Surprise me Softly: The Element of Surprise in Designing Museum Experiences

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Experience design has become a widely discussed topic. Museums use experience design for engaging their visitors and culture offers exceptional tools for it. Visual arts and music are particularly effective in eliciting visitors' emotions. However, there are a number of visual and acoustic cues that influence museum visitor response behaviours. Understanding the ways in which the human brain processes information provides a basis for furthering experience design principles. This study focuses on the emotion of surprise, considered especially effective for engaging visitor attention, providing meaning and affecting memory. The methodology involved monitoring psychophysiological responses and self-reports to assess research participants' reactions to visual/acoustic stimuli. The aim was to confirm/detect types of sensory stimuli that generate the emotion of surprise, to see if participants have similar reactions to stimuli and whether individuals' self-reports are aligned with their psychophysiological reactions. The results showed that musical stimuli are more effective than visual arts in eliciting surprise. While the study showed no clear indications that visual cues have an effect on surprise, musical cues, such as rapid attack, large pitch variation, higher harmonics, slow tempo with a sudden interruption, and sudden change in loudness do seem to play a role. Other cues, such as major key, 4/4 meter, timbral difference, and diatonic harmony also have an impact on the elicitation of surprise. These are important implications for designing museum experiences.

Keywords: Experience design; museum experiences; emotions; surprise; visual and music cues

Introduction

In the last two decades, a rise in the experience economy has been noted within business communities. Museums are not an exception to this trend, especially due to the fact that the cultural sector possesses relevant tools for experience design, especially those related to the sense of sight (visual arts, film, design) and hearing (music and sounds). Experiences are important, since they engage visitors and have a substantial impact on the formation of memory of the visited attraction, possibly also affecting visitors' loyalty. Designing a museum experience for a wide audience, however, is not an easy task, since experiences are "inherently personal, existing only in the mind of an individual"[1]. Principles of experience design which have so far proved successful include, among others, the need to focus on a specific theme, and the need to use sensory stimuli that can engage visitors. Engagement may be "on an emotional, physical, intellectual, or even spiritual level"[2]. Thematic focus enables an easier understanding of the message that museums wish to convey, while sensory stimuli enhance probability of engagement. Visitors' emotional engagement can be particularly strong. The design of an experience aimed at eliciting a specific emotion will mostly depend on what the theme of the exhibition is. However, there are a number of abstract cues which may affect visitor experience, even though visitors are usually unaware of their potency. Visual and acoustic cues are common in experience design, and there are a number of them that are often used. Museums can greatly benefit from understanding the principles of using individual visual and acoustic cues in designing *universal* experiences which have the desired impact on all, or at least the majority of visitors.

This article is grounded in the need for categories/universals that enable us to understand environmental stimuli that can be used in museum experience design. It is based on research into using various visual (colour, form, symmetry, texture) and musical (melody, loudness, rhythm, harmony, contrast) cues as environmental stimuli, with a focus on generating the emotion of surprise. The overall aim of this research was to detect whether there are universal reactions to stimuli specifically designed to elicit the emotion of surprise and the associated valence (positive or negative). The following research questions were posed:

1. What are the reactions of research participants to visual and aural stimuli specifically designed to elicit the emotion of surprise?

2. Are there differences in the level of surprise among research participants?

3. To what extent are perceived emotions (participants' self-reports) and induced emotions (measured by psychophysiological response) correlated?

The answers to these questions were used as a basis to develop guidelines for designing museum experiences based on surprise.

The article is structured as follows: first, there is an explanation of the need for universal categories in the human brain for drawing the meaning out of environmental stimuli. This is followed by an explanation of brain/mind reactions to unexpected (surprising) stimuli. Then, some ideas for artistic visual and musical cues for designing surprising experiences are presented. The results of the study researching the stimulation of surprise by visual/musical stimuli are then discussed, and finally, conclusions are drawn with recommendations for further research.

Universals and emotions

That the human mind seeks structures and patterns in order to interpret its environment has been confirmed within many scientific disciplines (psychology, neuroscience, philosophy, anthropology, art theory, music and heritage interpretation, to name but a few). Such structures are usually referred to as *universals*, and they have been widely discussed, starting from Aristotle's theory of universals, which he treats as qualities or features which objects or things

[1] PINE, Joseph B. II and GILMORE, James H. Welcome to the Experience Economy. In: *Harvard Business Review July-August*, Brighton, MA: Harvard Business Publishing, 1998, p. 97–105, accessed June 2, 2020, https://hbr.org/1998/07/welcome-to-the-experience-economy

[2] PINE, Joseph B. II and GILMORE, James H. Welcome to…, p. 97–105

have in common[3]. Moreover, although universals are inherently physical qualities of things, for Aristotle, they exist in the mind[4].

