Lived experience and virtual reality: visual method of analysis based on video recordings and the Valence-Arousal diagram

Experiencia vivida y realidad virtual: un método visual de análisis basado en grabaciones de vídeo y el diagrama Valence-Arousal

Charles-Alexandre Delestage*
Bordeaux Montaigne University
Maître de Conférences in Information and Communication Sciences
MICA Laboratory, UR 4426
Bâtiment MSH de Bordeaux
10 Esplanade des Antilles,
33607 PESSAC Cedex, France

charles-alexandre.delestage@u-bordeaux-montaigne.fr
https://orcid.org/0000-0002-7842-049X

University of Franche-Comté
Associate Researcher
ELLIADD Laboratory, EA 4661

Willy Yvart**
University of Franche-Comté
Maître de Conférences in Information and Communication Sciences
ELLIADD Laboratory, EA 4661
30-32 rue Mégevand,
CS 81807-25030, Besançon Cedex, France

willy.yvart@univ-fcomte.fr
https://orcid.org/0000-0002-7569-7557

Editor: Rogelio del Prado Flores

https://doi.org/10.36105/stx.2024n12.07

Recibido: 15 de agosto 2023
Aceptado: 30 de agosto 2023

* Charles-Alexandre Delestage es profesor asociado en la Université Bordeaux Montaigne y miembro del laboratorio MICA. Sus investigaciones se centran en la experiencia emocional del individuo en un contexto cultural mediatizado y en el ecosistema cultural francés de realidad virtual. Es tesorero de la sociedad científica Visual Modi que organiza la Conferencia Internacional sobre Métodos Visuales de Tenerife, España.
** Willy Yvart es doctor en Ciencias de la Información y la Comunicación y doctor en Ciencias y Tecnologías de la Ingeniería. Es profesor asociado universitario en la Universidad de Franche-Comté y miembro del laboratorio ELLIADD. Especialista en tecnologías y técnicas audiovisuales, también es miembro de la organización de la Conferencia Internacional sobre Métodos Visuales de Tenerife, España y miembro de la sociedad científica Visual Modi.

ABSTRACT

The specificity of Virtual Reality is that it offers the user almost complete sound and visual immersion, relying heavily on the sensation of presence, activated by audio and visual indications of the simulated space and strongly linked to the emotional dimension of the virtual reality experience. From the point of view of experience design research, since the user is immersed in a virtual world, real-time feedback on his or her experience is more difficult than for other media. The aim of this article is to present a visual qualitative approach to collecting traces of a virtual reality user's lived experience using a visual method protocol involving synchronous virtual real-world video recordings and the Spot Your Mood tool (Yvart, Delestage, Leleu-Merviel, 2016).

Keywords: virtual reality, emotion, video capture, experience, visual methods.

RESUMEN

La especificidad de la realidad virtual es que ofrece al usuario una inmersión sonora y visual casi completa, basándose en gran medida en la sensación de presencia, activada por indicaciones sonoras y visuales del espacio simulado y fuertemente vinculada a la dimensión emocional de la experiencia de realidad virtual. Desde el punto de vista de la investigación en diseño de experiencias, al estar el usuario inmerso en un mundo virtual, la retroalimentación en tiempo real sobre su experiencia es más difícil que en el caso de otros medios. El objetivo de este artículo es presentar un enfoque cualitativo visual para recoger rastros de la experiencia vivida por un usuario de realidad virtual mediante un protocolo de método visual que implica grabaciones de vídeo sincrónicas del mundo real virtual y la herramienta Spot Your Mood (Yvart, Delestage, Leleu-Merviel, 2016).

Palabras clave: realidad virtual, emociones, video captura, métodos visuales.

INTRODUCTION

Immersive technologies open a wealth of possibilities in terms of heritage and cultural valuation. These technologies make it possible to offer media content on wide spread available media (smartphones, computers) or specific media (VR headsets[1]/AR[2]) within cultural insti-

1 Virtual Reality.
2 Augmented Reality.

tutions or outside the walls (Nahon, 2020). Despite a certain craze since the introduction of consumer headsets in 2016, sales of headsets are only expected to reach 21.76 million units by 2023 (Statista, 2023). So, it's hard to see virtual reality as fully established in the home. VR is perceived, rightly or wrongly, by the general public as a new technology, and is not yet seen as the new medium it is becoming alongside the historical (television, press, radio) as well as the recent (video games), and is slow to make its entry (Laurell *et al.*, 2019). However, a growing number of virtual reality projects from institutional or audiovisual players are pointing the way to what is possible in terms of cultural valorization (Mona Lisa: Beyond the Glass, The Scream VR, Lady Sapiens, etc.).

The use of VR carries an incentive factor due to its innovative aspect, particularly with young people, but also carries the risk of distracting the user's attention from the object of mediation (Guggenheim effect) (Puig *et al.*, 2020). This "Wow" effect is not without consequences for the adoption of VR. During this study, we noted in the positioning questionnaires that a small majority of our population (12 out of 22) had already had access to VR experiences, many of whom had never returned (7 out of 12). The underlying concept that can be found in the economic sciences is that of continuity. Why return to it after a test or, on the contrary, not subscribe to this new technology and relegate it to the same graveyard as BetaMax or other LaserDiscs? Laurell *et al.*, explore the potential limits from an economic point of view, and through social media mining the issue of VR's difficulties to be pervasive they conclude that::

> [b]oth the technological performance and the number of complements available constitute barriers to adoption at present. Price point also seems to play a role, but less attention is devoted to this parametre [...] a cautious approach is presently to be preferred given limited adoption and the fact that the technology doesn't seem entirely ready at this point. Given exponential improvements in performance and availability of complementary goods, we do not exclude the possibility that this phenomenon will evolve positively in the coming years". A recent study by Yang and Han looked at the intrinsic motivations behind the expectation of continuance. The authors then consider: "Both utilitarian value and hedonic value have positive impacts on RV users' continuance intention. Among the four constructs reflecting RV device and service-related attributes, content quality and ease of use have significant impacts on the utilitarian value and hedonic value. Visual attractiveness is positively associated with hedonic value while portability affected only utilitarian value (Yang, Han, 2020, p. 473).

