



Effects of Virtual Reality Feedback on Indirect Vision Performance in Minimally Invasive Endodontic Operations

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Motivation

Motivation - Problem Statement

- For dental operation, mirror handling is crucial.
- Realistic environment with VR and haptic technology
- Psychomotor skill acquisition requires context-specific designs [1].
- Practicing motor skills with computer generated guidance methods found to be beneficial [2, 3].

However, practicing mirror handling for dental operation with guidance is under-investigated.

[1] HH Kaufman, RL Wiegand, and RH Tunick. "Teaching surgeons to operate—principles of psychomotor skills training." In: *Acta Neurochirurgica* 87.1 (1987), pp. 1–7.

[2] Sara Samuel, Carmine Elvezio, Salaar Khan, Laureen Zubiaurre Bitzer, Letty Moss-Salentijn, and Steven Feiner. "Visuo-haptic vr and ar guidance for dental nerve block education." In: *IEEE Transactions on Visualization and Computer Graphics* (2024).

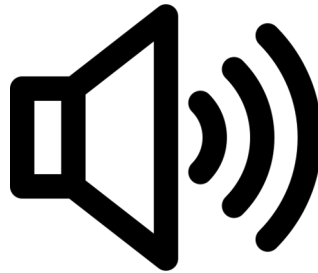
[3] Laura Marchal Crespo and David J Reinkensmeyer. "Haptic guidance can enhance motor learning of a steering task." In: *Journal of motor behavior* 40.6 (2008), pp. 545–557.

Motivation - Aims

Explore and compare 3 mirror guidance methods for practicing
minimally invasive endodontic access cavity preparation



Visual guidance



Verbal guidance



Haptic guidance

Motivation - Research Questions

R1: How effective was each guidance methodology in terms of **task execution** performance in comparison to other conditions?

R2: How effective was each guidance methodology in terms of **mirror handling** performance in comparison to other conditions?

R3: What was the **users' perception** of the system?

Motivation - Hypotheses

H1: Users of the system with guidance would perform better in task execution than users of the system without guidance.

H2: Users who used the system with guidance would perform better in terms of mirror handling than users who used the system without guidance.

H3: Users would perceive the system with guidance as more positive than the system without guidance.

Related Work

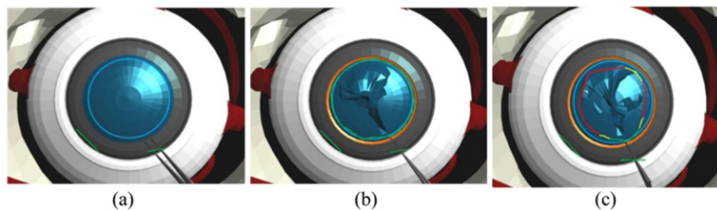
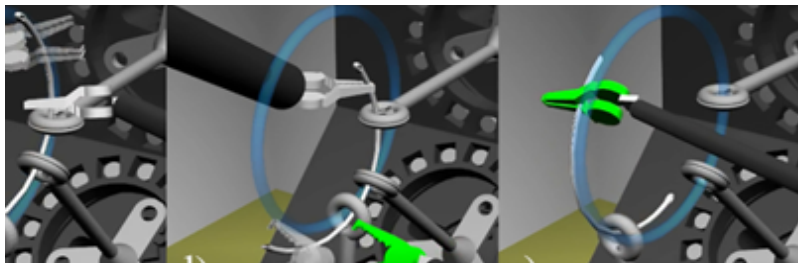
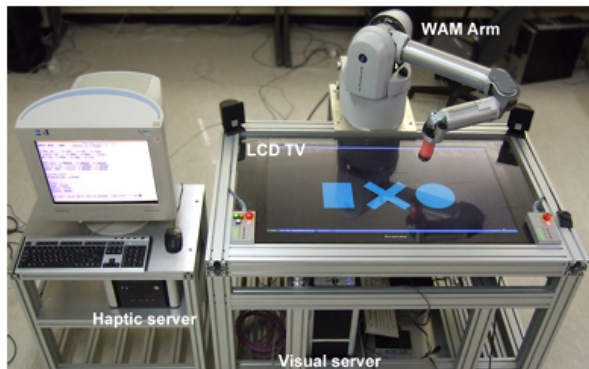


Fig. 4 Visual guidance for capsulorhexis – a ideal, b accurate and c least-accurate trajectories



FIGURE 1. (A) Participant driving the wheelchair simulator. (B) Top view of the pathway the participants were required to complete.

