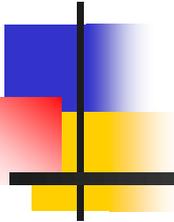


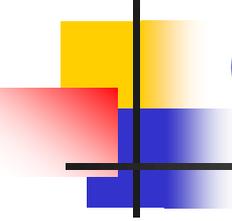
# **Influences of Inter-Stream Synchronization Errors among Haptic Media, Sound, and Video on Quality of Experience in Networked Ensemble**



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# Outline

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- **Background**
- **Purpose**
- **Networked ensemble**
- **Experimental system**
- **Assessment method**
- **Assessment results**
- **Conclusions and future work**

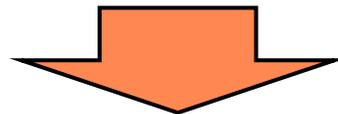
# Background

**Efficiency of collaborative work over a network can be greatly improved by using haptic media together with other media such as sound and video.**

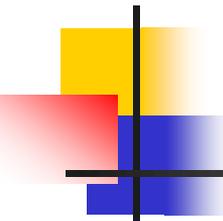
**Ex. A networked ensemble in which multiple musical instruments are played together via network.**

**Sounds of musical instruments have to be synchronized with each other:**

**➔ The networked ensemble may have severe constraints on synchronization errors.**



**It is necessary to investigate the influences of synchronization errors in a networked ensemble.**



# Purpose (1/2)

\*1 Tatematsu *et al*, IEEE CQR, June 2010.

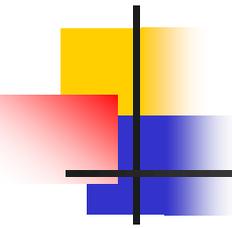
## Previous work <sup>\*1</sup>

### Networked performance of tambourine

- A user operates a haptic interface device at a remote place with another haptic interface device to beat a tambourine while watching video and listening to sound of the tambourine.
- The inter-stream synchronization quality among haptic media, sound, and video is assessed.

## Problems

- Only one musical instrument is played, and an ensemble is not performed.
- In a networked ensemble, because sounds of instruments have to be synchronized with each other, performance of the ensemble is more difficult than beating the tambourine owing to the network delay.
- The quality of sound and the resolution of video are low.



# Purpose (2/2)

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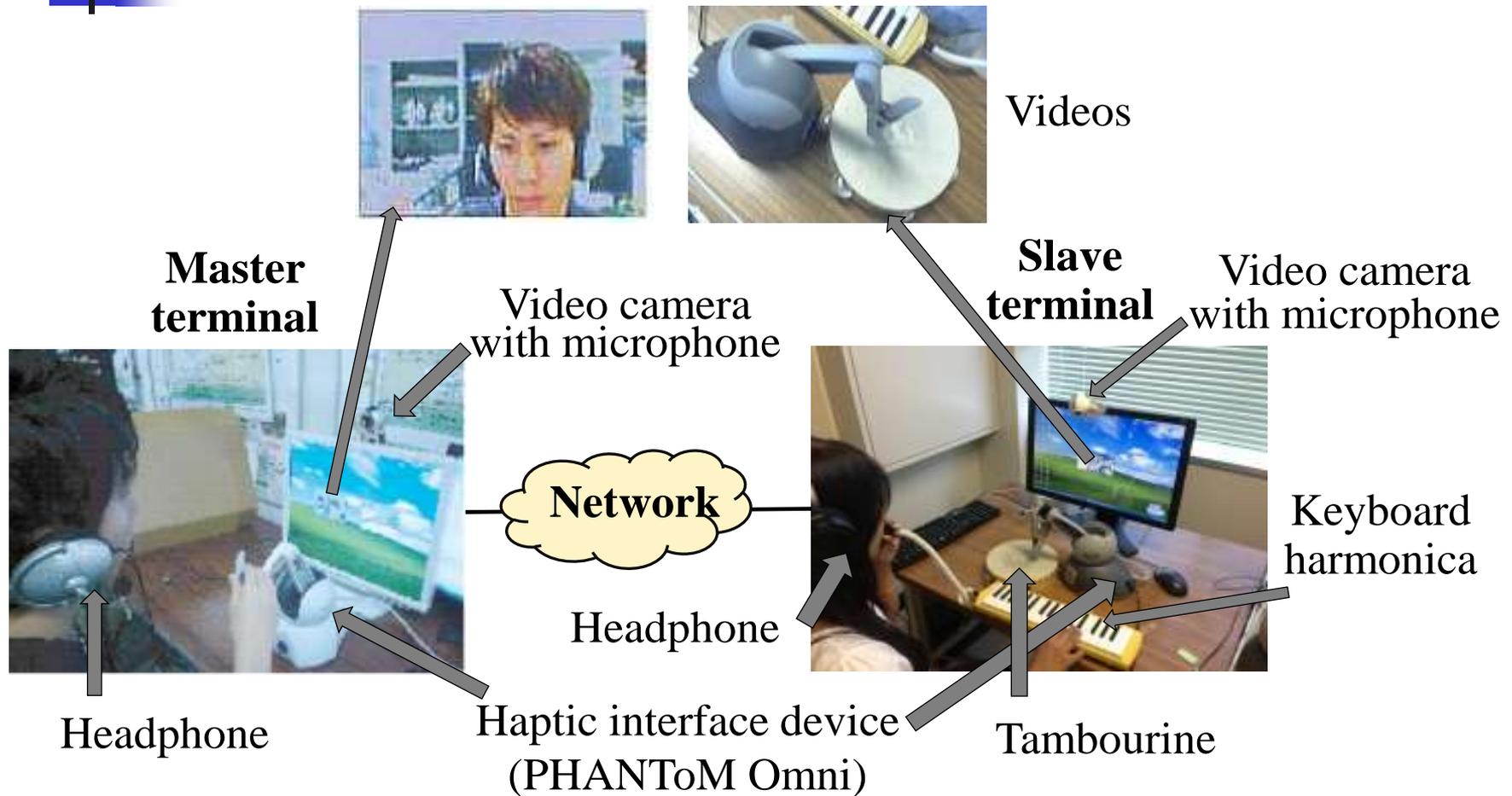
## This work

