# The Extent of the Proteus Effect as a Behavioral Measure for Assessing User Experience in Virtual Reality

Martin Kocur
University of Regensburg
Regensburg, Germany
martin.kocur@ur.de

Niels Henze
University of Regensburg
Regensburg, Germany
niels.henze@ur.de

Valentin Schwind
Frankfurt University of Applied Sciences
Frankfurt, Germany
valentin.schwind@fb2.fra-uas.de

## ABSTRACT

Assessing the user experience (UX) while being immersed in a virtual environment (VE) is crucial to obtain insights about the quality and vividness of the experience created by virtual reality (VR) systems. These valuable insights are necessary to understand a user's response to VEs and, therefore, to advance in VR research. However, a standardized and effective measure for assessing UX is still missing. Consequently, this lack of suitable measures hinders researchers to gain knowledge and understanding about the effects of VEs on users and in turn slows down the progress in VR technology. To tackle this problem, we propose a behavioral measure for assessing UX based on a phenomenon known as the Proteus effect, which describes changes in behavior and attitude due to the embodiment of avatars with stereotypical characteristics. As avatars are a crucial part of an immersive experience, the extent of behavioral changes caused by the embodiment of avatars may pose an opportunity to implicitly quantify the UX of a VE. This paper discusses an alternative behavioral measure and contributes to the debate about suitable methods for assessing UX in VR systems.

## CCS CONCEPTS

• **Human-centered computing** → **Virtual reality**; • **Applied computing** → *Computer games.*

## KEYWORDS

virtual reality, Proteus effect, body ownership illusion, user experience

## 1 INTRODUCTION AND BACKGROUND

In recent years, VR has evolved into an established technology in research, industry and even on the consumer market [23]. Despite the use of VR technology across various fields, e.g. clinical VR for psychotherapeutic purposes [31], in the automotive industry as a prototyping tool [43] or for entertainment purposes such as gaming [34], there is still a lack of suitable measures for assessing the UX of VR applications. This lack in turn impedes our understanding of the users' experiential responses to the presented stimuli in VR. As the UX of applications can significantly affect the quality of interaction with a system and also fosters innovation [35], it is therefore an important determinant of a product's success [15, 40]. By focusing on the users and aiming to understand their experiential responses during or after interaction with VR applications, HCI research contributes to the progress of immersive technologies and drives the development of increasingly advanced VR systems. Consequently, we need ways to quantify the UX of VR applications so that VR researchers and designers can gain a deeper understanding about the effects of their VEs on users and learn how to develop immersive applications, which achieve the ultimate goal of sophisticated and vivid VR experiences.

Although the term UX is widely accepted and has evolved into a buzzword in HCI research, there is no consensual and clear definition of UX [24]. A well-known definition is proposed by the International Organization for Standardization (ISO) in the ISO 9241-210 where UX is defined as "a person's perceptions and responses that result from the use and/or anticipated use of a product, system or service". In contrast to the mainly task- and performance-related concept of usability [14], this definition represents the notion of UX as a subjective and qualitative phenomenon occurring while and after interacting with a product [29]. This is in line with Hassenzahl and Tractinsky [14], who described the three facets of UX consisting of a dimension called *beyond the instrumental*, which represents the fact that interactive systems should not only focus on efficiency and effectivity, but rather consider the hedonic and aesthetic quality. The second facet put emphasis on a user's *emotion and affect* during and after interaction with a system and the third one points out the importance of *the experiential* perspective comprising of the user's internal states such as the mood, expectations, motivation and needs [12, 14]. This approach illustrates the conceptual complexity of UX and inherently specifies the requirements for a potential measure to be able to assess the UX of interactive applications consisting of multiple interwoven dimensions [26].

