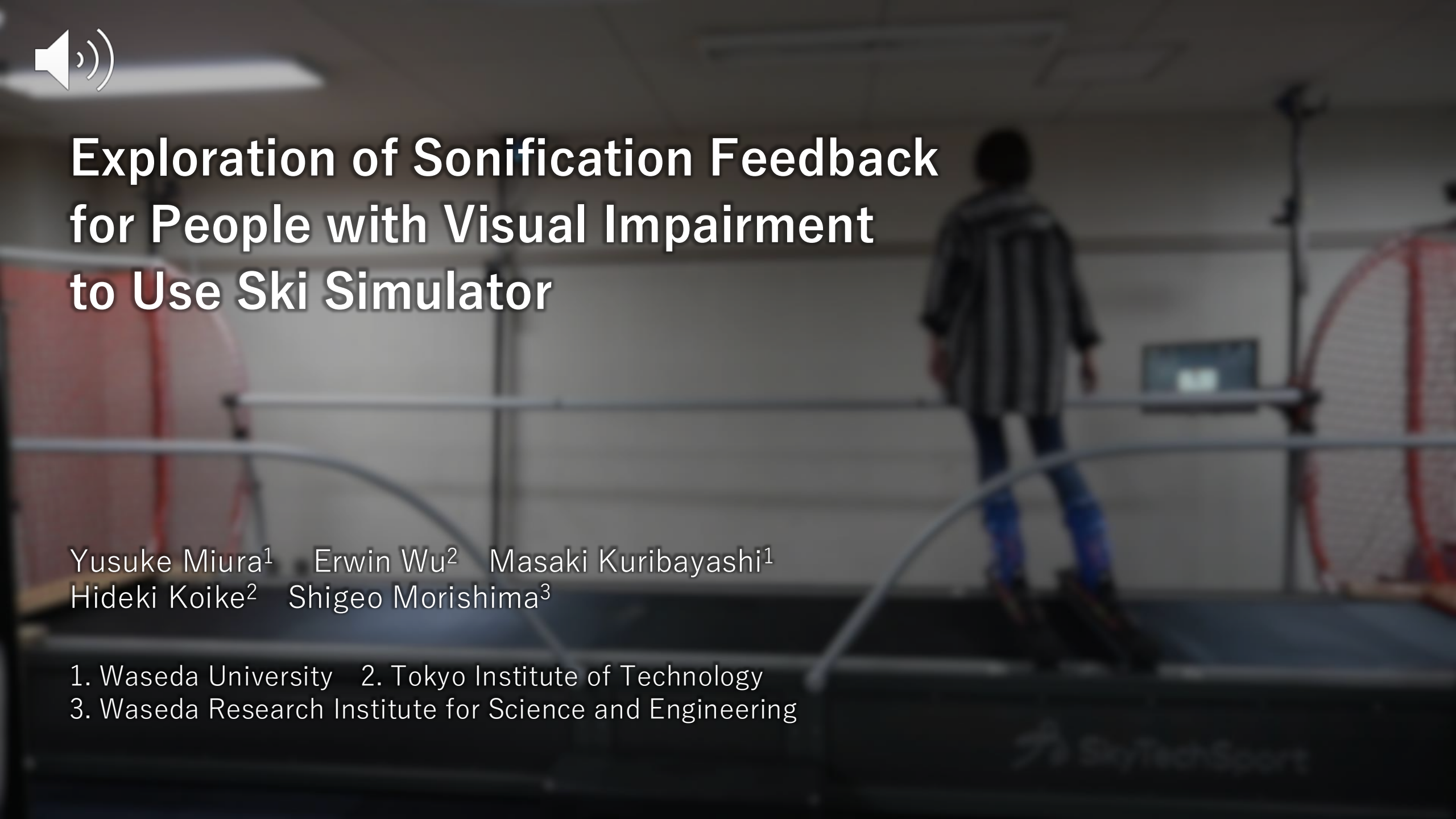


Exploration of Sonification Feedback for People with Visual Impairment to Use Ski Simulator

Yusuke Miura[1] Erwin Wu[2] Masaki Kuribayashi[1]
Hideki Koike[2] Shigeo Morishima[3]

1. Waseda University 2. Tokyo Institute of Technology
3. Waseda Research Institute for Science and Engineering

Blind Skiing

Sighted guides guide visually impaired (VI) skiers with their voices

https://youtu.be/9Zk--BrrvaQ

Blind Skiing

Problems:

1. Visually impaired skiers cannot practice alone
2. It takes a long time to be a guide
3. Skiers' performance depend on guides

Sighted guides guide visually impaired (VI) skiers with their voices

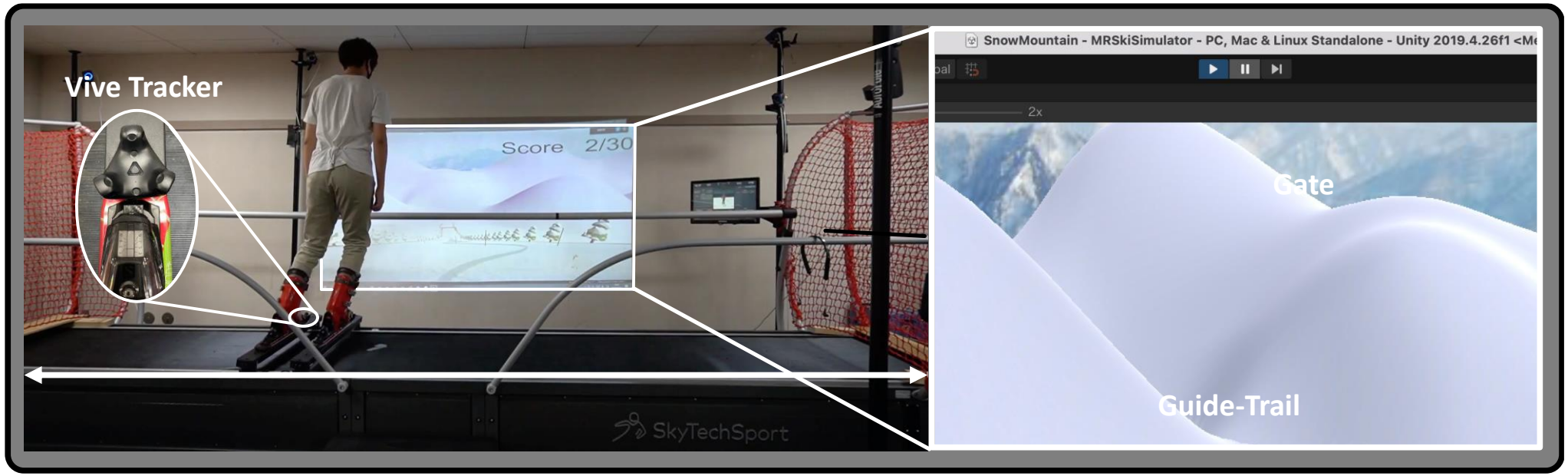
Indoor Ski Simulators may Solve These Problems

Indoor Ski Simulator

People can train skiing all year round without environmental constraints

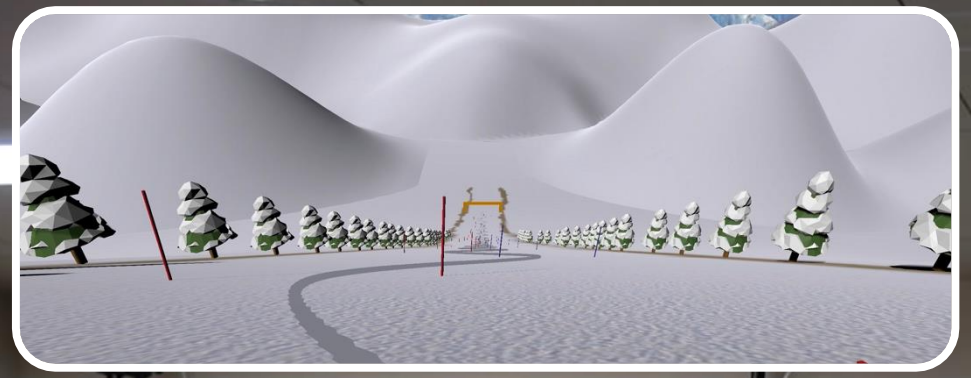
Ski Training System Using Ski Simulator [1, 2, 3]

Previous research: Using visual effects to promote efficient ski training



Limitation
PVI cannot use the simulator as it is designed only for sighted people

[1] Aleshin, et al. “Alpine skiing and snowboarding training system using induced virtual environment”, Science and Skiing IV, 4: 137-144, 2009.
[2] Wu, et al. “How to vizski: Visualizing captured skier motion in a vr ski training simulator”, VRCAI ‘19.
[3] Matsumoto et al. “Skiing, fast and slow: Evaluation of time distortion for vr ski training”, AHs ‘22.



Research Goal: Develop feedback system
to enable independent ski training for the visually impaired

Set Up

Implement gates, guide-trail, gate-passed sound [3]

[3] Matsumoto et al. “Skiing, fast and slow: Evaluation of time distortion for vr ski training”, AHs ‘22.

Two Types of Sonification Feedback

Feedback	Continuous Error Sound (Baseline method)	Advance Turn Sound (Proposed method)
		
Key Idea	Previous study using a driving simulator [4]	Interview with PVI and their guides
Type	Continuous sound	Single sound

[4] Parseihian, et al. “Exploration of sonification strategies for guidance in a blind driving game”, CMMR ‘17.

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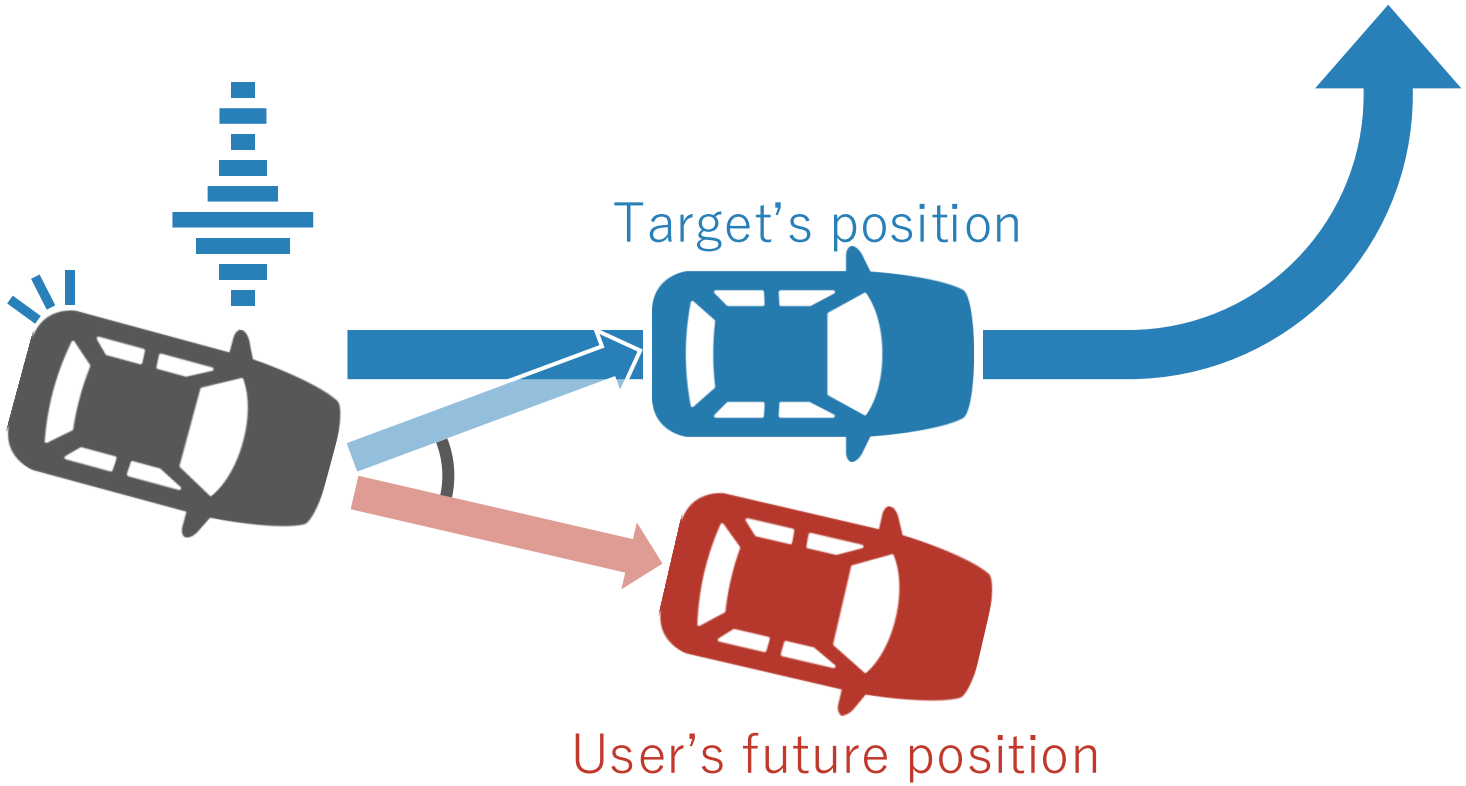
Feedback to Assist PVI in Following a Trail [4]