The very nature of the mind is to perceive its environment in organized patterns, as was first proposed by Gestalt psychologists such as Max Wertheimer and Kurt Koffka. This accounts for the tendency to group different sensory cues in recognizable patterns (for example, according to their proximity, similarity, continuity, closure and connectedness. This disposition of the mind is innate and is most probably a result of evolution[5]. Whenever confronted with new information gathered through sensory pathways, the brain first tries to find existing information about it, for example, by accessing the temporal lobe, where episodic/autobiographical memories are formed and indexed. If pre-existing prototypes/categories are found in memory, the mind easily finds the meaning of the sensory input. If not, it searches further, engaging other parts of the brain to extract more information. This requires higher-order processing that involves interpretation, which Kris and Gombrich referred to as a *beholder's share*, meaning that the beholder has to engage in its own creativity to access the meaning[6]. This is why perceptions of the same stimulus by different people may differ substantially, and the search for universals sometimes seems pointless. However, while there are serious limitations to cross-cultural knowledge about universals, since "no one can really know conditions in all societies"[7], there is a large body of evidence to support the assertion that the human mind needs to seek universals, and that this need is inherent in all cultures. It is highly unlikely that every individual or culture will conceive or respond to certain stimuli in the same way; however, studies have shown that some concepts do occur universally. Principles of grouping are found to be innate to all humans' senses. These have been widely discussed in relation to the sense of sight[8] and hearing[9], but are also common to the sense of smell[10], taste[11] and touch[12]. Regardless of the sense, the brain/mind tends to group different elements into a meaningful pattern, or to put them into categories. This has been proven to be a cross-cultural feature which arises directly from human physiology[13].

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[3] Apples have many similar qualities (e.g. red colour, ripeness) and may differ according to these qualities (lighter or brighter red colour, more or less ripe) but they all share a universal "appleness" or "applehood". These qualities are called "universals".

[4] REGIS, Edward Jr. Aristotle on Universals. In: *The Thomist: A Speculative Quarterly Review* 40(1), 1976, p. 135–152, accessed June 2, 2020, https://muse.jhu.edu/issue/34079.

[5] In a natural environment, it is practically impossible to see the object as a whole, such as an animal in the woods, so the brain had to develop ways to differentiate the figure from its ground or to perceive objects close to each other as a group, such as a herd of buffalos.

[6] KRIS and GOMBRICH, cited in KANDEL, Eric R. *Reductionism in Art and Brain Science: Bridging the Two Cultures*. New York: Columbia University Press, 2018, p. 226.

[7] BROWN, Donald E. Human Universals, Human Nature and Human Culture. In: *Daedalus* 133(4), 2004, p. 49.

8 For example, TSE, Peter Ulric and PALMER, Stephen E. Visual Object Processing. In: Weiner, Irvin B et al. (eds). *Handbook of Psychology 4, Experimental Psychology* 2nd edn. Hoboken, NJ: John Wiley and Sons, 2003, p. 181–210.

[9] For example, LEVITIN, Daniel J. *This is Your Brain on Music: The Science of a Human Obsession*. New York, Dutton, 2006, p. 322.

[10] MILLAR, Becky. Smelling Objects. In: *Synthese* 196, 2019, p. 4279–4303.

[11] SPENCE, Charles and YOUSSEF, Jozef. Constructing Flavor Perception: From Destruction to Creation and Back Again. In: *Flavour* 5(3), 2016, p. 1–10.

[12] GALLACE, Alberto and SPENCE, Charles. *In Touch with the Future: The Sense of Touch from Cognitive Neuroscience to Virtual Reality*. Oxford: Oxford University Press, 2011, p. 469.

[13] LEVITIN, Daniel J. *This is Your Brain on Music*…, p. 322

For example, in their study of preference for visual art, Lindell and Mueller[14] confirmed the important role of prototypicality, which is considered a universal sign of beauty. The brain/mind likes prototypes since it easily identifies with them. Prototypes may differ between cultures, but an inherent feature of the mind is to seek them. Along the same lines, Levitin[15] claims that prototypes in music (such as rock riffs or salsa rhythms) are stored in memory; in spite of the transformations individual musicians might make in, say, pitch, scale, harmony or tempo, we can still recognize a certain musical piece and identify its style.

