










# Holistic Quality Assessment of Mediated Immersive Multisensory Social Communication

Alexander Toet<sup>1</sup>  , Tina Mioch<sup>1</sup> , Simon N. B. Gunkelel<sup>2</sup> ,  
Camille Sallaberry<sup>1,3</sup> , Jan B. F. van Erp<sup>1,3</sup> , and Omar Niamut<sup>2</sup> 

<sup>1</sup> TNO Human Factors, Soesterberg, The Netherlands

{lex.toet, tina.mioch, camille.sallaberry, jan.vanerp}@tno.nl

<sup>2</sup> TNO ICT, The Hague, The Netherlands

{simon.gunkel, omar.niamut}@tno.nl

<sup>3</sup> University of Twente, Enschede, The Netherlands

**Abstract.** Communication through modern immersive systems that afford the representation of a wide range of multisensory (visual, auditory, haptic, olfactory) social and ambient (environmental) affective cues can provide compelling experiences that approach face-to-face communication. The quality of a mediated social communication experience (QoE) can be defined as the degree to which it matches its real-life counterpart and is typically assessed through questionnaires. However, available questionnaires are typically extensive, targeted at specific systems, and do not address all relevant aspects of social presence. Here we propose a general holistic social presence QoE questionnaire (HSPQ), that uses a single item for each of the relevant processing levels in the human brain: sensory, emotional, and cognitive, behavioral, and reasoning. The HSPQ measures social presence through the senses of spatial presence (= telepresence + agency) in the mediated environment and social interaction (= interaction + engagement) with the other persons therein. Initial validation studies confirm the content and face validity of the HSPQ. In future studies we will test the stability, sensitivity, and convergent validity of the HSPQ.

**Keywords:** Mediated social communication · Social presence · Quality of experience

## 1 Introduction

### 1.1 Towards Mediated Multisensory Social Presence

Humans have a social and personal need for communication to maintain their interpersonal relationships. In our digital age, human social interaction is often mediated. Given the inherent human need for affective communication to establish trust and mutual understanding, mediated social communication should afford the same affective characteristics as face-to-face communication.

Modern multisensory immersive technologies can provide highly realistic mediated experiences by presenting the user with vivid immersive and extensive representations

of real or virtual spaces. Social interaction through shared and mediated immersive environments can closely approximate the experience of face-to-face meetings by eliciting a sense of *social presence*: the sense of being in the same space as - and having social interaction with - other individuals [1]). The sense of being in a mediated environment is known as the sense of *spatial presence* [2], and consists of two components: the feeling of being located in the mediated environment rather than in the immediate physical environment (*telepresence*) together with the feeling of being able to act within that environment (*agency*). The sense of having social interaction with another individual involves a sense of *intimacy* (the feeling of connectedness or engagement that communicators feel during an interaction [3]) and a sense of *immediacy* (the psychological distance between the communicators [3]). Hence, social presence is inherently bidirectional (involving a sense of mutual awareness).

To assess how successful a communication system is in providing its users a sense of social presence, we need instruments that quantify the quality of their experience (QoE [4]). In this study, we define the *quality of a mediated experience* as the extent to which the experience agrees with its unmediated counterpart. Telepresence is optimal when the user is not aware that the communication is mediated. Social presence increases with the availability and perceived quality of (multisensory) social cues (supporting the senses of intimacy and immediacy), the behavioral realism and the interactivity (supporting the sense of agency) of the communication system. Although many different definitions of QoE have been presented in the literature, there is an ongoing debate about the nature of this construct, and a robust holistic framework with validated associated quality measures is still lacking [4]. Questionnaires are the currently most widely used tools to measure (social) presence [1, 5, 6]. However, most existing questionnaires are targeted at specific systems while their items only tap into a subset of all factors that contribute to social presence [7]. As a result, their scope is limited, and they only provide incomplete information.

The way we experience our environment and the people therein involves different processing levels in our brain that all contribute to the subjective quality of the experience [8]. Therefore, we will first discuss a conceptual holistic framework that describes how multisensory stimulation affects our brain at different processing levels, and we will link these levels to relevant perceptual, affective, and cognitive outcomes. Then we will present an efficient holistic social presence QoE questionnaire (HSPQ) that includes a single item for each of these outcomes and we will discuss the results of initial validation tests. In our future work we will use the HSPQ for the development of a novel immersive multi-sensory communication platform that affords mediated affective communication by providing users an experience of social presence through synchronized bidirectional sensing, digitization, transmission and replication of auditory, visual, and tactile information.