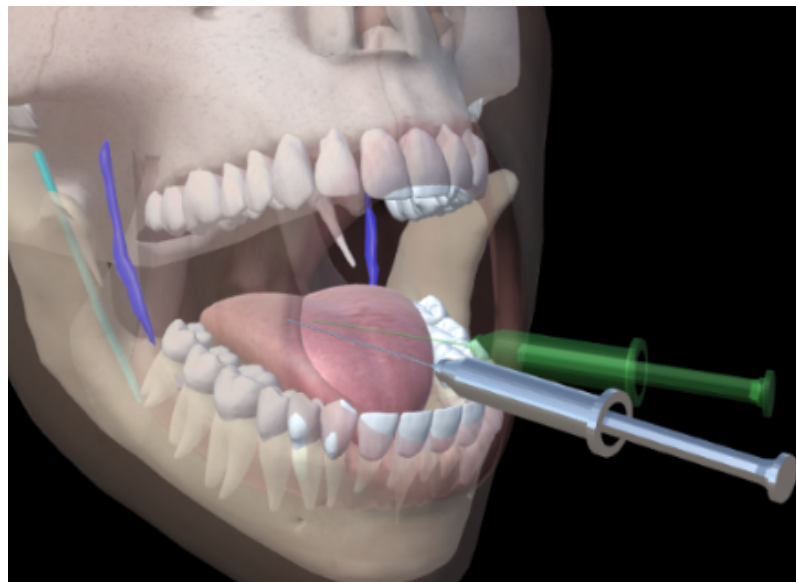


Figure 1: Experiment in progress. Visual (left), haptic (center), and haptic + visual conditions.

Related Work - Visuo-Haptic VR and AR Guidance for Dental Nerve Block Education

- A system for practicing inferior alveolar nerve block in VR environment
- Provided force feedback on the syringe and dynamic visual guidance
- **Result**: Students were more confident and had better performance in the real situation.

Takeaway: Practicing in a realistic digital environment with guidance yield a positive outcome on the trainees.



System Overview

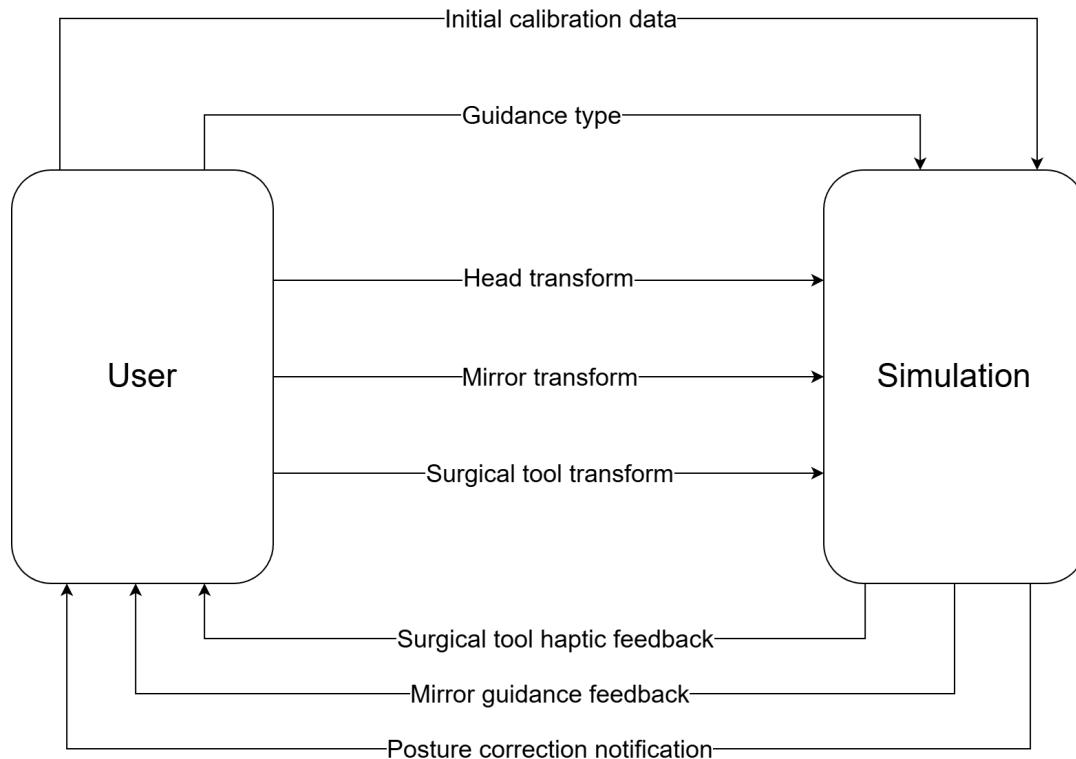
System Overview



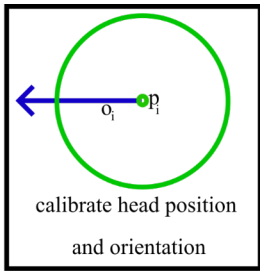
- Developed from Dental Simulator
- Implemented posture notification for ergonomics
- Implemented 3 guidance methods (visual, verbal, and haptic)