- We handle the networked ensemble in which a user can remotely plays the tambourine while watching video and listening to sound of the keyboard harmonica played by another user.
- We examine the influences of inter-stream synchronization errors among haptic media, sound, and video by QoE (quality of experience) assessment.

In the QoE assessment, we handle two cases (called *cases 1 and 2* ).

- **Case 1:** Low quality sound and normal video as well as haptic media.
- **Case 2:** Higher quality sound and stereo video with higher resolution than those in case 1.

# Networked ensemble (case 1)



**A user of the master terminal remotely controls PHANToM of master terminal in order to play the tambourine with PHANToM of slave terminal while watching video and listening to sound.**

# Networked ensemble (case 2)

Videos



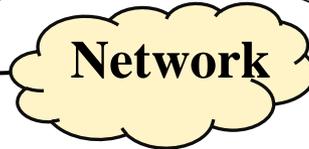
**Master terminal**

**Slave terminal**

Headphone

Stereo video camera

Polarized glasses  
3D display



Headphone

3D display

Microphone

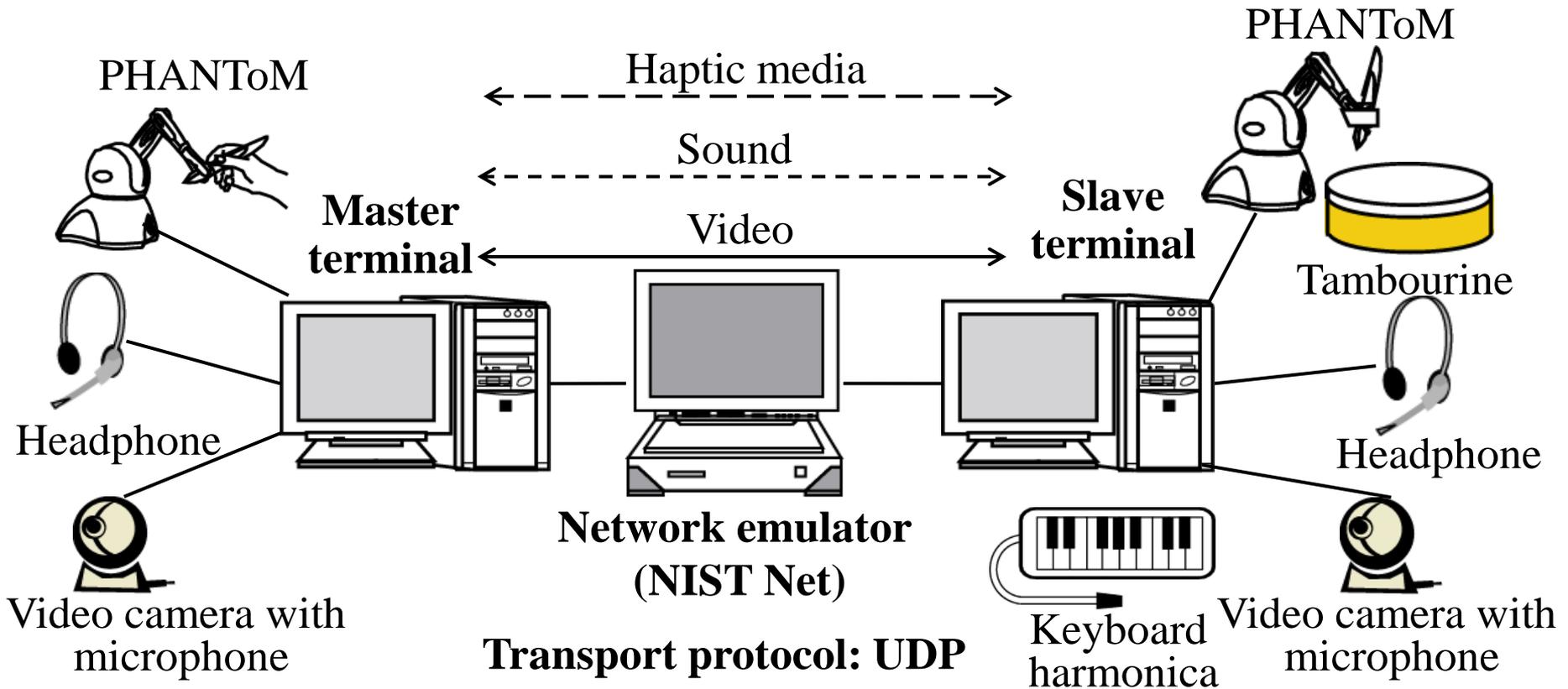
Haptic interface device  
(PHANToM Omni)

Microphone

Keyboard  
harmonica

Tambourine

# Assessment system (case 1)



**The network emulator (NIST Net) generates an additional constant delay for each packet transmitted between the two terminals.**

# Assessment method (1/3)

## Work contents

- A subject of the master terminal remotely controls PHANToM of the slave terminal by manipulating his/her PHANToM, and he/she actively plays the tambourine with PHANToM while watching video and listening to sound.
