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Watching live performances enhances subjective and physiological emotional responses compared to viewing the same performance on screen

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ABSTRACT

Live performances are known to evoke stronger emotional and physiological responses compared to recorded versions. However, isolating the effect of the physical presence of performers from other environmental factors remains a challenge. This study investigates the specific emotional and physiological responses elicited by a live performance compared to its identical recorded version, projected in the same theater under controlled conditions. Twenty-seven participants (19 females, 8 males, aged 21–67) attended a 5-minute 30-second performance combining dance, singing, and guitar, presented either live or as a video projection. Both formats were viewed under identical spatial conditions, with the screen positioned where the live performance took place. The viewing order was counterbalanced. Participants all completed self-report questionnaires on emotional states before and after each version of the show. A subset of participants was equipped with EEG headsets, electrodermal activity sensors, and photoplethysmography devices. Self-reported data indicated significantly higher pleasure and wakefulness after the live performance compared to the recorded version, while both formats equally reduced anxiety levels. A significant correlation was found between participants' screen viewing habits and their emotional engagement, suggesting that frequent exposure to digital performances might dampen emotional sensitivity to live experiences. Physiological measures revealed distinct patterns: skin conductance response frequency increased significantly in the final segment of the live performance but not in the video condition, indicating higher emotional arousal. Heart rate increased with musical intensity in both conditions, while EEG data showed reduced arousal levels during the live performance, possibly reflecting deeper cognitive absorption. This study provides evidence that live performances elicit stronger emotional and physiological engagement compared to their recorded counterparts, even under identical viewing conditions. The findings highlight the unique impact of performer-audience interaction and suggest that digital media cannot fully replicate the emotional richness of live experiences. Future research should further explore the mechanisms underlying emotional transmission in virtual environments.

Introduction

According to the French Ministry of Culture, a live performance refers to any show produced or broadcast by individuals who, with the aim of publicly presenting a creative work, ensure the physical presence of at least one performing artist. Dance, music, and theatre—in all their diverse forms (opera, popular music, choral music, brass bands, circus, street arts, storytelling, puppetry, etc.)—are considered part of the performing arts. Live shows are unique in that they foster direct interaction between artists and audiences, with each performance potentially varying based on the venue's energy and the audience's response.

Live performances are thought to evoke specific emotions and create strong emotional bonds between performers and spectators. Yet, most research on emotional mechanisms has taken place in laboratories. These controlled environments allow for precise measurement of emotional responses. Emotion triggers various physiological changes,

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particularly within the autonomic nervous system. Such changes—like variations in heart rate or skin conductance—can be reliably measured (Kim and André, 2008; LaRocco et al., 2020). However, laboratory settings have limitations. Stimuli are often artificial, and such contexts may fail to capture the complexity of real-life emotional experiences, especially those occurring during live performances.

In recent years, mobile neurophysiological devices have enabled researchers to explore emotions in naturalistic settings (e.g., Niso et al., 2023). These tools can measure heart rate, respiration, skin conductance, and brain activity. They are wireless, affordable, and quick to set up, allowing for reliable emotional data collection outside the lab (Gabriel et al., 2020; Krigolson et al., 2017; LaRocco et al., 2020). In parallel, hyperscanning techniques have been developed to synchronize data from multiple participants in real time, enabling the study of collective emotional responses in classrooms (Tan et al., 2023), cinemas (Michalareas et al., 2023), and concert halls (Chabin et al., 2021).

Recent research using mobile physiological measures has deepened our understanding of audience responses during live performances. Czepiel et al. (2025) demonstrated that physically seeing musicians perform in real time—rather than merely hearing them—enhances audience engagement, particularly at structurally important moments in Western classical music. This effect, measured through synchrony in cardiorespiratory responses, suggests that the visual presence of performers plays a key role in deepening collective attention and emotional resonance. However, such effects may be context-dependent.

Several studies highlight the emergence of physiological and behavioral synchrony among audience members (Tschacher et al., 2024). For instance, Tschacher et al. (2023a) found that synchrony in skin conductance and respiration was positively associated with self-reported aesthetic appreciation, while discomfort from sensors reduced synchrony. Similar effects have been observed in body movement and physiological signals across concert settings, including synchrony between musicians, between conductors and performers, and among audience members (Tschacher et al., 2023b). Such synchrony—measured through heart rate, respiration, and electrodermal activity—has consistently been linked to aesthetic appreciation and musical features, suggesting a shared embodied experience of music.

At the individual level, physiological data reveal how specific musical features influence attention and emotional engagement. Faster tempi increase physiological synchrony, indicating heightened arousal, while slower tempi are associated with more variable responses and decreased attentional focus (Czepiel et al., 2021). Sharing a live performance with a pianist has also been shown to reduce audience stress, as measured by heart-rate variability (Shoda et al., 2016). EEG recordings in concert-like conditions further demonstrate that improvised performances elicit greater neural signal complexity and stronger theta oscillations than rehearsed ones—both markers of increased alertness (Dolan et al., 2018, 2013; Tervaniemi et al., 2021). Moreover, emotional alignment among audience members appears to modulate neural synchrony: inter-brain coherence increases when individuals report feeling similarly intense emotions, but only when accompanied by high levels of pleasure (Chabin et al., 2021).

Despite these insights, explaining the benefits of live performance remains methodologically complex. The performers' physical presence may evoke emotional responses even before the performance begins, making it difficult to isolate its specific effects. Moreover, attending a concert involves a series of contextual and social stimuli—such as commuting, arriving at the venue, and interacting with others—that are absent in digital (Burland and Pitts, 2014). The performance environment itself also plays a crucial role. For example, room acoustics, such as reverberation, have been shown to influence both emotional and neural responses to music (Lawless and Vigeant, 2015). Furthermore, video editing in recorded formats can introduce its own emotional effects, complicating the interpretation of emotional responses (Uhrig et al., 2016). Together, these factors underscore the challenges of creating a valid "non-live" control condition. They also highlight the unique emotional, cognitive, and social dimensions of live music—qualities that are difficult to replicate in virtual settings.

