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SERIES P: TELEPHONE TRANSMISSION QUALITY,
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NETWORKS

Telemeeting assessment

Quality of experience assessment of extended reality meetings

Recommendation ITU-T P.1320

ITU-T

ITU-T P-SERIES RECOMMENDATIONS

TELEPHONE TRANSMISSION QUALITY, TELEPHONE INSTALLATIONS, LOCAL LINE NETWORKS

Vocabulary and effects of transmission parameters on customer opinion of transmission quality	P.10–P.19
Voice terminal characteristics	P.30–P.39
Reference systems	P.40–P.49
Objective measuring apparatus	P.50–P.59
Objective electro-acoustical measurements	P.60–P.69
Measurements related to speech loudness	P.70–P.79
Methods for objective and subjective assessment of speech quality	P.80–P.89
Voice terminal characteristics	P.300–P.399
Objective measuring apparatus	P.500–P.599
Measurements related to speech loudness	P.700–P.709
Methods for objective and subjective assessment of speech and video quality	P.800–P.899
Audiovisual quality in multimedia services	P.900–P.999
Transmission performance and QoS aspects of IP end-points	P.1000–P.1099
Communications involving vehicles	P.1100–P.1199
Models and tools for quality assessment of streamed media	P.1200–P.1299
Telemeeting assessment	P.1300–P.1399
Statistical analysis, evaluation and reporting guidelines of quality measurements	P.1400–P.1499
Methods for objective and subjective assessment of quality of services other than speech and video	P.1500–P.1599

For further details, please refer to the list of ITU-T Recommendations.

Recommendation ITU-T P.1320

Quality of experience assessment of extended reality meetings

Summary

Recommendation ITU-T P.1320 advises on aspects of importance for quality of experience (QoE) assessment of telemeetings with extended reality elements. The goal is to define the human, context and system factors that affect the choice of the QoE assessment procedure and metrics when extended reality telemeeting systems are under evaluation.

History

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Extended reality, quality of experience, QoE, telemeeting.

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Table of Contents

		Page
1	Scope	1
2	References.....	1
3	Definitions	2
	3.1 Terms defined elsewhere	2
	3.2 Terms defined in this Recommendation.....	2
4	Abbreviations and acronyms	2
5	Conventions	3
6	Overview of concepts and technologies used for XR telemeetings	3
	6.1 XR telemeeting.....	3
	6.2 Virtual reality (VR)	4
	6.3 Augmented reality	4
	6.4 Assisted reality	4
	6.5 Mixed reality (MR).....	4
	6.6 Mediated reality	4
	6.7 Metaverse	4
	6.8 QoE constituent	4
	6.9 Quality features	5
7	Use cases.....	6
	7.1 Use cases in 3GPP.....	6
	7.2 Spatial audio multiparty call.....	8
	7.3 Remote system operation over XR telemeeting	8
	7.4 XR conference	8
8	Factors influencing QoE of XR telemeetings.....	8
	8.1 Human influence factors (HIFs).....	8
	8.2 Context influence factors (CIFs)	10
	8.3 System influence factors (SIFs).....	11
9	Constituents of QoE in XR telemeetings.....	20
	9.1 Simulator sickness	20
	9.2 Immersion.....	20
	9.3 Presence, co-presence and social presence.....	20
	9.4 Plausibility.....	21
	9.5 Ethics of XR use	22
	9.6 Carving out mental space	22
	9.7 Fatigue and cognitive load.....	22
	9.8 Ability to reach goals.....	22
10	Test methods targeting XR telemeeting QoE	22
	10.1 Test paradigms.....	23

	Page
Appendix I – Related work in other standardization bodies and industry	25
I.1 3rd Generation Partnership Project (3GPP)	25
I.2 Virtual Reality Industry Forum (VRIF)	25
I.3 Moving Picture Experts Group (MPEG).....	25
I.4 Khronos Group	26
I.5 Video Quality Experts Group (VQEG)	26
I.6 European Network on Quality of Experience in Multimedia Systems and Services (Qualinet)	26
I.7 World Wide Web Consortium (W3C).....	26
I.8 ITU-T SG16/Q8 Immersive Live Experiences.....	26
Bibliography.....	27

Recommendation ITU-T P.1320

Quality of experience assessment of extended reality meetings

1 Scope

This Recommendation focuses on aspects of importance for the assessment of quality of experience (QoE) of different types of extended reality (XR) telemeetings, which may be a combination of telemeetings taking place in virtual reality (VR), augmented reality or mixed reality environments. It targets XR services aiming to immerse the user and augment the exchange of information by delivering interactive real-time uni- or multimodal sensory information for two-party and multiparty communication. The services include telemeetings taking place in a virtual location or a combination of virtual and real locations; telemeetings with mixtures of real and virtual participants; telemeetings with augmented elements for collaboration; virtual conferences; and joint teleoperation of equipment.

