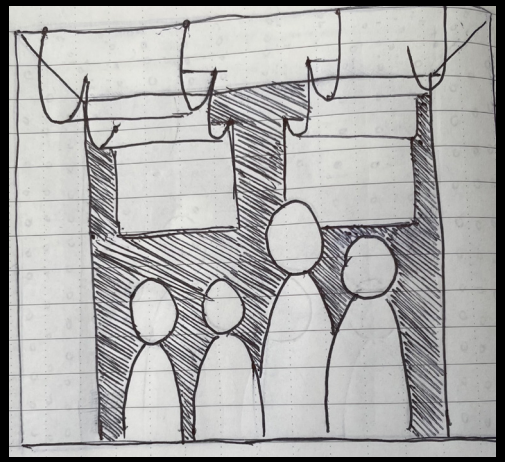
Different length EL wire strings attached to the ceiling, coming distributed throughout the entire room. Different wires light up based on different audio triggers. Brightness of wire can be mapped to parameters like pitch or loudness.

3. Windows



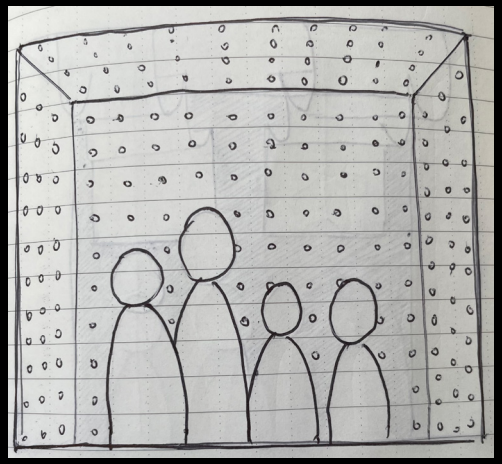
Screens mounted to different surfaces (walls and ceiling). These screens act as windows into a 3D world outside of the room. The 3D world (likely controlled by TD, Unreal or Unity) contains audio-reactive objects.

4. Curtains



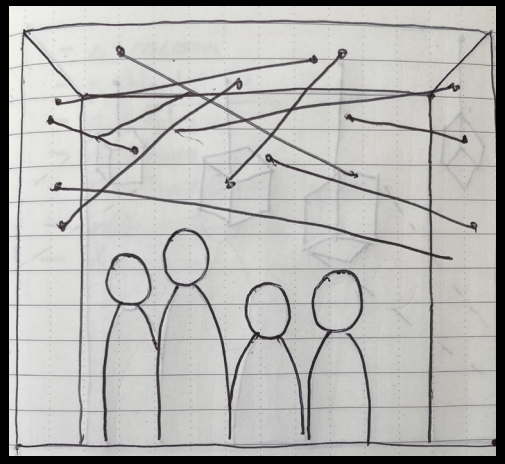
Textile suspended from the ceiling and covering the walls. Projector can display visual cues on different parts of these curtains based on music.

5. Matrix



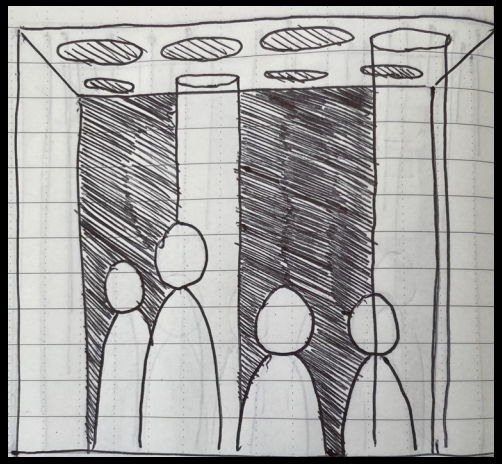
Matrix of LEDS covering the walls and ceiling. Either made with LED matrix units or strips. This matrix can then display the audio directly (like an oscilloscope or spectrogram). The spectrogram can wrap around the room, associating different parts with different frequency bands.

6. Web



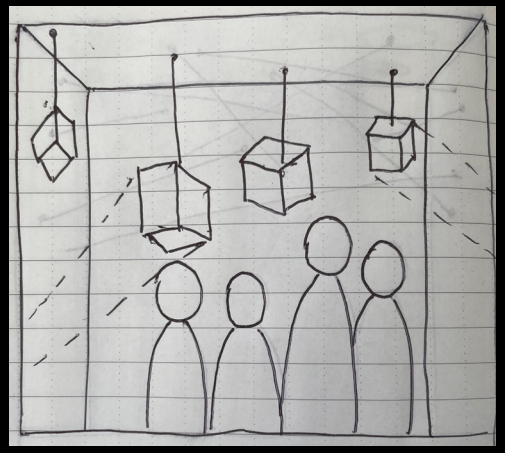
Web of EL wire covering parts of the ceiling and walls. Made in such a way that it acts as a beautiful enveloping light sculpture. Different strings are associated with different musical triggers. Brightness can be mapped to musical parameters like pitch or loudness. *Individual strings inside a complex web act as a visual metaphor for individual musical elements within a complex mix.*

7. Beams



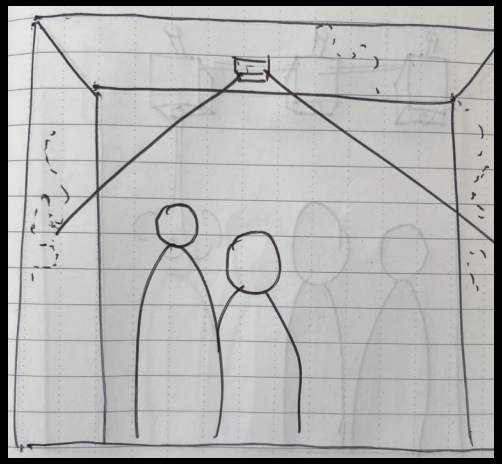
Ceiling mounted spots that create downward facing beams of light. These beams become visible through the use of smoke machines. Different beams light up based on different musical triggers.

8. Cubes



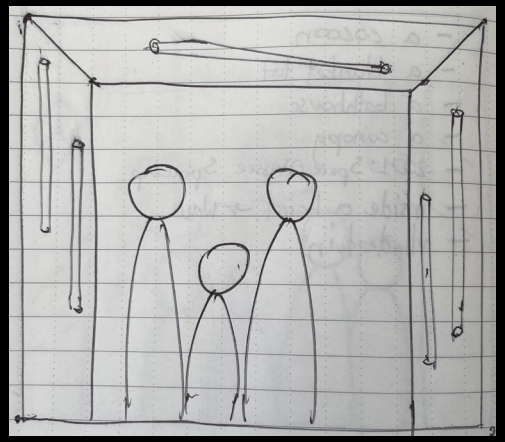
Cubes (or other sculptural shapes) suspended from the ceiling. Projector can display visual cues on them (projection mapping). These cues will be triggered by the music.

9. UV Laser



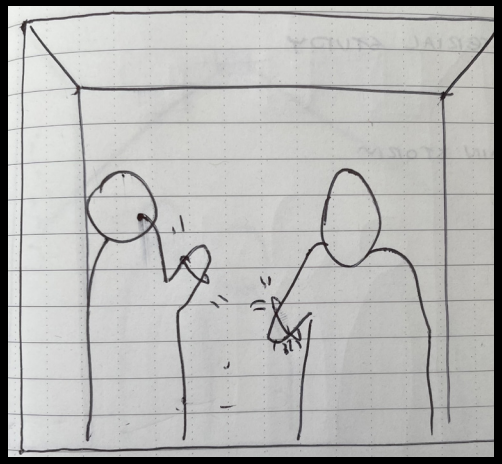
All surfaces are covered in UV reactive paint. There are lasers that are controlled by the audio that draw on these surfaces. This turns the walls into a giant display and unique display.

10. Bars



Surfaces are covered in LED bars. These bars react to the audio (brightness). Different bars light up based on different audio triggers. They should be placed in such a way to create an interesting effect.