The present study aimed to gain deeper insight into these emotional mechanisms by comparing the same artistic performance in two conditions: live and video. The performance was specially created by artists and neuroscientists for experimental purposes. Participants' emotional responses were assessed using portable EEG, electrodermal activity sensors, blood pulse monitors, and self-report questionnaires. Each participant experienced both conditions. In both cases, they were seated in the same theatre and in the same seat. During the video condition, the performance was projected at life size on a screen placed exactly where the live performance had occurred. This setup controlled for environmental variables, allowing us to isolate the effect of the performers' physical presence. We hypothesized that emotional and neurophysiological differences would result from this physical presence, rather than from contextual or spatial differences.

Methods

Participants

Twenty-seven individuals, comprising 19 women and 8 men, took part in the study, with ages ranging from 21 to 67 years (M= 39.37 years). All participants filled out an observation diary, but only 21 of them (14 women and 7 men) were equipped with physiological measuring devices.

Prior to participating in the study, participants received information regarding the aims and procedures of the experiment and gave their written informed consent to participate. In accordance with French law, the study was classified as psychology observational research outside of the Jardé law and so did not require submission to an ethics committee.

Course of the experiment

The experiment took place at a theatre with 136 seats and a surface area of 150 m^2. The stage itself has a surface area of 70 m^2. There were 7 sessions of the same show during the day, three in the morning and four in the afternoon. Each session included a live performance of the show and a version broadcast on video in a counterbalanced order. Each volunteer participated in a single session, with an average of 3.86 participants per session (SE = 0.46). Specifically, sessions 2, 4, 6, and 7 had three participants each, session 1 had four participants, session 3 had six participants, and session 5 had five participants.

At the beginning of the experiment, participants began by completing pre-test questionnaires (Fig. 1). Some participants were then equipped with EEG headsets and measurement modules for electrodermal activity and photoplethysmography. Then the live performance was either presented in the first phase, followed by the video of the same performance in the second phase, or the order was reversed with the video in the first phase and the show in the second phase. This counterbalanced order was intended to neutralize any potential effect of order on results. Before resuming the experiment, participants coloured a mandala for a few minutes to distract themselves from what they had just watched. Then they watched either the show or the video again. After each phase, the participants completed questionnaires relative to the emotional impact of the performance. Finally, the physiological measuring devices were removed from the participants who were equipped.

Artistic performance

A 5-minute 30-second show combining several disciplines was created by the performing company Kinetochore and the scientists involved in the project, exploring themes of individual and collective identity with a crescendo of rhythmic progression. The cast included three members: a dancer, a singer and a guitarist. The show was

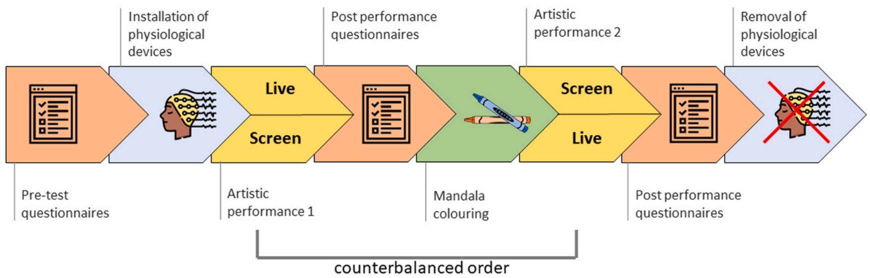

Fig. 1. Design of the study.

structured in three segments. The first segment (S1) is a contemplative moment where the group presents itself uniformly. The performers don't look at the audience, but rather sway synchronously in place, gazing into the distance. The fourth wall is palpable. In the second segment (S2) the artists look at the audience, breaking the fourth wall by noting their presence. A change of music allows each of the 3 artists to present his or her discipline and meet the other: singing, guitar and dance. This part is rather gentle (piano/medium nuance) with a moderate rhythm. In the third segment (S3), the music increases in intensity, volume (medium/high) and speed. The three artists face the audience and intensify their actions in each of their disciplines.

The live and virtual versions took place at the same seats of the theatre. In its virtual version, the show was projected onto a 5 m x 4 m full-size screen, located 4 m from the audience, the same distance as the artists in the live performance. The projection took place in the same room as the live performance. The video broadcast corresponded to the same performance by the artists and was recorded before the live session. A BENQ SX751 video projector was used for the broadcast, enabling the original proportions of the artists to be preserved on the screen (Fig. 2).

Questionnaires

At the beginning of the experiment participants had to fill a questionnaire covering socio-demographic and cultural aspects to ascertain their cultural sensitivity. Such as age, gender, relationship to screen-based entertainment and whether the participant is involved in any artistic activity(ies). In addition to these parameters, participants were asked to rate their frequency of cultural outings from 0: "never" to 5: "several times a week." Participants were also asked to rate their frequency of screen use from 0: "never" to 5: "several times a week."

Fig. 2. Example of the show presented on screen (top) and live (bottom). Light emerging from physiological devices can be observed in the audience. Note that both pictures were not taken at exactly the same time of the artistic performance, resulting in a stage lighting difference.

Subsequently, the participants completed several French versions of questionnaires designed to assess their emotional state.