While multiple QoE evaluation methodologies for telemeetings have been developed, novel XR telemeeting services may result in cognitive effects that are not covered by the existing Recommendations. These effects may include simulator sickness, fatigue, immersion or presence, for example. This Recommendation advises on the key QoE factors affecting user experience of an XR telemeeting service.

The purpose of this Recommendation is to find existing standardized methods that can be applied for assessing the QoE constituents of XR telemeetings, and direct the reader to the appropriate source. When a suitable standardized method is not available, this Recommendation will list the QoE influencing factors related to the QoE constituent in question and guide the reader to relevant scientific literature. Ultimately, this Recommendation specifies the categorization of system, human and context factors influencing XR telemeeting QoE.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

- [ITU-T G.1035] Recommendation ITU-T G.1035 (2021), *Influencing factors on quality of experience for virtual reality (VR) services*.
- [ITU-T P.10] Recommendation ITU-T P.10/G.100 (2017), *Vocabulary for performance, quality of service and quality of experience*.
- [ITU-T P.919] Recommendation ITU-T P.919 (2020), *Subjective test methodologies for 360° video on head-mounted displays*.
- [ITU-T P.1301] Recommendation ITU-T P.1301 (2017), *Subjective quality evaluation of audio and audiovisual multiparty telemeetings*.
- [ITU-T P.1305] Recommendation ITU-T P.1305 (2016), *Effects of delays on telemeeting quality*.
- [ITU-T P.1310] Recommendation ITU-T P.1310 (2017), *Spatial audio meetings quality evaluation*.

- [ITU-T P.1311] Recommendation ITU-T P.1311 (2014), *Method for determining the intelligibility of multiple concurrent talkers*.
- [ITU-T P.1312] Recommendation ITU-T P.1312 (2016), *Method for the measurement of the communication effectiveness of multiparty telemeetings using task performance*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

- 3.1.1 QoE** [ITU-T P.10]
- 3.1.2 QoE influencing factors** [ITU-T P.10]
- 3.1.3 telemeeting** [ITU-T P.1301]
- 3.1.4 degree of freedom (DoF)** [ITU-T G.1035]

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 virtual reality (VR): An environment that is fully generated by digital means. To qualify as virtual reality, the virtual environment should differ from the local environment.

3.2.2 augmented reality (AR): An environment containing both real and virtual sensory components. The augmented reality continuum runs from virtual content that is clearly overlaid on a real environment (assisted reality) to virtual content that is seamlessly integrated and interacts with a real environment (mixed reality).

NOTE – Based on [b-Rauschnabel].

3.2.3 assisted reality: An environment containing both real and virtual sensory components, where the virtual content is perceived as clearly artificial and overlaid (one end of the augmented reality continuum).

NOTE – Based on [b-Rauschnabel].

3.2.4 mixed reality (MR): An environment containing both real and virtual components that are seamlessly integrated and interact with each other in a natural way (one end of the augmented reality continuum).

NOTE – Based on [b-Rauschnabel].

3.2.5 diminished reality (DR): An environment with deliberately removed contents of the digital representation of the physical environment.

3.2.6 extended reality (XR): An environment containing real or virtual components or a combination thereof, where the variable X serves as a placeholder for any form of new environment (e.g., augmented, assisted, mixed, virtual or diminished reality).

NOTE – Based on [b-Rauschnabel].

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AR	Augmented Reality
CAVE	Cave Automatic Virtual Environment
CfE	Call for Evidence

CfP	Call for Proposal
CIF	Context Influence Factor
CPU	Central Processing Unit
DR	Diminished Reality
DoF	Degree of Freedom
GoP	Group of Pictures
GPU	Graphics Processing Unit
GSR	Galvanic Skin Response
HMD	Head-Mounted Display
HRTF	Head-Related Transfer Functions
MR	Mixed Reality
MTP	Motion-To-Photon
MTS	Motion-To-Sound
NBMP	Network-Based Media Processing
OMAF	Omnidirectional Media Format
PCC	Point Cloud Compression
QIF	Quality Influence Factor
SIF	System Influence Factor
URLLC	Ultra-Reliable Low Latency Communications
VC	VideoConferencing
V-PCC	Video-based Point Cloud Compression
VR	Virtual Reality
VVC	Versatile Video Coding
XR	Extended Reality

5 Conventions

None.