One of the basic experience design principles, as per Pine and Gilmore, is attributing a theme to each experience. This enables the visitor to immediately identify with the presented topic, thus enabling him or her to clearly associate and match the product/service/experience with his or her expectations. The theme should be "concise and compelling"[16], that is, compelling enough to draw interest, and concise in order to provide a clear meaning. Museums whose exhibitions are thematically organised according to this principle should profit from it, since it is easier for the visitor to understand the message. As mentioned, there is also biological theory to back this up; the human brain requires clear structure in order to extract the meaning from a certain situation or sensory stimulus. Thus, the brain creates a framework, or a schema, within which it places different elements, trying to understand how they are connected in a meaningful narrative.

If a museum visitor understands the message, it is an indicator of a quality interpretation. It does not, however, necessarily affect visitors' memories. A strong experience design principle with high probability of affecting memory is the use of the senses,[17] since it can have a substantial effect on eliciting visitors' emotions. Emotions instigate "specific response behaviours"[18], so that once evoked, visitors react to the stimulus with a response behaviour; for example, they may cry, laugh, move their bodies, and so on. Emotional arousal creates an affective connection with the museum's theme as well as with the institution itself. Successful museum experience design should therefore seek to engage visitors in thematic experiences while eliciting an emotional response from them.

The emotion of surprise – the human brain on the unexpected

Psychologists have yet to agree on the exact number of emotions. Without a doubt, there are a lot of them, which makes experience design based on emotions extremely complex. Usually, studies focus on basic emotions (joy, sadness, anger, fear, surprise and disgust), as they are cross-cultural. Surprise denotes a feeling which occurs as a result of an unexpected or astonishing stimulus, and has been often used in experience design. This is due to the fact that oversupply of the same type of stimulus may lead to saturation. In such cases, the brain benefits from novel information. Moreover, "massive familiarity with the stimulus … reduces aesthetic ratings"[19]. Thus, introducing novelty/surprise can be effective in stimulating arousal,

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[14] LINDELL, Annukka K. and MUELLER Julia. Can Science Account for Taste? Psychological Insights into Art Appreciation. In: *Journal of Cognitive Psychology* 23(4), 2011, p. 453–475.

[15] LEVITIN, Daniel J. *This is Your Brain on Music…*, p. 322

[16] PINE, Joseph B. II and GILMORE, James H. Welcome to…, p. 103.

[17] PINE, Joseph B. II and GILMORE, James H. Welcome to…

[18] COHEN and ARENI, 1991, cited in PRAYAG, Girish et al. Understanding the Relationships Between Tourists' Emotional Experiences, Perceived Overall Image, Satisfaction, and Intention to Recommend. In: *Journal of Travel Research* 56(1), 2017, p. 41–54.

[19] LINDELL, Annukka K. and MUELLER Julia. Can Science Account for Taste? …, p. 464.

a connection which has previously been recognized by the marketing industry[20]. Positive surprises often exceed customer expectations, arousing excitement and interest. Surprise has also proven to be an important emotional response in customers[21]. Studies on visual stimuli have shown, however, that moderate levels of novelty are preferred[22]; too much leads to lack of meaning, while too little is under-stimulating. In order to stimulate interest and generate an emotional response from the listener, musicians apply unexpected deviations from established schema (e.g. of a piece) by suddenly varying melody, harmony, contour, pitch, rhythm, and so on.[23] These deviations generate high levels of appreciation by the listener, as long as the main schema is still recognizable.

An informal experiment performed by the author in 2019 aiming to detect participants' reactions to an unexpected stimulus involved serving devilled eggs, half of which were predictably yellow in colour, while the other half were dyed an unnatural and unexpected green. The taste remained the same: the only difference was colour. The study reported higher initial consumption of yellow eggs, while the green eggs were consumed more cautiously. However, once participants had overcome the surprise of the unnatural green colour, they proceeded to consume both. The experiment confirmed that while novelty/surprise might be a drawback (in this case, the colour green may have been suggestive of toxic food), as long as the basic schema remains the same (i.e., people are being fed eggs and not an unknown substance), the mind is curious enough to consume. This experiment set the ground for further research by stirring the researcher's curiosity on the desirable level of surprise/novelty and the sensory cues that could be used in the design of a stimulus aimed at eliciting certain desired emotions from museum visitors.