These questionnaires included

- Brief Mood Introspection Scale (BMIS; Mayer, 1988). The BMIS is a 16-item mood adjective scale that contains 16 adjectives. Participants evaluate their current emotional state by rating from 1 to 4 (with 1 being low and 4 being high) the degree to which 16 different adjectives described their mood (e.g., happy, tired, gloomy, active). BMIS was presented 3 times: at the beginning of the experiment and after the live and the video versions of the performance. The BMIS was selected because it quantifies mood at a given moment in time, enabling us to measure the mood of our participants immediately after the show (in live and video formats). Furthermore, the Pleasant-Unpleasant and Arousal-Calm subscores are derived from Russell's Circumplex Model (Posner et al., 2005), which aligns with our EEG measurements of valence and arousal. Consequently, the Pleasant-Unpleasant subscore (ranging from 16 to 64) and Arousal-Calm subscore (ranging from 12 to 48) are the only ones that are used.
- The State-Trait Anxiety Inventory-Y (STAI- Y; Spielberger, 1983). This scale has 20 items for assessing state anxiety and 20 items for assessing trait anxiety. All items are rated on a 4-point Likert scale, and higher scores indicate greater anxiety. Only the state version of STAI-Y was used in this study (score ranging from 20 to 80). Participants completed the questionnaire three times: once before the experiment, once after the video of the show, and once after the live show. The objective was to assess whether anxiety levels were impacted following the live or video show.
- Chapman Physical anhedonia scale (Chapman et al., 1976). This test assesses anhedonia. It contains 61 true-false items to assess individual differences in the ability to experience pleasure from physical or sensory experiences. The score ranges from 0 to 61. Participants had to fill the Chapman questionnaire only once before the experiment. The objective was to exclude any participants with elevated levels of anhedonia (>30), yet none were excluded (maximum measured score = 29, mean = 11.33, SE = 1.11).

Physiological measuring devices

Electroencephalography EEG

Emotiv EPOC+ EEG headsets were used to measure the brain's electrical activity. These headsets have 14 electrodes and 2 reference electrodes. Only the references and 4 electrodes (F3, F4, AF3, AF4) were used in this study. EEG data were low-pass and high-pass filtered (Butterworth) between 1 and 30 Hz, with a notch filter set at 50 Hz using MatLab software.

To remove ocular artifacts, we performed a principal component analysis. We estimated the number of eyeblink artifacts based on the electrodes close to the eyes. F7 and F8 were parallel to muscles responsible for horizontal movements of the eyes and thus became good predictors of horizontal eye movements. Similarly, AF4 and F8 and AF3 and F7 predicted vertical eye movements (see Chabin et al., 2021 for a more complete description). After the regression of the ocular artifacts, data were resynchronized and down-sampled to 125 Hz based on the timestamps. All segments of the show were grouped together to get enough data for analysis. Data were averaged over 2 s time windows. Epochs were excluded using a semi-automated rejection procedure with a threshold of ± 75 μV as well as a visual inspection to remove every artifact. A spectral analysis focusing on alpha frequency (8–12 Hz) was performed on each electrode separately, as well as more conventional measures of valence and arousal. The EEG processing of valence and arousal was based on methods from previous studies and involved a two-dimensional arousal-valence design (Gabriel et al., 2021, 2020; Ramirez et al., 2015; Ramirez and Vamvakousis, 2012). To determine the valence level, the cortical hemispheres' activation levels were compared (Coan and Allen, 2003). The F3 and F4 electrodes were used to compare alpha activity in the right and left hemispheres located above the prefrontal lobe. Valence was thus calculated by comparing the alpha power at electrodes F3 and F4, i.e., by applying the following formula: AlphaF4 – AlphaF3. The arousal level was determined by calculating the ratio of beta (12 −28 Hz) and alpha (8 −12 Hz) band power at electrodes AF3, AF4, F3, and F4, which can be a reasonable indicator of an individual's arousal level (Chabin et al., 2020a, 2020b; Ramirez et al., 2015). We chose to use this indicator instead of the more conventional theta/beta ratio because recent studies suggest that theta/beta ratio may rather be a marker of cognitive processing capacity (Clarke et al., 2019). Arousal was calculated as follows: (BetaF3 + BetaF4 + BetaAF3 + BetaAF4)/(AlphaF3 + AlphaF4 + AlphaAF3 + AlphaAF4.

Electrodermal activity and photoplethysmography

Shimmer (Dublin, Ireland) sensors (Shimmer3 GSR+ Unit) were used to record electrodermal activity (EDA) and photoplethysmography (PPG), which detects fluctuations in microvascular blood volume resulting from the pulsation of the circulatory system, i.e. the pulse. Data were collected using ConsensysPRO software, processed and analyzed using AcqKnowledge software. Electrodermal activity data were first cleaned using an IIR low-pass filter set at 1 Hz and phasic activity was extracted from the tonic signal using a high-pass filter with a cutoff frequency of 0.05 Hz. Subsequently, the mean magnitude (no-responses were considered to be zero) of all skin conductance responses (SCR) and the number of SCR per minute during each show segment for each subject were measured. A low-pass filter with a cutoff frequency of 0.05 Hz was applied to the tonic signal in order to account for phasic changes. Additionally, the mean skin conductance level (SCL) was calculated for each show segment for each subject.

For PPG, the signal was cleaned using a 3 Hz low-pass filter. Subsequently, the heart rate in beats per minute (BPM) was calculated for each interbeat period, and the mean BPM for each show segment was determined for each subject.

Thus, four variables were employed to assess the autonomic nervous system during the three segments of the show: mean SCR magnitude, SCR per minute, mean SCL, and mean heart BPM. They were computed for each session: live and video, and each segment of the show: S1, S2 and S3. Due to substandard electrodermal signal quality, four participants were excluded from the electrodermal parameter analysis. Consequently, the subsequent analysis was conducted on 17 subjects for the following parameters: mean SCR magnitude, SCR per minute, and mean SCL.

Statistical analysis

For the behavioural data, we compared the means of BMIS (BMIS-Pleasant/Unpleasant and BMIS-Awake/Calm) and STAI-Y before the experiment, after the video session and after the live session. We considered the order effect using a partially repeated measures ANOVA with two factors: type of session (before, video, live), and order (video followed by live or live followed by video). When the ANOVAs showed significant differences, LSD post hoc tests Statistical tests were performed using Statistica software. The partial Eta-squared statistic (η_p^2) was employed to measure effect size.