In the task of trail following using a driving simulator,

feedback about the user's future position and the target's position is effective



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Feedback to Assist PVI in Following a Trail [4]

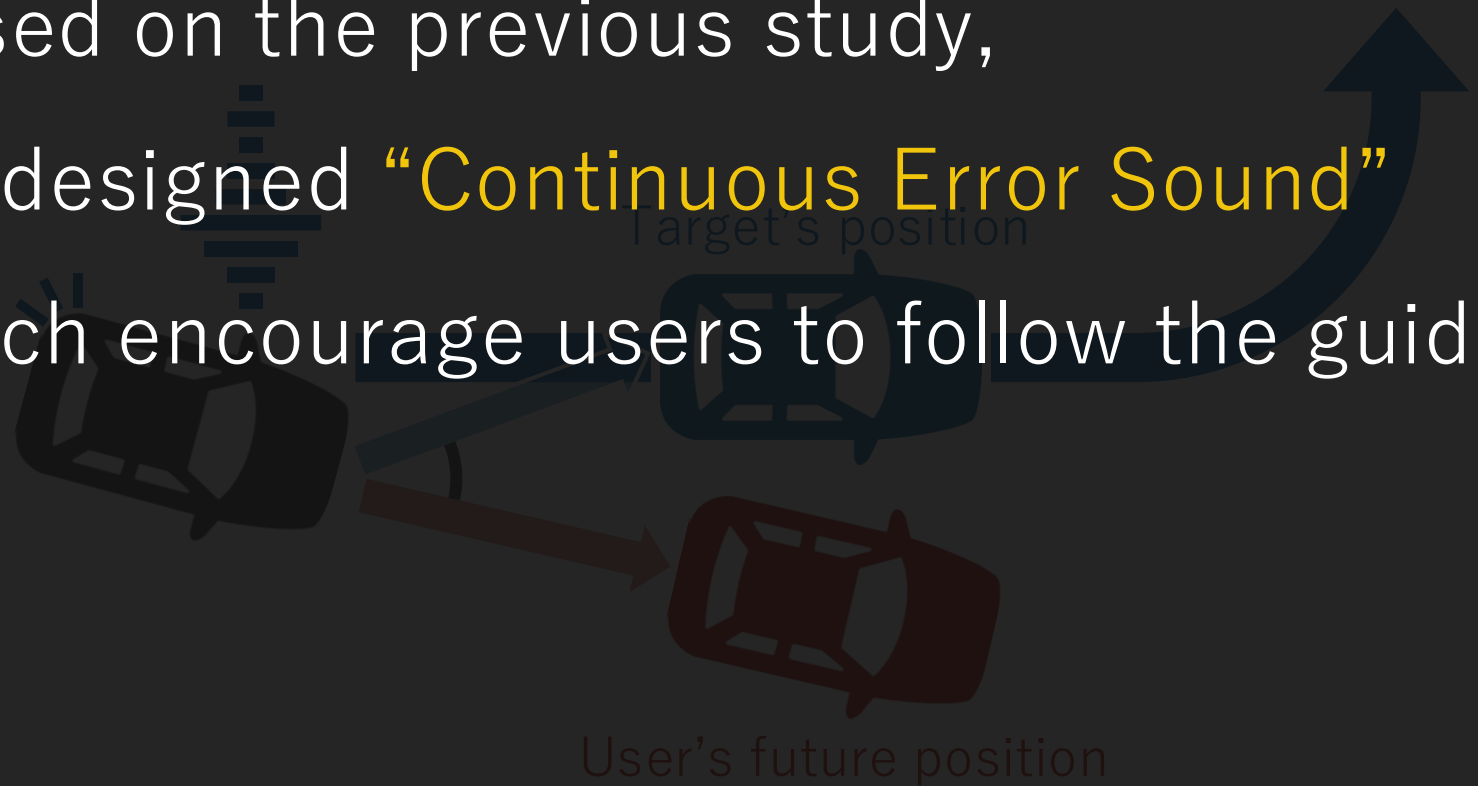
In the task of trail following using a driving simulator,

feedback about the user's future position and the target's position is effective

Based on the previous study,

we designed "Continuous Error Sound"

which encourage users to follow the guide's trail

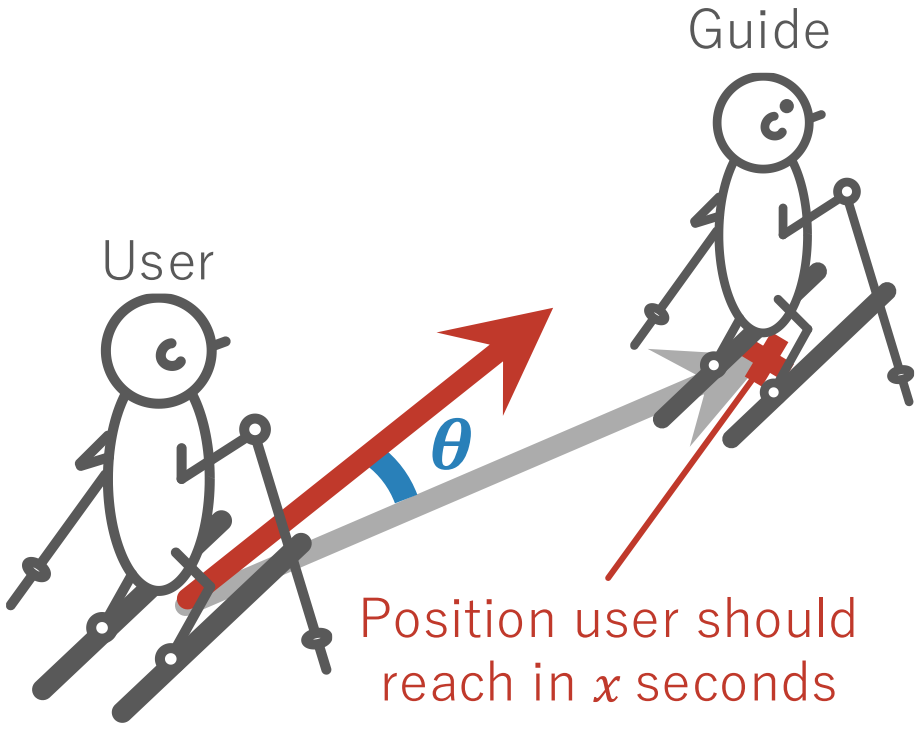


[4] Parseihian, et al. "Exploration of sonification strategies for guidance in a blind driving game", CMMR '17.

Baseline Method: Continuous Error Sound (CES) [4]

Step 1

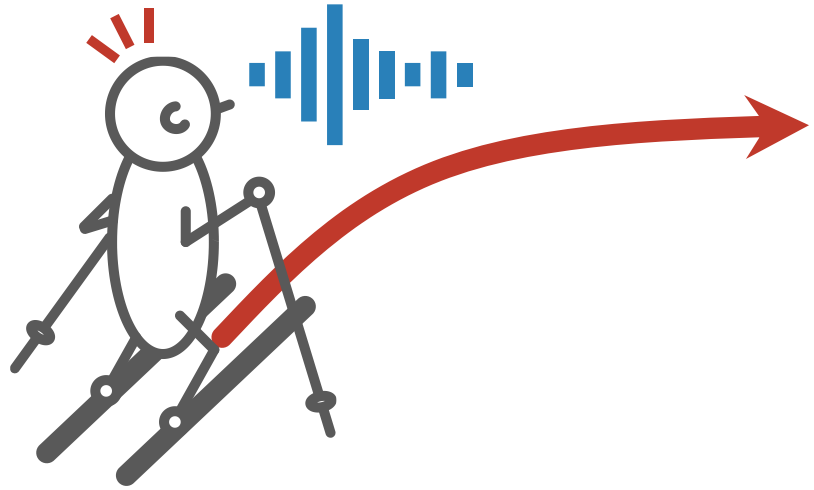
Calculate $\boldsymbol{\theta}$



Step 2

Change sound parameters according to $\boldsymbol{\theta}$

Pitch, volume, emission direction change



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Continuous Error Sound

Two Types of Sonification Feedback

	Continuous Error Sound (Baseline method)	Advance Turn Sound (Proposed method)
Feedback		
Key Idea	Previous study using a driving simulator [4]	Interview with PVI and their guides
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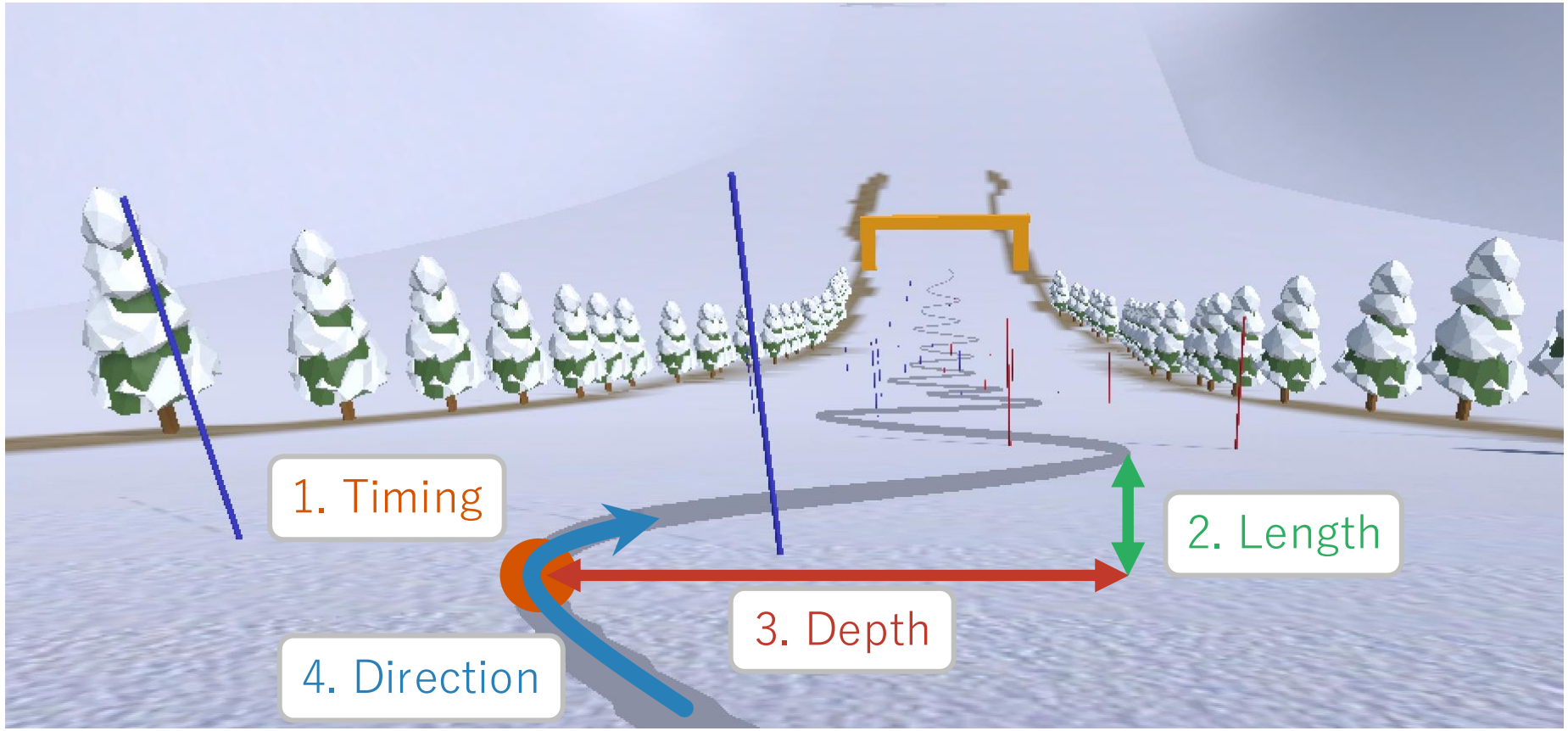
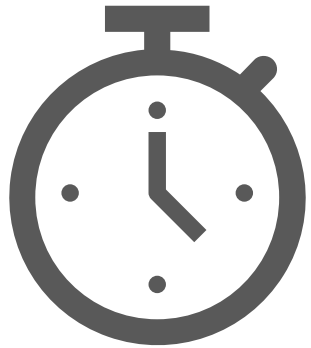
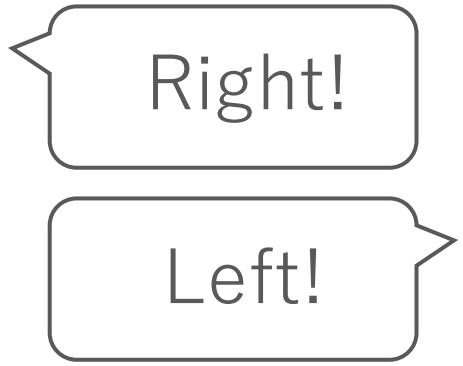
A Ski Turn Is Composed of 4 Elements