11. Wristbands

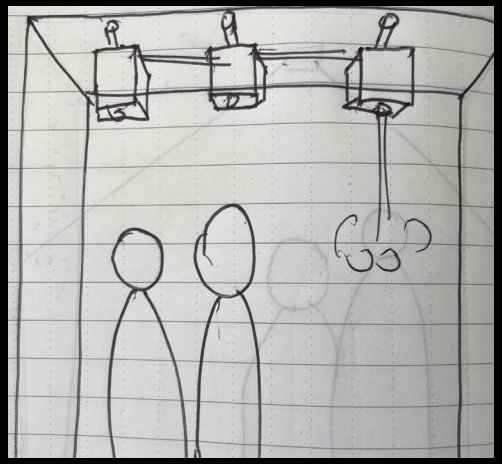


All guests are given audio-reactive remote controlled wristbands. They will light up based on different audio cues. Because the lightsource is wearable, the visual cues will come all over the place.

12. Canopy

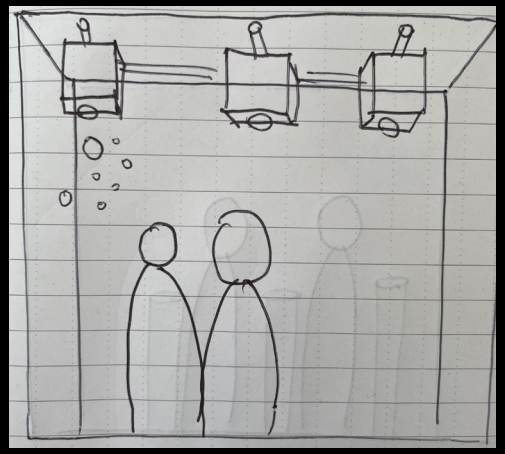
A tree-like canopy made from EL-panels. Different parts of this canopy light up based on different audio triggers. The armatures holding the panels (or leaves) can be 3D printed out of transparent material, so they light up as well.

13. Smoke



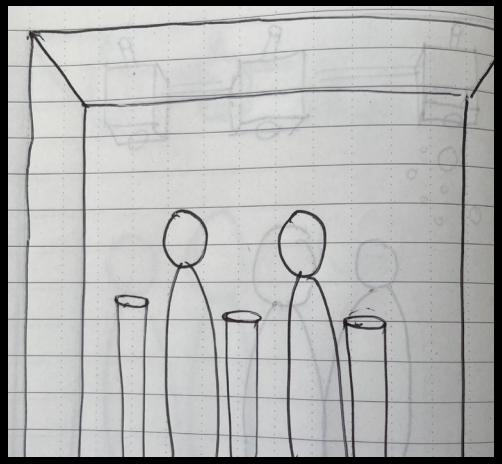
Ceiling mounted smoke machines that create visual cues by creating smoke in different locations based on auditory cues. The effect can be enhanced by using lasers or spots to accentuate the smoke.

14. Bubbles



Ceiling mounted bubbles machines that create visual cues by creating bubbles in different locations based on auditory cues. These bubbles should be combined with light reflecting off of them, creating a beautiful effect.