There are different ways of consuming live performances, and this may depend on the cultural capital of each individual or on the type of show or concert (Roose and Vander Stichele, 2010). Therefore, it is reasonable to hypothesize that cultural habits can influence the emotional response to a performance, depending on the viewer's perspective. For instance, an individual who is accustomed to watching shows on a smartphone might prefer the video version of the show due to its enhanced convenience and increased level of enjoyment. To test this link, we also performed non-parametric correlations (Spearman correlation) to determine whether there was a relationship between the participants' cultural outing frequencies and screen frequencies and their BMIS and STAI-Y scores. Specifically, for the BMIS Pleasant-Unpleasant, BMIS Arousal-Calm, and STAI State scales, the score after the video was subtracted from the score after the live performance for each participant. This process yielded a delta that accounts for the difference between the two experimental conditions. This delta was then correlated with the frequency of cultural outings and the frequency of screen use.

Regarding the neurophysiological data, valence and arousal data from the EEG were analysed with ed paired Student's t-tests to compare the mean levels of brain activity between the live show and its replay on a screen. The Cohen's d was used to measure effect size. We also compared the electrodermal responses and heartbeats. Given that a considerable number of psychophysiological data (EDA and PPG) did not adhere to a normal distribution, we employed non-parametric Wilcoxon tests to ascertain any differences in autonomous responses between live and video sessions at each show segment. To investigate the impact of increasing emotional intensity, we conducted a Friedman test (separately for live and video sessions) with Segment as a within-subjects factor. In instances where Friedman tests yielded a significant main effect, Conover post hoc tests (Bonferroni correction) were performed. The Kendall's W value (W) was employed to measure effect size.

The sample size of this study may appear to be smaller than that of other studies in the field of live performances (Shoda et al., 2016; Swarbrick et al., 2019; Theorell and Bojner Horwitz, 2019). However, it should be noted that other studies have employed similar (Holmes et al., 2006; Trost et al., 2024) or even smaller sample sizes (Chabin et al., 2021; Dolan et al., 2013). While larger sample sizes are generally preferred for maximizing statistical power, conducting statistical analysis with sample sizes between 20 and 30 participants can be justified under specific research contexts, particularly in exploratory and pilot studies. The mathematical foundation remains valid regardless of sample size, although smaller samples inherently lead to reduced statistical power, increasing the risk of Type II errors (Field, 2013). Consequently, our findings should be interpreted with appropriate caution regarding generalizability and the potential for false negatives. Such approaches are common in fields where participant recruitment is challenging, like studies involving rare clinical populations or highly specialized experimental setups (Cohen, 2013), as was the case in our experiment.

Results

Psychometric data

BMIS scores revealed that participants experienced differences in their pleasantness level (Pleasant-Unpleasant scale) ($F(2,50)= 3.558$; $p = 0.04$; $\eta_p^2= 0.12$). Pleasantness was significantly higher after the live performance ($M= 51.444$; $SE= 1.607$) compared to after the video of the performance (M= 49.630; SE= 1.464; $p = 0.03$) and compared to before the experiment ($p = 0.003$). There was no effect of the order on the pleasantness felt after the video or after the live show (Fig. 3 top left).

No relationship was found between the difference in pleasantness after the live and after the video (pleasantness delta), and the participants' cultural outing frequency ($r = -0.080$; $p = 0.693$). The relationship between the pleasantness delta and participants' screen frequency was also non-significant ($r = 0.054$; $p = 0.789$).

Differences of arousal level (Arousal-Calm scale) were also observed ($F(2,50)= 6.205$; $p = 0.004$; $\eta_p^2= 0.20$). The arousal level was smaller after the live performance and the video than before the experiment ($p < 0.0001$ between before the experiment and after the video; $p = 0.02$ between before the experiment and after the live performance). Moreover, the arousal level was significantly higher after the live performance (M= 27.444; SE= 0.882) than after the video (M= 25.667; SE= 0.809; $p = 0.03$). There was no effect of the order (live performance or video first) on the arousal level felt after the video or the live performance (Fig. 3 top right).

Correlation analysis shows that the relationship between the difference in arousal level after the performance and after the video (arousal delta), and participants' frequency of cultural outings is not significant ($r = -0.098$; $p = 0.628$). However, the correlation analysis shows that the relationship between the arousal delta and the screen frequency is significant ($r = -0.390$; $p < 0.05$).

Differences in anxiety were also observed ($F(2,50)= 9.767$; $p = 0.0003$; $\eta_p^2= 0.28$). Compared to before the experiment, participants were less anxious after the live performance (M= 44.185; SE= 1.740; $p < 0.0001$) and after the video (M= 44.259; SE= 1.904; $p < 0.0001$). Participants experienced similar degree of anxiety after the performance and after the video (p = n.s.). An order effect was found ($F(1,25)= 4.365$; $p = 0.04$). Participants were more anxious when viewing the show followed by the video, than when watching video and the show (Fig. 3 bottom).

Correlation analysis shows that the relationship between the difference in anxiety after the performance and after the video (delta anxiety), and participants' frequency of cultural outings is not significant ($r = 0.257$; $p = 0.195$). The relationship between delta anxiety and participants' frequency of screen viewing was also non-significant ($r = 0.052$; $p = 0.796$).

Neurophysiological data

Electrodermal and cardiac activities

Wicoxon signed-rank tests were conducted to compare psychophysiological data between the live performance and the video for each segment of the show. However, the tests did not reveal any significant differences.

To assess the effect of the segments of the show on data, we conducted Friedman tests, separately for the live performance and the video, with Segment as the main factor. The Friedman test indicates that the factor Segment has no significant effect on the mean SCR magnitude for the live performance (X^2=2.167; $p = 0.338$; W=0.09), nor for the video (X^2=5.636; $p = 0.060$; W=0.26).

The Friedman test revealed no significant effect of Segment in SCR per minute for the video session (X^2=0.818; $p = 0.644$; W=0.02). However, the factor Segment did show a significant effect for the live session (X^2=8.818; $p = 0.012$; W=0.26). Post-hoc Conover tests indicate a statistically significant differences between S2 (M = 2.004(1.709)) and S3 (M = 3.235(1.809)), with a p-value of 0.007, as long as between S1 (M = 2.096(1.439)) and S3 with a p-value of 0.045. See Firgure 4B for details.