Because of this complexity and due to the ease of application, self-reports through questionnaires have become established as a common measurement instrument for the UX of non-immersive applications, such as websites or other desktop applications [41]. Typically for assessing the UX, post-experience questionnaires are applied so that users interact with an application and are surveyed after the experience. However, research calls post-experience questionnaires for quantifying UX into question, as they mainly assess the remaining impressions *after* the interaction and, therefore, neglect the "momentary, primarily evaluative feeling (good-bad) while interacting with a product or service" [13]. This becomes even more detrimental for immersive virtual realities, as the users have to take off the head-mounted display (HMD) and leave VR to complete the questionnaires. This can result in systematic biases such as high variances among the measures caused by previous breaks in the virtual experience [27, 32]. Although researchers try to tackle this problem by embedding questionnaires into the VE for assessing the experience of users [1, 27, 32], the core of this issue remains unsolved, as the users are still surveyed at a certain point in time about a temporary and context-sensitive phenomenon that can dynamically change. In line with Slater [36], who argued that "researchers must move away from heavy reliance on questionnaires in order to make any progress in this area" regarding the concept of presence as a frequently used metric for the UX in immersive VR [10, 39], researchers seek for alternative approaches that capture the multidimensional concept of UX.

To support research finding alternative measures, we propose a behavioral metric based on the *Proteus effect*—a phenomenon that users change their behavior in accordance to the common expectations associated with the avatar's appearance [42]. In this paper, we discuss the extent of the Proteus effect as an implicit UX metric and contribute to the debate about appropriate measures for assessing the UX of virtual realities.

## 2 ASSESSING UX IN VR USING THE PROTEUS EFFECT

As Bohil et al. [7] stated that the "ultimate goal of designers and users of VR environments is a computer-generated simulation that is indistinguishable to the user from its real-world equivalent", a high UX for VR means a lifelike experience for users even in unrealistic or fictional VEs. Therefore, the basic idea behind behavioral measures is that the more present the users feel in a VE, and the higher the realism and vividness of the users' experience, the more the users will behave as they would in the same situation happening in the real world. Insko [16] described an example: if a virtual ball is thrown at the users' head and the users react to this threat by ducking, then we would assume that they feel present in the VE and have a realistic experience. Similar could be shown for body ownership illusions - the sense of embodying foreign or artificial bodies [8]. González-Franco et al. [11] showed that users instinctively reacted to a virtual knife stabbing a virtual hand by moving the threatened hand out of the way to avoid harm. The authors found a high activity in the motor cortex area as an indicator for this protective behavior and showed that stronger cortical responses were associated with higher degrees of perceived embodiment over the virtual arm. This supports the idea that the more the users are able to accept the virtual body as their own manifested in a stronger sense of embodiment, the more their behavior would match their behavior in a corresponding real world situation. We replicated these findings by removing fingers on a virtual hand resulting in strong emotional responses such as phantom pain [17, 33]. Although theses experiments illustrate VEs that induce negative feelings such as pain, from a pure UX perspective a higher perceived pain with a stronger motor reaction would be an indicator for a better UX created by such VR applications. Therefore, VR enables designers like no other current technology to create embodied experiences that simulate how it would feel to experience such a scenario in a sophisticated and lifelike way.

As VR can theoretically render an avatar—the digital self - representation of the user—in any desired style, designers can, therefore, even make users experience VEs while being in a different body as if they were self-transformed. Interestingly, Yee et al. [42] found that this self-transformation can result in behavioral changes based on the visual appearance of the avatars. The authors, for example, showed that the embodiment of attractive avatars increased confidence during a dialogue in VR and coined the term Proteus effect for this phenomenon [42]. We also found that avatars whose appearance is associated with physical fitness and athleticism can decrease the perception of effort during physical exercise [18, 19, 21]. Likewise, avatars resembling Albert Einstein as a stereotype for superior intelligence could increase cognitive performance [5]. Results indicate that users adapt their behavior to conform with the common expectations and stereotypical assessments connected with the avatars' visual appearance. As these behavioral changes correlate with important experiential characteristics of virtual realities, such as the sense of presence or perceived body ownership [4, 37], we propose the extent of the Proteus effect as an implicit UX metric.