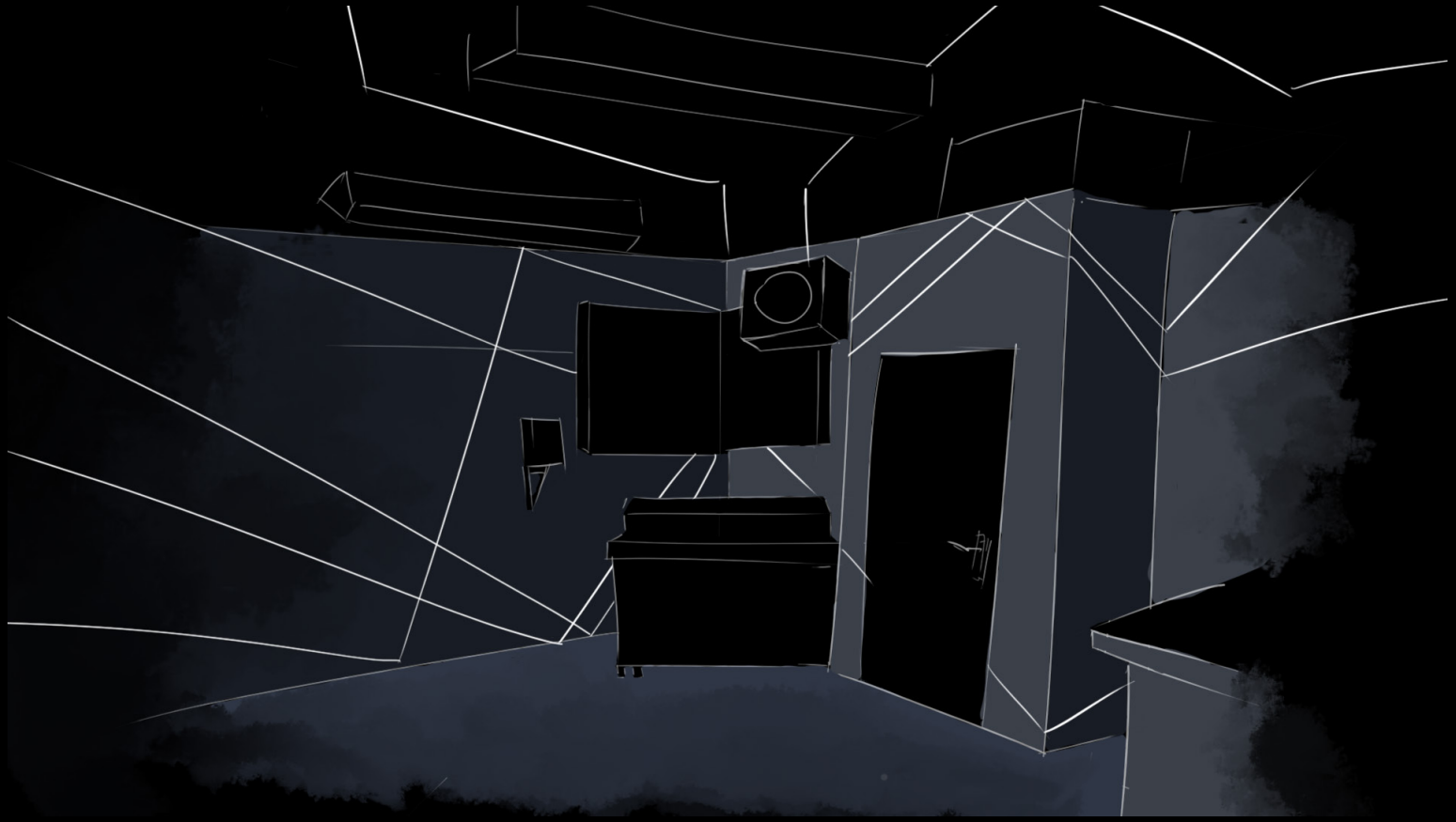
15. Pillars



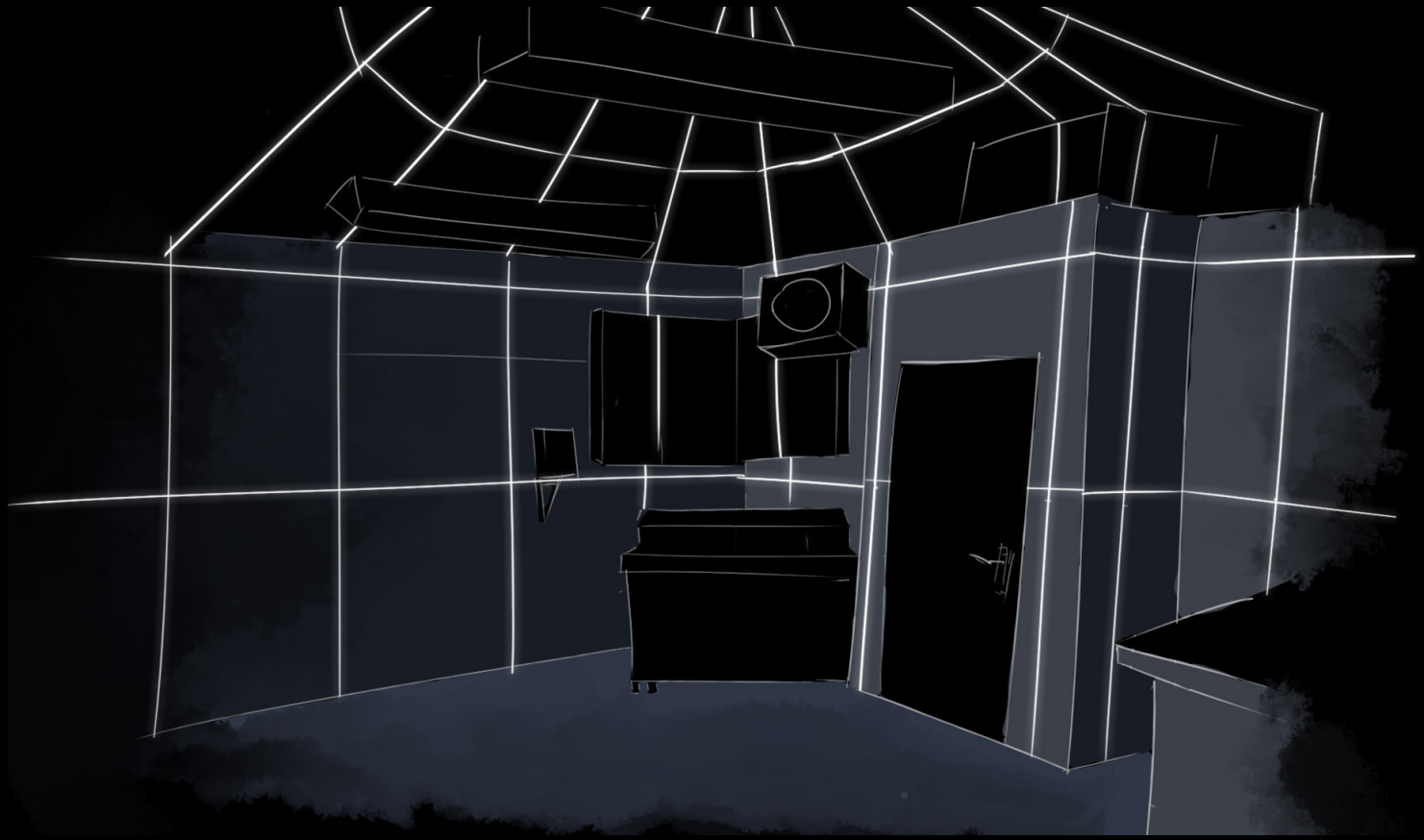
Cylindrical pillars that can light up are placed on the ground throughout the space. Different pillars light up based on different audio triggers.

appendix d: form iteration 1

Web (Option 1)

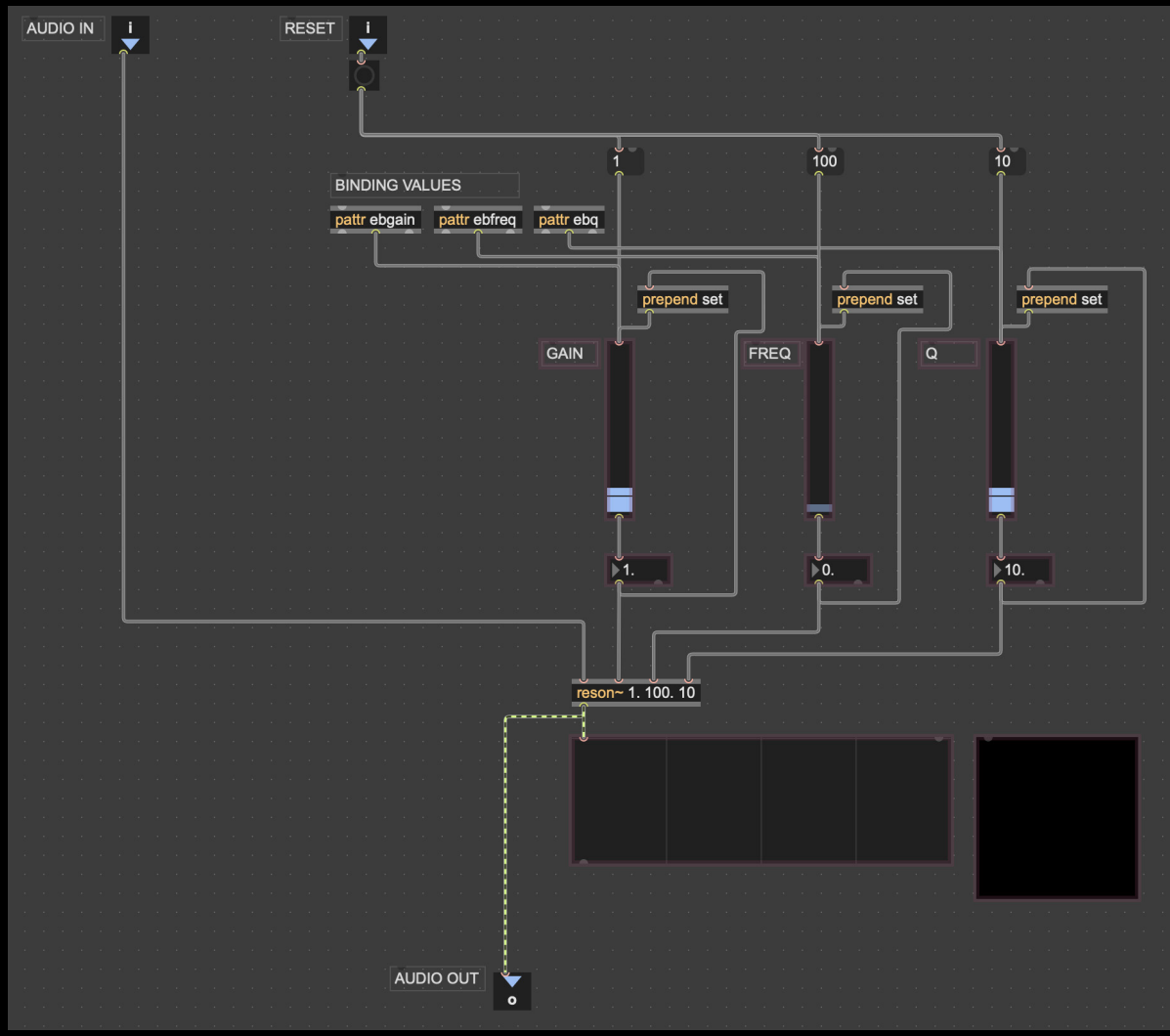


Web (Option 2)