With regard to the mean SCL, no significant effect of the Segment factor was observed during the live session (X^2=3.647; $p = 0.161$; W=0.11) or the video session (X^2=5.765; $p = 0.056$; W=0.17). See Firgure 4 C for details.

Finally, the mean heart BPM was found to be significantly impacted

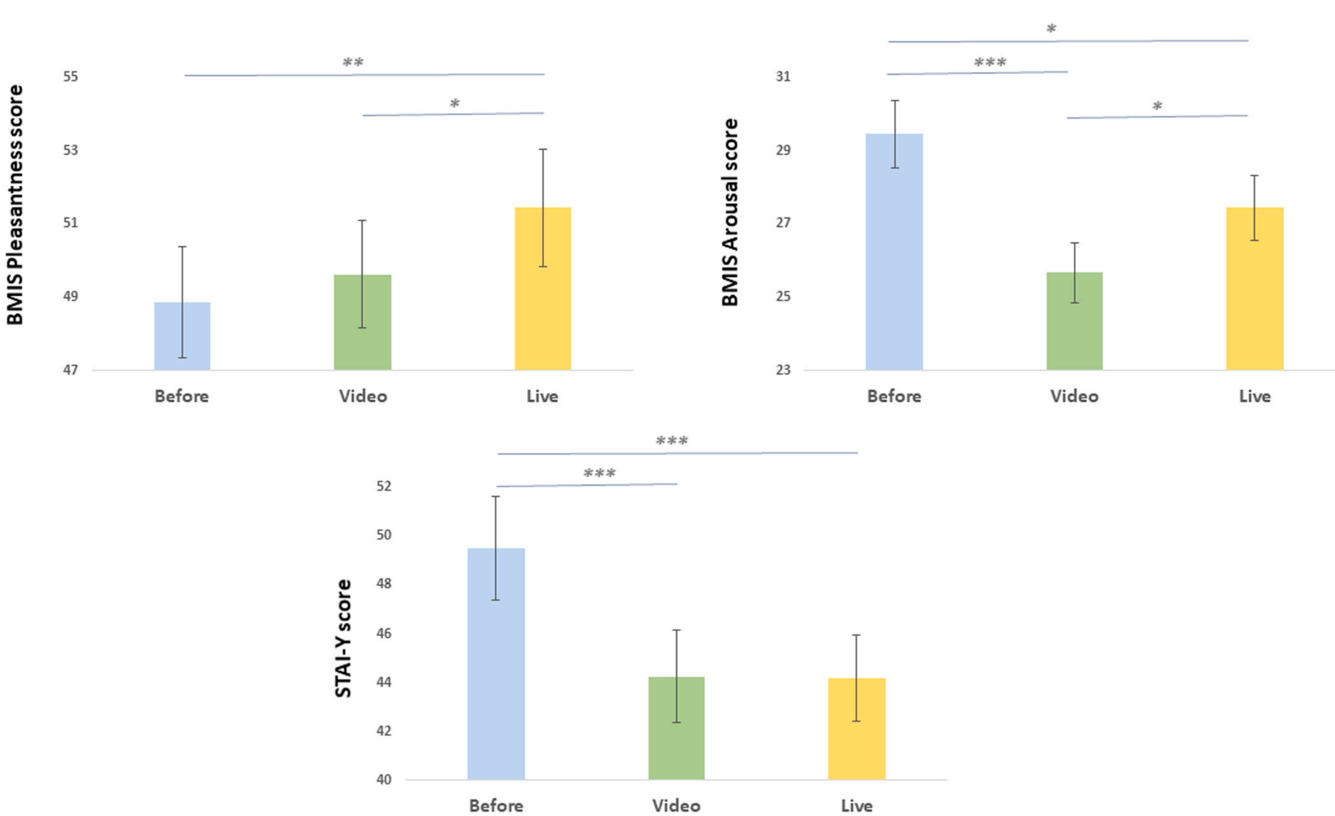

Fig. 3. BMIS and STAI-Y Scores before the experiment (Before), after video of the performance (Video), and after the live performance (Live). Top left: BMIS score on the Pleasant-Unpleasant subscale. Top right: BMIS score on the Arousal-Calm subscale. *: $p < 0.05$; **: $p < 0.01$, ***: $p < 0.001$. Error bars represent standard error.

by the Segment factor for both the live session (X^2=11.810; p = 0.003; W=0.28) and the video session (X^2=10.667; p = 0.005; W=0.25). Subsequent Conover tests demonstrated a notable difference between S2 (M=72.343(8.040)) and S3 (M=74.642(8.236)) in the live session, with a p-value of 0.005. A similar contrast was observed between S2 (M=71.682(9.435)) and S3 (M=73.899(8.167)) in the video session, with a p-value of 0.011. See Fig. 4D for details.

Cerebral activity

No difference of valence was observed but participants significantly exhibited a lower state of arousal during the live performance (M = 0.801(0.11)) than when watching the performance on screen (M = 0.854(0.12); t (18)= -2.455; p = 0.024; cohen's d= 0.62) (Fig. 5).

Discussion

Attending an artistic performance, whether live or on video, is an emotional experience. People can feel the vibrations of the music, the expressions of the artists, the reactions of the crowd. Our questionnaires presented during the live show specifically developed for neuroscientific purpose confirm the benefits of attending the performance of the artists, with an increase of reported pleasure and relaxation. Moreover, watching a performance, whether live or on screen, did reduce the participants' anxiety states and arousal level. These results are consistent with those obtained by Merrill et al. (2023), which found that heart

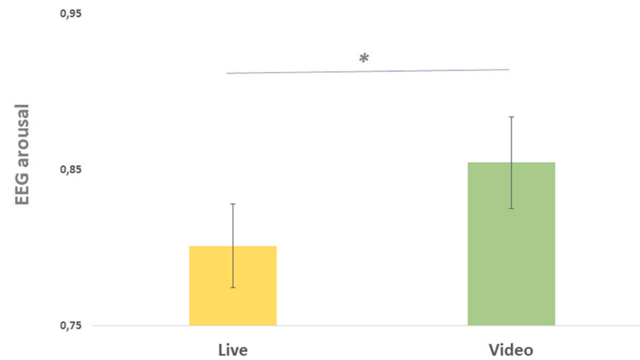

Fig. 5. Difference of arousal recorded with the EEG during the live show and the video version. *: $p < 0.05$. Error bars represent standard error.