Artistic visual and acoustic cues for designing surprising experiences

The theme of a museum or exhibition certainly has the strongest effect in terms of communicating meaning to visitors, allowing them to easily identify with the content of the exhibition. However, a number of subliminal cues, which can be communicated via abstract elements such as colour, light and sound, also impact the visitor's experience, and these kinds of stimuli have the potential to elicit surprise. Previous research into aesthetic appreciation of art suggests that the main visual elements influencing ratings are colour, form, symmetry, complexity, laterality, abstraction, prototypicality and novelty[24]. When it comes to acoustic cues, loudness, pitch, contour, timbre, tempo, spatial location, rhythm, reverberation, meter, harmony, melody[25] can all impact how we perceive and act upon a musical stimulus. From a number of these cues, the conscious mind extracts information from what the individual already knows by looking into the memory, seeking to find recognisable elements and categorising the experience according to them in order to draw meaning from the sensory input. Once provided, this classification forms the basis for memorable experiences and/or actions by the visitor.

Although there are a number of studies aiming to match different sensory stimuli with basic

[20] For example, GAD, Thomas. *Customer Experience Branding: Driving Engagement Through Surprise and Innovation*. London: Kogan Page, 2016, p. 168.
[21] DIXON, Michael et al. Surprise, Anticipation, and Sequence Effects in the Design of Experiential Services. In: *Productions and Operations Management* 26(5), 2017, p. 945–960.
[22] LINDELL, Annukka K. and MUELLER Julia. Can Science Account for Taste? …, p. 453–475.
[23] LEVITIN, Daniel J. *This is Your Brain on Music…*, p. 322
[24] LINDELL, Annukka K. and MUELLER Julia. Can Science Account for Taste? …, p. 453–475.
[25] LEVITIN, Daniel J. *This is Your Brain on Music…*, p. 322

emotions, there is scant evidence regarding concrete sensory cues and the emotion of surprise; although there are a few, studies that focus on surprise and the sense of sight[26], hearing[27], touch[28] and smell[29] are rare.

Li et al.[30] found that the visual cues that have a direct relation to the emotion of surprise are uniqueness, rareness and irregularity, and these can be achieved by using contrast textural difference, mutual information (mutual dependence between the two variables), and movements of an object or changes in a variable that follow no discernible pattern or trend.

When it comes to acoustic cues, a sharp amplitude envelope (or rapid attack) and large pitch variation have been detected as having importance in eliciting surprise[31]. Sounds that are dominated by higher harmonics[32], a fast tempo, and increasing the subdivision of rhythmic units (beats) from whole and half notes to eighth notes and even to sixteenth notes[33] have also been shown to have this effect.

It is evident, however, that these findings relate to a very small number of cues which may elicit surprise; there are no scientifically proven results regarding a number of other visual cues such as colour, form, symmetry or acoustical ones such as melody, loudness and rhythm. A number of studies[34] have detected the importance of synaesthesia (merging of the senses), confirming the interrelationships between different senses in eliciting an emotional response in the beholder. Aware of the complexity of the task, this study has been specifically designed, based on existing knowledge and experiences, to try to at least partially fill this gap.

Research

The purpose of this study was to gain greater understanding of the relationship between various visual/aural stimuli and the emotions they evoke. The aims were to confirm/detect types of sensory stimuli that evoke the emotion of surprise, to see if participants have similar reactions to stimuli, and to establish whether self-reported responses were aligned with participants' psychophysiological reactions. The main hypothesis of the study was that there are visual/acoustic cues (such as colour, form, symmetry for the sense of sight or tempo, rhythm, melody, pitch for the sense of hearing) related to surprise, which appeal equally to the majority of people and may act as near-universal stimuli. This was measured by means of both physiological measures and self-reporting measures. It was expected that there would

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[26] For example, LI, Yia, et al. Measuring Visual Surprise Jointly from Intrinsic and Extrinsic Contexts for Image Saliency Estimation. In: *International Journal of Computer Visions* 120, 2016, p. 44–60.

[27] SCHERER, Klaus R. and OSHINSKY, James S. Cue Utilisation in Emotion Attribution from Auditory Stimuli. In: *Motivation and Emotion* 1, 1977, p. 331–346.

[28] IOSIFYAN, Marina and KOROLKOVA, Olga. Emotions Associated with Different Textures During Touch. In: *Consciousness and Cognition* 71, 2019, p. 79–85.