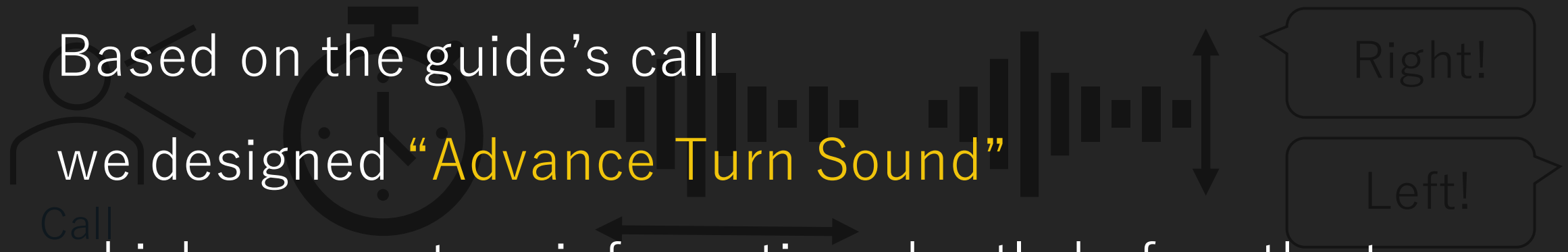


Relationship Between Guide's Call and Turn Information

	Timing	Length	Volume	Word
Call				
Turn information	Timing	Length	Depth	Direction

Relationship Between Guide's Call and Turn Information

Timing | Length | Volume | Word



Based on the guide's call

we designed "Advance Turn Sound"

which convey turn information shortly before the turn

Turn information: Timing | Length | Depth | Direction

Proposed Method: Advance Turn Sound (ATS)

Timing

Turn timing

Length

Turn length

Direction

Turn direction

Pitch

Turn depth

Difference Between Guide's Call and ATS

- To reduce cognitive load:
  - We used sonification method instead of text-to-speech [5, 6]
  - We changed two means of conveying information [7, 8]

[5] Mascetti, et al. "Sonification of guidance data during road crossing for people with visual impairments or blindnes", International Journal of Human-Computer Studies, Volume 85, 2016.
[6] Klatzky, et al. "Cognitive load of navigating without vision when guided by virtual sound versus spatial language", Journal of experimental psychology: Applied, 12(4), 2006.

Difference Between Guide's Call and ATS

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[7] Giorgio, et al. "WatchOut: Obstacle Sonification for People with Visual Impairment or Blindness", ASSETS '19.
[8] Dubus, et al. "A Systematic Review of Mapping Strategies for the Sonification of Physical Quantities", PLoS ONE 8(12), 2013.

Difference Between Guide's Call and ATS

- To reduce cognitive load:
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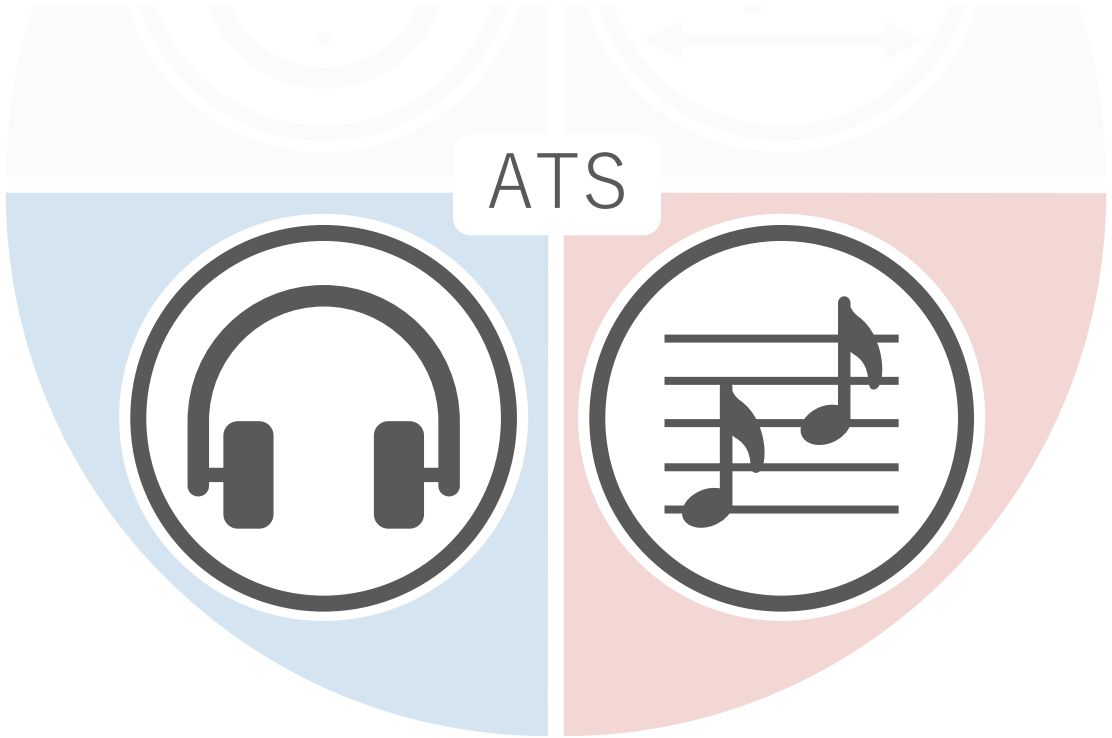
  - We changed two means of conveying information [7, 8]

Word

Direction

Turn Direction



Volume

Pitch

Turn Depth

[7] Giorgio, et al. "WatchOut: Obstacle Sonification for People with Visual Impairment or Blindness", ASSETS '19.
[8] Dubus, et al. "A Systematic Review of Mapping Strategies for the Sonification of Physical Quantities", PLoS ONE 8(12), 2013.

Proposed Method: Advance Turn Sound (ATS)

Timing

Turn Timing

Length

Turn Length

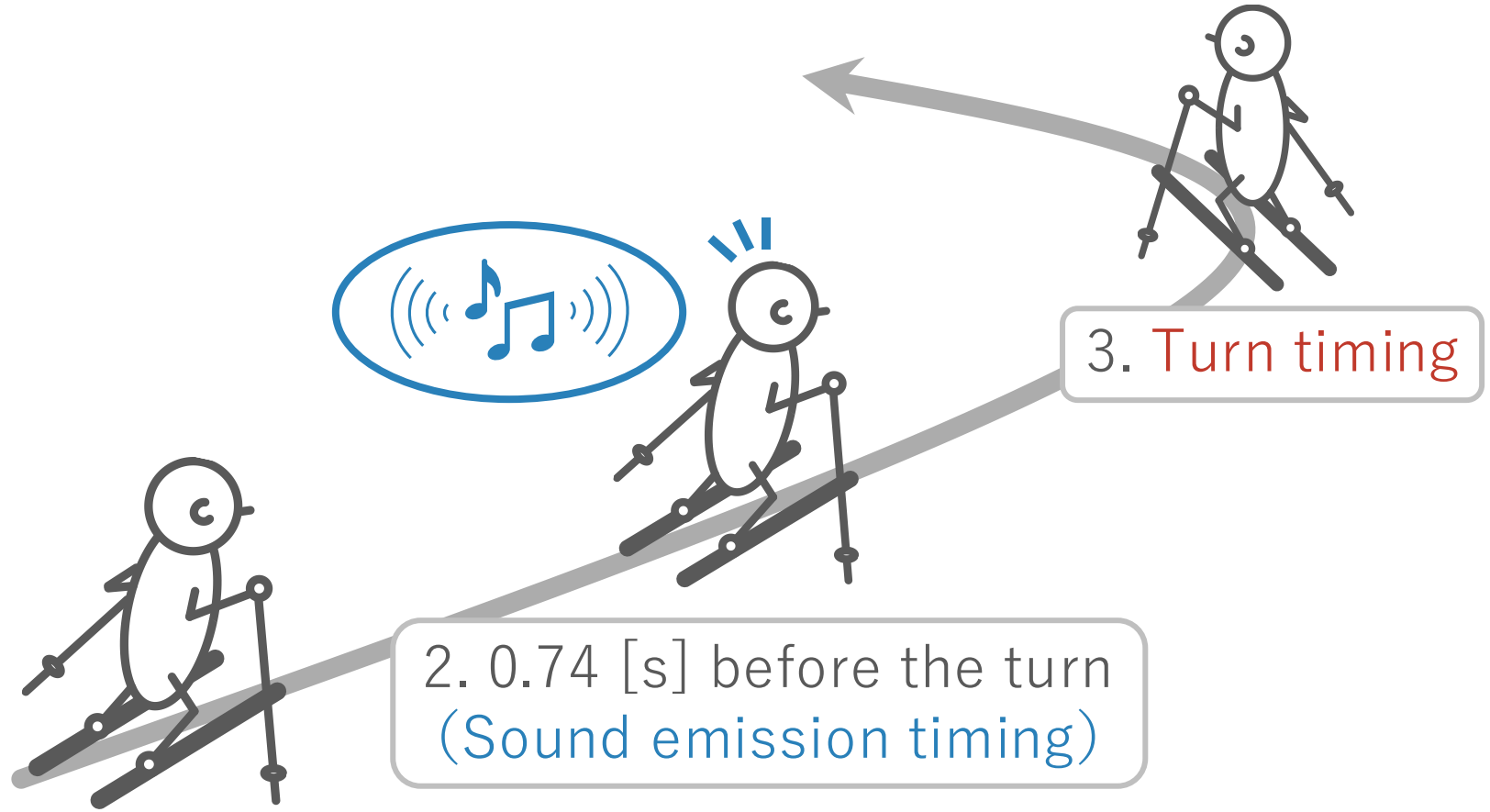
Direction

Turn Direction

Pitch

Turn Depth

ATS Is Emitted 0.74 seconds Before Turn Timing



Proposed Method: Advance Turn Sound (ATS)