6 Overview of concepts and technologies used for XR telemeetings

This clause introduces concepts and technologies associated with extended reality (XR) telemeetings. A characterization of all types of telemeetings, including XR telemeetings can be found in [b-Skowronek].

6.1 XR telemeeting

The XR telemeeting technology aims to substantially improve the telemeeting experience, for example, through spatial reproduction of audio and video, and to enhance the exchange of information with augmented elements, for example, by using virtual avatars or virtual objects and by better immersing the participants and increasing their sense of (co-)presence. A telemeeting can take place in a virtual location or a combination of virtual and real locations; it can have a mixture of real and virtual participants; or augmented elements for collaboration.

6.2 Virtual reality (VR)

Virtual reality immerses users in a fully artificial (computer-generated) digital environment. The term virtual reality refers to a computer-generated environment in which the user can perceive, feel and interact in a manner that is similar to a physical place. This is achieved by combining stimulation over multiple sensory channels – such as sight, sound and touch – with force-feedback, motion tracking and control devices. In an ideal virtual reality (VR) system, the user would not be able to distinguish an artificial environment from its physical counterpart. While none of the current VR systems would be able to pass this criterion, significant advances in the perceptual fidelity of virtual environments have been achieved over the last few years. The virtual environment itself is a computer-generated three-dimensional model of a physical environment, in which the user can navigate and interact with the objects that it contains.

6.3 Augmented reality

Augmented reality overlays digital objects on the real-world environment with spatial registration that enables geometric persistence concerning placement and orientation within the real world. Augmented reality superimposes a layer of digital content over the real physical world such that users see virtual models at fixed positions and orientations mixed in with the actual world around them.

6.4 Assisted reality

Assisted reality overlays digital information or objects on the real-world environment with the aim to assist the user in obtaining a better understanding of the physical environment rather than to merge virtual objects with the real world [b-Rauschnabel].

6.5 Mixed reality (MR)

Mixed reality is the merging of real and virtual worlds to produce hybrid environments, where physical and digital objects coexist and interact in real-time. Hence, mixed reality (MR) is similar to AR, but the digital objects spatially interact with the real-world objects, rather than being superimposed as 'floating images' on top of the real-world objects.

6.6 Mediated reality

Sometimes the terms mediated reality or computer-mediated reality are used to describe VR, AR, MR and diminished reality (DR) with one encompassing term. In that respect, this Recommendation considers mediated reality and computer-mediated reality as synonyms for XR.

6.7 Metaverse

The metaverse is a digital reality that combines aspects of social media, online gaming, AR and VR to allow users to interact virtually. Users in the metaverse will be able to immerse themselves in a space where the digital and physical worlds converge. An important characteristic of the metaverse is the persistence of its content, meaning that virtual or augmented content is spatially attached to specific physical objects (e.g., a digital vase on a user's physical desk), or attached to a specific geographic location through geocoordinates in order to provide different users a shared experience [b-Rauschnabel].

6.8 QoE constituent

A QoE constituent is formed during an individual's experience of a service and contributes to its QoE. It is considered to be formed by a cognitive process which aggregates a multitude of quality features (see definition of quality features in clause 6.8). This aggregation, however, needs neither to form orthogonal dimensions, as is conventionally the goal of multidimensional quality assessment methods, nor to result in QoE constituents that are independent from each other.

Moreover, a QoE constituent can encompass aspects that are linked to the perception of speech, audio or video signals as well as other aspects such as, for instance, simulator sickness, immersion, feeling of presence, feeling of co-presence or usability. That means the quality features used can encompass perceptual representations of the audiovisual signals, body reactions (e.g., in case of simulator sickness) and other sensory input, contextual information or other characteristics that refer, for instance, to the direct perception, action, interaction or usage instance of the service [b-Möller].

Furthermore, QoE constituents can be differentiated from quality influence factors (QIFs [ITU-T P.10]) by using a process model perspective: QoE constituents are aspects formed inside the QoE formation process in the experiencing person's mind, which is happening during the experience with the service. QIFs can be aspects that influence the QoE formation process from outside the process, and can stem from inside or outside the experiencing person. Alternatively, QIFs can influence the characteristics of the XR meeting and with this all relevant signals and contextual information that form the input to the QoE formation process.