[29] For example, GLASS, Sandra T. et al. Do Ambient Urban Odors Evoke Basic Emotions? In: *Frontiers in Psychology* 5, 2014, accessed June 2, 2020, https://www.frontiersin.org/articles/10.3389/fpsyg.2014.00340/full; BENSAFI, Moustafa et al. Psychophisiological Correlates of Affects in Human Olfaction. In: *Neurophysiologie Clinique* 32, 2002, p. 326–332; CROY, Ilona et al. Basic Emotions Elicited by Odors and Pictures. In: *Emotion* 11(6), 2011, 1331–1335.

[30] LI, Yia et al. Measuring Visual Surprise…, p. 44–60.

[31] SCHERER, Klaus R. and OSHINSKY, James S. Cue Utilisation…, p. 331–346.

[32] GABRIELSSON, Alf and LINDSTRÖM, Erik. The role of structure in the musical expression of emotions. In: JUSLIN, Patrik N. and SLOBODA, John A. (eds). *Handbook of Music and Emotion: Theory, Research, Applications*. Oxford: Oxford University Press, 2010, p. 368–400.

[33] FERNÁNDEZ-SOTOS, Alicia et al. Influence of Tempo and Rhythmic Unit …

[34] For example, KANTONO, Kevin et al. Emotional and Electrophysiological Measures Correlate to Flavor Perception in the Presence of Music. In: *Physiology & Behavior* 199, 2018, p. 154–164.

be some degree of correspondence between self-reported emotions and psychophysiological reactions to the stimuli. The combination of psychophysiological measures and self-reports allowed researchers to observe whether there is any correspondence between perceived and induced emotions.

The starting point for the research was the drive to come up with recommendations for a typology of different visual and aural stimuli that could be used in experience design to elicit the emotion of surprise. The detection of types of stimuli which result in reactions or perceptions shared by the majority of people would enable us to create near-universal museum experiences, avoiding negative perceptions of museums' offerings.

Research design and methodology

Fig. 1: *Visual stimulus designed by visual arts students.* Source: Original design by visual arts students at the Lamar Dodd School of Art, University of Georgia, USA in coordination with Prof. Mac Balantine

A broad partnership was involved in the research design: visual artists and musicians (both professionals and students) were in charge of designing the visual/acoustic stimuli, guided by academics in the fields of art, music, cultural heritage and cultural tourism. A software development expert was engaged to design the platform for presenting the stimuli. Finally, the research experiment was designed in collaboration with a psychology researcher. The study combined both quantitative and qualitative methods. The stimuli design benefited from the existing knowledge obtained from previous studies on the connections between surprise and vision[35] and hearing[36]. However, since these studies provide very little information on cues appropriate for designing surprising stimuli, this study combined some of these cues with newly introduced ones. The visual cues to be tested focused on colour, form, texture, contrast and light, while the acoustic cues used pitch, timbre, unexpected changes/large contrasts, loudness and tempo. These were selected based on several brainstorming sessions/workshops involving artists, musicians, visual arts and music students, and a researcher specialised in cultural heritage management and cultural tourism. In terms of approaches suggested by the existing literature, for visual stimuli, we investigated contrasting textural difference (based on Li et al.[37]), while for auditory stimuli we focused on sharp amplitude envelopes (rapid attacks) and large pitch

[35] LI, Yia et al. Measuring Visual Surprise…, p. 44–60.
[36] SCHERER, Klaus R. and OSHINSKY, James S. Cue Utilisation…, p. 331–346; FERNÁNDEZ-SOTOS, Alicia et al. Influence of Tempo and Rhythmic Unit...
[37] LI, Yia et al. Measuring Visual Surprise…, p. 44–60.

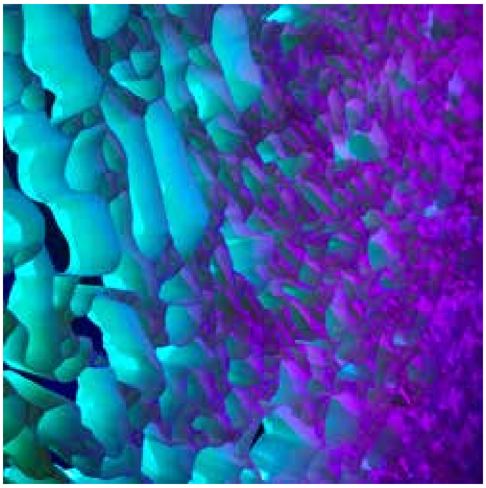

Fig. 2: *Visual stimulus designed by the visual artist Paula Reynaldi.*
Source: Original design by Paula Reynaldi

variations (based on Scherer and Oshinsky)[38] and sounds dominated by higher harmonics (based on Gabrielsson and Lindström[39]). Newly introduced cues were based on professional knowledge and the experiences of the working groups involved and are further described below.