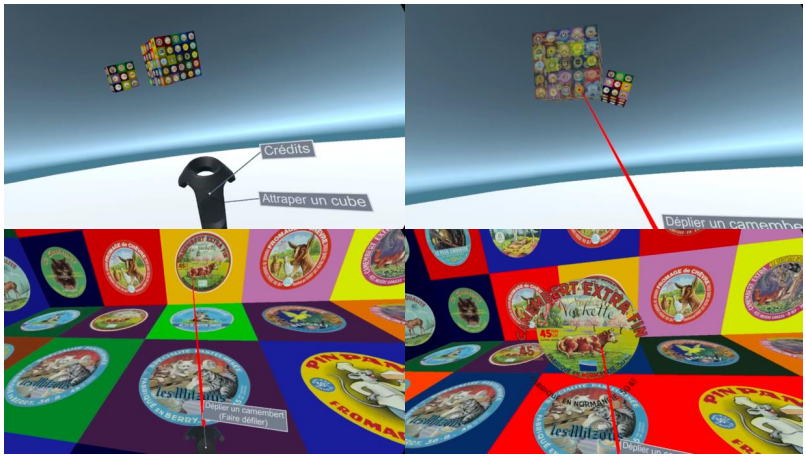
The expectation of VR adoption is therefore largely based on eminently hedonic aspects, which we wanted to evaluate using the SYM protocol protocol (Yvart *et al.*, 2016).. However, we highlight the need to go beyond the novelty or fashion effect inherent in any new technol-

ogy, which implies being able to present both to museographers and to the host structures themselves the contributions of VR, and to show them in addition to the results of a "classic" scientific study a popularizing and transparent mediation of the experience of the participants in the said study.

Device presentation

The system studied was designed as part of the CPER/FEDER NUMERIC action *Archives Augmentées* program, directed by Jean-Marie Dallet, Frédéric Curien and Charles-Alexandre Delestage. The action was based on the exploitation of the Garnaud collection at the Musée du Papier d'Angoulême, which includes camembert labels printed by the Bardou-Le Nil factories during the 20th century. The labels were digitized and cut into layers representing the different parts of the label from an iconographic point of view. The entire collection is grouped into categories based on the label's theme (famous people, mills, monks, etc.). Each theme is then distributed over the facets of a cube analogous to the famous Rubik's Cube, whose size varies dynamically according to the number of labels in the collection. The colored background of the facets varies randomly according to a predefined palette, inspired by the work of Vasarelli. As shown in Figure 1, All these cubes float around the user in space (1) and can be selected by the user for consultation. At this point, the cube becomes translucent (2) and is placed around the user, metaphorically bringing the latter into the cube (3). The user can then choose to unfold the iconographic layers of labels to view them in the space of the cube (4). Alternatively, they can return the cube and select another for consultation.

FIGURE 1: VIRTUAL REALITY DEVICE ILLUSTRATIONS (1) TOP LEFT, (2) TOP RIGHT, (3) BOTTOM LEFT, (4) BOTTOM RIGHT



SOURCE: PREPARED BY AUTHORS.

The demonstrator was presented to participants in 2 different rooms between 09/17/2019 and 09/26/2019. Each offered a 15m² space for virtual reality. The headset used was an HTC Vive Pro with wireless link, to enable individuals to move more freely around the dedicated space. The simulation used a single joystick for interaction with the digital cubes and labels.

System evaluation method

The experiment was based on a multimodal exploratory method involving 22 individuals. Our sample comprised 22 people (9 women, 13 men)[3] aged between 18 and 50, with an average age of 26. The participants were students of the DUT Métiers du Multimédia et de l'Internet, the Master 2 Design Communication et Packaging and the Master 2 Marques et Produits Jeunesse, as well as lecturers in these degrees. The latter were recruited on a voluntary basis via posters offering to take part in a virtual reality experience without compensation. The three modalities followed the following scenario:

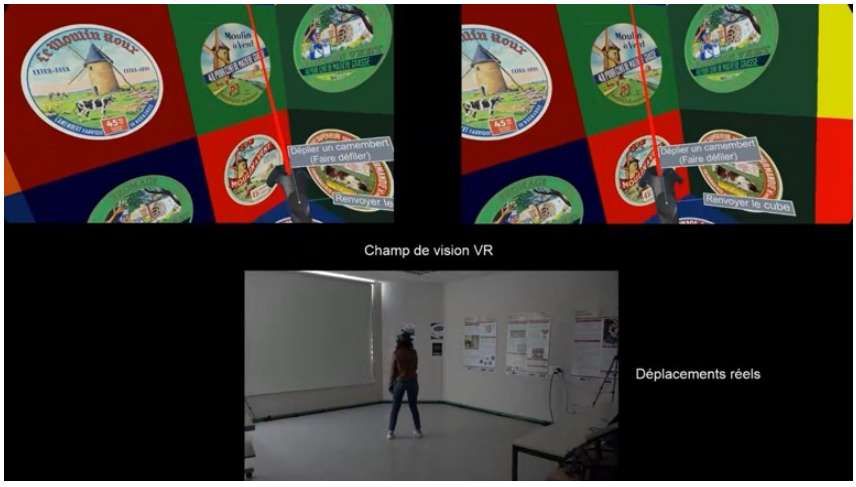
- A positioning questionnaire designed to characterize the co-participant and, in particular, to determine his/her acculturation to museums, VR and video games;
- A check-in on SYM before putting on the VR helmet to find out their initial emotional state;
- Experimentation with the device itself, which lasted as long as the co-participant wished;
- A second check-in on SYM after the VR helmet had been removed in order to determine their emotional state as a result of the experiment.
- A questionnaire for evaluating the system, based in particular on an assessment of the desire to return to VR and the desire to repeat a similar experiment (through VAS), and a grid composed of antinomic adjectives with scores in the form of VAS.

The entire binocular field of view is recorded synchronously with a "third-person" control camera. We regard the video as a record of the experiment, enabling us to reliably retrace what happened. The notes and/or memories are much more incomplete, even if they do not pose the problems of conservation and space management involved in video capture (lossy compression to be chosen without too much degradation of quality, storage, file naming, etc.). What's more, video allows us to follow the individual's wanderings in the real world

3 None of the sample identified themselves as transgender or non-binary, which implies a correspondence between sex and gender.

during his virtual journey, particularly when confronted by the simulation's[4] chaperone. Video capture also enables us to transcribe *a posteriori* the movements and sometimes highly instructive informal verbalizations ("thin", "oops", laughter) produced by the co-participants. As shown in Figure 2, For their processing, we represented the videos by rendering the co-participants' stereoscopic field of view resynchronized at the top with the outside viewpoint filmed from the rear-left corner of the room where the experiment took place. This gave us 22 videos formatted as follows:

FIGURE 2. VIDEO TRACKS



SOURCE: PREPARED BY AUTHORS.

These video traces, which of course also include an audio recording of any comments, can be used for two purposes. On the one hand, they can be used to stimulate subjective *re-situ* interviews as described by (Schmitt, 2012). By confronting the participant with the trace of his or her field of vision, it is possible to deepen the constructions of meaning during interviews and to return to portions of the lived experience that escape questionnaires or interviews based solely on memory. Secondly, these videos can be presented as part of scientific mediation between researchers, the museographer and the host organization. This makes it possible to revisit cases that seem problematic, and to go back over the participant's itinerary to diagnose and amend.

4 The chaperone is a translucent grid that appears in the helmet's field of vision only when the helmet gets too close to the boundaries of the play area. This device prevents you from leaving the perimeter and injuring yourself, without being permanently displayed in the helmet, and thus disrupting the individual's immersion.

This means that, first of all, we need to be able to identify cases that stand out either positively or negatively from the general trend. To do this, we add a second device to the test protocol: SYM (Yvart *et al.*, 2016). The latter allows us to indicate by pointing on a Valence-Arousal space (allowing all emotional states to be represented a verbally according to Russell (Russell, 1980)) the emotional state before and after experimentation.

EVALUATION METHOD AND RESULTS

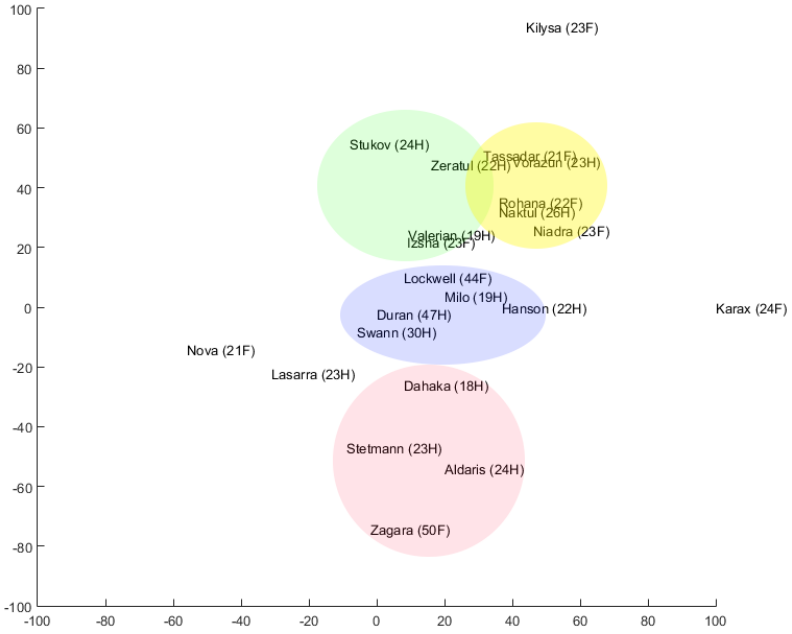
Cluster creation based on SYM delta scores

By comparing scores before and after exposure to the tested device, we can assess emotional experience. This approach is inspired by the method used with music in the second experiment of (Yvart, 2019)avoir pour destination l'industrie traditionnelle de la musique ou être spécialement prévue pour être synchronisée à des images. Dans ce cas, la musique recherchée est généralement perdue dans des bases de media musicaux disposant de leurs propres Systèmes de Recherche d'Information (SRI. Only the *delta* carries information. Indeed, the starting locus is irrelevant. Co-participants arrive with their life baggage and their mood of the day or period (particularly in the case of people with thymic disorders). What interests us, however, is the effect on the individual in terms of changes in arousal and hedonic valence.