Timing

Turn Timing

Length

Turn Length

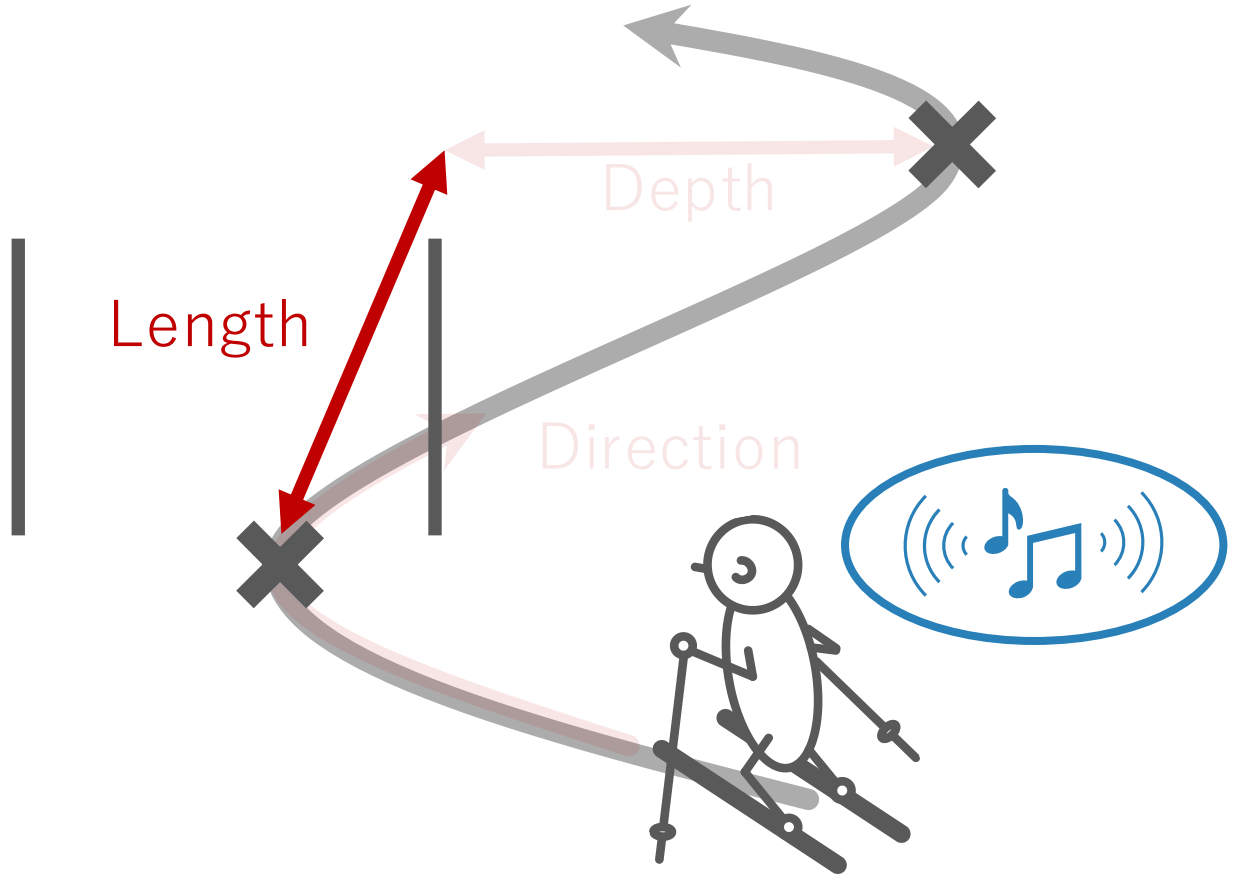
Direction

Turn Direction

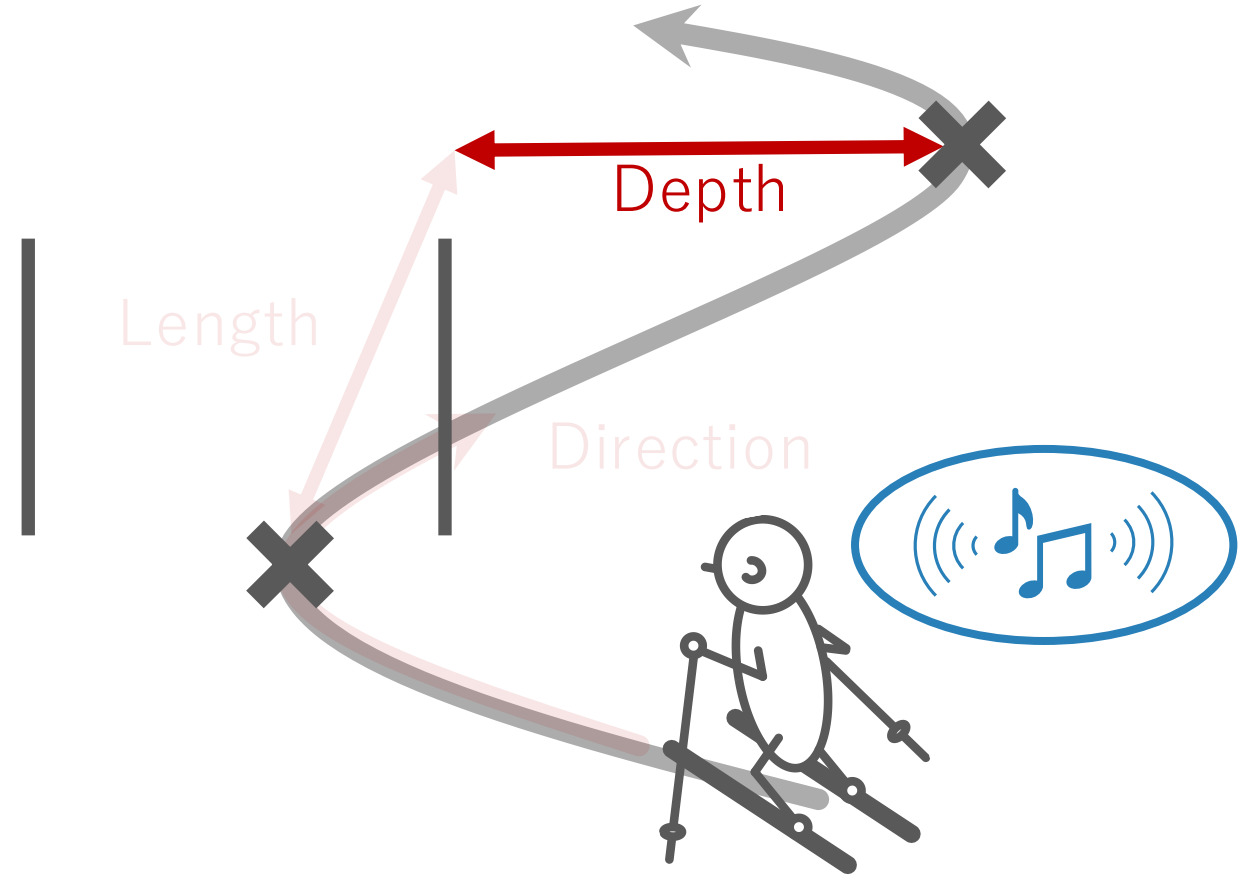
Pitch

Turn Depth

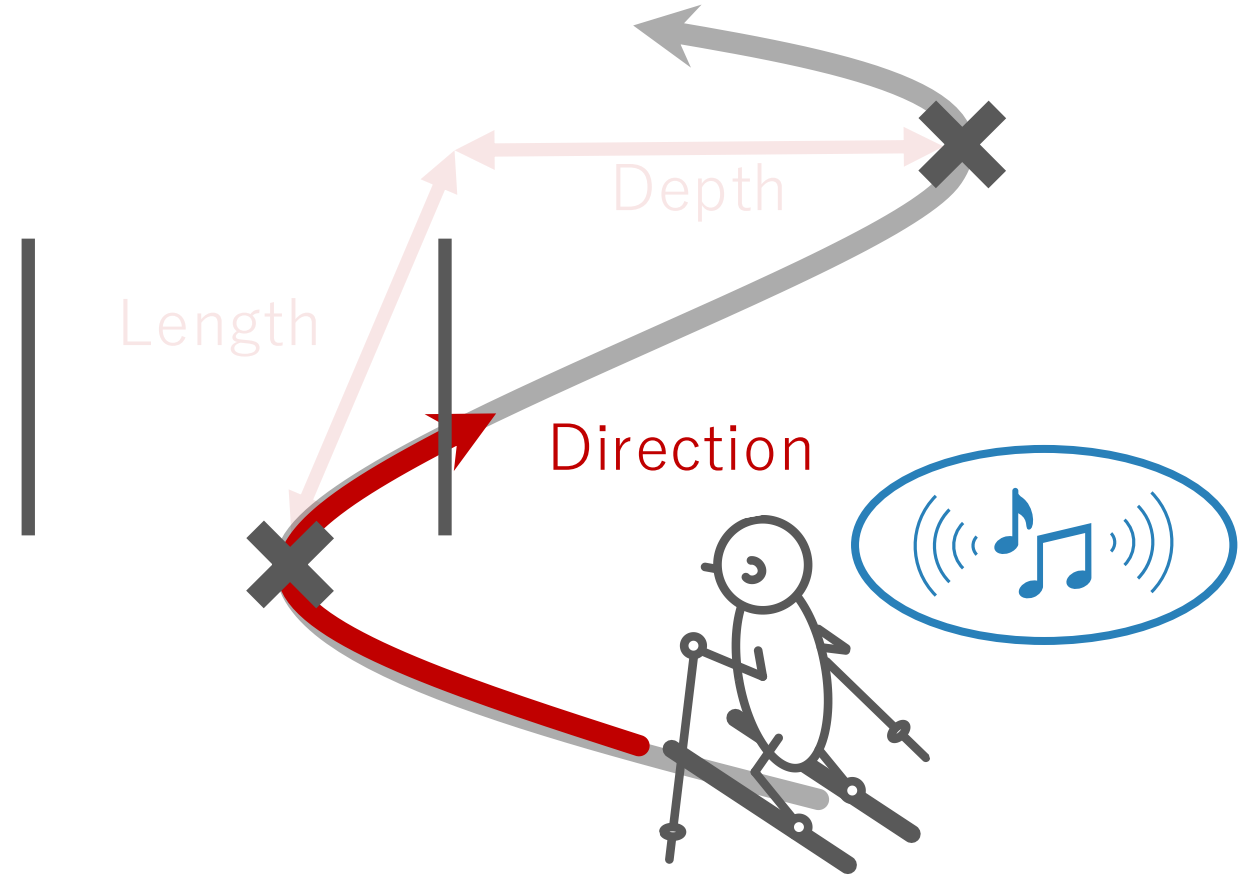
The Longer the Next Turn, the Longer the Sound



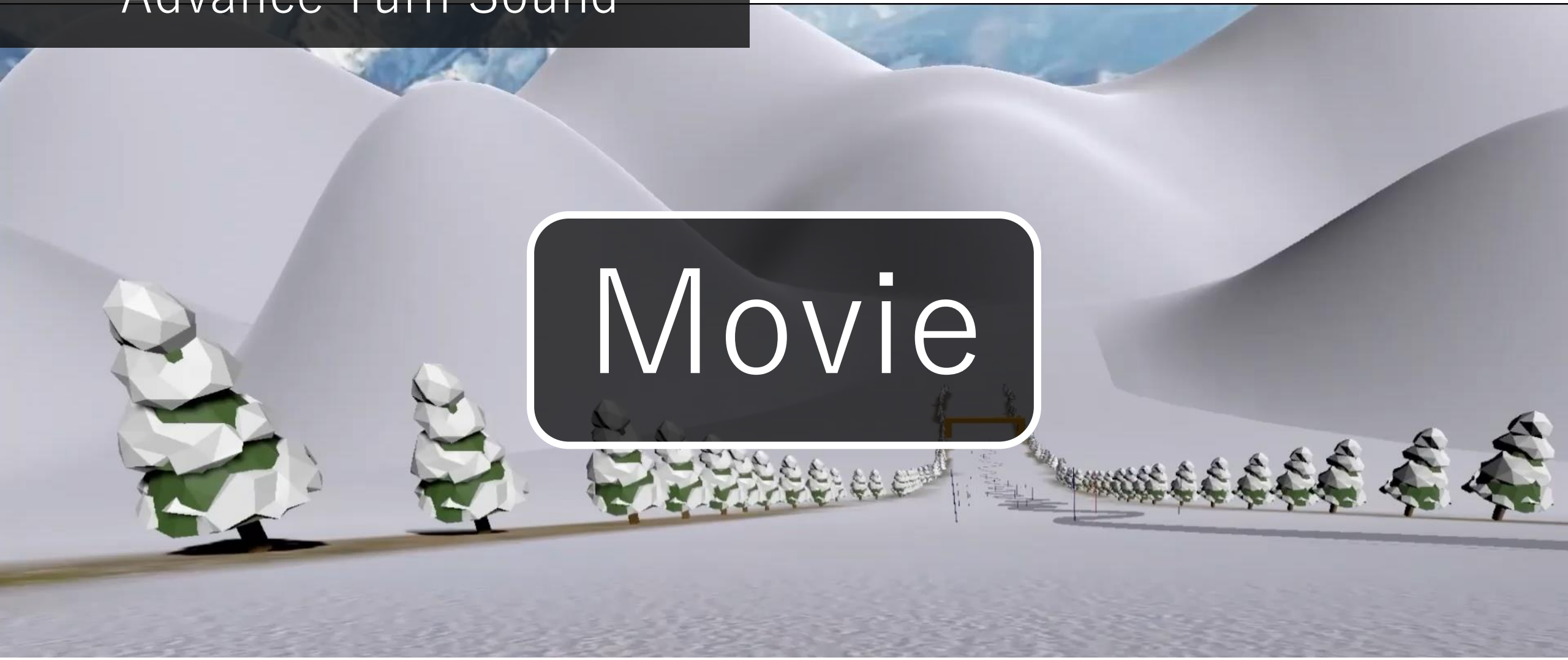
The Deeper the Next Turn, the Higher the Pitch