rate decreased over the course of a live concert. These decreases could be attributed to the calming and relaxing nature of the concert experience. Today such benefits are well-known and are for example employed in healthcare since watching a film on a projector while removing a cast or pin has been shown to reduce fear and anxiety (Richey et al., 2022). However, in addition to these overall positive effects, we show that measuring emotions on a live session elicit specific behavioural and neurophysiological responses compared to the video version, even though it is the same show, presented with the same dimensions as the

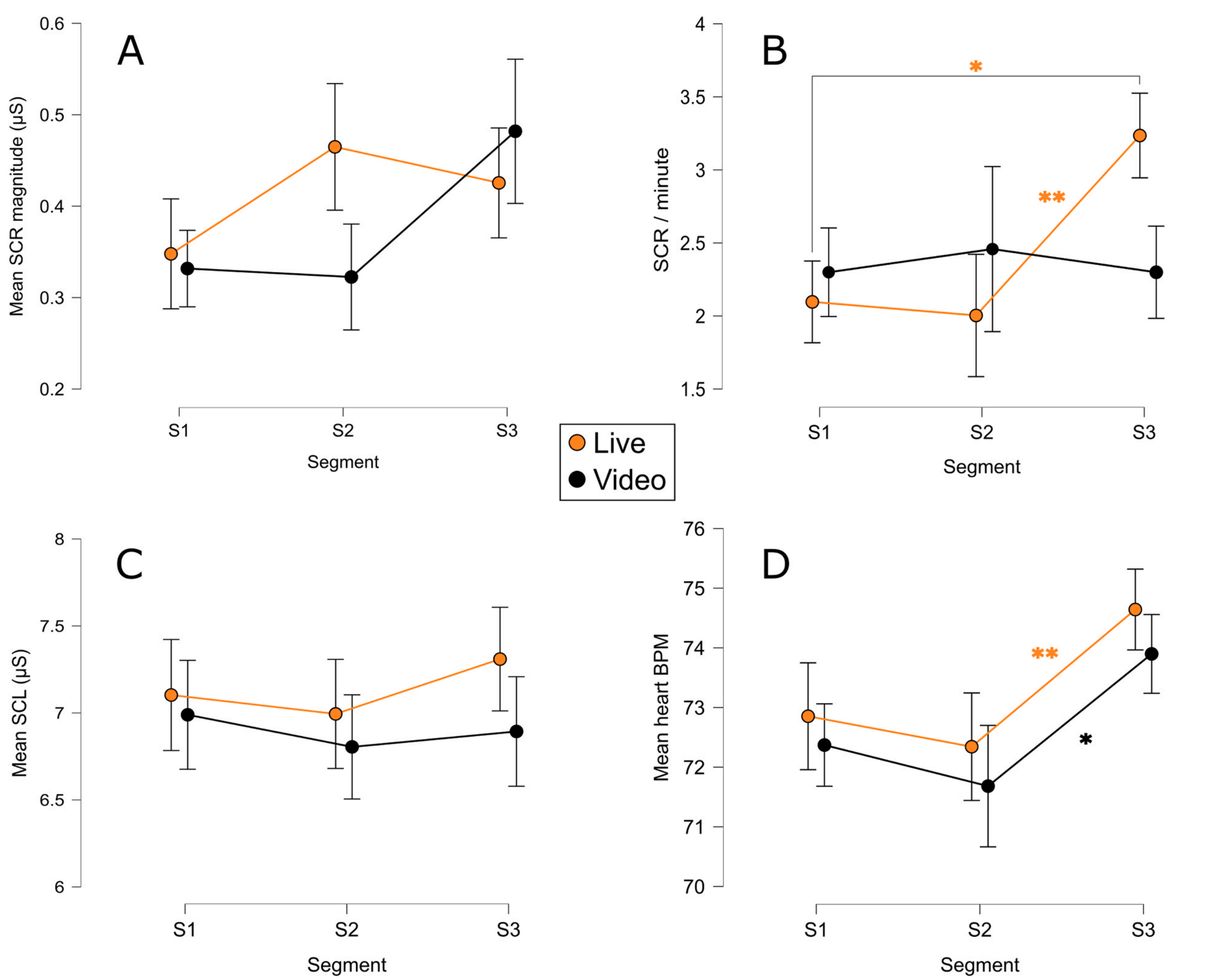

Fig. 4. Means and standard error bars for the three segments of the show (S1, S2 and S3) and each session (live and video). *: $p < 0.05$; **: $p < 0.01$. A: mean SCR magnitude. B: SCR per minute. C: mean SCL. D: mean heart rate.

live performance, and taking place in the same environment at the same seat. This was intended to remove confounding factors that are often present when comparing a live show to a virtual version that can be watched at home, sitting alone on the couch, making a pause when desired. There was no video editing either, as video editing is sometimes considered an art that allows users to create videos that capture and convey emotion in a more meaningful way. In virtual versions of a live performance, it is consequently important to separate what belongs to the performance itself to what belongs to video editing.

