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Understanding psychological mechanisms to improve virtual spaces and Metaverse events

Steffen Ronft [1 2] | Ann-Kathrin Beck [1]
[1] RPTU Kaiserslautern-Landau
[2] SRH Fernhochschule – The Mobile University

Abstract

For online meetings and events, three-dimensional virtual spaces emerged. These virtual spaces are accessible via avatars and can be part of an entire virtual world, a so-called Metaverse. Besides technical aspects, design and use of virtual spaces is also interesting from a psychological perspective. One relevant psychological aspect addressed in this paper is the effect of lighting on perception. A literature analysis including peer-reviewed articles on lighting research and information technologies, especially comparing items and scales was conducted. Additionally, market statistics and technical specifications of monitor devices were reviewed. The results showed that many measurement instruments have a similar basis, but no standard in items or scales can be identified. Further, there is a wide range of technical parameters of monitor devices. Hence, several challenges become apparent for valid and practice-oriented research. Increasing the user experience in virtual spaces will therefore be a joint task for science and practice.

1. Introduction

In the recent years people shift several activities online (Damar, 2021), like meetings and events into virtual spaces. For instance, due to the COVID-19 pandemic, many scientific conferences have been shifted from physical to online events (Falk & Hagsten, 2020). Online events can be distinguished between streaming formats as well as video conferencing, and events that take place in a three-dimensional virtual space that can be accessed by an avatar. These spaces can be part of a Metaverse, which is an immersive virtual world using the metaphor of the real world but without its physical limitations (Davis et al., 2009).

These three-dimensional spaces are especially exciting for future research because they can be individually designed. Besides the technological aspects, these developments are also interesting from a psychological point of view. Users perceive them as an environment comparable to an immersive computer game. Hence, similarly, these environments can influence users' emotions and behavior (Slater, 2009). Specially, research on perception can make an important contribution to evaluate and improve virtual environments and Metaverse events. Psychology is therefore an increasingly relevant factor and should be given greater consideration in a systematic approach known as event psychology (Ronft, 2021b; Wrobel & Winnen, 2021).

Regarding the complexity of psychological mechanisms, the following approaches focus on psychology of perception, environmental psychology and visual communication. For example, lighting is an essential component of the perception of spaces and is already well studied regarding psychological and biological effects (e.g., Westland et al., 2017; Tomassoni et al., 2015).

In this paper, the status quo and challenges of adopting scientific methods from the physical environment to virtual environments are identified and discussed. Emphasis is placed on the transferability of items and scales for space perception. Additionally, the technical limitations and challenges of research in virtual environments are highlighted. Lastly, the prerequisite to improve virtual spaces and events are pointed out.

2. Theoretical Background

2.1 Virtual spaces and Metaverse Events

Virtual worlds are defined by Dionisio et al. (2013) as persistent, computer-generated environments for

Corresponding author
Steffen Ronft
E-Mail: steffen.ronft@mobile-university.de

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multiple users, in remote physical locations, to interact in real time for working or gaming purposes.

In this context, virtual events can take place in closed platforms or in open systems. Open systems are also termed *Metaverse* (Dionisio et al., 2013). The term *Metaverse* originated in a 1992 science fiction novel and described a colossal, spherical planet that users can access through virtual reality technology (Stephenson, 1992). The focus of a Metaverse is not on the photorealistic reproduction of the physical environment, but rather on the creative implementation of interaction possibilities; it is discussed as an new iteration of the internet (Dwivedi et al., 2022). The activities in Metaverse refers to augmented and virtual reality services and equipment (Damar, 2021).

Virtual spaces can be visited both via two-dimensional screens or via augmented or virtual reality devices. Opaque Virtual Reality (VR) glasses are generally more suitable for immersive applications and are particularly popular in a gaming context. The sales volume of VR and Augmented Reality (AR) devices is increasing rapidly. According to a study by market research agency TrendForce, sales of VR and AR headsets nearly doubled to 9.9 million units from 2020 to 2021. The market is forecasted to grow to 14.2 million units in 2022 and 18.1 million units in 2023 (TrendForce, 2022).