- One of authors plays a keyboard harmonica at the slave terminal.
- Performed music: “Mary Had a Little Lamb”
- Tempo: 100 bpm (beats per minute)
- Hitting the tambourine once every 2 beats

# Assessment method (2/3)

## Assessment types

<b>Assessment</b>	<b>Additional constant delay of haptic media</b>	<b>Relations of additional constant delay of three media streams</b>
<b>Assessment 1</b>	<b>10 ms</b>	<b>Additional constant delay of one media stream is different from those of the other media streams.</b>
<b>Assessment 2</b>	<b>50 ms</b>	
<b>Assessment 3</b>	<b>10 ms</b>	<b>Additional constant delays of the three media streams are different from each other.</b>
<b>Assessment 4</b>	<b>50 ms</b>	

**The combination of assessment type (assessment 1, 2, 3, or 4) was selected in random order for each subject.**

# Assessment method (3/3)

## QoE assessment after practice

- Operability of PHANToM
- Synchronization quality of haptic media and video
- Synchronization quality of haptic media and tambourine's sound
- Synchronization quality of video and tambourine's sound
- Synchronization quality of sounds
- Comprehensive quality (the weighted sum of the other five types of qualities)

## Five-grade impairment scale

Score	Description
5	Imperceptible
4	Perceptible, but not annoying
3	Slightly annoying
2	Annoying
1	Very annoying