Direction of the Next Turn = Emission Direction

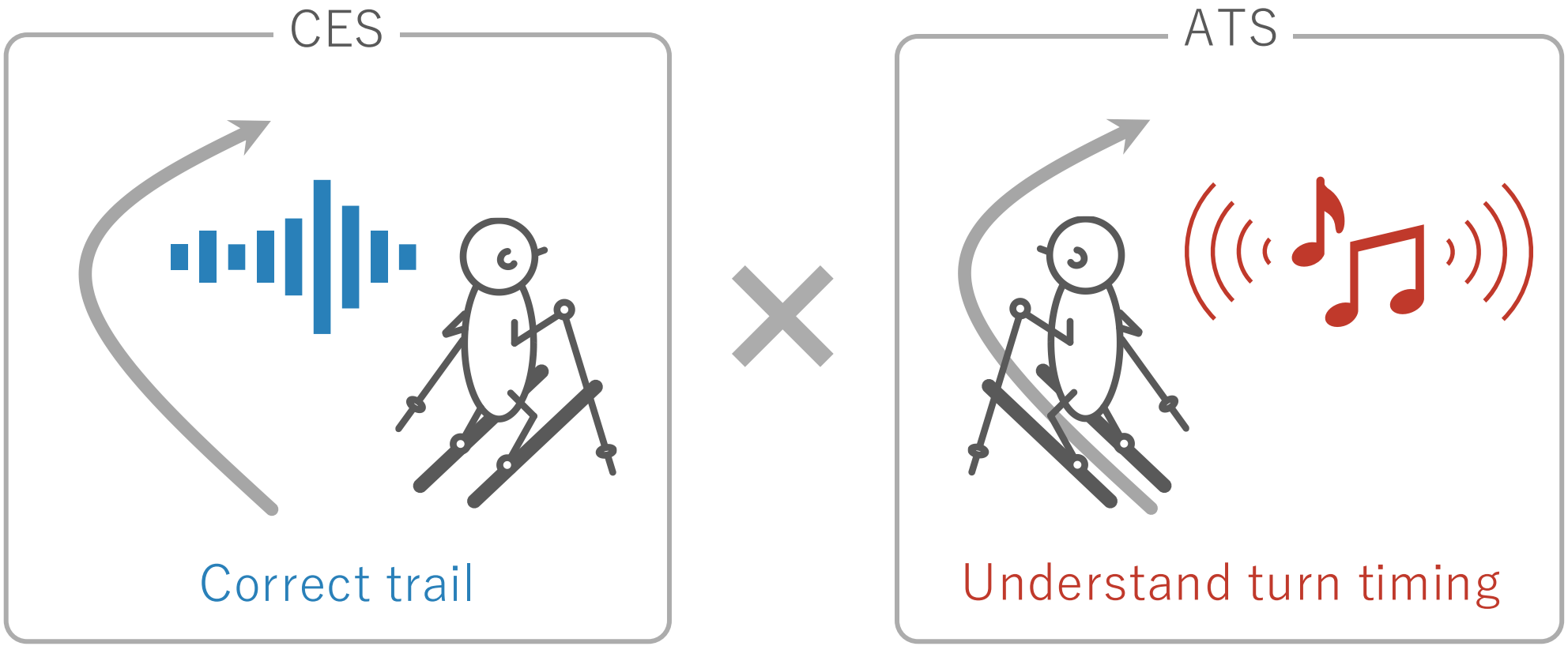


Advance Turn Sound



Mix: Combination of CES and ATS

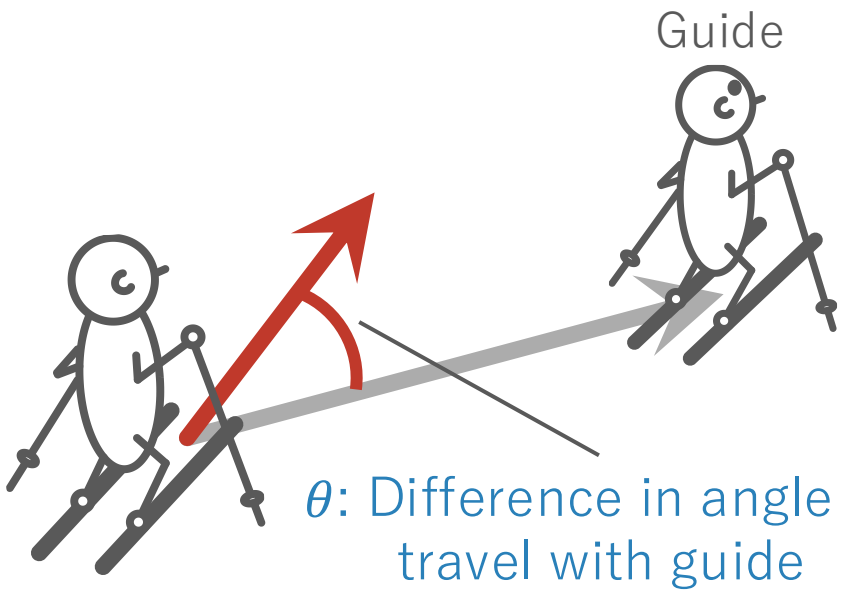
Mix allows users to both correct trail and understand turn timing



CES Emission Conditions to Reduce Cognitive Load

Condition 1

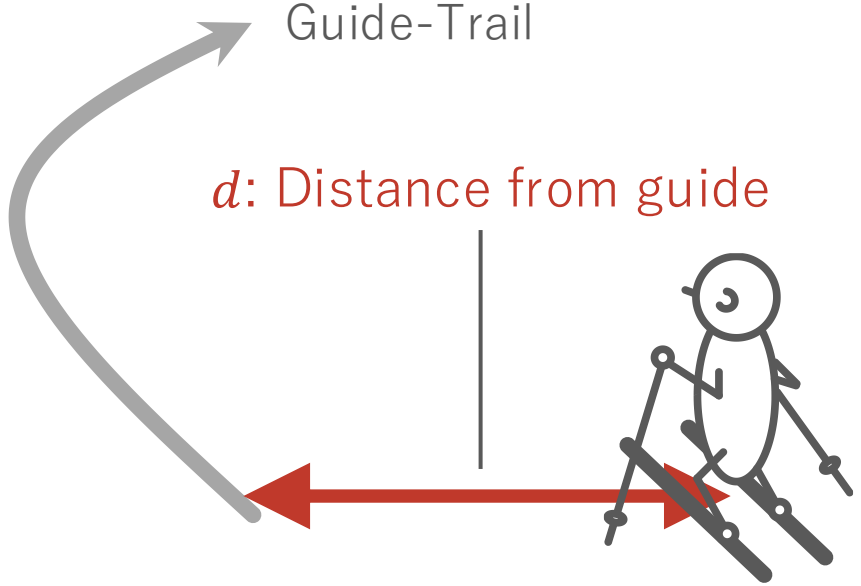
θ is large



OR

Condition 2

d is large



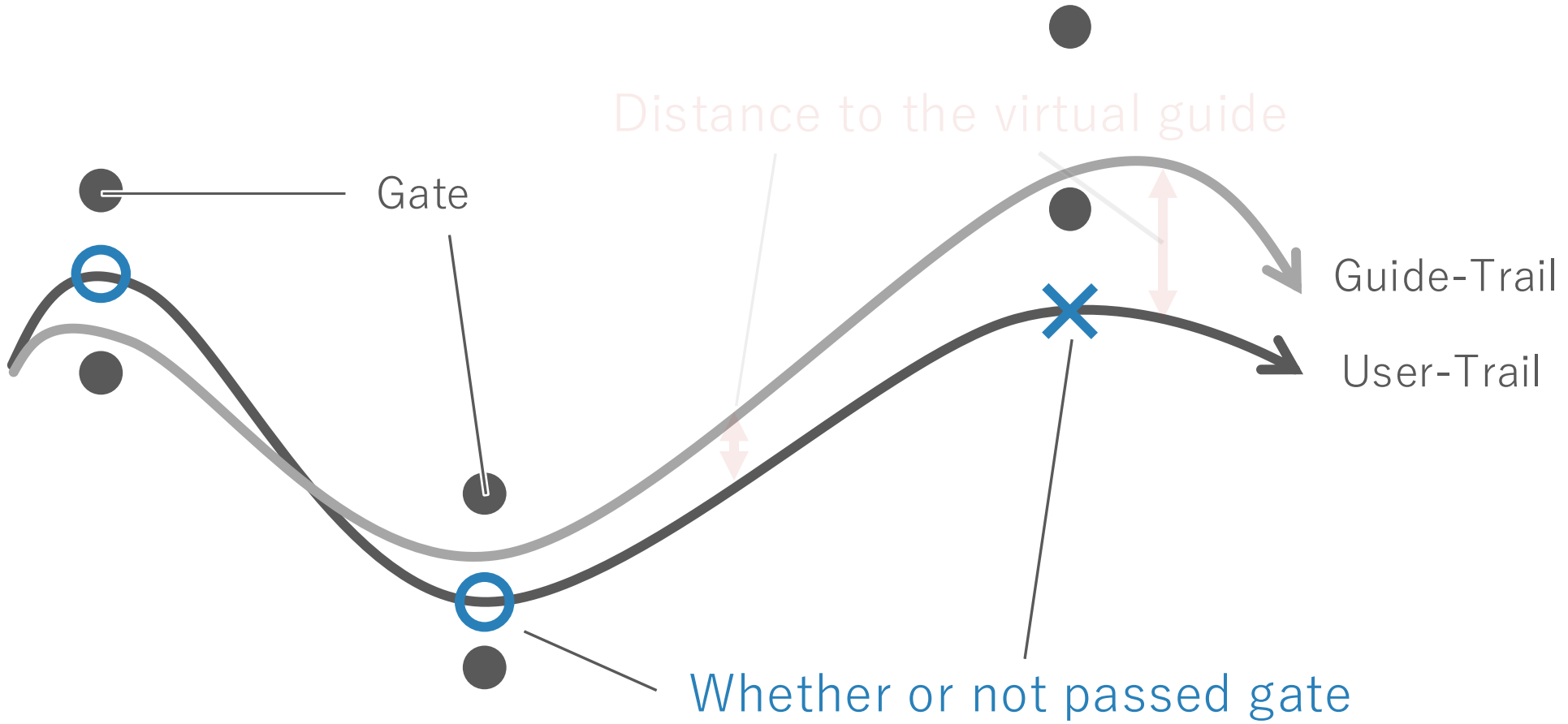
User Study with 4 Visually Impaired People

Experimental Conditions

Condition	Guide	CES	ATS	Mix
				
Device	Voices	Speakers	Speakers	Speakers
Total trial number	2 × 4 users	2 × 4 users	2 × 4 users	2 × 4 users