The *delta* thus measured becomes a trace of the emotional impact of the VR experience just had (Yvart *et al.*, 2021). We apply a fully arbitrary scale to the Valencia-Arousal space, ranging from -100 to 100 on both axes, as can be seen in the Figure 3. With this scale, we can determine an average impact of the experiment. This average gives a variation of 16 on the abscissa (valence) and 9 on the ordinate (arousal). Given the size of the scale, whose maximum range is from -100 to +100 on each axis, the result is a tiny variation that gives a neutral overall trend, which would indicate that overall, the experiment had no effect. This is where the quantitative approach loses all interest. If this average could be seen as a "global trend", it would make it possible to discern the most divergent cases visually.

It is possible to plot the variation in Valence-Arousal back to the origin of the graph. This allows us to disregard the initial state of the co-participants, which is fluctuating and, above all, uncorrelated with the experiment in progress:

FIGURE 3. RELATIVE DELTA ON VA VALUES[5]



SOURCE: PREPARED BY AUTHORS.

By visualizing the diagram, we can use a methodical visual analysis to group co-participants together to help analyze the impact the experiment has had on them. We can already see that there is no correlation between gender or age. Variation is what interests us, since its measurement is a trace of the VR experience. We can see that, far from the global trend announced by the calculation of a simple average, it is possible to see the emergence of groups of individuals whose qualitative study would be interesting. A first group (pink) seems to reflect individuals who have been tired by the experience, with no great hedonic variation. A second group (topaz) shows an opposite effect, as the experiment stimulated them to arousal, with no notable hedonic variation. A third group (gold), made up of hedonic enhancers and arousal enhancers, showed an amusement effect. Finally, a fourth group (azure) includes individuals who do not seem to have been greatly affected by the experience.

5 *Note:* we anonymize co-participants using the names of characters from the Starcraft videogame universe. The XXG code appended to the name refers to the age and gender of the person, so 23F is the code for a 23-year-old woman.

Cluster validation

To validate the formation of clusters, we compared the scores attributed to the adjectives proposed in the post-VR questionnaire[6] in each of the clusters, as shown in Figure 4. For each qualifier, the following scores were calculated for the corpus as a whole, then for each cluster of interest:

- Average score;
- Variance;
- Level of adjective to describe the proposed VR experience;
- Level of consensus about this adjective in the population.

FIGURE 4: AVERAGE COMPARISONS OF QUALIFIERS BY SUB-GROUP WITH THE OVERALL AVERAGE

		Interactif/ "Interactive	Amusant/ Fun	Bluffant/ Bluffing	Inédit/ Unprecedented	Marquant/ Striking	Désagréable/ Unpleasant	Lassant/ Boring	Banal/ Banal	Perturbant/ Disturbing
All	Average	**71%**	**63%**	**63%**	**78%**	**74%**	**14%**	**53%**	**20%**	**45%**
	Variance	**8%**	**8%**	**5%**	**4%**	**5%**	**2%**	**7%**	**3%**	**12%**
	Qualifiant	**Quite**	**Quite**	**Quite**	**Quite**	**Quite**	**Few/Not**	**No opinion**	**Few/Not**	**Not very**
	Consensus	Medium	Medium	Medium/Strong	Strong	Medium/Strong	Strong	Medium	Strong	Weak
Impassive	Average	61%	**66%**	58%	67%	**67%**	11%	**50%**	40%	**46%**
	Variance	10%	**9%**	3%	6%	**3%**	2%	**12%**	5%	**5%**
	Qualifiant	Quite	**Quite**	No opinion/Quite	Quite	**Quite**	Few/Not	**No opinion**	Not very	**Not very**
	Consensus	Medium/Weak	Medium	Strong	Medium	Strong	Strong	Weak	Medium/Strong	Medium/Strong
Amused	Average	58%	79%	73%	87%	88%	**17%**	**56%**	**16%**	**45%**
	Variance	15%	6%	4%	2%	1%	**4%**	**11%**	**2%**	**14%**
	Qualifiant	No opinion/Quite	Quite/Very	Quite	Very	Very	**Few/Not**	**No opinion**	**Few/Not**	**Not very**
	Consensus	Weak	Medium	Strong	Strong	Strong	Strong	Weak	Strong	**Weak**
Awake/ Stimulated	Average	95%	58%	81%	94%	79%	9%	**56%**	8%	**49%**
	Variance	0%	17%	4%	1%	4%	1%	**14%**	2%	**28%**
	Qualifiant	Very/Extreme	No opinion/Quite	Very	Very/Extreme	Quite/Very	Few/Not	**No opinion**	Few/Not	**No opinion/Not very**
	Consensus	Strong	Weak	Strong	Strong	Strong	Strong	Weak	Weak	Disagree
Tired	Average	**67%**	**58%**	**67%**	**78%**	60%	**21%**	**55%**	14%	**49%**
	Variance	**10%**	**8%**	**4%**	**4%**	13%	**1%**	**1%**	1%	**5%**
	Qualifiant	**Quite**	**No opinion/Quite**	**Quite**	**Quite**	Quite	**Peu**	**No opinion**	Few/Not	**No opinion/Not very**
	Consensus	Medium/Weak	**Medium**	Strong	Strong	Weak	Strong	Strong	Strong	Medium/Strong
Other positive	Average	80%	**60%**	48%	57%	**68%**	11%	41%	13%	23%
	Variance	2%	**3%**	1%	4%	**4%**	1%	1%	1%	11%
	Qualifiant	Very	**Quite**	Not very	No opinion	**Quite**	Few/Not	Not very	Few/Not	Few/Not
	Consensus	Strong	Strong	Strong	Strong	Strong	Strong	Strong	Strong	Weak
Other negative	Average	**67%**	41%	29%	83%	**79%**	**14%**	**56%**	40%	57%
	Variance	**4%**	1%	4%	0%	**9%**	**2%**	**15%**	5%	37%
	Qualifiant	**Quite**	Not very	Peu	Very	**Quite/Very**	**Few/Not**	**No opinion**	Not very	No opinion
	Consensus	Strong	Strong	Strong	Strong	Medium	Strong	Weak	Medium/Strong	Disagree