Figure 1 uses this process model perspective to visualize the relationships between the different aspects of QoE, QoE constituents, quality features and QIFs.

6.9 Quality features

A quality feature is a perceivable, recognized and nameable characteristic of an individual's experience of a service which contributes to its quality [b-Brunnström2013], [b-Jekosch].

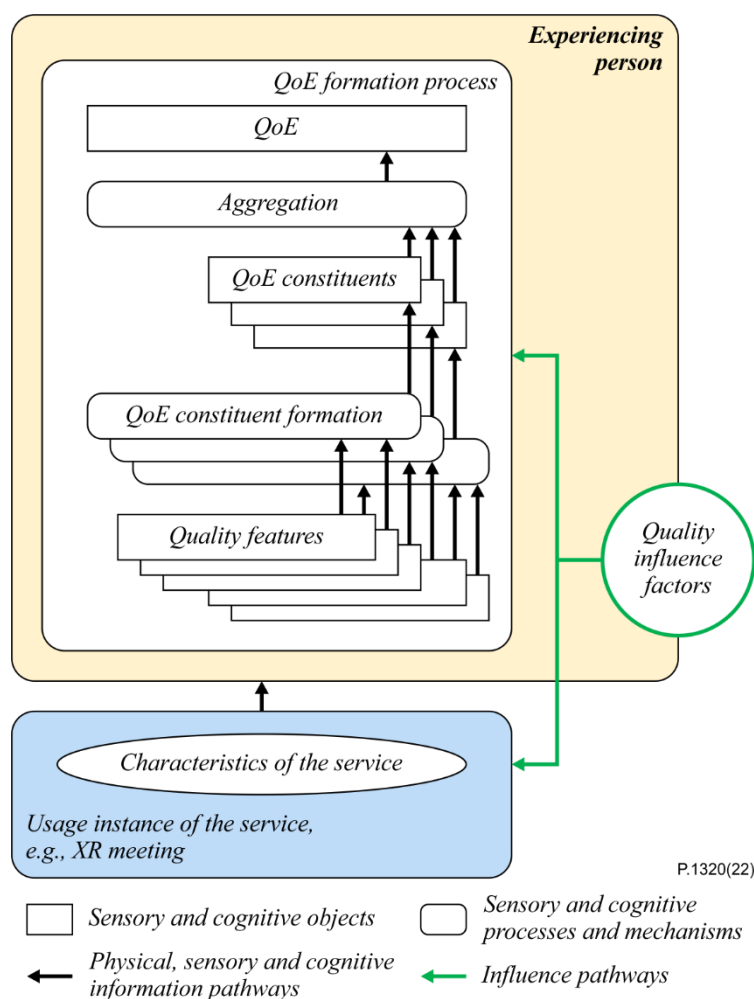


Figure 1 – Visualization of the relationships between QoE, QoE constituents, quality features and QIFs

7 Use cases

7.1 Use cases in 3GPP

The 3rd Generation Partnership Project (3GPP) has published a technical report [b-TR 26.928] on XR technology in 5G. In that report, seven core use cases with a total of 23 individual use cases are specified. A number of those use cases address content delivery for conversational situations and can thus be considered use cases for XR telemeetings. Table 1 summarizes those use cases; for a full description, refer to chapters 4 and 5 of [b-TR 26.928] as well as its appendices.

Some new use cases including AR remote cooperation, AR Conferencing and shared AR conferencing experience can be found in [b-TR 26.998].

Table 1 – Overview of use cases from 3GPP's technical report [b-TR 26.928] that can be considered XR telemeetings

Core use case	Individual use case (parentheses: use case number according to TR 26.928)	Aspect of use case relevant for present Recommendation
Real-time XR sharing	(7) Real-time 3D communication	Video telephony call with partially captured (e.g., face) and partially reconstructed (e.g., back of head) 3D representation of conversation partner
Real-time XR sharing	(8) AR guided assistant at remote location (industrial services)	Remote expert helps local technician to work on a physical object/machine, both use audio video communication and AR overlays
Real-time XR sharing	(11) Real-time communication with a shop assistant	Client and shop assistant use audio video communication and AR overlays to place 3D representations of items for sale in the client's environment
Real-time XR sharing	(17) AR animated avatar calls	Similar to use case "Real-time 3D Communication": telephony call in which one conversation partner does not transmit video data, hence that partner is represented by a full 3D reconstruction
Real-time XR sharing	(23) 5G shared spatial data	Co-located people wearing an XR head-mounted display (HMD) collaboratively interact with a detailed 3D virtual model from their own perspective into a shared coordinate system (using a shared map)
XR mission critical	(9) police critical mission with AR	Police officers on site and in a police station use audio video communication and additional data using AR overlays and control of drones is also considered
XR conference	(12) 360-degree conference meeting	Multiparty telemeeting in which all conversation partners communicate in a virtual 3D representation of a real meeting room; in a variation of this use case mediated representations of the remote participants are projected into a real meeting room by means of AR for those who are actually in that room