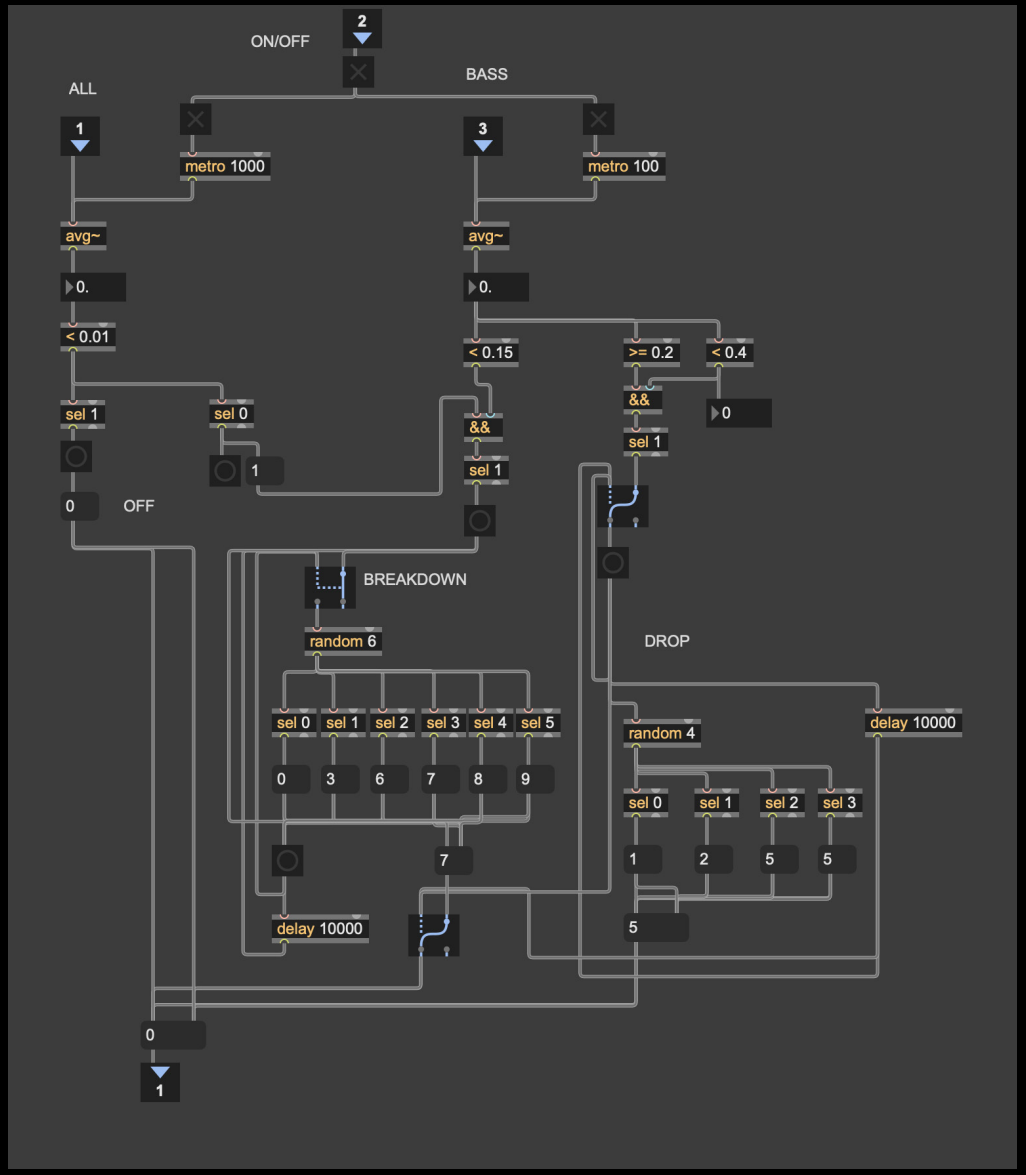


appendix e: max/msp

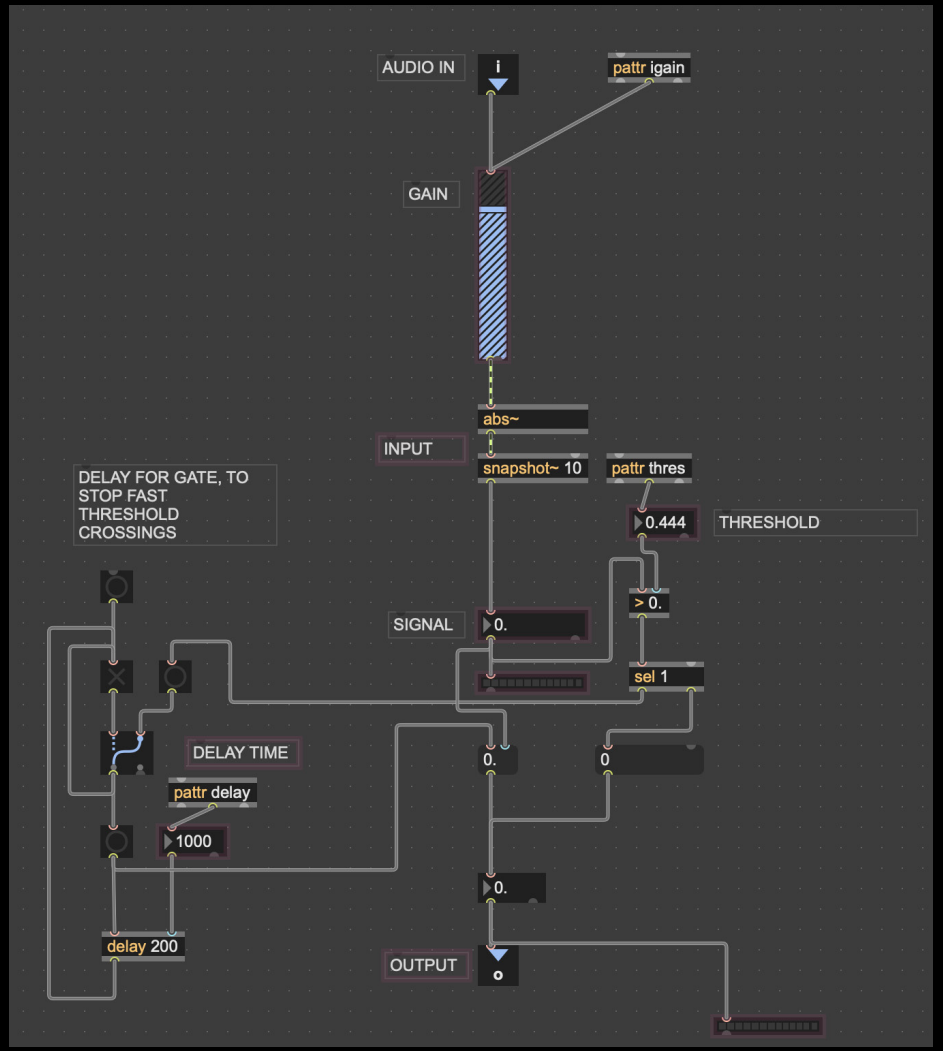
Band-Pass Filter



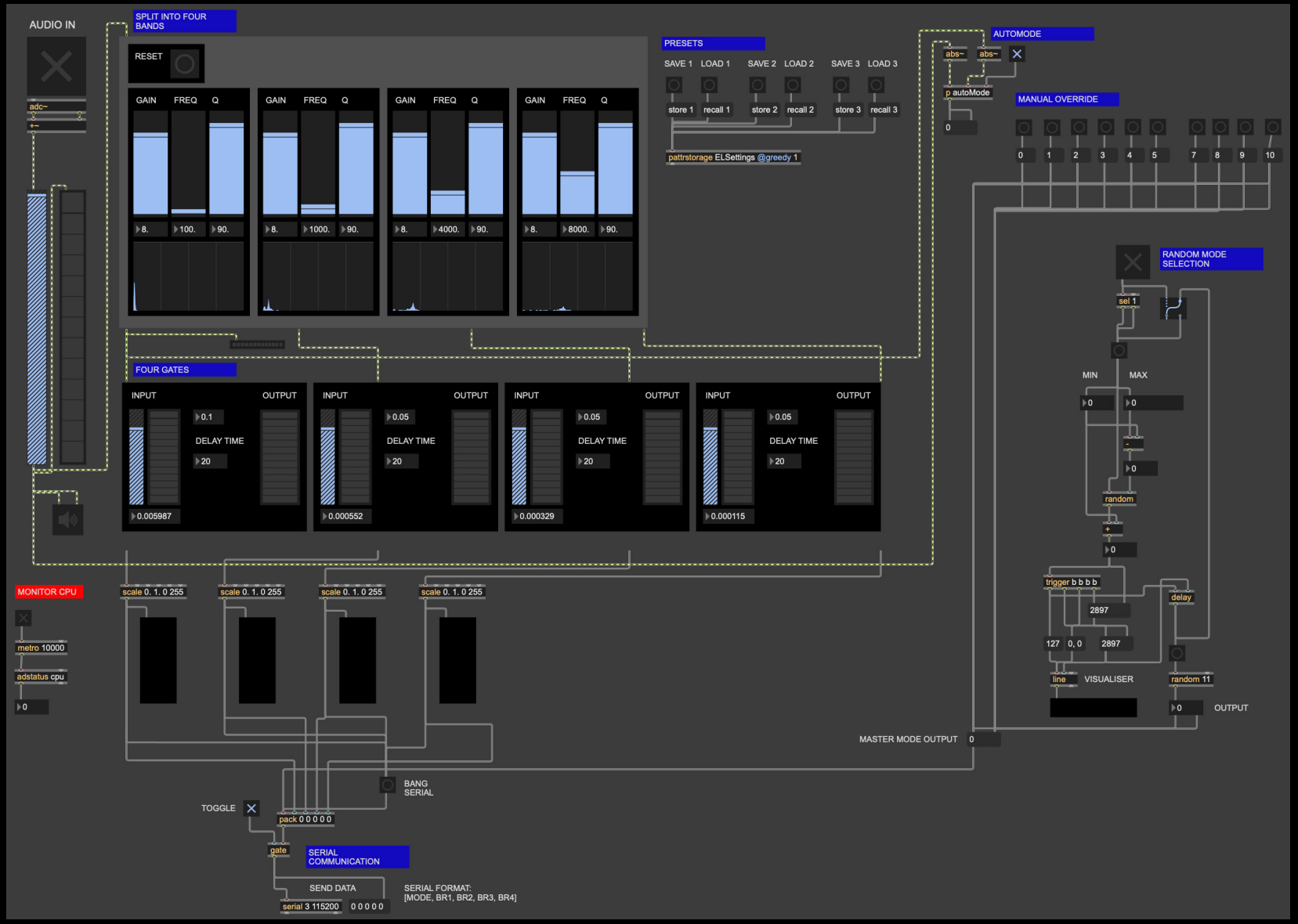
Automatic Mode Switching



Noise Gate



Main Patch


AUDIO IN
SPLIT INTO FOUR BANDS
RESET
GAIN FREQ Q
8. 100. 90.
8. 1000. 90.
8. 4000. 90.
8. 8000. 90.
PRESETS
SAVE 1 LOAD 1 SAVE 2 LOAD 2 SAVE 3 LOAD 3
store 1 recall 1 store 2 recall 2 store 3 recall 3
pattrstorage ELSettings @greedy 1
AUTOMODE
abs~ abs~
p autoMode
MANUAL OVERRIDE
0 1 2 3 4 5 7 8 9 10
RANDOM MODE SELECTION
sel 1
MIN MAX
random
trigger b b b
delay
2897
127 0, 0 2897
line
VISUALISER
random 11
OUTPUT
FOUR GATES
INPUT OUTPUT
DELAY TIME
0.1 0.05 0.05 0.05
20
0.005987 0.000552 0.000329 0.000115
MONITOR CPU
metro 10000
adstatus cpu
scale 0. 1. 0 255
MASTER MODE OUTPUT 0
BANG
SERIAL
TOGGLE
pack 0 0 0 0 0
gate
SERIAL COMMUNICATION
SEND DATA
serial 3 115200 0 0 0 0 0
SERIAL FORMAT:
[MODE, BR1, BR2, BR3, BR4]

appendix f: arduino

```ino
#include "FastLED.h"

// Pins connected to MOSFETS
#define GROUP_1_PIN 5
#define GROUP_2_PIN 7
#define GROUP_3_PIN 9
#define GROUP_4_PIN 11

// Keeps track of inputs
uint8_t gate1 = 0;
uint8_t gate2 = 0;
uint8_t gate3 = 0;
uint8_t gate4 = 0;

// For randomised mapping for Sync Random mode
int randomMapping[] = {0,1,2,3};
unsigned long lastSwitchTime = 0;
unsigned long switchInterval = 0;

unsigned long lastSwitchTimeMode = 0;
unsigned long switchIntervalMode = 0;

float level1 = 254.0;
float level2 = 254.0;
float level3 = 254.0;
float level4 = 254.0;

int MODE = 0;

unsigned long fluidInterval = 3;
unsigned long lastFluidTime = 0;

// 0: OFF, 1: SYNC+CORRESPONDENCE, 2: SYNC+RANDOM, 3: SLOW NOISE, 4: TEST, 5: NOISE (FAST)
// 6: NOISE (SINGLE 1), 7: NOISE (SINGLE 2), 8: NOISE (SINGLE 3), 9: NOISE (SINGLE 4)

void setup() {
    Serial.begin(115200);
    pinMode(GROUP_1_PIN, OUTPUT);
    pinMode(GROUP_2_PIN, OUTPUT);
    pinMode(GROUP_3_PIN, OUTPUT);
    pinMode(GROUP_4_PIN, OUTPUT);
}

void loop() {
  updateInputs();
  switch (MODE){
    case 0:
      offMode();
      break;
    case 1:
      syncCor();
      break;
    case 2:
      syncRandom();
      break;
    case 3:
      noiseSlow();
      break;
    case 4:
      testMode();
      break;
    case 5:
      noiseFast();
      break;
    case 6:
      noiseSingle(10, 0, GROUP_1_PIN, GROUP_2_PIN, GROUP_3_PIN, GROUP_4_PIN);
     break;
    case 7:
      noiseSingle(10, 0,GROUP_2_PIN, GROUP_1_PIN, GROUP_3_PIN, GROUP_4_PIN);
     break;
    case 8:
      noiseSingle(10, 0,GROUP_3_PIN, GROUP_2_PIN, GROUP_1_PIN, GROUP_4_PIN);
     break;
    case 9:
      noiseSingle(10, 0,GROUP_4_PIN, GROUP_2_PIN, GROUP_3_PIN, GROUP_1_PIN);
     break;
    default:
      offMode();
      break;
  }


}

void syncCor(){
  // The lights work like containers that lose brightness level at a rate of *0.6.
  // Every time an input value is received, it is added to the brightness level.
  // This causes every input to have a 'tail', making the light animations a bit smoother.

  // Light levels are decreased at specific interval
  if (millis()-lastFluidTime > fluidInterval){
    level1 = level1 * 0.6;
    level2 = level2 * 0.6;
    level3 = level3 * 0.6;
    level4 = level4 * 0.6;
    lastFluidTime = millis();
  }

```

```
  // Current inputs get added to the levels. Scaled using factor f.
  int f = 20;
  level1 = level1 + (gate1*f/255);
  level2 = level2 + (gate2*f/255);
  level3 = level3 + (gate3*f/255);
  level4 = level4 + (gate4*f/255);

  // Levels are clamped at 0
  if (level1<1){
    level1 = 0;
  }
  if (level2<1){
    level2 = 0;
  }
  if (level3<1){
    level3 = 0;
  }
  if (level4<1){
    level4 = 0;
  }

 // Levels are written to groups
  analogWrite(GROUP_1_PIN, int(level1));
  analogWrite(GROUP_2_PIN, int(level2));
  analogWrite(GROUP_3_PIN, int(level3));
  analogWrite(GROUP_4_PIN, int(level4));

}
void syncRandom(){
  // The following randomly maps the inputs to different light groups

  unsigned long currentMillis = millis();
  if (currentMillis - lastSwitchTime >= switchInterval) {