SOURCE: PREPARED BY AUTHORS.

6 The adjectives proposed were: "Interactive"-"Fun"-"Bluffing"-"Unprecedented"-"Striking"-"Unpleasant"-"Boring"-"Banal"-"Disturbing" (English translation from French, original words present in the appendix). They were proposed according to the results of the 2020 SELL study on the words most used to describe virtual reality.

For each cluster, video recording was used to record the way in which individuals moved through the space (more or less static, frequent movements), as well as the time spent consulting the device. The Figure 5 shows the responses to the VAS and time spent per individual classified by cluster group.

FIGURE 5: TABLE OF RESPONSES TO POST-EXPERIENCE QUESTIONNAIRE VAS AND TIME OF RV USE

Groupes		VR à nouveau	Expérience similaire	Interactif	Amusant	Bluffant	Inédit	Marquant	Désagréable	Lassant	Banal	Perturbant	Durée
Tous	Moyenne	85	84	71	63	63	78	74	14	53	20	45	10:34
	Ecart-type	23,1	23,3	27,7	26,8	22	19,1	21,9	13	26	18	33,7	
Fatigués	Stetmann	86	90	81	21	44	92	20	21	50	13	15	14:40
	Dahaka	100	100	74	52	54	62	42	4	44	23	65	32:36
	Aldaris	73	64	93	75	85	60	78	31	68	21	57	21:44
	Zagara	100	100	20	84	84	99	100	28	58	0	58	12:55
Stimulés	Stukov	100	100	100	0	100	100	100	0	100	0	100	04:51
	Zeratul	95	93	92	59	64	98	52	14	72	30	5	07:39
	Valerian	100	100	100	96	62	79	74	0	14	0	0	07:08
	Izsha	98	98	87	76	98	98	89	21	39	2	89	13:03
Amusés	Tassadar	24	73	68	69	56	94	94	50	37	21	92	07:23
	Vorazun	100	100	0	100	100	100	100	0	100	0	0	15:38
	Rohana	74	58	43	42	66	80	88	17	78	36	65	04:39
	Naktul	95	95	77	85	89	69	78	11	14	13	15	10:29
	Niadra	92	79	100	100	56	92	79	9	52	12	54	14:06
Neutres	Lockwell	52	54	24	70	60	46	48	34	65	36	37	03:20
	Milo	99	99	99	98	65	98	85	1	2	19	52	05:42
	Duran	26	28	48	27	73	73		8	81	72	73	05:01
	Swann	98	97	71	68	34	50	69	1	50	32	20	05:32
N/A	Hanson	93	95	93	39	44	45	78	22	44	22	61	10:19
	Nova	100	100	53	47	42	84	100	23	83	24	100	11:37
	Lasarra	61	22	81	34	15	81	57	5	29	56	14	12:48
	Kilysa	100	95	65	70	57	81	82	8	46	13	2	07:12
	Karax	97	98	82	70	43	44	45	4	32	5	5	04:09

SOURCE: PREPARED BY AUTHORS.

"Impassive" group

This group is relatively heterogeneous when it comes to their verbal qualification of VR. Swann and Milo are very enthusiastic about returning to VR or re-experiencing a similar game. Lockwell, for his part, is more mixed, while Duran's response to these two questions is negative. It's notable that the time spent in the demonstrator is shorter than for the other groups (4min54 on average vs. 10min34 for the rest of the sample).

This group stands out as a borderline case. This is in line with what Charles-Alexandre Delestage had already observed in his use of SYM to evaluate audiovisual programs (Delestage, 2018) Neutral declarants or declarants expressing a neutral variation in their SYM scores cannot be integrated into stereotyped audience classes. We have both people who have been relatively enthusiastic as well as people who no longer want to re-experience VR and therefore do not constitute a captive audience, following the example of their fairly short journey times. What's more, analysis of the video footage shows the experience to be a fleeting one, with each person highly mobile in space, staying in the cubes for only a short time.

The result is that for this group, the opinion is less consensual than in the overall sample. Similarly, only the "unpleasant" item scored slightly less critically. For the group, although the consensus is not always significant, the experience was judged less interactive, less bluffing, less novel and more banal than in the overall opinion. The lack of consensus and difference from the average confirms us in considering this group as a borderline case for the study and the method deployed and requires a more detailed interview feedback to discriminate the expectations of this type of audience with regard to VR.