Table 1 – Overview of use cases from 3GPP's technical report [b-TR 26.928] that can be considered XR telemeetings

Core use case	Individual use case (parentheses: use case number according to TR 26.928)	Aspect of use case relevant for present Recommendation
XR conference	(13) 3D shared experience	Conversation partners collaborate in a virtual environment to perform a task
XR conference	(14) 6DOF VR conferencing	Virtual world in which conversation partners are represented by avatars, avatars can move in the virtual world and can communicate with others when they are near enough
XR conference	(15) XR meeting	Remote participants experience a virtual representation of a real environment and can communicate with local participants who are physically present in that environment, local participants can communicate with remote participants using AR
XR conference	(16) Convention / poster Session	Similar to XR Meeting: local and remote participants join a physical poster session, presenters and listeners may be physically present or participate remotely
Spatial audio multiparty call	(18) AR avatar multiparty calls	Multiparty call in which remote participants are placed in each local environment using AR, whereas spatial audio is used (a) for rendering each conversation partner in the direction of his/her geolocation and (b) for sharing individual acoustic scenes when desired (e.g., "hear what I hear" feature)
Spatial audio multiparty call	(19) Front-facing camera video multiparty calls	Multiparty video telephony in which spatial audio is used to keep the acoustic location of the conversation partners at the same spot relative to the video display (e.g., mobile phone)
XR multimedia Streaming	(20) AR streaming with localization registry	While this is mainly a streaming-only scenario based on the example of an AR museum guide, a variation allows for a communication with a travel guide avatar
XR multimedia streaming	(21) Immersive six degrees of freedom (6DoF) streaming with social interaction	An extension of a streaming-only scenario ("immersive game spectator mode") based on the example of watching in real-time a game (or other event) as a remote spectator: in this extension, however, the spectator can communicate with the avatars of other spectators

Related work on XR meetings has been conducted by ITU. For that reason, additional information concerning some use cases is provided in the following to clarify the relation of XR telemeetings to telemeetings considered in existing Recommendations.

7.2 Spatial audio multiparty call

In [b-TR 26.928], two use cases (Nos 18 and 19) are grouped into a core use case "spatial audio multiparty call". The detailed descriptions in [b-TR 26.928] actually reveal two aspects that qualify this core use case as an XR meeting.

First, according to the definition in clause 3.2.1, using spatial audio technology for a telemeeting already qualifies as an XR meeting. In terms of quality assessment, it should be noted that a number of assessment methods for such "spatial audio meetings" are described in [ITU-T P.1310], [ITU-T P.1311] and [ITU-T P.1312]. Also, the combination of spatial audio with video (over ordinary displays) has been addressed in some of these methods. That means the core use case "spatial audio multiparty call" comprises additional individual use cases that are addressed in the aforementioned Recommendations.

Second, the combination of spatial audio with other XR elements such as a visual representation by means of VR or AR also qualifies as an XR meeting. In terms of quality assessment, however, this is a new use case that has not been covered in the aforementioned Recommendations and thus requires further study.

7.3 Remote system operation over XR telemeeting

This is in general a new field, a combination of telemeeting technology with physical objects and machines which leads to a cyberphysical system remotely controlled by multiple persons.

7.4 XR conference

A virtual conference experience typically happens with multiple participants. As an example, almost 2000 participants participated in IEEE VR 2020 [b-Ahn]). The experience may involve different types of events, which are sub-parts of the XR conference with different requirements, such as plenary talks, parallel sessions, workshops, poster sessions or demonstrations [b-ACM].

Hybrid conferences may be held with virtual participants represented by remotely operated telepresence robots [b-Neustaedter].