      // Shuffle the mapping array
      shuffleArray(randomMapping);
      lastSwitchTime = currentMillis;
      // Randomize the switch interval (for variety)
      switchInterval = random(1000, 4000);
    }

  // Map groups according to random mapping
  int gates[] = {gate1, gate2, gate3, gate4};
  int mappedGates[4];
  mappedGates[0] = gates[randomMapping[0]];
  mappedGates[1] = gates[randomMapping[1]];
  mappedGates[2] = gates[randomMapping[2]];
  mappedGates[3] = gates[randomMapping[3]];

  // This works exactly the same as in syncCor()
```

```
  if (millis()-lastFluidTime > fluidInterval){
    level1 = level1 * 0.6;
    level2 = level2 * 0.6;
    level3 = level3 * 0.6;
    level4 = level4 * 0.6;
    lastFluidTime = millis();
  }

  int f = 20;
  level1 = level1 + (mappedGates[0]*f/255);
  level2 = level2 + (mappedGates[1]*f/255);
  level3 = level3 + (mappedGates[2]*f/255);
  level4 = level4 + (mappedGates[3]*f/255);


  if (level1<1){
    level1 = 0;
  }

  if (level2<1){
    level2 = 0;
  }
  if (level3<1){
    level3 = 0;
  }
  if (level4<1){
    level4 = 0;
  }

  analogWrite(GROUP_1_PIN, int(level1));
  analogWrite(GROUP_2_PIN, int(level2));
  analogWrite(GROUP_3_PIN, int(level3));
  analogWrite(GROUP_4_PIN, int(level4));

}
void offMode() {
  // Write '0' to all light groups
  analogWrite(GROUP_1_PIN, 0);
  analogWrite(GROUP_2_PIN, 0);
  analogWrite(GROUP_3_PIN, 0);
  analogWrite(GROUP_4_PIN, 0);
}

void testMode() {
  // Turn everything on
  analogWrite(GROUP_1_PIN, 255);
  analogWrite(GROUP_2_PIN, 255);
  analogWrite(GROUP_3_PIN, 255);
  analogWrite(GROUP_4_PIN, 255);
```

```
}

void noiseFast(){
  // Fast noise (p1 determines speed)
  noiseMode(5,0);
}

void noiseSlow(){
  // Slow noise (p1 determines speed)
  noiseMode(12,0);
}

void noiseMode(int p1, int p2) {
  // Set X position for each group
  int group1X = 1;
  int group2X = 20000;
  int group3X = 30000;
  int group4X = 40000;

  // Generate noise
  uint8_t noise1 = constrain(inoise8(group1X+(millis()/p1)),p2,255);
  uint8_t noise2 = constrain(inoise8(group2X+(millis()/p1)),p2,255);
  uint8_t noise3 = constrain(inoise8(group3X+(millis()/p1)),p2,255);
  uint8_t noise4 = constrain(inoise8(group4X+(millis()/p1)),p2,255);

  noise1 = int(mapCurve(noise1));
  noise2 = int(mapCurve(noise2));
  noise3 = int(mapCurve(noise3));
  noise4 = int(mapCurve(noise4));

  // Write values to light groups
  analogWrite(GROUP_1_PIN, noise1);
  analogWrite(GROUP_2_PIN, noise2);
  analogWrite(GROUP_3_PIN, noise3);
  analogWrite(GROUP_4_PIN, noise4);


}

void noiseSingle(int p1, int p2, int pin1, int pin2, int pin3, int pin4) {
  // Does noise on single arm
  uint8_t noise1 = constrain(inoise8((millis()/p1)),p2,255);
  noise1 = int(mapCurve(noise1));
  analogWrite(pin1, noise1);
  analogWrite(pin2, 0);
  analogWrite(pin3, 0);
  analogWrite(pin4, 0);
}
void updateInputs (){
  if (Serial.available() > 0) {

    // Read inputs from serial and assign to variables in the right order
    MODE = Serial.read();
    gate1 = Serial.read();
    gate2 = Serial.read();
    gate3 = Serial.read();
    gate4 = Serial.read();

  }
}

float mapCurve(float x) {
  // Does non-linear noise mapping to better work with the brightness of the EL-wire
    float normX = x / 255.0;

    if (x <= 0) return 0;
    if (x >= 255) return 255;

    // Apply separate power functions for low and high ranges
    float lowCurve = pow(normX, 3.0);
    float highCurve = pow(normX, 1.8);

    float blendFactor = smoothstep(0.3, 0.6, normX);

    // Interpolate between both curves
    float output = (1 - blendFactor) * lowCurve + blendFactor * highCurve;

    return constrain(output * 255.0, 0, 255);
}


float smoothstep(float edge0, float edge1, float x) {
    x = constrain((x - edge0) / (edge1 - edge0), 0.0, 1.0);
    return x * x * (3 - 2 * x);
}
void shuffleArray(int arr[4]) {
    for (int i = 3; i > 0; i--) {
        int j = random(i + 1);
        int temp = arr[i];
        arr[i] = arr[j];
        arr[j] = temp;
    }
}