According to a study by PricewaterhouseCoopers (PwC), AR and VR are expected to have already increased the global Gross Domestic Product (GDP) by 46.5 billion USD in 2019. For 2030, PwC expect that AR und VR technology contribute a GDP increase of 1,542 billion USD and provide over 23 million new jobs (PwC, 2019). Regardless of whether these gigantic forecasts are accurate, there will be many meetings in virtual environments in the coming years.

Therefore, the number of trade shows, product launches, press conferences, corporate meetings and other events such as concerts – that are already purely virtual or hybrid – are expected to increase. Consequently, virtual environments and associated technologies are actively discussed in event management (Drengner & Wiebel, 2020) and already identified as future research needs (Drengner, 2022; Wreford et al., 2019).

2.2 Environment as an influencing factor of psychological mechanisms

Psychological effects in social interaction in virtual spaces

The human psyche is a complex entity and is influenced by many extrinsic and intrinsic factors. In addition to intrinsic prerequisites such as memories, experiences and prior knowledge, extrinsic stimuli from the environment also have an effect on people. These stimuli are processed cognitively and emotionally, creating the perceived subjective reality. Humans are used to moving and interacting in a physical environment. In virtual environments, however, some of these behaviours can only be transferred to a limited extent. Depending on the technical platform, for example, freedom of movement and interaction with other people is limited. Instead of social communication, which is largely also non-verbal via facial expressions and gestures (Solowjew, 2021), users have to resort to pre-defined reaction buttons, text and video chats.

Technologies such as facial expression recognition (FER), which relies on optical cameras, or facial electromyogram (fEMG), which relies on electrodes to detect electrical activity through facial muscle movements enable to mirror human facial expressions to the avatar (Cha & Im, 2022). Beyond these approaches, initial platforms such as doob meta xr use a "speech to mimic" feature (doob group AG, 2022) that provides an imitation of corresponding facial expressions through an AI-based voice analysis. However, in the virtual imitation of mimic and gesture multiple psychological mechanisms become apparent, such as the Uncanny Valley effect (Mori et al., 2012; Ronft, 2021a). This effect describes implicit expectations of verbal and nonverbal responses from a human-looking robot or avatar that cannot be met by a non-human conversation partner due to nowadays technical capabilities. Unexpected responses from robots or avatars can trigger a diffuse feeling of uncanniness and rejection.

As can be seen from such complex mechanisms, the social-psychological consideration of virtual space is a comprehensive topic. Since visual communication is a key element for virtual social interaction, visual perception in virtual spaces is highly relevant.

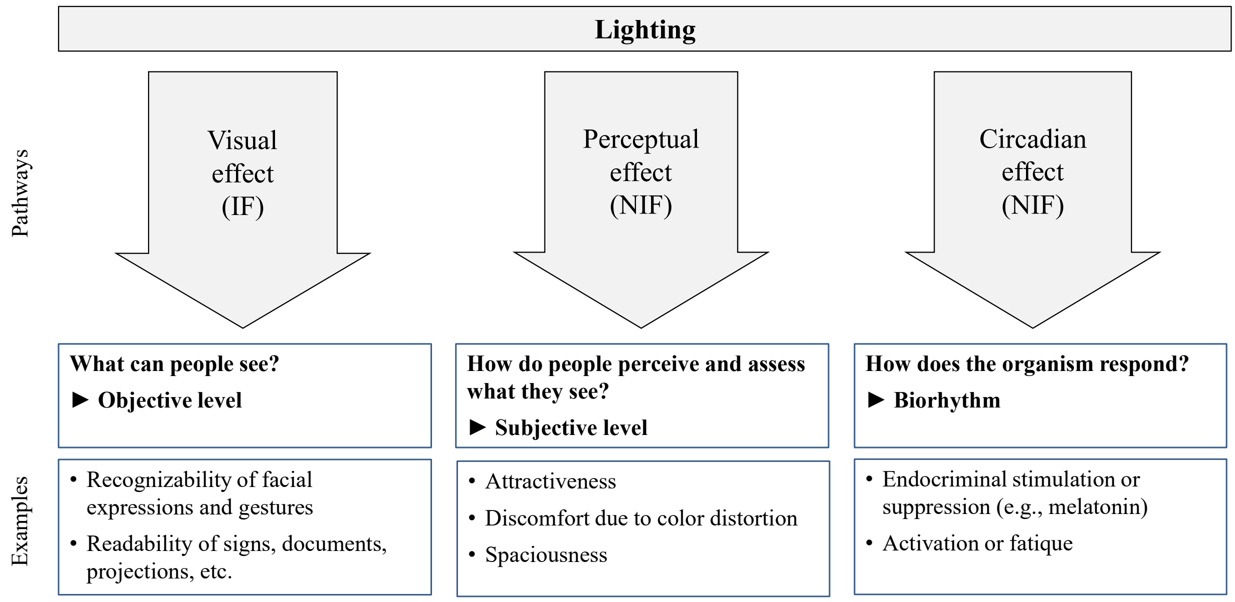
Psychological effects of visual perception and lighting