Evaluation Measurements

1. Number of gates passed and 2. Mean distance to the virtual guide



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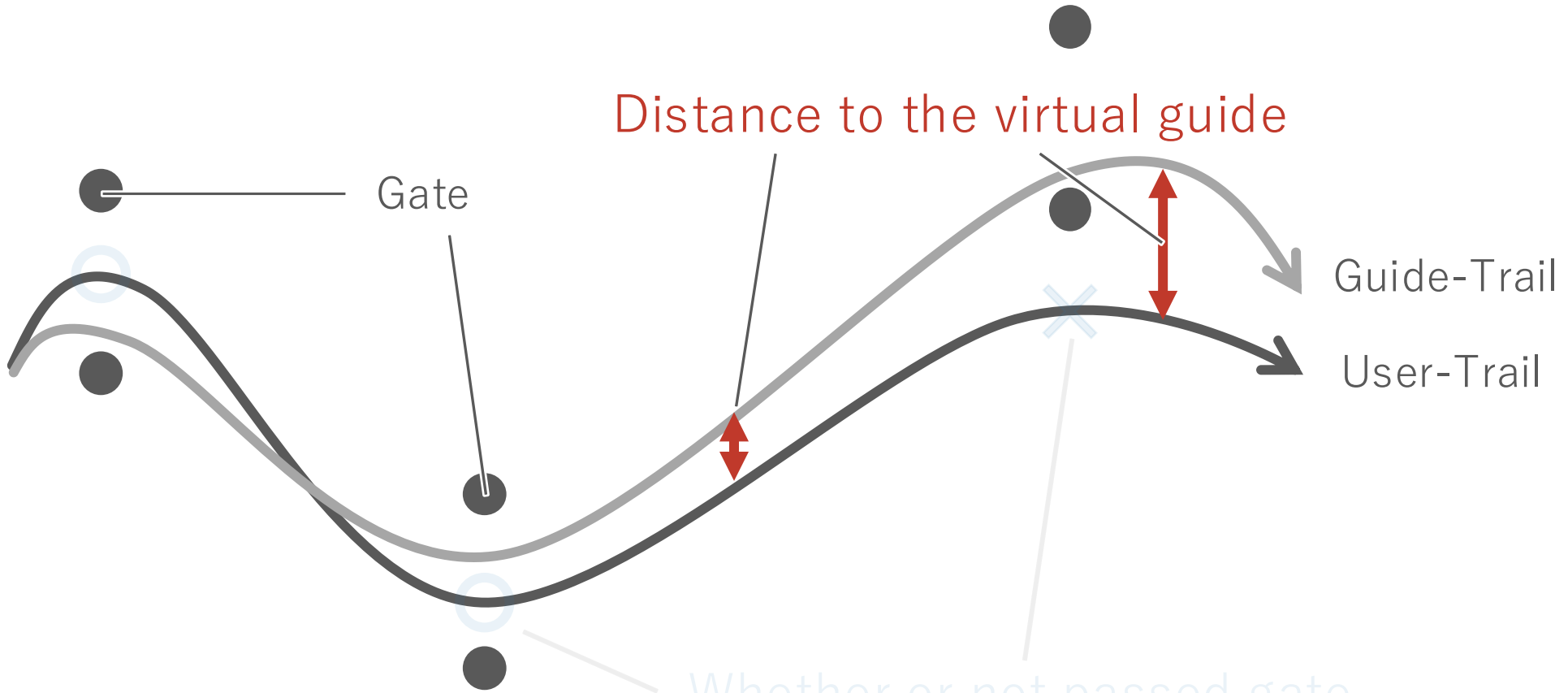
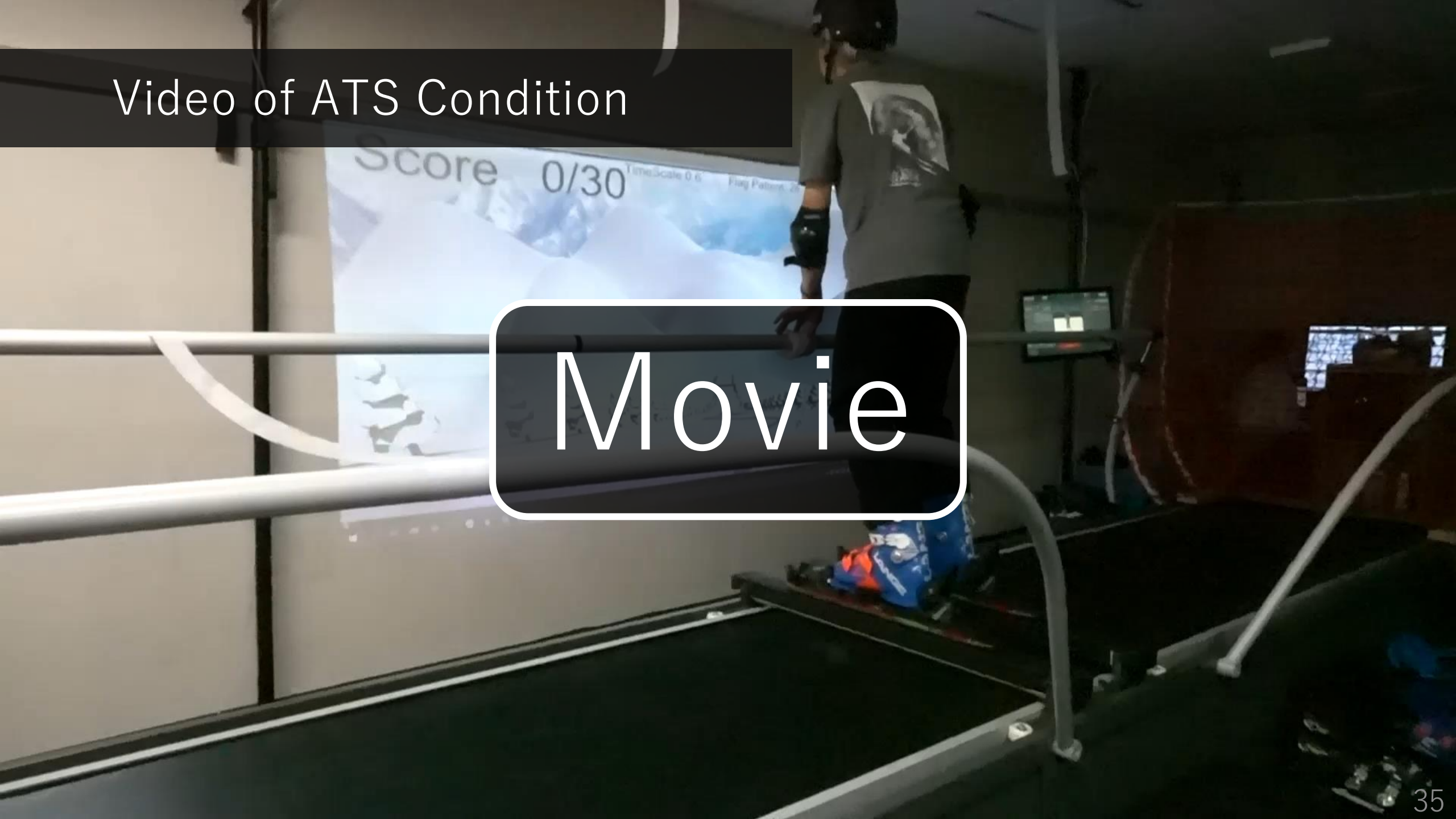
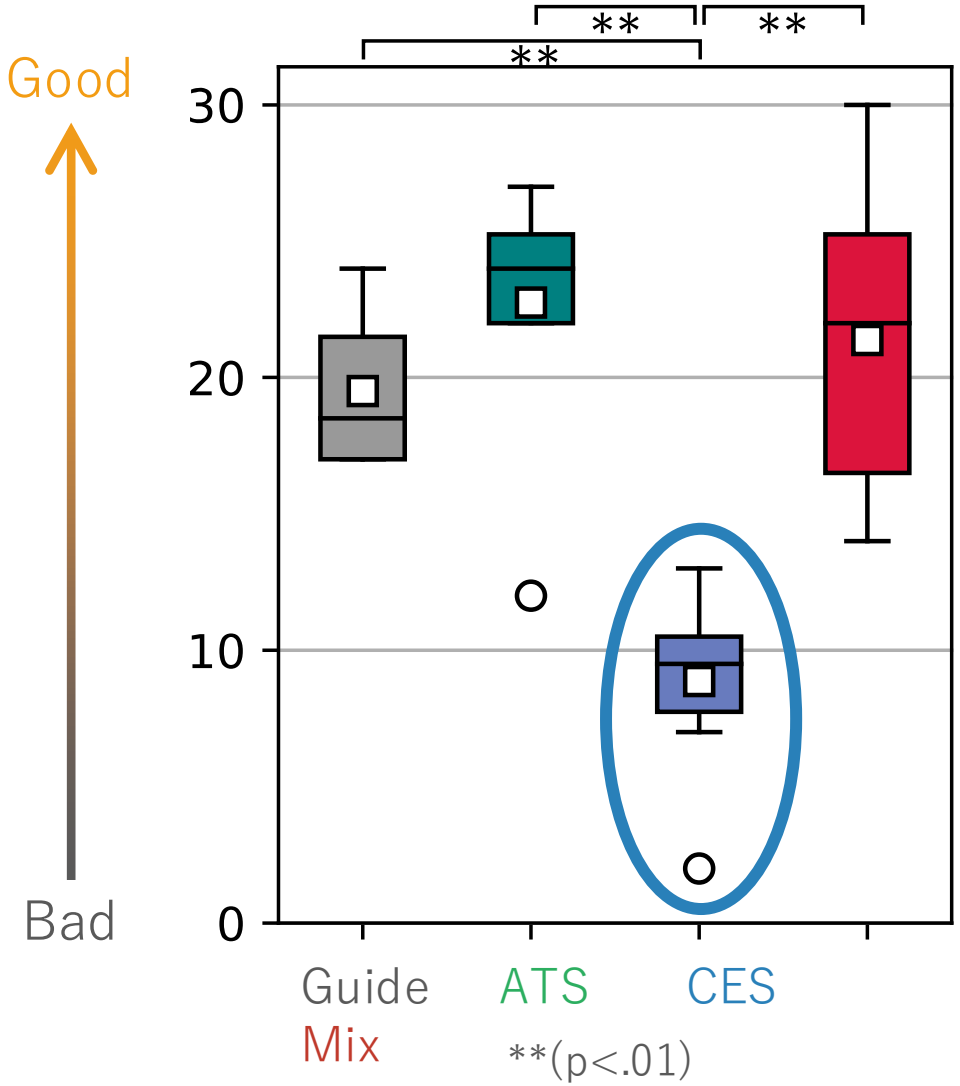


Video of ATS Condition



Result - Number of Gates Passed

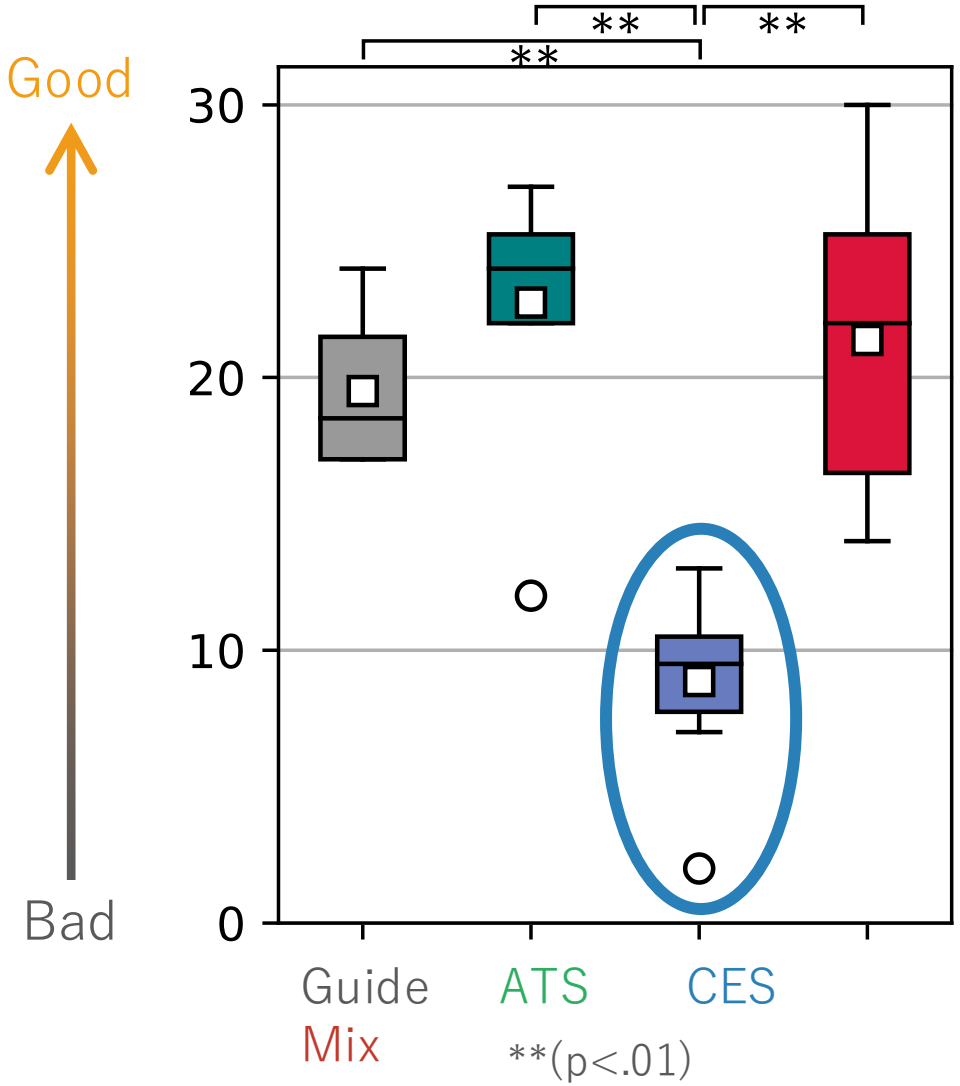


In CES condition:

Number of gates passed

was significantly smaller

Result - Number of Gates Passed



In CES condition:

Number of gates passed

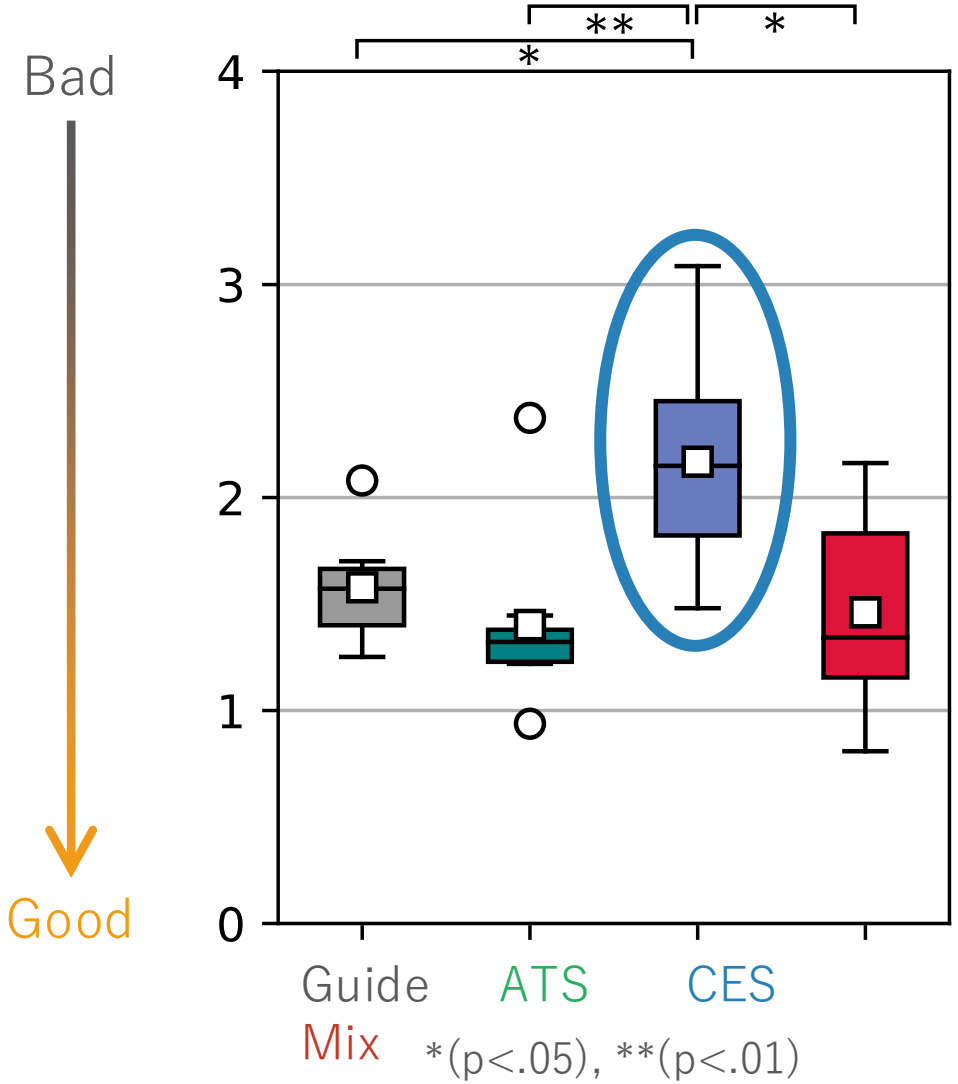
was significantly smaller

Cause:

CES is not feedback

according to the position of gates

Result – Mean Distance to the Virtual Guide

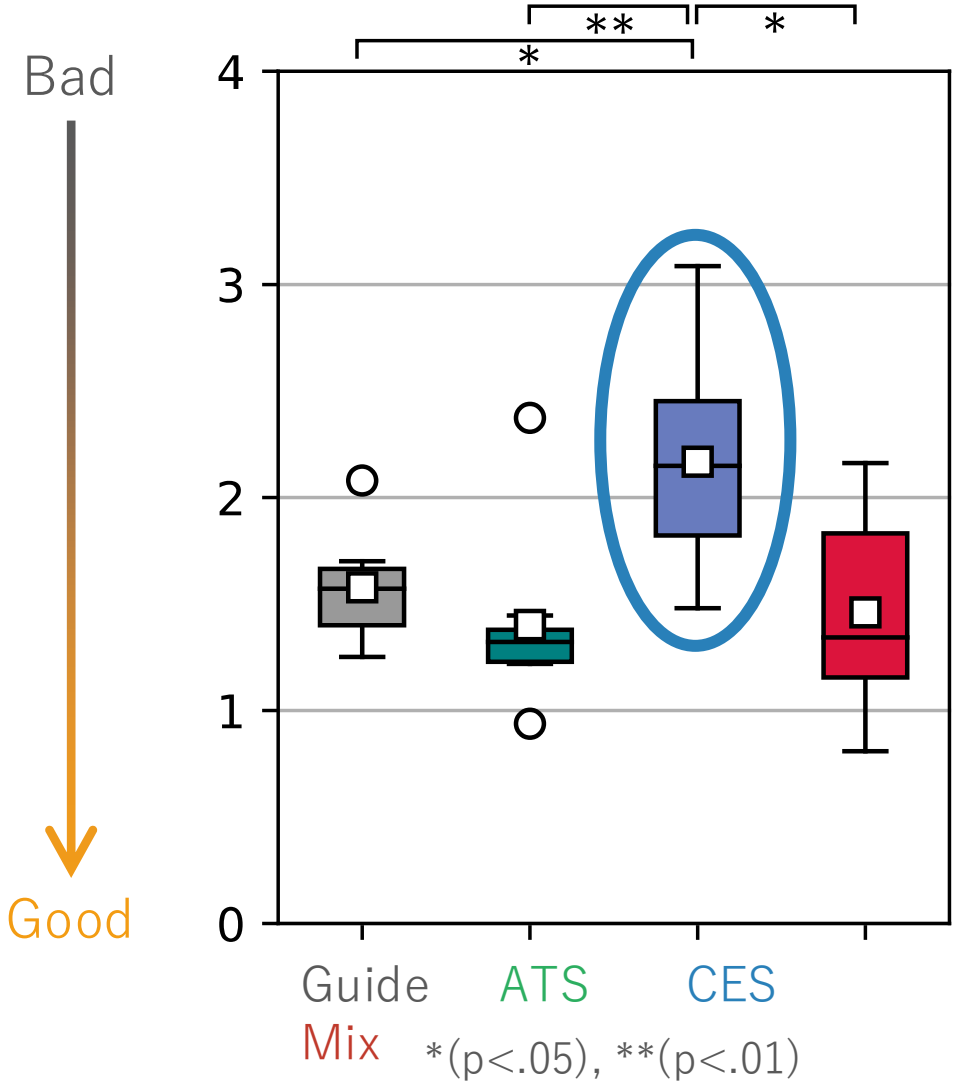


In CES condition:

Mean distance to the virtual guide

was significantly larger

Result – Mean Distance to the Virtual Guide



In CES condition:

Mean distance to the virtual guide

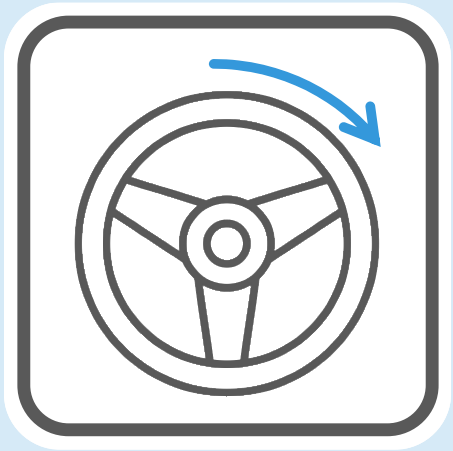
was significantly larger

Therefore:

CES is not effective for trail-following

in the ski simulator

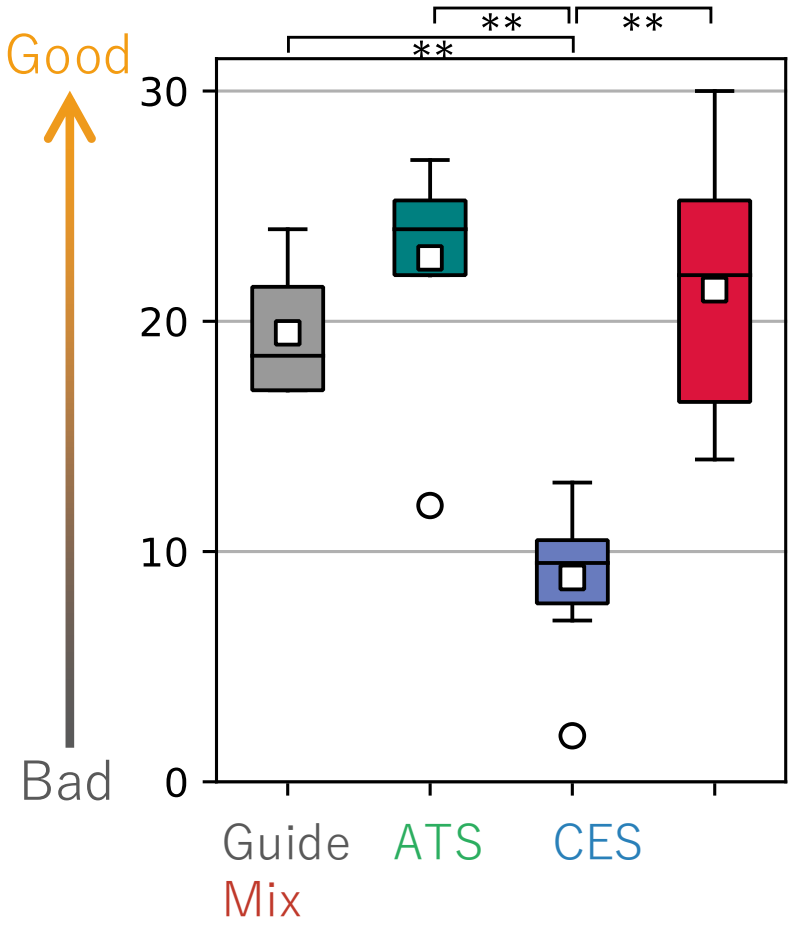
Why Was CES Not Effective in the Ski Simulator?

Task	Driving Simulator	Ski Simulator
		
Way to turn	Use handle	Use entire body with center of gravity shift
Sudden turn	Easy	Hard

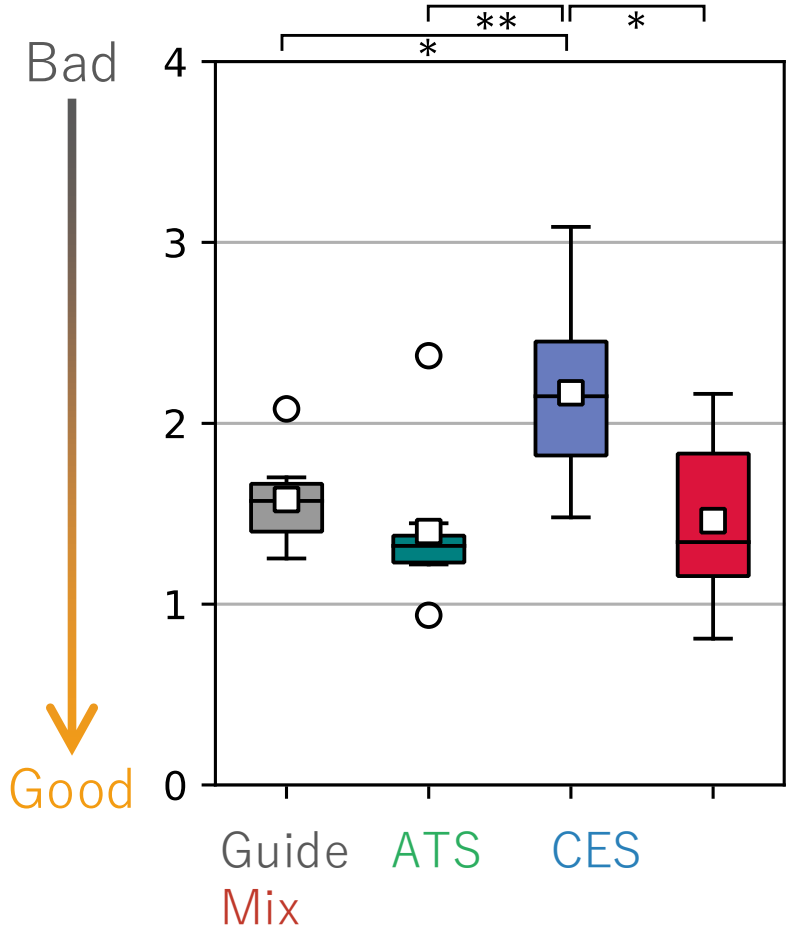
CES is inappropriate in situations involving repetitive speedy turns