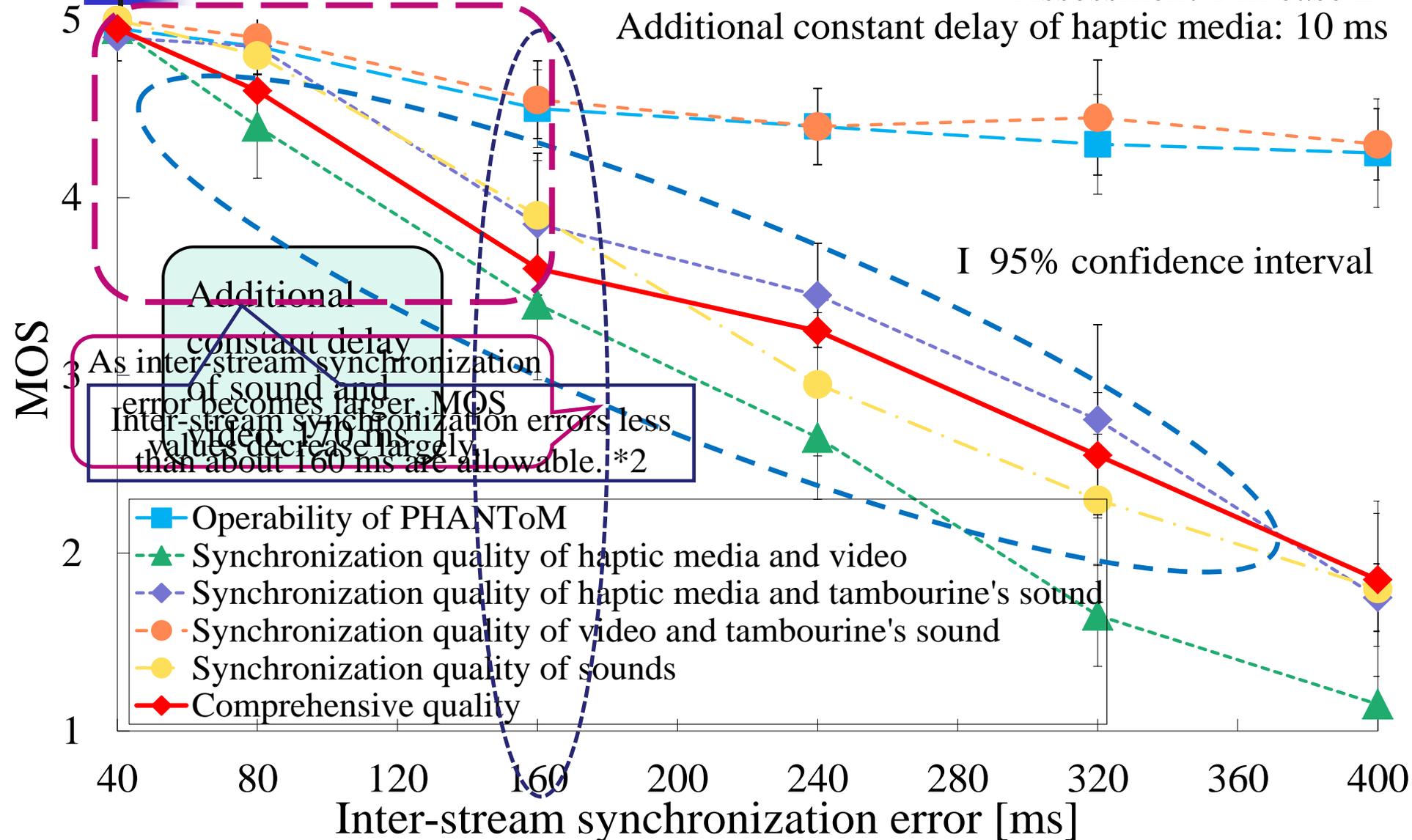
We obtained the *mean opinion score* (MOS).  
The subjects were 20 persons whose ages were between 21 and 31.

# Assessment results (1/2)

\*2 ITU-R BT. 1359-1, Nov. 1998.