Humans perceive their visual environment via light sensitive rods and cones on the retina and synthesize an image from it. In the physical environment, visual information is induced by light reflections from daylight or electric lighting on objects. In virtual spaces, the display emits the necessary light stimuli. Regardless of whether visual stimuli originate from reflections or displays, in addition to the perceptual processes, biological and psychological effects can be assumed.

The biological and psychological effects of lighting can be divided into visual effects, perception effects and circadian effects (Fig. 1). On an objective level, the visual path influences which information can be perceived visually at all. The perceptual path, on the other hand, describes the subjective perception of the perceived information. Finally, the circadian path describes the effects on the human organism. By stimulating or suppressing the production of hormones such as melatonin, humans are activated or fatigued. So, parameters of lighting, such as colour temperature, brightness, etc., impact people's daily lives and can determine their emotions (Ronft, 2021c).

For example, blue-enriched lighting has impact on alertness and cognitive performance due to a

Figure 1
Image-forming (IF) and non-image forming (NIF) pathways of lighting effects (adapted from Ronft, 2021c, p. 213)



melatonin suppression (Chellappa et al., 2011). Recent studies also indicate that artificial lighting has an impact on perceived comfort and temperature (Bluyssen et al., 2011; Chraibi et al., 2016; Huebner et al., 2016).

Effects on cognitive performance and affective states have already been documented by various studies and are the subject of lively debate (e.g., Baron et al., 1992; Hawes et al., 2012; Hygge & Knez, 2001; Knez, 2001; Knez & Enmarker, 1998; Kretschmer et al., 2012). Recent studies also provide concrete evidence on which lighting conditions can be stimulating or inhibiting for interactions and cooperative behavior (Kombeiz et al., 2017; Ronft & Ghose, 2018, 2019; Steidle et al., 2013).

Visual perception is important for spatial orientation processes and thus navigation (Hidayetoglu et al., 2012; Suzer & Olgunturk, 2018). Regarding virtual spaces, unlike physical spaces, do not require physical-realistic light sources to enable visual orientation. However, in the context of game design, the effects of virtual lighting on orientation are also investigated (Knez & Niedenthal, 2008; Marples et al., 2020); further psychological mechanisms are increasingly being explored.

3. Contemporary state of research

3.1 Scope of literature review

A literature review was used to compare existing instruments to measure psychological effects of lighting, to discuss their transferability for virtual environments, as well as the implications for the design of virtual spaces. The literature reviewed ranges from journal articles on light research from the 1970's to present day research in virtual spaces and information technologies. In a further step, market statistics and technical specifications of visual devices were reviewed to reflect the relevance to the present research field.

3.2 Instruments and scales to measure psychological effects of lighting

There are various instruments and scales for measuring the psychological effects of lighting. The literature review showed that semantic differential rating scales are common for the subjective assessment of perceived environments. However, questionnaires differ in the following parameters: Level of scaling, polarity of semantic differential scale, number of items, source of adaptions, and environments of investigation (for details see table 1).