Although the level of anxiety was similar after viewing both versions of the show, participants' had more pleasure and were more relaxed after the live version compared to the video version. This is in accordance with results from previous studies showing stronger positive reactions when listening to live music as opposed to a recorded piece (Holmes et al., 2006; Noll, 2015; Theorell and Bojner Horwitz, 2019). Higher engagement from the audience is also observed with live compared to recorded music (Merrill et al., 2023; Swarbrick et al., 2019). Neurophysiologically, such increased engagement during live performances may relate to the activity of the mirror neuron system (MNS), a network involved in action understanding, emotional resonance, and social connection (Rizzolatti and Craighero, 2004). The MNS is particularly responsive when observing live actions performed by others, especially when those actions are emotionally expressive or socially directed. Indeed, the positive emotional states present in live music could have been attributed to the visual presence of the artists, a connection between the audience and artists not being possible using video. Here we took into account the visual aspect of the performance by showing the same performance on a screen at the real size of the participants. We show that this lack in perceiving emotional nuances could not be attributed to a reduced dimension of the screen because the screen was placed at the same place than the live show, and the audience was seating at the same seat. However, informal discussion with the audience at the end of the show revealed that spectators were more experiencing eye contact with artists during the live show. It is then possible that participants don't implicitly seek eye contact in video versions, since they know they are not faced to the actors, but to their image. This subtle dissociation in interaction may also modulate sensorimotor resonance. Recent research shows that the mirror neuron system responds differently depending on whether an action is observed live or on video: live interactions are associated with stronger and more sustained oscillatory activity in sensorimotor and visual cortices (Karimova et al., 2024). This suggests that the embodied simulation of observed actions, emotions, and intentions is more vivid when the performer is physically present, even if the visual input is otherwise matched. Furthermore, it has been shown that several contextual and relational factors modulate the MNS, such as the perceived intentionality of the actor, the emotional content of the movement, or the social relationship between observer and actor (Kemmerer, 2021). These dimensions are naturally richer in live interactions where micro-expressions, eye contact, and shared space enhance the perception of agency and mutual presence. Recent work has highlighted the essential role of non-verbal communication in shaping emotional resonance and interpersonal connection. For instance, facial expressions, gesture dynamics, body posture, and gaze direction have been shown to be processed more accurately and elicit greater empathic responses in real-life interactions compared to mediated ones (Gallagher and Varga, 2023; Li et al., 2024). Even subtle non-verbal cues—such as blink rate or muscle tension—are more readily perceived and interpreted in face-to-face contexts, amplifying emotional understanding and engagement (Wagner et al., 2023). When watching a performance on a screen, we can feel a certain emotional distance, as we are separated from the real environment, and cannot perceive all the nuances and details of the performance. Han and Johnson (2012) pointed out that the absence of non-verbal emotional cues in virtual environments can restrict students' online interactions and their ability to perceive emotions. Online learning environments have a limited ability to express one's personality and perceive the facial communication of others (Wang and Reeves, 2007). Considering this, the diminished MNS activation in virtual contexts may also underlie the reduced emotional impact of screen-based performances. As hybrid and remote experiences become more common, understanding how non-verbal communication is filtered, diminished, or even distorted by screens is increasingly crucial—not only in performing arts, but in broader domains such as education, telehealth, and digital collaboration. Enhancing the fidelity and visibility of these cues in virtual formats could thus play a key role in improving emotional connectedness and cognitive engagement (Marini and Porciello, 2023).

Interestingly, while participants' cultural outing habits and their viewing of live performances on screen were not associated with the emotions experienced during the show, we did find a link between the frequency of screen use and the varying levels of arousal experienced after both the live and video versions. Participants who were less accustomed to watching live performances on their screens felt more emotion and were more alert to them during the live show. Conversely, participants with a higher frequency of watching live performances on their screens felt less emotion during the artistic performance. Our access to computer-generated worlds is changing the way we feel, think and solve problems (Georgiev et al., 2021). We are now used to reveal the negative impact of screen use on the capacity to perceive emotional nuances, with high levels of media emotion regulation being associated with lower emotional knowledge and empathy (Coyne et al., 2023). A decrease in psychological well-being is also reported in adolescents who spent more time on electronic communications and screens (e.g., social media, the Internet, SMS, and games) (Twenge et al., 2018). However, our results suggest that the reality might be more complex. People watching concert exclusively on videos may be more trained to feel emotions via this media, and less in live situations.

When considering the psychophysiological responses, we found that heart rate exhibited a significant increase between the second (S2) and the third (S3) part of the performance, both in live and video conditions. This increase, reflecting higher levels of arousal, could correspond to the escalating tempo and intensity of the performance, in line with previous studies (Bernardi et al., 2009; Koelsch and Jäncke, 2015; Watanabe et al., 2017). This finding is consistent with previous research indicating that heart rate tends to increase with musical tempo, reflecting heightened arousal levels (Bernardi et al., 2009; Koelsch and Jäncke, 2015; Watanabe et al., 2017). For instance, Bernardi et al. (2009) found that listening to music with increasing tempo led to a corresponding increase in heart rate, suggesting a relationship between musical tempo and cardiovascular response. This synchronization suggests that as the performance intensifies, regardless of the medium, there is a corresponding increase in physiological arousal as measured by heart rate. It is important to note that the genre of the show quite varies according to the segments. Therefore, it can be assumed that the genre has an impact on heart rate. Indeed, research has shown that music genre influences heart rate, regardless of tempo (Sills and Todd, 2015).

However, we did not observe differences in heart rate during the live show compared to its screen broadcast. This contrasts with previous findings suggesting that live performances can elicit stronger physiological responses than recorded ones. For instance, a pianist's live performance has been shown to alter the audience's heart rate toward relaxation or reduced anxiety compared to a recorded version (Shoda et al., 2016). One possible explanation for the discrepancy is that in our video condition, the performers were visually present and displayed at a similar size as in the live condition, which may have reduced differences in engagement. The importance of seeing a musical performance has been highlighted in prior work, showing significantly higher electrodermal responses for audiovisual presentations compared to audio-only formats (Chapados and Levitin, 2008). In addition, the relatively short duration of the show in our study—although necessary to ensure the same audience experienced both conditions—may have influenced the strength of physiological responses. The performance environment itself also plays a crucial role. For example, room acoustics, such as reverberation, have been shown to influence both emotional and neural responses to music (Lawless and Vigeant, 2015). Furthermore, video editing in recorded formats can introduce its own emotional effects, complicating the interpretation of emotional responses (Uhrig et al., 2016). Together, these factors underscore the challenges of creating a valid “non-live” control condition. They also highlight the unique emotional, cognitive, and social dimensions of live music, qualities that are difficult to replicate in virtual settings.