Assessment 1 in case 2

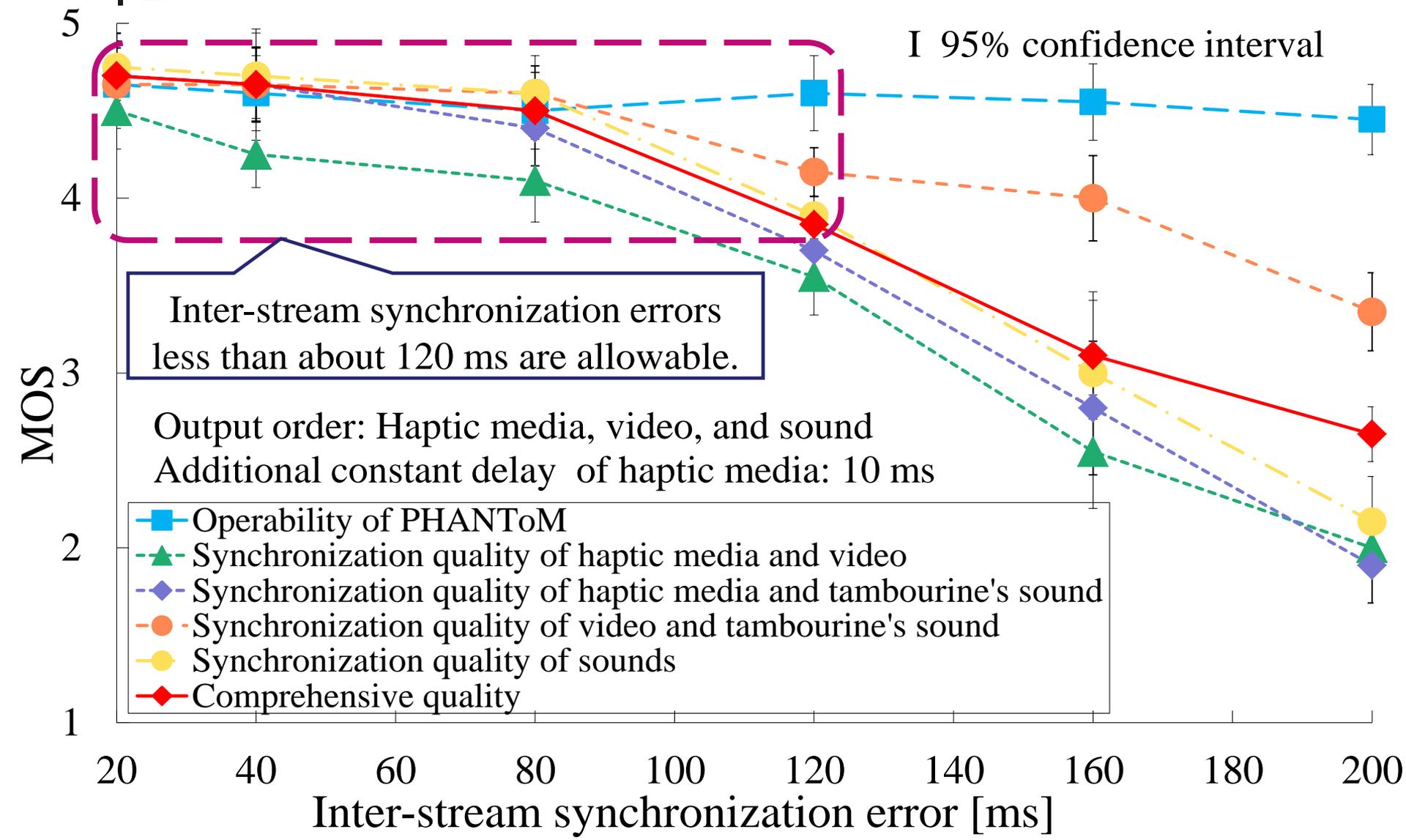
Additional constant delay of haptic media: 10 ms

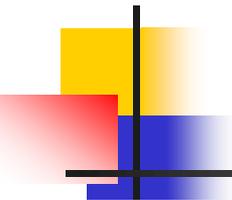


# Assessment results (2/2)

Assessment 3 in case 2

I 95% confidence interval



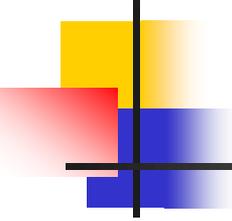


# Conclusions

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**We dealt with a networked ensemble with a keyboard harmonica and a tambourine by using haptic media, sound, and video.**

- **We investigated the influences of inter-stream synchronization errors among haptic media, sound, and video by QoE assessment.**
  - **We also examined the influences when high quality sound and stereo video with high resolution were employed.**
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- **Allowable inter-stream synchronization errors are clarified.**
    - **For example, when the network delay of haptic media is 10 ms, and it is different from those of sound and video inter-stream, synchronization errors less than about 160 ms are allowable.**
  - **QoE hardly depends on the different quality of video and sound.**



# Future work

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- **Investigation of the work dependency of human perception by dealing with the networked ensemble with different music and tempos**
- **Handling a networked orchestra with several musical instruments**