## 1.2 A Holistic Framework for Multisensory Perception

In natural conditions we experience our immediate physical environment through direct sensory input, which is converted into neural signals in the central nervous system and transmitted up to the cortex, resulting in a continuous stream of perceptions. A system that artificially stimulates our senses in correct harmony by presenting the right

(congruent, consistent) sensory cues associated with a familiar (natural) multisensory percept in the correct (appropriate spatiotemporal) way can evoke the illusion of a natural (unmediated) percept. In other words, for highly naturalistic sensory stimulation, our brain cannot distinguish whether a consistent multisensory holistic percept originates from our direct physical (real-world) environment or a mediated (possibly fabricated) one. Thus, technology that substitutes the (natural) sensory input from our physical environment by signals representing a different (e.g., sensed remote or even simulated virtual) environment, can in principle evoke the illusion of a direct (physical, unmediated) experience of that environment [9]. Schreuder et al. [10] presented a holistic conceptual framework that describes how multisensory environmental stimulation affects our brain at the sensory or perceptual, emotional, cognitive, behavioral and decision-making levels. In the next section we will first discuss the need for QoE measures, and we will give a brief overview of the state-of-the-art in this field. Then, in Sect. 2, we will present a new social presence questionnaire that directly links to the relevant outcomes at each of the relevant processing levels identified by Schreuder et al. [10].

### 1.3 The Quality of Mediated Immersive Experiences

Given the increasing availability of systems that afford mediated immersive social interactions between people, there is a need for metrics that efficiently and fully evaluate their QoE. Existing social presence questionnaires predominantly address the sensory components of mediated presence experiences. An exception is the Virtual Experience Test (VET [11]) that provides a more holistic measure of a mediated social presence experience by including affective, cognitive, active and relational dimensions in addition to its sensory dimension. However, the instrument is designed for the development of virtual environments and games and is not sufficiently general for the evaluation of multisensory social communication systems. Also, the VET only measures the quality of social interaction at the behavioral and reasoning levels, but not on the sensory, emotional, and cognitive levels.

Next to being holistic, relevant, sensitive and reliable, QoE measures for social presence should also be convenient and nonintrusive and generalizable across different communication systems [1]. Since there is currently no measure that meets all these criteria, the development of QoE metrics for social presence is still an ongoing effort [4]. In the next section we will present a social presence questionnaire based on items for each of the processing levels in the conceptual framework of Schreuder et al. The resulting tool will be efficient (it uses a concisely formulated single item to measure each relevant outcome) and holistic (it addresses all relevant outcomes), and therefore nonintrusive and generalizable. Then, in Sect. 3, we will briefly discuss some preliminary validation studies. The conclusions of this study will be presented in Sect. 4.

## 2 A Holistic Social Presence Measure

In this section we present a new holistic social presence questionnaire (HSPQ) that taps into each of the five relevant (sensory, emotional, cognitive, behavioral and decision making) processing levels for multisensory environmental stimuli identified by

Schreuder et al. [10]. The HSPQ (Table 1) measures social presence through the senses of spatial presence (= telepresence + agency; 5 items) in the mediated environment and social interaction (= interaction and engagement) with the other persons therein. Since social interaction inherently involves a bidirectional exchange of physical and emotional signals, we maintain a distinction between the internal (“*own*”; 5 items) and external (“*the other*”; 5 items) assessment perspectives for this subscale of the HSPQ. Social presence is optimal when both spatial presence and social interaction are optimal. An optimal quality of spatial presence (= telepresence + agency) is achieved:

- at the sensory level, when system (QoS) parameters do not degrade the mediated representation (item 1: fidelity),
- at the affective or emotional level, when the mediated environment evokes similar emotions as its unmediated counterpart (item 2: consistency),
- at the cognitive level, when the mediated environment is experienced as natural (item 3: naturalness),
- at the behavioral level, when the mediated environment affords natural behavior without any limitations or restrictions (item 4: agency), and
- at the reasoning or decision-making level, when the mediated environment allows one to think in a similar way as in its unmediated counterpart (item 5: reasoning).

An optimal quality of social interaction is achieved:

- at the sensory level, when system factors do not affect the immediacy of the sensory impression that people have of one another (items 6 and 11: immediacy),
- at the affective or emotional level, when the mediation process does not degrade the feeling of intimacy (items 7 and 12: intimacy and engagement),
- at the cognitive level, when the mediation process does not affect the feelings of involvement between people (items 8 and 13: naturalness),
- at the behavioral level, when the system affords natural communication behavior without any limitations or restrictions (items 9 and 14: behavior), and
- at the reasoning level, when the fact that the communication between partners is mediated does not affect their reasoning and decision making (items 10 and 15: reasoning).