8 Factors influencing QoE of XR telemeetings

This clause identifies the XR telemeeting specific influencing factors affecting the QoE constituents listed in clause 9. They are divided into three categories: human (clause 8.1), context (clause 8.2) and system (clause 8.3) influencing factors. These factors can also be mixed [b-Reiter], [b-Skowronek-3]. Other relevant XR-related QoE influencing factors collected in [ITU-T G.1035] are mentioned here, but not explained in detail.

8.1 Human influence factors (HIFs)

Human influence factors (HIFs) refer to any characteristics of a user that have an influence on QoE, including the background and the mental, psychophysiological and physiological state of a user [b-Brunnström, [b-Reiter]. Next to the fidelity of the representation of a mediated environment and the persons therein, the experienced quality of an XR meeting experience may also depend on highly subjective secondary factors such as personal relevance [b-Toet-2] and the user's context (e.g., task, available information: [b-Hägner], [b-Lee-2]), current (mental and physical) state, personality [b-Alsina], [b-Hofer], [b-Sacau], engagement and involvement (e.g., enjoyment, flow, and mental absorption or attention [b-Lee-2]).

8.1.1 Characteristics of the perceptual and cognitive processes

A user's visual, auditory, olfactory and tactile acuity can all affect the perceived quality of an XR telemeeting [b-Skowronek-3], [ITU-T G.1035]. For example, impaired visual or hearing acuity will influence the perception of any degradations in the audio and video signals.

QoE is a complex cognitive construct, resulting from the technical aspects of a telemeeting system. During an XR telemeeting, users can be confronted with different technical possibilities to communicate remotely, resulting in high cognitive load and fatigue. The user's cognitive process (i.e., the way concepts and information are formulated and processed) will determine the level of cognitive load and thus ultimately the quality of the experience.

8.1.2 Internal state of individual participants

One aspect of the internal state of individual participants is their tendency to experience simulator sickness [ITU-T G.1035]. If a participant is experiencing simulator sickness during an XR meeting, then the quality of the overall experience is correspondingly degraded [b-Toet-1].

Another such aspect is their tendency to experience immersion [ITU-T G.1035]. Immersion is the extent to which a system can replace the user's natural sensory input with mediated input, while presence refers to the user's interpretation of immersion. Since it appears likely that presence requires a tendency for immersion, Witmer and Singer [b-Witmer-1] developed the Immersive Tendency Questionnaire (ITQ) to measure the propensity for immersion. However, no correlation has been found between immersion and ITQ ratings [b-Agrawal], and only a partial negative correlation between the ITQ and presence measured with the Presence Questionnaire (PQ) [b-Witmer-1], [b-Nystad, b-Youngblut] and a partial positive correlation between the ITQ and presence measured with the Slater-Usch-Steed (SUS) [b-Slater] questionnaire [b-Youngblut].

The level of expertise can also influence QoE, for example in the sense of technical expertise about the system (when a user understands the technology, the experience is rated differently than it is by a naive user), the expertise to use the system to achieve a goal [ITU-T G.1035], and the expertise about the subject of the XR meeting, which influences cognitive load etc. [b-Skowronek-3].

Spatial intelligence and introversion both affect the experience of spatial presence, such that higher degrees of spatial intelligence and introversion correspond to higher degrees of spatial presence within the sense of presence [b-Jurnet-1], [b-Jurnet-2].

8.1.3 Conversation behaviour

The conversation behaviour of participants will influence the structure and flow of the conversation during a meeting and thus they will influence the QoE perceived by the participants. Here, aspects such as, for instance, the formality of the conversation or communication discipline (see [b-Mengis]) determine conversation behaviour.

Moreover, the degree of involvement, that is the extent to which participants actively contribute to the XR meeting, can also influence the QoE. Passive participants tend to perceive quality degradations more critically than actively engaged participants, see e.g., [b-Schmitt], [b-Skowronek-1].

8.1.4 Relations between participants

People in close relationships typically experience higher levels of social presence when communicating through XR, particularly when the communication medium affords interpersonal affective social touch [b-Longa], [b-Fermoselle], [b-Gavrilovska], [b-Haritaipan], [b-Huisman].

The arrival of the tactile Internet will stimulate the integration of the haptic modality into digital communication devices and interfaces, with remote personal communication, health care and teleoperation becoming the primary market domains [b-Jewitt]. Mediated social communication including touch can contribute significantly to a feeling of social presence in the context of collaborative tasks performed in shared virtual environments. However, since mediated social touch can cause feelings of discomfort between strangers [b-Smith], a closer (e.g., romantic) relationship may be preferred for this kind of tactile stimulation [b-Rantala], [b-Suvilehto].