There Are No Significant Differences Except for CES

Number of gates Passed

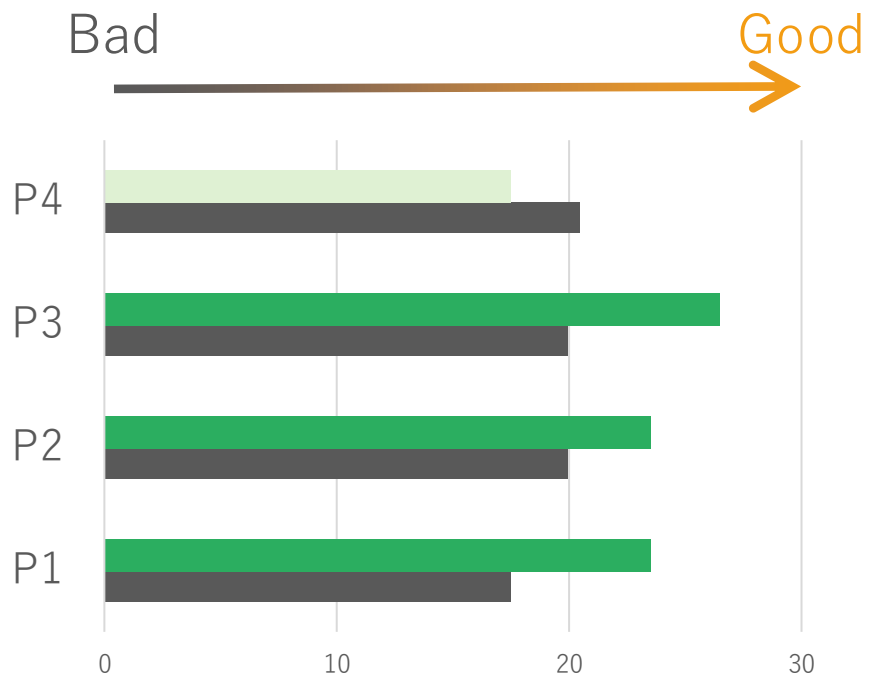


Mean distance to the virtual guide

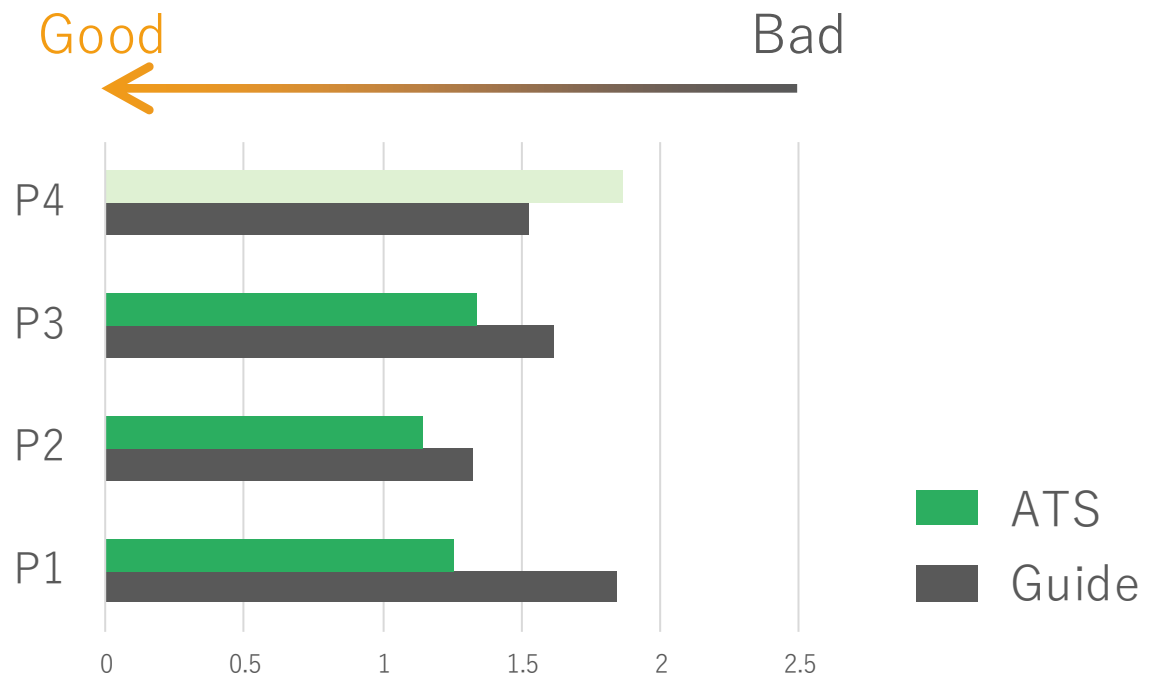


3 out of 4 Perform Best in ATS Condition

Number of gates passed



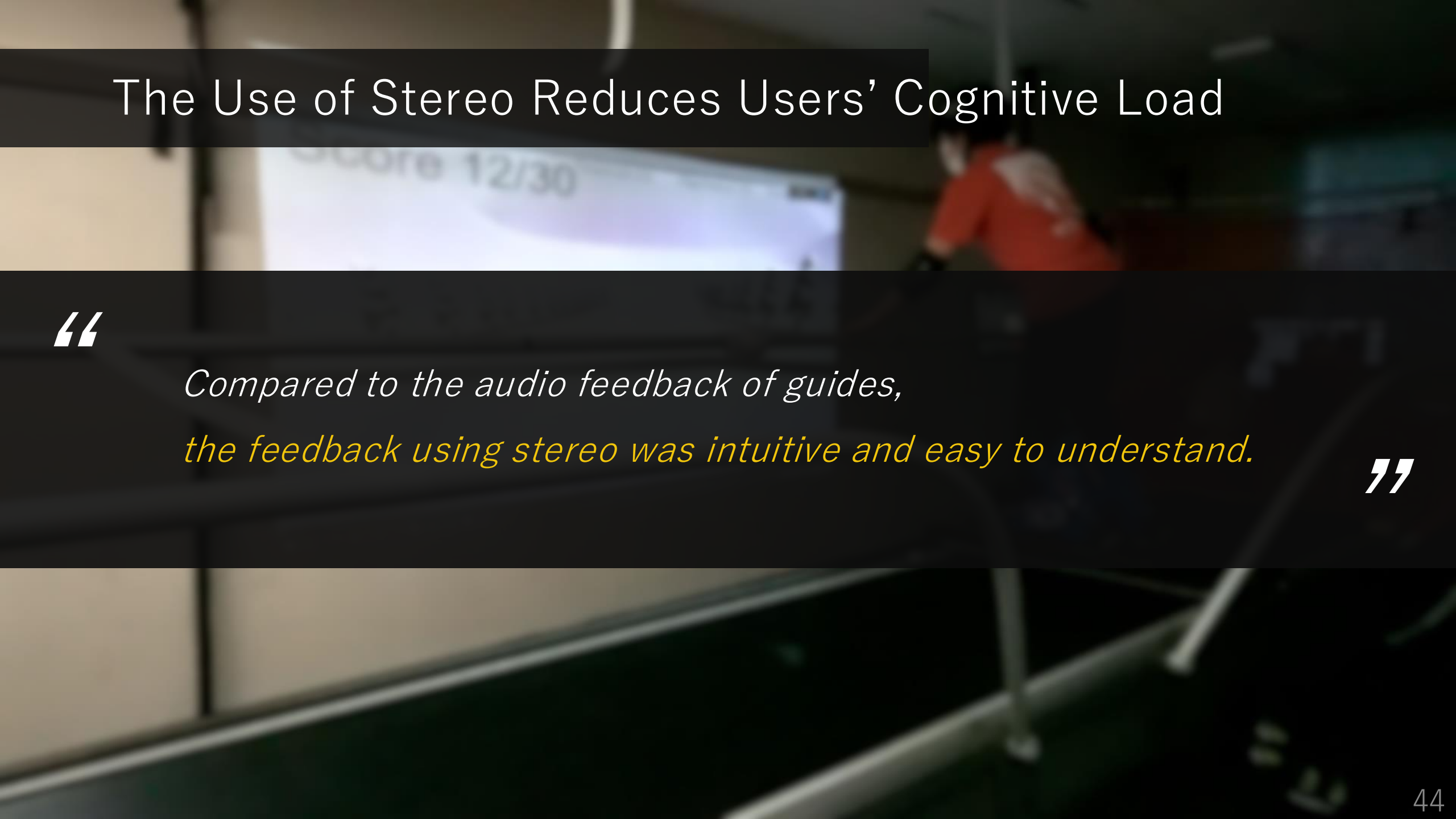
Mean distance to the virtual guide



ATS Allows Turn Preparation

“I was able to understand the information about the turn in advance and prepare for the next turn.”

The Use of Stereo Reduces Users' Cognitive Load



"

Compared to the audio feedback of guides,

the feedback using stereo was intuitive and easy to understand.

"

Future Work① – Emission Timing of ATS

“I could understand the meaning of ATS,

but I turned as soon as I heard the sound.”

The optimal emission timing of ATS varies from user to user

Idea

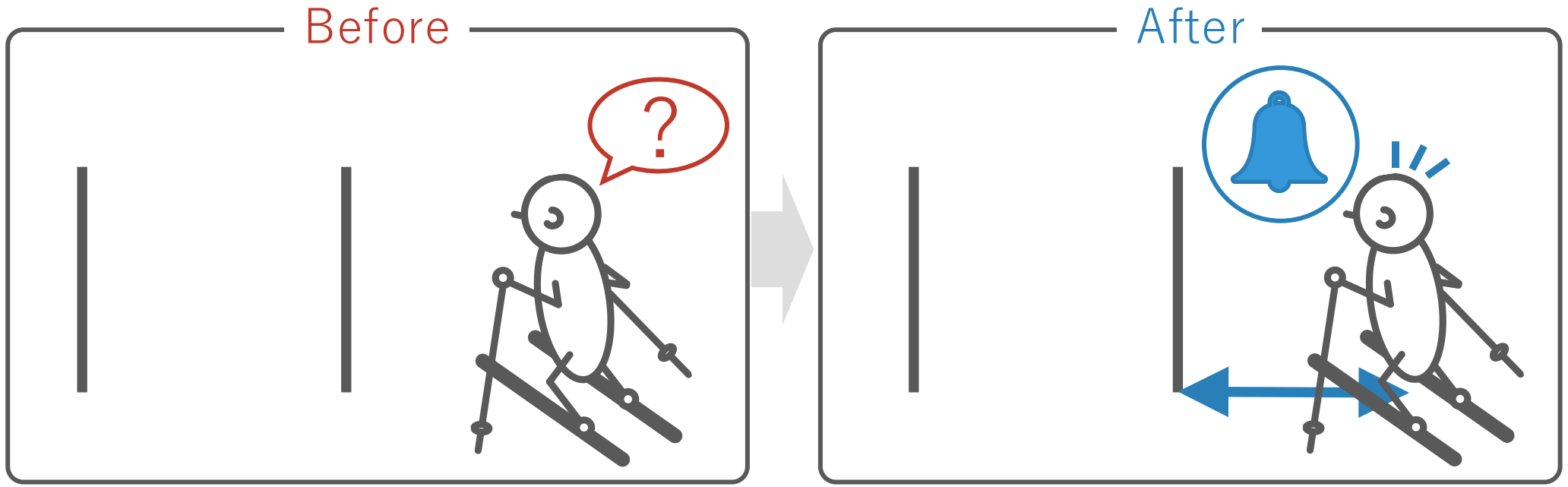
Change the emission timing according to individual preferences

Future Work② – Improvement of Gates Passed Sound

Limitation: No feedback is provided if users fail to pass through gates

Idea

Emit sound according to the distance from an inner gate if users fail



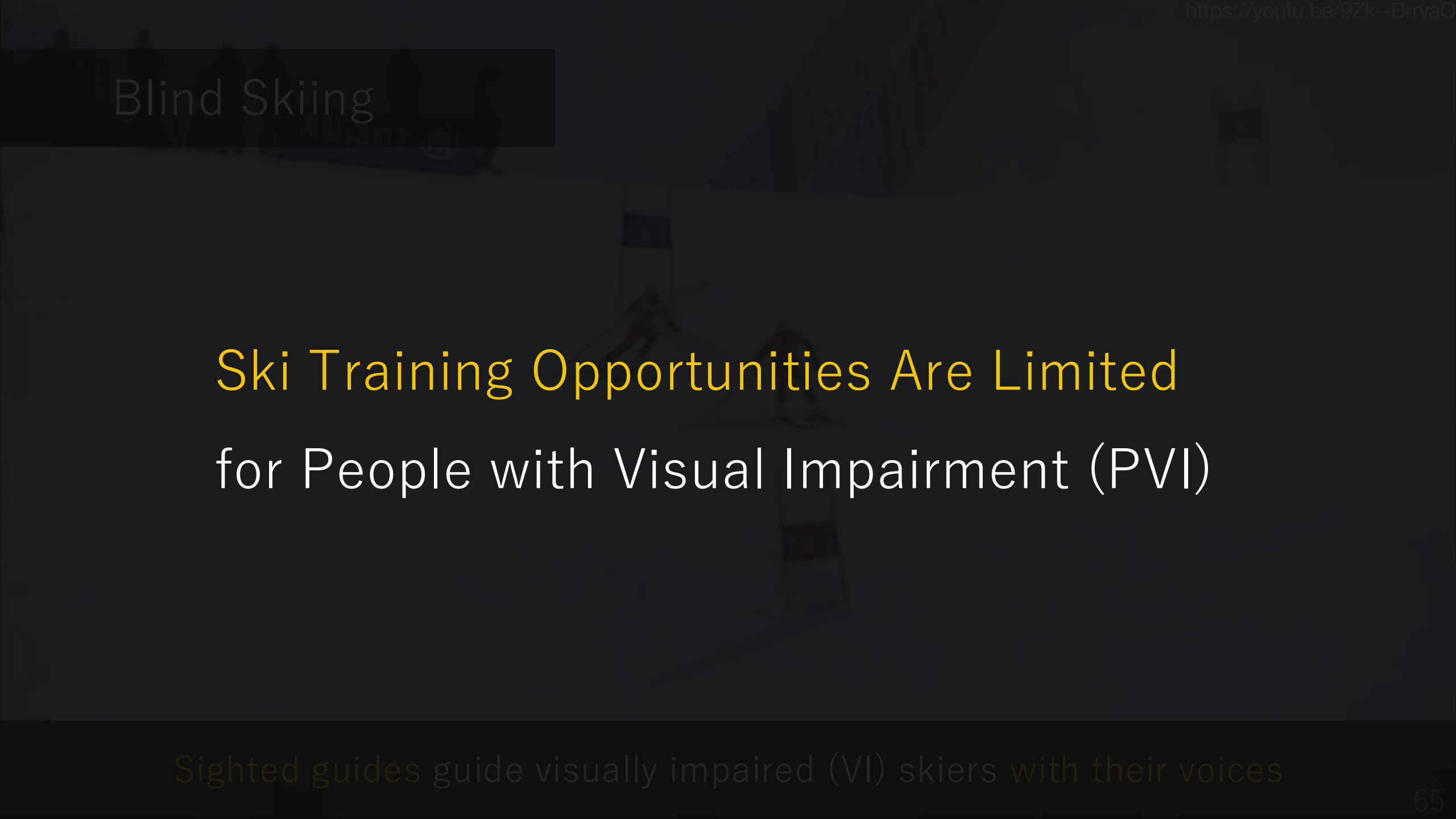
We Explored the Sonification Feedback to Assist PVI in Independent Ski Training

Based on the previous study and the interview with VI skiers and guides, we designed CES and ATS

Our user study revealed:

- CES significantly decreases the mean distance to the virtual guide
- ATS can be as effective as feedback given by human guides

Appendix


https://youtu.be/9Zk--BrrvaQ
Blind Skiing
Ski Training Opportunities Are Limited
for People with Visual Impairment (PVI)
Sighted guides guide visually impaired (VI) skiers with their voices

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Bumski
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SLOPES
www.GRAVITYSLOPES.com

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https://www.ski-simulator.com/