We, for example, showed that male users embodying muscular avatars had a higher grip strength with a lower perceived exertion compared to when embodying avatars with a medium muscularity [19]. When they were able to exert more physical force and felt less exerted while being embodied in a muscular avatar, the users had to consciously or unconsciously regulate their physical effort as it is impossible that a momentary change of the users' self-perception can increase their actual physical power. Consequently, they tried to conform to anticipated stereotypes and behaved as they thought persons with this specific characteristics would behave and perform in a corresponding real world scenario. We, therefore, hypothesize that the degree of their behavioral adaptation in terms of the physical effort they put in an exercise correlated with their UX. The more pronounced the change in behavior, the more lifelike and vivid the experienced VR and vice versa. In other words: the higher the extent of the Proteus effect, the higher the UX of a VR application. Assuming, for instance, that we aim at comparing two different VEs regarding their UX. Similar to the concept of elicitation studies [25], the Proteus effect can be used to predict the users' behavior in VR. Hence, researchers can employ, e.g. avatars with stereotypical characteristics, to trigger the expected behavioral changes and compare to what extent these changes occur in different VEs. Already simple adjustments to an avatar's appearance can result in informative changes in behavior, such as a taller body height of an avatar can cause a more confident behavior [42] or older-looking avatars can decrease walking speed [30]. If a user behaves more confidently when embodying the same tall avatar or walks slower while being embodied in the same old-looking avatar in a VE compared to another, we hypothesize that the UX of a VE is higher compared to the other one. This is in line with the aforementioned example by Insko [16], who stated that the more the behavior in VR, e.g. walking slower when embodying an elderly avatar, matches the expected behavior in a corresponding real world scenario, e.g. stereotypical thinking that elderly walk slower, the higher the UX of a VR application. Therefore, we propose that the extent of behavioral changes caused by the Proteus effect can be used to implicitly operationalize the UX of VR applications.

## 3 LIMITATIONS AND CONCLUSION

Our proposed behavioral measure for assessing UX in VR poses some challenges and limitations. When using the Proteus effect, the users' stereotypical assessments have to be anticipated to predict the expected behavior in VR. However, stereotyping can be a highly individual process depending on a variety of contributing factors. We, for example, could not decrease the physical performance when embodying participants in non-muscular compared to muscular avatars during physical exercise [19]. It seemed that the non-muscular avatars were associated with high athleticism due to the low body fat rather than with a limited physical power. This example illustrates the complexity of designing appropriate avatars which represent such characteristics that elicit the desired users' associations to trigger the expected effects. If users are unfamiliar with the used stereotypes, perceive them differently than predicted or even avoid their activation [6], the expected behavioral changes can fail to occur or even be misleading. Hence, this can confound the applied measure resulting in false assumptions about the UX of a VR system. To reduce the variance in the behavioral responses and, therefore, minimizing the risk of confounding, the characteristics of the target population as well as the applied stereotypes have to be well-known.

Research also agrees that the Proteus effect is context-sensitive. Banakou et al. [5] found that users embodied in Einstein in a single-user VE had a higher cognitive performance compared to a casual embodiment. We, however, could not replicate these findings in a collaborative VE where two users played a cognitively demanding game while sharing the same virtual space [20]. We argue that competition or other psychological mechanisms underlying social interaction, e.g. behavioral confirmation [38], are seminal moderators, and, therefore, mediate or even extinguish the Proteus effect. Consequently, the context of a virtual scenario can affect the degrees of behavioral changes caused by the Proteus effect, e.g. being alone as opposed to being together with others in a VE. Beside the reciprocal impact of multiple characters, other contextual factors such as the narrative created through the scenario or the atmosphere and mood created through the design of the environment have to be considered when comparing different VEs in terms of their UX [3].

Although the Proteus effect seems to be a valid phenomenon with consistent effect sizes between small and medium [28], researchers need to know how to measure behavioral changes caused by the embodiment of avatars. Performance measures, e.g exerted force [19], perceived exertion [18], walking speed [30] or cognitive performance [20], may pose one opportunity to indirectly quantify the Proteus effect. More complex behavioral changes, which provide profound insights about the users' experience but can hardly be evaluated through quantitative methods, could be assessed qualitatively by independent observers. For example, embodying non-humanoids such as animals may lead to behavioral responses such as flapping the arms while embodying a bat [2] or crawling on all fours while being embodied in a tiger [22]. Independent observers could analyze these complex behavioral responses by observing the users during virtual embodiment to identify behavior patterns. As already shown in previous work investigating the recognition of musical genres based on dancing behavior [9], automatic classification algorithms could further be used to analyze recorded motion data and identifying certain behavior. Even if these approaches may be promising to better understand the users' experiential responses while being immersed in VEs, more research about the Proteus effect is needed to gain a deeper knowledge about this phenomenon and to validate it as a potential behavioral measure for UX in VR applications.

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