"Amused" group

Tassadar (21F), Vorazun (23H), Rohana (22F), Naktul (26H) and Niadra (23F) make up this group. What the members of this group have in common is that they underwent a significant increase in valence and arousal between the beginning and end of the experiment. Since this evolution suggests amusement, we decided to name this group accordingly. The average running time of the experiment hovers around the sample average, with some notable differences (4´39 for Rohana to 15´38 for Vorazun).

Tassadar commented on the experience: *You soon forget the weight of the helmet, but it's still a bit stressful to be crossed*. In fact, in the proposed universe, protruding objects were moving towards the player, and at the same time, the player could go beyond the edges of the cubes if he wanted to. It's easy to understand what he means when he talks about being "run through", as can be seen in the video, where he takes a step back when the first cube runs through him.

This group is more homogeneous than the previous one, with lower variances indicating stronger consensus. We note that in this group, the experience is judged to be more amusing, more bluffing and, above all, more original and memorable. *Conversely*, it is judged less interactive, although the consensus is less strong, notably due to Vorazun's out-of-field response to this item.

"Awake/stimulated" group

Stukov (24H), Zeratul (22H), Valerian (19H) and Izsha (23F) make up this group. They all underwent a significant increase in arousal, with little change in their hedonic valence. Like Vorazun in the previous group, Stukov's approach to VAS is clumsy and binary, which is detrimental to our treatment. Although the results must be tempered by Stukov's lack of understanding of how VAS work, we can see that the opinion of this group differs positively from that of the total sample on many items. The three items for which the variation in score is most striking are the interactive character, and the "bluffing" and "unprecedented" aspects. These three qualifiers, taken in their common meanings, clearly reflect a link with attention and therefore, as Yvart has shown on the basis of Russell and Thayer's work, with an anhedonic increase in arousal (Russell, 1980; Thayer, 1989; Yvart, 2019)avoir pour destination l'industrie traditionnelle de la musique ou être spécialement prévue pour être synchronisée à des images. Dans ce cas, la musique recherchée est généralement perdue dans des bases de media musicaux disposant de leurs propres Systèmes de Recherche d'Information (SRI. Arousal and stimulation seem to spill over into a certain enthusiasm not found in the overall trend. In fact, in this group, the weighting qualifiers of the opinions tend towards "very" or even "extremely" precisely on the three highlighted items, which tends towards an experience of wonder, although there is no great amusement. This sense of wonder also seems to be reflected in the strong tendency to want to repeat the experience or a similar one. Turning to the positioning questionnaires, it's worth noting that this group is made up of members who could be described as gamers who are not accustomed to museums. This opens an interesting perspective on gamification with or without museum VR, in order to attract this kind of population to structures they don't normally frequent.

"Tired" group

The group we call "tired" for the sake of identification consists of Dahaka (18H), Stetmann (23H), Aldaris (24H) and Zagara (50F). Fatigue is a concept well defined in the medical field as "a situation where less force is produced than predicted by the contractile machine" (Macintosh, Rassier, 2002). Neither in everyday language nor in academic studies is fatigue reduced

to this simple parameter of physical strength. A fortiori, VR-induced fatigue is not only muscular in nature, but can also be felt psychologically, in a sense akin to lassitude (Iskander et al., 2018). In SYM's evaluation of the delta of scores, fatigue is seen as a quasi-anhedonic decline (without much variation in valence) affecting arousal in particular. Arousal is the individual's bio-physio-psychological activation. It is self-assessed, which necessarily induces biases, but the objective measurement of fatigue poses invasive problems that we refuse to accept. Moreover, in the literature, fatigue is still mainly assessed by questionnaire (Iskander et al., 2018; Wessely, 1999). Indeed, VR itself is already invasive, and if we were to perceive this invasiveness, it should not be confused with that of a possible biopac.

It is possible to compare the time spent with the[7] helmet on the head with the declared fatigue. We calculate fatigue as the absolute value of a negative variation in arousal.

While the average time spent by this group is well above the sample average (20´29 vs. 10´34), there is a quasi-exponential proportionality apart from the special case of Dahaka (18H), to which we'll return later, and Zagara, which can be explained by the fact that she is the oldest member of our sample, implying less endurance over the long term. Apart from Zagara, given the extreme duration of Dahaka's experiment, he should be one of the most fatigued on the declarative. Yet, as it turns out, he is the least fatigued of the group. It's worth remembering that Dahaka is not only the youngest member of the panel, he's also the biggest consumer of video games on any type of device. This implies a high level of enthusiasm that can compensate for fatigue.

Stetmann stands out from the rest of the sub-group on 3 items. It should be noted, however, that Stetmann is a video game enthusiast for whom video games are "*a large part of [his] time, [his] hobbies and even [his] life*". At the same time, he is the only member of the total sample population to have already visited the virtual museum of camembert boxes in VR. So, he's no stranger to the content of the game on offer, or to VR technology. For him, beyond the fatigue, the experience is neither fun nor memorable.