Many of the instruments used today are based on lighting research by Flynn (Flynn et al., 1973; Flynn et al., 1979; Flynn & Spencer, 1977) who developed a bipolar 7-point semantic differential rating scale. These itemset and rating scale, which were analysed by a factor analysis (Flynn & Spencer, 1977), is the basis for contemporary questionnaires. Knowing Flynn´s results, other instruments were developed and validated with additional procedures. For instance, Vogels` atmosphere questionnaire (2008) uses a principal component analysis (PCA) to gain insight into the underlying dimensions of the various item terms. To enable the international applicability of the atmosphere questionnaire, a lexicon was compiled to describe relevant terms. In Vogels' publication, the discriminatory power of the items was also tested by conducting the questionnaire in eleven different physical spaces. This intensive testing of a measurement instrument is rather an exception. Studies usually rely on the instruments and scales

Table 1
Overview of questionnaires to assess psychological effects of lighting in virtual and physical environments

Questionnaire	Level of Scaling	Polarity of semantic differential scale	Number of items	Adapted from	Environment of investigation
Abd-Alhamid et al., 2019	5-point	bipolar	12	Cauwerts, 2013; Liang et al., 2019; Kuang et al., 2005; Odabaşioğlu & Olguntürk, 2015	virtual & physical
Canazei et al., 2016	4-point 6-point 4-point	unipolar bipolar unipolar	38 6 1	Vogels, 2008 Cervinka et al., 2009	physical
Chamilothori et al., 2019	5-point	unipolar	13	Flynn et al., 1973; Vogels, 2008; Rockcastle et al., 2017	virtual
Chen et al., 2019	7-point	bipolar	12	Flynn et al., 1979	physical & virtual
Flynn & Spencer, 1977	7-point	bipolar	19	Flynn et al., 1973	physical
Flynn et al., 1973	7-point	bipolar	34	-	physical
Flynn et al., 1979	7-point	bipolar	30	Flynn & Spencer, 1977	physical
Hendrick et al., 1977	7-point	bipolar	27	Flynn et al., 1973	physical
Knez & Niedenthal, 2008	5-point	unipolar	10	-	virtual
Loe et al., 1994	VAS	bipolar	10	Flynn et al., 1973	physical
Mahdavi & Eissa, 2002	7-point	unipolar	10	Flynn et al., 1973	physical
Newsham et al., 2004	VAS	bipolar	15	Hendrick et al., 1977; Veitch & Newsham, 2000; Loe et al., 1994; Mahdavi & Eissa, 2002	virtual
Newsham et al., 2005	VAS	bipolar	15	Newsham et al., 2004	virtual
Newsham et al., 2010	VAS	bipolar	4	Hendrick et al., 1977	virtual
Odabaşioğlu & Olguntürk, 2015	5-point	bipolar	36	Flynn et al., 1973; Flynn et al., 1979; Flynn & Spencer, 1977; Yildirim et al., 2007	physical
Rockcastle et al., 2017	7-point	bipolar	7	Flynn et al., 1979	virtual
Vogels, 2008	5-point and 7-point	bipolar	9	Flynn & Spencer, 1977	physical
Yildirim et al., 2007	5-point	bipolar	8	-	physical
Zimmons, 2004	7-point	bipolar	15	Flynn et al., 1979	virtual

Note: VAS indicates Visual Analogue Scale, which is scored with values from 0-100.

used in comparable studies or well-documented and therefore replicable approaches such as those of Flynn and Spencer (1977) or Vogels (2008).

Reliable methods from psychological research are also used to measure emotions in lighting research. Established tests such as the Self Assessment Manikin (SAM) are used to determine the effect of light on emotions (Ronft & Ghose, 2018, 2019; Wilms & Oberfeld, 2014; Wu & Wang, 2015). The nonverbal SAM inventory uses pictograms to classify a person's state of mind. Such tests are credited for being able to be used cross-culturally and regardless of the subject's language level (Morris, 1995). To gain further insight into emotional states not captured by the SAM test, self-reports on semantic scales are be obtained. For example, 5-point bipolar semantic differential scales with values ranging from -2 (e.g., demotivated) to +2 (e.g., motivated) and 0 (as neutral) allows scoring for affect labels like motivation, creativity, comfort, happiness and anxiousness (Houser & Tiller, 2003; Wu & Wang, 2015).