```

appendix g: data user test

Quantitative: Questionnaire 1 (Perceived Localisation)

perceived localisation										
condition A				*condition B*				*condition C*		
	participant	**rating**			**participant**	**rating**			**participant**	**rating**
	1	8			1	8			1	9
	2	6			2	5			2	4
	3	7			3	9			3	7
	4	8			4	8			4	1
	5	7			5	7			5	9
	6	6			6	8			6	4
	7	8			7	8			7	2
	8	8			8	9			8	5
	9	9			9	4			9	2
	10	8			10	7			10	10
	11	5			11	4			11	4
	12	5			12	8			12	6
	13	9			13	6			13	3
	mean	7,23			**mean**	7,00			**mean**	5,08
	standard dev.	1,36			**standard dev.**	1,73			**standard dev.**	2,93
	median	8			**median**	8			**median**	4
	min	5			**min**	4			**min**	1
	max	9			**max**	9			**max**	10

Quantitative: Questionnaire 1 (Immersion)

immersion										
condition A				*condition B*				*condition C*		
	participant	**rating**			**participant**	**rating**			**participant**	**rating**
	1	10			1	10			1	10
	2	8			2	7			2	9
	3	8			3	9			3	8
	4	9			4	5			4	3
	5	6			5	9			5	10
	6	7			6	9			6	5
	7	10			7	8			7	4
	8	6			8	7			8	5
	9	8			9	8			9	6
	10	10			10	8			10	4
	11	9			11	5			11	6
	12	7			12	8			12	7
	13	10			13	8			13	3
	mean	8,31			**mean**	7,77			**mean**	6,15
	standard dev.	1,49			**standard dev.**	1,48			**standard dev.**	2,48
	median	8			**median**	8			**median**	6
	min	6			**min**	5			**min**	3
	max	10			**max**	10			**max**	10

Quantitative: Questionnaire 1 (Interaction Qualities)

intimate				
	condition A	**condition B**	**condition C**	mean
	4	4	5	4,333333333
	4	3	5	4
	3	4	5	4
	3	3	1	2,333333333
	3	3	2	2,666666667
	3	2	4	3
	5	2	4	3,666666667
	3	2	3	2,666666667
	3	5	3	3,666666667
	2	4	4	3,333333333
	5	2	4	3,666666667
	4	2	4	3,333333333
	5	2	5	4
mean	3,615384615	2,923076923	3,769230769	
standard dev.	0,9607689228	1,037749043	1,23516842	
median	3	3	4	
min	2	2	1	
max	5	5	5	

unfamiliar				
	condition A	**condition B**	**condition C**	mean
	1	1	1	1
	1	4	2	2,333333333
	4	2	2	2,666666667
	3	3	2	2,666666667
	3	4	2	3
	5	4	2	3,666666667
	4	3	4	3,666666667
	4	2	2	2,666666667
	2	4	4	3,333333333
	4	4	3	3,666666667
	2	4	2	2,666666667
	2	1	4	2,333333333
	4	2	1	2,333333333
mean	3	2,923076923	2,384615385	
standard dev.	1,290994449	1,187542172	1,043907845	
median	3	3	2	
min	1	1	1	
max	5	4	4	

welcoming				
	condition A	**condition B**	**condition C**	mean
	3	3	4	3,333333333
	3	2	5	3,333333333
	4	4	5	4,333333333
	5	4	2	3,666666667
	3	3	5	3,666666667
	2	3	4	3
	4	4	4	4
	3	4	5	4
	5	4	3	4
	5	4	3	4
	5	2	4	3,666666667
	3	4	3	3,333333333
	4	4	5	4,333333333
mean	3,769230769	3,461538462	4	
standard dev.	1,012739367	0,7762500258	1	
median	4	4	4	
min	2	2	2	
max	5	4	5	