For this last group, there was once again more strong or medium consensus than the overall trend for the whole sample. With a strong consensus, the experience was judged as not very unpleasant, rather unprecedented, rather "bluffing", not very or not at all banal, and a mixed opinion was given on the wearying side. An analysis of the overall trend shows that this group differs only slightly from the others. Another striking fact is that no qualifier is strongly marked as "very" or "strongly". This raises the question of whether the fatigue experienced by this group is not also reflected in the completion of the final questionnaire, and thus in the continuation of the co-participant survey in general. This fatigue could, for example,

7 It should be remembered that the co-participants in the study were in full control of the duration of the experiment.

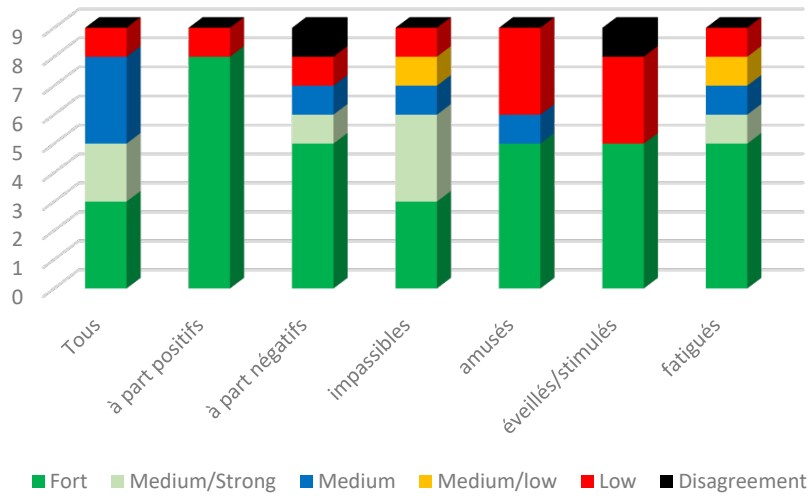
be reduced by postponing the questioning of this part of the sample, which is made safer by the possibility of relying on the video traces to fill in any memory gaps. Once again, this is an avenue to be explored beyond this exploratory experiment.

Discussion

As shown in Figure 6, the use of SYM as a means of visualization seems to create sub-groups of co-participants within a larger cohort. Our analysis shows that these groups seem to express more convergent opinions about a fairly spread-out overall trend. This visual method, approached here on an exploratory basis, opens up some rather interesting prospects, which could enable us to move from the quantitative to the qualitative, according to an experimental scenario yet to be deployed:

- complete the positioning questionnaires;
- SYM's first score;
- testing the system;
- second score;
- visual representation and grouping;
- dividing the sample into sub-samples;
- deployment of questionnaires or specialized interviews, depending on the group.

FIGURE 6 CONSENSUS REPRESENTATION



SOURCE: PREPARED BY AUTHORS.

This perspective could enable us to delve more deeply into the groups of interest to the museographer or researcher (depending on the problem) and could allow us to deploy qualitative methodologies on a necessarily smaller but also more homogeneous sample. It could also enable us to adapt the protocol for, say, people who could be assimilated to the "tired" group. Taking fatigue into account could result in the framing of VR use by a narrative or other device inviting the user to modulate his or her use of the headset, which should be able to significantly improve the individual's experience in terms of attention to content. The preservation and formatting of video traces could then be used as a memorial support, as in a subjective *re-situ* interview methodology.

However, it is important to consider the current state of this research, which is exploratory and still based on a sample too small to assess the prospect of decimation for a shift from qualitative to quantitative. However, this is a method that has yet to be evaluated and reproduced in the manner of a meta-study. It is therefore advisable not to stop at this study, but to reproduce it to confirm or refute the prospects that are emerging. What's more, as the proposed VR experience is a research demonstrator, it is necessarily less accomplished than a professional production on behalf of a museum and cannot suffer direct comparison with more accomplished experiences such as *Mona Lisa: Beyond The Glass*. As Kilysa notes:

> [t]he way the box lands on us gives a great effect. Complicated for the ceiling boxes, especially the big ones. It's hard to tell the boxes apart. It's interesting to be able to break down the different elements of a 3D graphic, but there's a certain redundancy, given that they're all just Camembert boxes.

CONCLUSION

While the technologies involved in spatial positioning methods for VR headsets, combined with additional sensors to be placed on the participant, enable fine-grained analysis of user behavior in virtual reality, the use of qualitative and visual methods as described in this article nonetheless sheds light on the perception of the user experience. Cross-referencing data from the Valence-Arousal space with questionnaires and tracking of user movements in the space enables an assessment of how individuals feel about the experience they are offered. This type of protocol, which is more flexible and less costly, enables cultural mediation managers or other professionals involved in LBE experiences to estimate the effects perceived by users, without any additional equipment for the user.

The advantage of developing this type of protocol is that it is independent of headset brands and models. At a time when VR is mainly developed by the GAFAMs in terms of both hardware and software, the analysis of data derived from people's experience benefits

from the use of open protocols that are independent of the technologies used to experience virtual reality.

The protocol could be improved, however, with regard to the analysis of user movements; if the cultural experience demonstrator studied carried an interactive element generating a recoil movement in most participants, it would be relevant to study more subtle movements in relation to the content. To this end, the synchronization of individual skeletal tracking with direct feedback from the simulation's interactive elements would enable this finer level of exploration. In addition, the inclusion of the Valencia-Arousal space directly into the simulation as a possibility for immediate feedback of the individual's experience would give access to the emotional dynamics of the individual's experience, and to more precise modeling of points of interest within virtual reality itself.

REFERENCES

Anderson, E. W., Sullivan, M. W. (1993). The Antecedents and Consequences of Customer Satisfaction for Firms. *Marketing Science*, *12*(2), 125143. https://doi.org/10.1287/mksc.12.2.125

Bhattacherjee, A. (2001). Understanding Information Systems Continuance : An Expectation-Confirmation Model. *MIS Quarterly*, *25*(3), 351. https://doi.org/10.2307/3250921

Delestage, C.-A. (2018). *L'expérience émotionnelle ou la performance des programmes de télévision. L'horizon de pertinence comme déterminant de la construction de sens par le spectateur*. Sciences de l'information et de la communication. Université de Valenciennes et du Hainaut-Cambrésis.