3.3 Usage behaviour and technical specifications of devices

Research that investigates effects in virtual space needs to consider the technical specifications and the usage of devices. For this purpose, a review of technical differences of devices was conducted. The technical specifications of devices differ significantly. In particular, there are differences between viewing virtual content through VR glasses or monitors. VR glasses allow 360° viewing through head movements, resulting in an immersive experience (Kronqvist et al., 2016).

Even though many VR glasses are already in use, virtual content is predominantly viewed through monitors. This can be deduced from the global sales statistics in 2021, showing that 9.9 million AR and VR devices sold (TrendForce, 2022) compared to 144 million PC monitors (IDC, 2022). Even though millions of VR glasses are sold, this does not imply that they will also be used for virtual events. Video games remain key to the usage of VR glasses, but in a survey of 4,000 U.S. gamers, 60% reported participating in non-gaming activities or events within video games in 2021 (Activate Consulting, 2022).

All devices have technical limitations that affect and restrict the visual display of virtual content. Even in the case of monitors that are currently widespread in daily practice, there are notable differences (see table 2). For example, screen size, brightness, resolution and many other specifications can affect the visual perception of virtual content.

Table 2
Technical specifications of monitors affect visual perception

Category	Popular types and value ranges
Aspect ratio	4:3, 16:9, 21:9, 9:16, etc.
Backlight technology	LCD, LED, QLED, OLED, QD-OLED, AMOLED, EDGE-LED, Direct-LED, etc.
Brightness	150 - 1.000 NITs or cd/m^2
Color space	sRGB, DCI-P3, Adobe RGB, etc.
Contrast ratio	1000:1, 5000:1, 10000:1, etc.
Curvature	1800R to 4000R
Drivers and Software	Graphic drivers, Browser, Settings in Operating System, etc.
Dynamic range	Non-HDR, HDR, HDR10, HDR10+, etc.
Frame / refresh rate	60Hz, 100Hz, 120Hz, 144Hz, 240Hz, etc.
Glare type	glare, non-glare
Panel type	Twisted Nematics (TN), In Plane Switching (IPS), Patterned Vertical Alignment (PVA), Multi-Domain Vertical Alignment (MVA)
Resolution	1280 × 720 Pixel (HD), 1.920 x 1.080 Pixel (FHD), 3840 x 2160 Pixel (UHD / 4K), 7680 x 4320 Pixel (8K), etc.
Response time	0.5 - 20 ms. etc.
Screen size	14 Inch, 15.6 Inch, 17 Inch, 19 Inch, 23 Inch, 24 Inch, 27 Inch, 32 Inch, 38 Inch, 43 Inch, etc.
Viewing angle	120° - 178° (horizontal) 15° - 60° (vertical)

Note: These data correspond to the contemporary state of monitors available on commercial market and may deviate due to technical advancements. This information was obtained by the authors.

4. Discussion

4.1 Lack of standardized instruments and scales

The literature review showed that there are a wide range of different research approaches to study the psychological effects of lighting. One challenge to consider is the lack of standardization in measurement instruments.

Many instruments use a semantic differential scale but differ in the level and polarity of scaling and number of items used. For example, Zimmons (2004), Newsham et al. (2010) and Canazei et al. (2016) assess pleasantness. The construct ´pleasantness´ is not explicitly defined in the individual studies. Therefore, the experimenters assume that ´pleasantness´ is an intuitive known construct by all subjects.

All three studies use the identical bipolar terms pleasant-unpleasant for rating, but Zimmons (2004) uses a 7-point Likert scale, Newsham et al. (2010) use a VAS with ratings from 0-100, while Canazei et al. (2016) use a 4-point scale.