Qualitative: Questionnaire 2

Id	Group	Order	Did you notice differences in immersion between the different light modes? Please explain why.	Did you notice differences in perceived localisation (i.e. where the sounds come from) of the audio between the different light modes? Please explain why.	Please leave any additional opinions, questions or comments here.
1	1	ABC	yes - I felt more immersed in the last one, especially after the first form I started to pay more attention to reflect towards the questions	yes especially at the beginning due to how the lights answer to the music	the last mode is very peaceful and warm and makes me feel at ease. the first 2 are more hectic and disruptive. it was difficult to notice the difference between the first 2 modes. maybe the second was more hectic than the first?
2	1	ABC	Yes, I feel like the whole installation is very immersive, because it surrounds you with light. The last mode does this best imo	Yeah if it flikkers then the sound comes more from where the light appearance.	I think the different lighting modes give different feelings, and this could be in contrast or complementary to the music. Would love to see it live through a whole dj set.
3	1	ABC	I realised that it is boring when it is not connected each other music and lights.	I did not realized that specifically but the last one is so familiar and normal and it was boring.	I like the second one most. It was clear how you choose which notes of music will affect the light and which way.
4	1	ABC	Yes I noticed. At the beginning it was very fast and at some point I got eye constrain and the last light mode was going slower which I enjoyed more however I wanted to dance less.	I didn't notice much differences in perceived localisation.	
5	1	ABC	O thought when it flicked too fast or slow it became less immersive. The 2nd for me seemed more immersive	No, i didn't I'm sorry :(	I thought overall it was immersive and i liked how the veins lingered after they switched off. The coordination between sound and light was nice, but localised sound to light could be a bit more obvious. Nice job! I felt like i was in a brain
6	2	CBA	yes, sometimes when the light was more in synch with the music I would be more immersed, but when the light flickered too fast or to short I would be less immersed.	Barely, It didn't really feel like the sound was coming from the same point as where the light flashed.	The difference between mode 2 and 3 was difficult for me to notice, but 3 felt more immersive and natural than 2. it also felt less aggressive.
7	2	CBA	Yes. The more contrast between light and darkness combined with the rhythms, the more immersive it felt	Yes, with the lights triggering on different beats it kind of felt like the different hits/ parts of the spectrum were in different parts. Not necessarily drastically but I imagine if I wasn't sober it would be insane.	Beautiful beautiful beautiful, I LOVED it! :)
8	2	CBA	Yes / If the movement of the lighting sync well with the sound rhythm, it feels more immersive	Not too much.. Maybe because this room is small and we don't have a lot speakers at different corners? So it's very obvious that the sound is coming from one source	The first test has drasfic difference from the next two. Sometimes I wonder the stillness added a lot of calmness. Sometimes I feel unease.
9	2	CBA	Yes, I was further immersed each time. I could feel the music more, and I had fewer (distracting thoughts.)	Yes, again, I experiened more perceived localisation each round. During the second round I was thinking about the phenomenon a little and didn't so much hear the sound coming from different places, but more so link sounds to a location. In the third round I stopped thinking and could actually feel and hear the audio coming from different places.	The track was awesome, the lighting sick!!!!!!!
10	2	CBA	Yes. I felt more immersed in the second and third light mode than in the first one. I think that is because the light mode was more in sync with the music, pulling me in more.	I thought that the second light mode was the most versatile when it came to sound locations. However, that might also be because I was most attentive to the locations of the sounds in the second round.	
11	2	CBA	Yes! One reason for this was the difference in how fast the changes were in different light modes. But the difference in immersion was caused most of all by the alignment between certain parts of the lights display aligning with certain musical cues. As a side effect, this drew my attention to different parts of the space.	I thought that the second light mode was the most versatile when it came to sound locations. However, that might also be because I was most attentive to the locations of the sounds in the second round.	
12	2	CBA	I felt immersed in all of the three but in different modes. during the first mode I felt more immersed because it was more difficult to identify the source of light, so I was feeling it was all around me. The second one I felt it was more connected to the music and that increased my sense of immersion. While the third one, made me feel more welcomed because it felt more static but at the same time it was not the one I felt the most immersed into probably for the same reason.	Yes. The difference was caused by the alignment of visual and musical cues. My visual attention being drawn into different directions caused this, which was really fun.	Love the idea, make it bigger/more elaborate
13	1	ABC	Yeah A felt much more tied in with the music making it more part of the environment where C felt more like an object to observe. B was kinda immersive but too confusing and distracting	The first mode made it hard to notice where the sound came from because I was focused on the different sources of lights, while in the second one it seemed the audio came from the place behind the console because it was the main source of light. Same for the third mode, I perceived the audio coming more from the corner of the room behind the console, while I felt less connected if I was moving around the room and getting closer to the opposite sides.	I felt that the second one was the best mode to feel immersed yet welcomed and a bit disoriented at the same time. The light coming from one main source made it feel less confusing but at the same time the speed increased the sense of connection to the music, therefore a general feeling of immersion.
				Yeah for C not so much but for A and B i think so mostly when the kick lined up with the long arm gripping around me it felt like the sound was also filling the room more	one of the things that made it more immersive to me was the play between the wires and the tiles. like the ones that were going over the tiles made that whole grid more defined which connected it more to the physical environment

appendix h: club night questionnaire

Quantitative: Immersion Scores

immersion in exhibition space (0-10)				immserion light installation (0-10)		
	participant	score			participant	score
	1	10			1	10
	2	8			2	8
	3	10			3	10
	4	10			4	10
	5	8			5	9
	6	10			6	10
	7	10			7	8
	8	7			8	7
	9	8			9	8
	10	8			10	9
	11	8			11	10
	12	8			12	8
	13	9			13	8
	14	6			14	6
	15	7			15	8
	mean	8,466666667			mean	8,600
	standard dev.	1,302013093			standard dev.	1,242118007
	median	8			median	8
	min	6			min	6
	max	10			max	10

Quantitative: Interaction Qualities

IQ: intimate (Likert 1-5)			IQ: welcoming (Likert 1-5)			IQ: unfamiliar (Likert 1-5)		
	participant	score		participant	score		participant	score
	1	3		1	3		1	4
	2	3		2	5		2	1
	3	5		3	5		3	4
	4	5		4	4		4	1
	5	5		5	5		5	1
	6	5		6	4		6	4
	7	4		7	4		7	3
	8	3		8	4		8	4
	9	5		9	4		9	3
	10	4		10	4		10	3
	11	3		11	4		11	2
	12	4		12	4		12	4
	13	4		13	4		13	3
	14	4		14	4		14	4
	15	5		15	4		15	4
	mean	4,133333333		mean	4,133333333		mean	3
	standard dev.	0,8338093878		standard dev.	0,5163977795		standard dev.	1,195228609
	median	4		median	4		median	3
	min	3		min	3		min	1
	max	5		max	5		max	4

Qualitative

contributions to immersion		interplay sound and light	
spatial configuration	9	lights enhancing music	2
light animations	5	synchronisation	7
the crowd	2		

Please explain why. (Immersion in bar40)	Please explain why. (Installation contribution to immersion)
Lost sense of perception of the room and the installation was visible om all 3 axis	Mostly the scale and positioning of the lighting made the inmersion effective
Love the people and the music, of course	It enhanced the music and the vibe
The lighting was remarkably put in such an organic way, that it made me immerse to the fullest	Read laat answer
i felt immerse thanks to how lights were spread out in the space. also the smoke was helping feeling immersed and bar40 is a small room.	the lights "hug" the space and the people dancing - I felt the smoke was also helping dispersing the light - with this installation the lights become a rythmic presence that stimulate and enhance the experience, elevating the evening. usually the lights are very distant and sterile.
The lights really gave me energy, I had the feeling that there was more to the room versus reality. And the flickering of the lights made it feel like the thunder was really in the room, It just made the place feel more like an fedtival experience.	Normally the room is very red and industrial, It gives it just a basic club feeling. With the installation it had way more going on at the same time which made u focus more on getting lost in the music and visuals.
The audioreactive installation made all the difference.	Its organic shape, different modes and audioreactive functionality made for a very immersive experience. The light responding in real time with the dynamics of the music made for some truly magical moments.
The vibe of the people was ecstatic! A great community with great music.	It was hauntingly gorgeous and reflected the music beautifully.
	It definitely contributed to the immersion in the sense that the threads creeped out of one corner so in a way both physically and psychologically it pulled you in towards the booth. For a weekender this suited nicely because club-goers are there to stay and want to be sucked in.
The space is small what makes it intimate, but could also feel cramped. With the lighting that surrounds you it doesn't feel like this since the light 'hugs' you.	Yeah same as the answer before.
I felt more immersed than usual in the environment, thanks to the seamless combination of music, lighting, and the space itself. I appreciated how the lights were designed specifically for that setting, turning its small size into a strength rather than a limitation. Unlike other crowded club nights I've experienced at Bar40, the lighting made the space feel intimate rather than oppressive.	The light installation made me feel as if I had stepped into a cocoon—a protected, intimate space. Its placement felt perfectly suited to the setting; the already small environment amplified the sensation of being enveloped in a close, sheltered space. Yet, rather than feeling confining, it was cozy and comforting, despite the cool tones of the lights.
the lightning bolt at the top, i felt covered	the lighting kind of covered a lot of the area at the top
The light installation enhanced the experience of the audio, it felt like an experience.	the lights moving to the beats and the harmonic spectrum made it feel like you were in a kind of strange other world. Only thing that could have made it better if there was more contrast between the lights (the bar lights are hard to get rid of though).
the combination of light that reacts to the sound while wrapping up the space at the same time creates this sensation of being in a web of music	
The interaction between the sound and the light is quite unique and the small room makes it feel more immersive and intimate.	The light immediately drew my attention. The way in which it interacts with the sound makes it very captivating. It did sometimes make me focus more on the visuals than on the sound of the music.
Compared to the average nightclub area it is small and intimate, which makes it immersive. The light installation also helped, but I now see there is a separate question for that.	The light installation had "tentacles" all around the room, meaning the light was all around me (especially standing in the front). As compared to other light installations I've seen, this one felt more like a part of the environment instead of just being in the room. Also, compared to light installations that are more spotlight-like, for example, the light from this one is much softer, adding to the environmental feel of the installation.