Diemer, J., Alpers, G. W., Peperkorn, H. M., Shiban, Y., Mühlberger, A. (2015). The impact of perception and presence on emotional reactions : A review of research in virtual reality. *Frontiers in Psychology*, *6*. https://doi.org/10.3389/fpsyg.2015.00026

Ducheneaut, N., Yee, N. (2012). Les jeux vidéo en ligne, un miroir de la personnalité des internautes ? *Questions de communication*, *21*, 21. https://doi.org/10.4000/questionsdecommunication.6571

Huang, M., Alessi, N. (1999). *Presence as an emotional experience*. American Psychological Association. https://doi.org/10.1037/e705302011-011

Iskander, J., Hossny, M., Nahavandi, S. (2018). A Review on Ocular Biomechanic Models for Assessing Visual Fatigue in Virtual Reality. *IEEE Access*, *6*, 1934519361. https://doi.org/10.1109/ACCESS.2018.2815663

Kim, K. (2016). Is Virtual Reality (VR) Becoming an Effective Application for the Market Opportunity in Health Care, Manufacturing, and Entertainment Industry? *European Scientific Journal, ESJ*, *12*(9), 14. https://doi.org/10.19044/esj.2016.v12n9p14

Laurell, C., Sandström, C., Berthold, A., Larsson, D. (2019). Exploring barriers to adoption of Virtual Reality through Social Media Analytics and Machine Learning – An assessment of technology, network, price and trialability. *Journal of Business Research*, *100*, 469474. https://doi.org/10.1016/j.jbusres.2019.01.017

Lee, H., Jung, T. H., tom Dieck, M. C., Chung, N. (2020). Experiencing immersive virtual reality in museums. *Information, Management*, *57*(5), 103229. https://doi.org/10.1016/j.im.2019.103229

Macintosh, B. R., Rassier, D. E. (2002). What Is Fatigue? *Canadian Journal of Applied Physiology*, *27*(1), 4255. https://doi.org/10.1139/h02-003

Nahon, D. (2020). *Les technologies immersives : État de l'art, enjeux, opportunités et perspectives*. Paris: SITEM 2020.

Puig, A., Rodríguez, I., Arcos, J. Ll., Rodríguez-Aguilar, J. A., Cebrián, S., Bogdanovych, A., Morera, N., Palomo, A., Piqué, R. (2020). Lessons learned from supplementing archaeological museum exhibitions with virtual reality. *Virtual Reality*, *24*(2), 343358. https://doi.org/10.1007/s10055-019-00391-z

Riva, G. (2005). Virtual Reality in Psychotherapy : Review. *CyberPsychology, Behavior*, *8*(3), 220230. https://doi.org/10.1089/cpb.2005.8.220

Russell, J. A. (1980). A circumplex model of affect. *Journal of Personality and Social Psychology*, *39*(6), 11611178. https://doi.org/10.1037/h0077714

Schmitt, D. (2012). *Expérience de visite et construction des connaissances : Le cas des musées de sciences et des centres de culture scientifique*. Sciences de l'information et de la communication, Université de Strasbourg. https://theses.hal.science/tel-00802163

Sherman, W. R., Craig, A. B. (2019). *Understanding virtual reality : Interface, application, and design*. Morgan Kaufmann. https://doi.org/10.1016/C2013-0-18583-2

Statista. (2023). Volume of the VR headsets market worldwide from 2018 to 2028. *Statista*. https://www.statista.com/forecasts/1331896/vr-headset-sales-volume-worldwide

Thayer, R. E. (1989). *The Biopsychology of Mood and Arousal*. USA: Oxford University Press.

Wessely, S. (1999). Chronic Fatigue Syndrome. In Y. Ono, A. Janca, M. Asai, N. Sartorius (Éds.), *Somatoform Disorders*. Springer Japan. https://doi.org/10.1007/978-4-431-68500-5_10

Yang, H., Han, S. (2020). Understanding virtual reality continuance : An extended perspective of perceived value. *Online Information Review*, *ahead-of-print*(ahead-of-print). https://doi.org/10.1108/OIR-02-2020-0058

Yvart, W. (2019). *Qualification (a)verbale de l'humeur musicale : Nouvelles perspectives pour la synchronisation dans l'audiovisuel* [Phdthesis, UPHF ; UMons]. https://web.umons.ac.be/fpms/fr/evenements/qualification-averbale-de-lhumeur-musicale-nouvelles-perspectives-pour-la-synchronisation-dans-laudiovisuel-par-monsieur-willy-yvart/

Yvart, W., Bougenies, F., Delestage, C.-A. (2021). Traces de ressentis en cours d'expérience : Méthodes et outils. In H. Boulekbache-Mazouz, B. Galinon-Melenec, S. Leleu-Merviel (Éds.), *La trace, du sensible au social*. CNRS Editions, 5, 125173.

Yvart, W., Delestage, C.-A., Leleu-Merviel, S. (2016). SYM: Toward a New Tool in User's Mood Determination. *Proceedings of EmoVis 2016, ACM IUI 2016 Workshop on Emotion and Visualization, Sonoma, CA, USA, March 10, 2016*, 2328. https://doi.org/10.48550/arXiv.1902.02996