### 3 Validation

We performed a preliminary validation study to assess the content and face validity of the HSPQ.

Content validity was rated for each item by a panel of 10 experts, on a 4-point Likert scale (1 = “*not relevant*”, 2 = “*somewhat relevant*”, 3 = “*quite relevant*”, 4 = “*very relevant*”) [12]. The ratings were dichotomized (1, 2 = “*not essential*”; 3, 4 = “*essential*”) and the Content Validity Ratio was computed for each items as  $CVR = (n_e - N/2)/(N/2)$ , where  $n_e$  is the number of panel members that judge an item as “*essential*” and  $N$  is the total number of panel members [13]. The overall content validity of the HSPQ was quantified by the Content Validity Index (CVI), which is simply the mean of the CVR values

over all items in the test. The CVR exceeds the critical level of 0.62 [13] for most items, except for items 3 (.22) and 5 (.33). The CVI was 0.85. Thus, the HSPQ and most of its items have a high content validity, while only two items (3 and 5) need further refinement.

Face validity was tested by a panel of 10 participants, who rated the clarity (ambiguity) of each item on a 10-point Likert scale (0 = “I don’t understand this item”, 10 = “I understand this item”). The interrater agreement was quantified through the intraclass correlation coefficient (ICC) with its associated 95% confidence intervals, based on a mean-rating (k = 3), consistency, 2-way mixed-effects model [14]. The ICC was 0.77 [0.56, 0.91] indicating good agreement between the different raters. On average, most HSPQ items scored above 8.0, except for items 2 (5.9) and 5 (6.5). Thus, it appears that these two items need to be reformulated.

**Table 1.** The holistic social presence questionnaire (HSPQ).

|                 |                                | Processing level  |   |   |   |  |
|-----------------|--------------------------------|---|---|---|---|--|
|                 |                                | Sensory   | Emotional   | Cognitive   | Behavioral  | Reasoning  |
| Social presence | Spatial presence               | [1: fidelity]<br><i>I have direct contact with the environment (I see, hear, feel, smell the environment without any restrictions or distortions)</i>                                 | [2: consistency]<br><i>My sensations agree with the environment (What I see, hear, feel, and smell matches the environment)</i> | [3: naturalness]<br><i>The environment appears natural</i>                  | [4: agency]<br><i>I can behave in a natural manner in the environment</i>           | [5: reasoning]<br><i>I can think in the environment as in normal life</i>                          |
|                 | Internal (“own”) perspective   | [6: immediacy]<br><i>I have direct contact with the other person(s). (I see, hear, feel, smell the other person(s), without any restrictions or distortions)</i>                      | [7: intimacy]<br><i>I feel engaged with the other person(s)</i>   | [8: naturalness]<br><i>The other person(s) appear natural to me</i>         | [9: behavior]<br><i>I can interact with the other person(s) in a natural manner</i> | [10: reasoning]<br><i>The other person(s) affects my thinking as in normal life</i>                |
|                 | External (“other”) perspective | [11: immediacy]<br><i>The other person(s) appear to have direct contact with me (The other person(s) appear to see, hear, feel, smell me without any restrictions or distortions)</i> | [12: intimacy]<br><i>The other person(s) appear to feel engaged with me</i>   | [13: naturalness]<br><i>I seem to appear natural to the other person(s)</i> | [14: behavior]<br><i>The other person(s) interact with me in a natural manner</i>   | [15: reasoning]<br><i>I appear to affect the thinking of the other person(s) as in normal life</i> |

## 4 Conclusions

We present a new holistic assessment tool for measuring the QoE of mediated social presence. The HSPQ uses a single item to tap into each of the relevant processing levels in the human brain: sensory, emotional, and cognitive, behavioral, and reasoning. The HSPQ measures social presence through the senses of spatial presence (= telepresence + agency) in the mediated environment and social interaction (= interaction and engagement with the other persons therein). The HSPQ distinguishes between the internal (“*own*”) and external (“*the other*”) assessment perspectives for the social interaction subscale of the HSPQ. Initial validation studies confirm the content and face validity of the HSPQ. We are currently refining the scope and formulation of some items in the HSPQ to further increase its content and face validity. Then, we will test its stability, sensitivity, and convergent validity in different mediated multisensory social communication settings. In our future work we will use the HSPQ for the development of a novel immersive multi-sensory communication platform that affords mediated affective communication by providing users an experience of social presence through synchronized bidirectional sensing, digitization, transmission and replication of auditory, visual, and tactile information.

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