As a result of the brainstorming sessions/ workshops, a total of three visual and aural stimuli were created in the form of image and sound files, including two visual stimuli (one designed by visual arts students and the other one by a visual artist) and one aural stimulus (designed by music students). The two visual stimuli, although using the same cues, differed in the selection of elements, possibly expressing surprise. The stimulus designed by visual arts students used the following cues (see Figure 1):
Colour – predominantly yellow, red and dark blue
Form – predominantly regular, sharp and pointy
Texture – lightly rough
Contrast – bright vs dark colours; sharp pointy forms on a smooth background
Light – undefined

The stimulus designed by the visual artist (Fig. 2)[40] focused on:
Colour – predominantly turquoise and purple with traces of dark blue
Form – irregular, elongated
Texture – combination of smooth and crumpled
Contrast – bright vs dark colours; smooth and crumpled areas; differences in colour hues creating the perception of lighter and darker areas
Light – bright and dark

As for the acoustic cue, the stimulus focused on the following cues:
Key – major
Meter – 4/4
Pitch variations (as per use of different instruments) – piano (high) and brass (ascending)
Timbre – percussion (piano) and wind instruments (brass)
Unexpected changes/large contrast – silent and tender piano vs loud and sharp brass music, unexpected transition, timbral differences
Loudness – soft and loud sections
Tempo – slow (piano, *mesto*) with a sudden interruption (brass)
Harmony - diatonic

[38] SCHERER, Klaus R. and OSHINSKY, James S. Cue Utilisation…, p. 331–346.
[39] GABRIELSSON, Alf and LINDSTRÖM, Erik. The role of structure in the musical expression of emotions…, p. 368–400.
[40] Paula Reynaldi is a visual artist of Argentinian descent living and working in Athens, Georgia, USA. For more, see: http://www.paulareynaldi.com/

The research sample consisted of 24 participants recruited on a voluntary basis. They were of a varying gender, age, origin and had varying prior levels of formal education with regards to visual arts and music. Beyond that, an important selection criterion was that they should not have visual or hearing impairments.

Participants in the study were asked to come to the laboratory individually, at different times, and the stimuli were presented to them on a laptop. Specifically designed web-based software that enabled both visual and audio presentation while recording user feedback was used to conduct the test. Participants were asked to give their consent before proceeding. After filling in their demographic information, they were presented with the slides the research group had designed. Each slide was followed by a question asking the participants to self-report on their own perceptions of the emotion that particular visual or audio slide elicited. Respondents could select only one of the following basic emotions: joy, sadness, fear, anger, disgust or surprise. At the same time, while experiencing the stimuli, participants' psychophysiological responses – heart rate variability (HRV), pulse, skin conductance responses (SCRs) and facial muscle movements (zygomaticus major and corrugator supercilii) – were recorded. The psychophysiological measurements recorded participants' induced (felt, generated by the body) emotions, while self-reporting offered them the possibility to express their perceived emotions.

Results and discussion

To assess whether the participants experienced the intended emotion of surprise, a number of statistical procedures were performed on the empirical results: a chi-square goodness of fit tests was used to assess the self-reports, while Repeated-measure ANOVAs were run for all of the four psychophysiological outcomes (heart rate, supercilii and zygomatic muscle responses, and skin conductance responses)[41].

Self-reports

Statistical analyses were performed using SPSS software (Version 24)[42]. Proportions of chosen emotions for each of the three stimuli can be found in Table 1. With respect to the self-reports, several chi-square goodness of fit tests[43] were conducted to establish whether the five emotions (anger, disgust, fear, joy, surprise) were equally selected. The frequency of self-reported surprise was compared to the frequencies of other chosen emotions for a given stimulus. For the aural stimulus, a chi-square test including all of the five emotions was found to be significant, X^2 (4, N = 24) = 22.67, p < .001. Hence, a series of post-hoc chi-square tests were performed, comparing the proportion of surprise to the proportions of each of the other emotions. In comparison to joy, surprise was not chosen more frequently (p = 1.00). However, when compared to anger, disgust, and fear, participants reported surprise significantly more often (p = .006). With respect to the visual stimulus created by the professional artist, three out of the five emotions – joy, surprise, and fear – were reported by participants. Moreover, a chi-square test yielded a significant result, X^2 (2, N = 24) = 23.25, p < .001, but not in favour of surprise. In fact, joy was found to be the dominating emotion, as confirmed by a significantly higher proportion compared to surprise (p = .003). Hence, it seems that the visual artist's

[41] ANOVA is an analysis of variance and repeated-measure ANOVA is used when different measures (in this case different stimuli) are taken on the same participants.