Initially, these aspects limit the direct comparability of study results. In addition, it is also difficult to assess which scaling is most suitable, even though there are arguments in the literature for a 7-point scaling. Already in 1924 Symonds and later Miller (1956) suggested that 7-point scales have a high reliability. Miller argues this with the assumption that the human mind has a span of apprehension capable of distinguishing about seven different items. A comprehensive literature review and research by Preston and Colman (2000) also concluded that 7-point, 9-point or 10-point scales are generally preferable.

The intention should be that constructs and scales that are not evidently comprehensive for all subjects should be defined and explained to avoid inaccuracies in the assessment. Such a procedure ensures the overall quality of a study.

Following Churchill (1979), who in the 1970s demanded the critical reflection of current marketing research methods and a stronger consideration of validity and reliability in measurement instruments, the discussion of quality criteria will also be appropriate for this area of research. Churchill (1979) postulated a paradigm of an eight-step procedure to develop measures:

1. Specify domain of construct
2. Generate sample of items
3. Collect data
4. Purify measure
5. Collect data
6. Assess reliability
7. Assess validity
8. Develop norms

Such a structured procedure or at least another transparent process should be documented and be comprehensible for a valid and reliable instrument.

Most of the reviewed studies are based directly or indirectly on the previous research, scales and items by Flynn (Flynn et al., 1973; Flynn et al., 1979; Flynn & Spencer, 1977). This result is consistent with the review of 68 lighting studies by Kong et al. (2022) published after the completion of the present study.

Despite this same fundament, no standardized questionnaire can be identified. With each adaptation, there may be changes in procedure, item design, and number of items that may affect the quality of the studies. In line with this conclusion, Allan et al. (2019) also claims in their review more consistence regarding the subjective assessment of light quality.

While standardized and well-validated scales and inventories exist for certain constructs in psychology, this should also be strived for in application-oriented research; Especially in this forward-looking research area of virtual environments and Metaverse platforms.

The transfer of psychological measurement methods from physical to virtual environments requires a scientifically coherent investigation considering and reflecting on existing methods and findings. This is a prerequisite for providing scientifically based recommendations for design implementations to improve virtual spaces.

4.2 Validity of study designs in terms of usage behaviour and device variety

In current application areas, virtual events such as trade shows are often participated through monitor devices and not via VR glasses. Therefore, for a biotic and valid measurement the used device must be considered in the study design. Watching content on a monitor compared to viewing in opaque VR glasses implies disruptive effects due to the present lighting conditions in the physical surrounding. These are accompanied by interfering variables such as distraction by other activities, interrupted eye contact with the monitor, etc. Even if these interfering variables do not manifest in VR, other issues such as motion sickness may occur (Chang et al., 2020).

To still be able to examine the psychological effect of virtual spaces as a dependent variable, these interfering variables should be ideally eliminated or at least controlled. Related to validity these inherent limitations of studies in virtual environments need to be critically reflected and discussed.

Regarding virtual spaces psychological and technical developments are interdependent. There is a wide range of technical parameters in which obligatory devices like VR headsets or monitors differ, potentially affecting individual perception and thus study results. Technical limitations also determine the viable options for improving user experience. Finally, it may not be technologically feasible to implement findings from psychological research or technological advances may precede psychological studies.

5. Conclusion

The aspects discussed above show the complexity of studying and improving virtual spaces. In transferring psychological measurement methods from physical to virtual environments, various challenges become apparent. Studies in this field are thus challenging and inherently limited in their validity. The implementation of scientific findings into practice is correspondingly challenging. Improvements in the design of virtual spaces based on psychological mechanisms are further affected and limited by technical specifications and the usage behaviour. Therefore, the validity and transferability of research findings in this field must be critically observed and reflected upon. It becomes apparent that interdisciplinary research approaches, solutions, and synergies from (event) psychology, perception research, information technologies and event management must be sought. The prerequisite for improving the event experience in virtual spaces and in the Metaverse is to understand the psychological mechanisms and to consider interdisciplinary scientific findings in their design. Increasing the user experience of virtual events will be a joint task for science and practice.

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