Did you notice something special or unique about the interplay between lights and music?	Please leave any additional thoughts or comments here.
The lights played along the music, even when I was not paying attention it was amplifying the music's rhythm	I mostly welcome the lack of purple lights in this installation.
The change in the lightening was totally unexpected, really creative and not mechanical at all	Loved it!! maybe it is better in a small room BUT increased on another size could be incredibly cool
Yes it was matched well with. The music	Thank you so much had a blast
I noticed different "states". the lights were calm and seem breathing, with sections turning on gently one after the other or together. the lights were audio reactive: it was noticeable that certain sounds were resonating with the behavior of the lights.	
Yea it sometimes looked like it was actually syncing but then you could at the same time see that other parts of the light installation weren't	Maybe make the lights spread out even further into the room next time
The 4 different strings were controlled by different bands in the audible frequency spectrum, making for a very satisfying experience.	Epic job Sem!
To me it worked super well, especially at the starting point of bar40 opening. darkness outside and in, with this creeping root-like installation worked gorgeously with the music.	
Yes to a certain degree. I noticed that different threads were responding to changes in the music but this wasn't super obvious.	It was quite white/blue/cold light (which is fine) but it perhaps would have been more immersive if there was also some variation/colour response. Aesthetically I found the form of the lines of the threads a little artificial and jagged — perhaps if the threads had wrapped around some of the uneven countours of the room and curves were smoother it would have felt more organic. This really didn't take away from the immersive aspect though just a visual consideration!
The speed changes on the music, which makes the visual and music come together	I heard many people say during the night that Sem is a legend.
The light installation deepened my connection to the music I was listening to. I noticed how the rhythm of the lights often synced with the tempo of the music, creating a dynamic interplay that enhanced my immersion in the sound.	it was cool! :)
Yes the lights changed depending on the rhythms and harmonic content :)	
I noticed that it kept changing and at times it seemed unpredictable and at other times it seemed more logical/natural and predictable.	I'm interested how it would be to have something similar but with more colours, mimicking something like synesthesia.
When the musical cues aligned with different arms of the light installation, it felt kind of like light and sound had the same source, which was nice.	

appendix i: project brief

DESIGN FOR our future

TU Delft

Personal Project Brief – IDE Master Graduation Project

Name student Sem Allush **Student number** 4,649,508

PROJECT TITLE, INTRODUCTION, PROBLEM DEFINITION and ASSIGNMENT
Complete all fields, keep information clear, specific and concise

Project title Design Opportunities in Cross-Modal Perception of Light and Sound in the Night Club

Please state the title of your graduation project (above). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

Introduction

Describe the context of your project here; What is the domain in which your project takes place? Who are the main stakeholders and what interests are at stake? Describe the opportunities (and limitations) in this domain to better serve the stakeholder interests. (max 250 words)

Few things in life are as moving and impactful as experiencing a captivating musical performance. An essential element contributing to the impact of any performance is the environment in which it occurs. During a musical performance, this environment is often shaped by lighting or projections, effectively turning it into a multi-sensory experience. Specifically, during concerts and in nightclubs, lights are used to complement, enhance, emphasise, or amplify the qualities and impact of the musical performance. The goal of this project is to approach lighting design for nightlife and the practice of VJing through the lens of cross-modal perception, to explore design opportunities, and to generate novel directions for development and experimentation within this context. Much research has been done in the domain of cross-modal perception, from how visual stimuli can alter the perception of melodies, to how it can help listeners distinguish individual elements in a larger composition, to changing the perceived length of percussive elements. Few of these findings, however, have been applied in context, which provides significant opportunity for exploration. The list of stakeholders consists of lighting designers, musicians, concertgoers, club owners, programmers, artists, curators, and other event organisers. This project could potentially lead to new ways of experiencing light and sound together, opening up opportunities in the realm of musical performance. It could allow lighting designers and VJs to gain a better understanding of how their work alters the perception of the performance, and how they could design for that. It could also give musicians the possibility to direct the lighting in such a way that it amplifies the message of their music.

→ *space available for images / figures on next page*

Introduction (continued): space for images

image / figure 1 Example of a night club.

image / figure 2

DESIGN FOR our future

TU Delft

Personal Project Brief – IDE Master Graduation Project

Problem Definition

What problem do you want to solve in the context described in the introduction, and within the available time frame of 100 working days? (= Master Graduation Project of 30 EC). What opportunities do you see to create added value for the described stakeholders? Substantiate your choice.
(max 200 words)

While using lights to enhance musical performances is nothing new, little research has explored the potential application of more directed cross-modal effects (e.g. ventriloquist effect, double flash illusion) in this context. Currently, most VJs work based on experience and intuition, suggesting an opportunity to bridge the gap between research and practice. Developing new ways of designing more targeted light installations that help accentuate or improve certain qualities of music could facilitate more impactful audiovisual experiences. This ranges from the perception of rhythm, melody, and harmony to the composition as a whole. By applying findings from prior research and studying methods from practitioners, a design can be developed that demonstrates novel cross-modal dimensions of expression in context.

In addition to applying learnings from research, another focus of this project will be assessing the desires of club goers, what kind of experience they want, and how lighting design can contribute. The results of this project could prove valuable to the stakeholders mentioned above, as it could generate new opportunities in the space of musical performance.

Assignment

This is the most important part of the project brief because it will give a clear direction of what you are heading for. Formulate an assignment to yourself regarding what you expect to deliver as result at the end of your project. (1 sentence) As you graduate as an Industrial design engineer, your assignment will start with a verb (Design/Investigate/Validate/Create), and you may use the green text format:

To design an installation that experientially explores and demonstrates cross-modal effects of light and sound in the context of the nightclub, to improve and expand the experience of guests.

Then explain your project approach to carrying out your graduation project and what research and design methods you plan to use to generate your design solution (max 150 words)

This project will consist of extensive desk research, discovering the breadth of knowledge available in the field of cross-modal perception, as well as extensive field research, discovering the breadth of knowledge available in the minds of practitioners. This will involve interviews, surveys, and observation in the context. Besides studying only those who design and perform, it is equally valuable to also study those who experience. It would be very beneficial to better understand how an audience experiences a musical performance and how the experiences differ from person to person (finding out what is desirable in the context is essential). After the initial research phase, the findings will be incorporated into a light installation design that will be tested in context, to assess if cross modal effects yield desirable outcomes in a nightclub setting. The results will be evaluated and the final design will be exhibited as a demo to inspire lighting designers and artists.

Project planning and key moments

*To make visible how you plan to spend your time, you must make a planning for the full project. You are advised to use a Gantt chart format to show the different phases of your project, deliverables you have in mind, meetings and in-between deadlines. Keep in mind that all activities should fit within the given run time of 100 working days. Your planning should include a **kick-off meeting**, **mid-term evaluation meeting**, **green light meeting** and **graduation ceremony**. Please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any (for instance because of holidays or parallel course activities).*

Make sure to attach the full plan to this project brief.
The four key moment dates must be filled in below

Kick off meeting	28 Oct 2024
Mid-term evaluation	19 Dec 2024
Green light meeting	17 Feb 2025
Graduation ceremony	17 Mar 2025

In exceptional cases (part of) the Graduation Project may need to be scheduled part-time. Indicate here if such applies to your project

Part of project scheduled part-time	
For how many project weeks	
Number of project days per week	

Comments:

Motivation and personal ambitions

Explain why you wish to start this project, what competencies you want to prove or develop (e.g. competencies acquired in your MSc programme, electives, extra-curricular activities or other).

Optionally, describe whether you have some personal learning ambitions which you explicitly want to address in this project, on top of the learning objectives of the Graduation Project itself. You might think of e.g. acquiring in depth knowledge on a specific subject, broadening your competencies or experimenting with a specific tool or methodology. Personal learning ambitions are limited to a maximum number of five.
(200 words max)

Apart from design, music is another one of my interests. So much so that I studied at the Conservatory of Amsterdam while I was doing the bachelors at IDE. It has always been a dream of mine to combine these two interests in a single project, and this seems like the perfect opportunity to do so. Since I studied music, I have access to many stakeholders in this context, which makes this project more feasible within the allotted time. Additionally, my hope is to gain a lot of knowledge and practical skills in the domain of lighting design. I have little experience designing lights, but am very eager to learn. Luckily, I have a lot of experience with (interactive) prototyping, gained during personal projects and my recent internship, which I think will prove beneficial during this project. After having done some preliminary research into the topic, I am eager to dive in and read as much literature as I can. At the same time, I am excited to learn from practitioners and see the tricks they have up their sleeves. My plan is to have the final design exhibited in a night club.