[42] SPSS is a software package for social sciences which is used to perform statistical analysis.

[43] The chi-square goodness of fit test is a statistical hypothesis test used to determine whether a variable is likely to come from a specified distribution or not.

stimulus did not evoke surprise to a significant degree. Finally, the student artists' stimulus was evaluated. Overall, three emotions were reported – joy, surprise, and disgust. Again, joy and surprise took up the majority of the self-reports, and a significant chi-square test result was observed, X^2 (2, N = 24) = 10.75, p < .005). However, there was no significant difference between the two most frequently reported emotions – joy and surprise (p = .405). Hence, even though surprise did not prove to be the main choice, neither were joy no disgust.

Tab. 1.

Emotion (per Stimulus)	Frequency	Percentage
Sound		
Anger	1	4.2
Disgust	1	4.2
Fear	1	4.2
Joy	10	41.7
Surprise	11	45.8
Visual artist		
Fear	1	4.2
Joy	19	79.2
Surprise	4	16.7
Visual student		
Disgust	1	4.2
Joy	14	58.3
Surprise	9	37.5

Note. Emotions that were not chosen at all (frequency and percentage = 0) were not included.
N = 24.

Psychophysiological measures

As mentioned, repeated-measure ANOVAs were conducted for all of the four psychophysiological variables – heart rate, supercilia and zygomatic muscle responses, and skin conductance responses. This analysis was chosen due to the dependent nature of the research design, meaning that all of the participants underwent all of the three experimental conditions. Hence, the ANOVAs involved a single factor – stimulus, with three corresponding levels – sound, professional visual artist, and student artists. The heart rate data was first screened for any potential outliers. It was decided that all results below 40 bpm would be excluded. Generally, medical professionals suggest that a normal resting heart rate falls between 60 and 100 bpm, but can fall as low as 40 for trained athletes[44]. After applying the exclusion criterion, 19 participants were considered for the analysis. Descriptive statistics for the heart rate, as well as the other psychophysiological measures, can be found in Table 2. The ANOVA test of the heart rate results did not yield a significant result, F(2, 18) = .22, p = .764, meaning that none of the three types of stimuli, on average, stood out as significantly higher (or lower) than the rest. Moreover, the mean values fell within the range of normal resting heart rate, meaning that we could not conclude that the stimulus-induced emotional experience resulted in a change in

[44] LASKOWSKI, Edward R. What's a normal resting heart rate? 2018, accessed August 17th, 2020, https://www.mayoclinic.org/healthy-lifestyle/fitness/expert-answers/heart-rate/faq-20057979

heart rate. Regarding the supercilii muscles measure, one participant was excluded from the analysis, as the score fell more than three standard deviations above the mean (N = 23). No participants were excluded from the analysis of the zygomaticus responses. Neither of the ANOVA results for the supercilii or zygomaticus were significant: $F(2, 22) = .70, p = .501$, $F(2, 23) = .65, p = .529$ respectively. Hence, these two psychophysiological responses did not differ between the three stimuli types of stimuli. Finally, the ANOVA result for the skin conductance responses yielded a significant result, $F(2, 23) = 7.73, p = .009$ (N = 24). Hence, a post-hoc pairwise comparison was performed, in order to determine which of the three stimuli evoked different responses. It was found that the aural stimulus evoked significantly higher responses, compared to the stimulus created by the art students ($p = .034$), and also in comparison to the professional artist's stimulus ($p = .028$). What this finding tells us is that sound was specifically effective in increasing the participants' physiological response, possibly indicating a stronger experience of the emotion of surprise.

Tab. 2: *Descriptives (minimum, maximum, mean, and standard deviation) of the four psychophysiological measures, per each stimulus*

Measure (per stimulus)	Minimum	Maximum	Mean	SD
Heart rate				
Sound	55.54	104.56	73.98	13.67
Visual artist	54.44	92.26	73.31	12.67
Student artist	59.79	94.31	73.04	11.38
Superscilli				
Sound	-9.07	16.42	.90	6.22
Visual artist	-23.84	7.65	-1.42	6.63
Student artist	-22.12	13.42	-0.22	6.90
Zygomaticus				
Sound	-13.08	12.79	-0.31	5.99
Visual artist	-7.29	5.04	-1.45	4.25
Student artist	-9.00	9.54	0.12	3.99
SCRs				
Sound	146.85	377.62	286.24	57.61
Visual artist	129.65	371.89	283.94	59.94
Student artist	120.10	370.17	282.69	60.89