Regarding the skin conductance parameters, SCR frequency is a measure derived from the phasic signal of electrodermal activity able to measure rapid variations in the nervous system in response to emotional and cognitive stimuli (Boucsein, 2012). Conversely, SCL is a tonic measure that reflects an overall level of arousal and fluctuates relatively slowly. The show being a short three-part performance evolving in a rhythmic crescendo from a contemplative, distant introduction to intense, expressive interaction with the audience, breaking the fourth wall, measuring the frequency of SCRs appears to be a more pertinent metric for accounting for the psychophysiological changes.

Only mean SCR frequency appeared to be significantly higher during the final segment (S3) of the performance compared to the first (S1) and second (S2) segments, and this only for the live performance. This finding suggests that arousal increases as a function of show intensity only when the show is presented live. Furthermore, while no statistical difference is obtained for the mean magnitude of SCRs over segments S1 to S3, the variation follows an expected inverted-U shape (Boucsein, 2012) during live performance (S2 being the highest, then S3 decreasing slightly). Nonetheless, this may still reflect an increase in arousal level over time. Although the show becomes increasingly stimulating as the segments progress, the average magnitude does not increase during the last segment and even tends to decrease.

As has been observed in various fields, there is a strong link between SCR frequency and cognitive engagement, as well as cognitive load (Foy and Chapman, 2018; Li et al., 2022; Nikula, 1991; Radhakrishnan et al., 2020). Therefore, our results could mean that live performances offer a more immersive and stimulating experience, keeping viewer alertness at a higher level than video shows, underlining the importance of live performances on the cultural scene. However, the number of participants is quite limited, and we have conducted non-parametric statistical tests. It is therefore essential to exercise caution when handling psychophysiological measurements.

The analysis of EEG signal is a well-known method to objectively measure emotional contagion between people attending the same concert (Chabin et al., 2021). Brain responses recorded via EEG during the performance revealed a lower physiological state of arousal in participants attending the live show compared to those watching it on a screen. In contrast, post-performance self-report questionnaires indicated higher subjective arousal following the live show. This apparent contradiction may be explained by the temporal and qualitative differences between the two types of measurement. EEG data reflects real-time neural activation during the show, potentially capturing a state of deep attentional engagement or absorption, often associated with lower external arousal markers (e.g., reduced beta activity, increased alpha/theta). On the other hand, questionnaires administered after the experience capture a retrospective evaluation of arousal that may reflect emotional resonance, excitement, or satisfaction following the event. In this context, the live show may have induced a state of immersive flow—a condition marked by focused attention and decreased physiological arousal during the activity, followed by heightened emotional impact and wakefulness afterward. This aligns with theories of aesthetic experience and flow states, where a person may feel calm and fully engaged during the experience, yet report high arousal and positive affect retrospectively (Nakamura and Csikszentmihalyi, 2014). This mechanism resembles certain meditative or creative states, where physiological relaxation during the activity is paradoxically followed by increased vitality, alertness, and positive mood (Basso et al., 2019; Conner et al., 2018). Our findings suggest that the live performance may elicit a similar dynamic: lower cortical arousal during, but higher emotional arousal after, the experience

A main limitation of this study is that participants viewed two times the same show, once in live and once in video. Therefore, in the second phase of the performance, participants were already familiar with the show and therefore had fewer emotions. Our washout period consisting of colouring a mandala was of course insufficient to reset the emotional states of the audience. However, this study was purposely designed to consider the fact that the theatre was only available for one day. Therefore, each session would be limited to one hour and would have a reduced number of participants. The crossover design allows for achieving an estimate with the same level of accuracy as a parallel design, but with fewer subjects. In this design, each individual acts as their own control, eliminating inter-subject variability in group comparisons and reducing the influence of covariates (Lim and In, 2021). Moreover, although the live show was not exactly the same every time (unlike the on-screen version), we assume that this has not influenced our results, even though the sense of novelty brought by small live variations compared to a recorded version is a significant motivation for attending a live performance (Brown and Knox, 2017). Another possible limitation is the relatively small size of the audience, with an average of 3.86 participants per session (SD = 1.21). Some spectators have indicated that they felt they were being watched. Being in a small group with strangers can prevent you from fully letting go of your emotions. This is also an important aspect of research in live environment where the experimenters need to be as discrete as possible to let the participant behave as close as possible as in real life. Being studied is known to change or improve the behaviour independently of changes in the experiment parameters or stimulus, the well-known Hawthorne effect (McCambridge et al., 2014). This bias has to be taken into consideration, particularly in research in real environments. Researchers should adapt accordingly and try their best to determine how participants' awareness of participating to a study might modify their behavior.

Conclusion

Despite significant advancements in digital viewing experiences, live performances continue to attract audiences, emphasizing the irreplaceable nature of in-person events. Our study confirms that live performances elicit stronger emotional and physiological responses compared to their recorded counterparts, even when viewed in identical environmental conditions. Self-reported measures and neurophysiological data indicate that the presence of live performers fosters a deeper emotional connection and heightened engagement, which cannot be fully replicated through video.

These findings underscore the unique role of live performances in human emotional experience, highlighting the importance of direct performer-audience interaction. Future research should further explore the mechanisms underlying this emotional resonance, particularly the subtle nonverbal cues and interactive dynamics that enhance live engagement. Additionally, investigating the limitations of virtual environments in conveying emotional depth could inform the development of more immersive digital experiences while reinforcing the value of live artistic expression.

CRediT authorship contribution statement

Damien Gabriel: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Julie Devos:** Writing – review & editing, Validation, Investigation, Formal analysis, Data curation. **Sandrine Chapuis:** Writing – review & editing, Validation, Project administration, Methodology, Funding acquisition, Conceptualization. **Alexandre Comte:** Writing – review & editing, Validation, Methodology, Investigation, Conceptualization. **Pierre-Edouard Billot:** Writing – review & editing, Validation, Supervision, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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