Conclusions

Controversies regarding universal stimuli to be used in museum experience design with the goal to affect visitor behaviour should be mitigated since the brain itself functions by searching for categories. This quest still seems far from achievable, due to the scarcity of studies that might provide some guidance, and due to a number of complex variables which may affect visitor experience. Besides, although our measurement of psychophysiological responses did provide some data on emotional responses, the process was far from being able to offer exact data on how to generate a specific emotion, such as surprise. The study did show that, according to participants' self-reported emotions, the aural stimulus was more effective in eliciting surprise than the visual stimuli. As for psychophysiological readings, only skin conductance responses varied significantly in response and, again, the aural stimulus was found to evoke significantly stronger responses than the visual stimuli.

This leads to a conclusion that sound potentially has stronger effects on both perceived (self-reported) and induced (physical response) surprise. This is an important finding which can be used in museum design; museum designers should consider the use of sounds/music if they want to design a surprising experience. The specific design of such aural stimuli should include a sharp amplitude envelope (rapid attack) and large pitch variation, as well as higher harmonics, which confirm the effectiveness in eliciting surprise by way of music. Sharp attack can be combined with manipulation of tempo, as in the aural stimulus developed for this study, which had a slow tempo with a sudden interruption (sharp amplitude envelope) and seems to have successfully elicited the emotion of surprise. A sudden change in loudness adds to the effectiveness. Although repeated experiments in future research may be performed to confirm this, these cues may serve as a starting point for museum experience design eliciting surprise.

It was not possible to reach any clear conclusions regarding visual cues which could be used in experience design based on this study. The research incorporated all the cues highlighted by Li et al.[45]: uniqueness – both works were specifically designed for this experiment and were unique; rareness and irregularity – the professional artist used irregular forms, while the students used relatively regular ones but sharp and pointy; contrasting textural differences – the professional artist employed a combination of smooth and crumpled and the students used a lightly rough texture; mutual information – there was dependence between presented objects in both works; and unexpected movements of an object in both works – an explosion in the students' stimulus. Contrast was achieved not only in texture but also by way of colours (bright vs dark or differences in colour hues) as well as forms (sharp pointy forms on a smooth background). As for other newly introduced cues, no clear conclusions can be made, although the stimuli used different colours (combination of warm and cold colours for the students' stimulus, possibly also expressing contrast; and cold colours for the professional artist's stimulus) and light (undefined for the students' stimulus, and *chiaroscuro* possibly again expressing contrast for the artist's stimulus). Conclusively, neither self-reported not psychophysiological measures showed significant responses.

This points to the necessity of future research, especially regarding visual cues that stimulate emotion; these are numerous and the role of each of them is yet to be determined. A strategy for future research may involve individuating each cue in a separate study and trying to define the effect of every single one on the elicitation of surprise. Furthermore, the quantity of novel and surprising cues that need to be included a sensory stimulus for it to have the desired effect is yet to be determined. As a response of the brain to the unknown, higher-order processing may contribute to the creation of new prototypes/categories to be stored in the memory. Thus, creativity applied in that process may be contributing to the growth and development of the mind itself; the brain creates new prototypes/categories to be upgraded with moderate amounts of novelty/surprise in order to stimulate itself to new possibilities (which is actually the process of learning) and the circle goes on. In this research, among all the psychophysiological responses measured, only skin conductance responses were found to be significant. As the majority of measures were found to be rather unreliable, future research might employ neuroimaging methods to detect the (near)universal level of novelty/surprise

[45] LI, Yia, et al. Measuring Visual Surprise…, p. 44–60.

to be introduced in the stimulus. Use of neuroimaging methods has, in recent years, greatly enhanced our knowledge of brain responses, and may provide some answers in the future.

The reason behind our observation of a stronger effect of the aural stimulus compared to the visual ones recorded may also be sought in the very nature of the stimulus: a musical piece takes place over a duration of time, and while the brain might anticipate what is about to happen, based on what has already happened, the listener cannot predict with absolute certainty, hence is open/vulnerable to surprise, whereas a visual stimulus is presented in an instant where the beholder sees everything at once. It might be that the sense of movement and the unexpected moments in visual stimuli may be more effective if presented in the medium of film. This is also an indication for museum experience designers and a possible subject of future research.

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