source: cgvr.cs.uni-bremen.de/research/dentalsim/

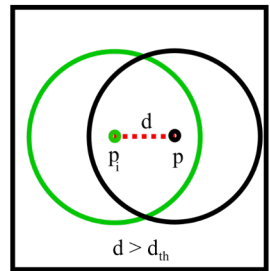
System Overview | Data Flow



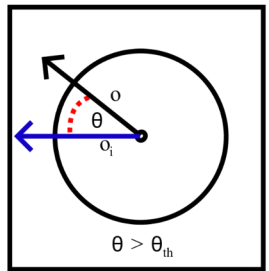
Algorithms and Methodology



If



or



No



Yes



Play notification sound

Posture Correction

Mirror Correction - Guidance Conditions



Condition 1

mirror is outside of
the optimal area



Condition 2

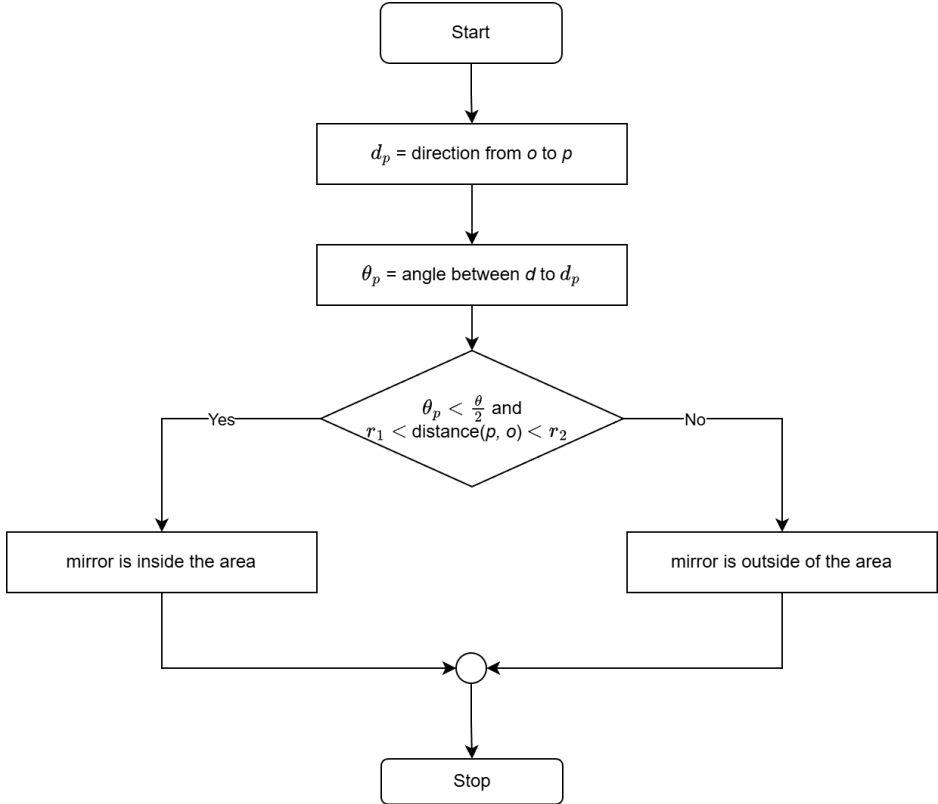
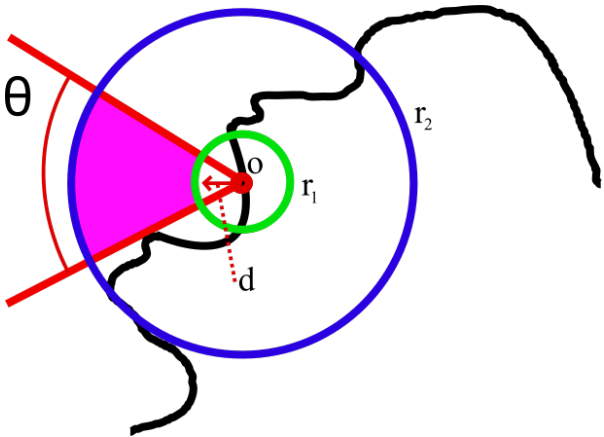
mirror oriented
incorrectly



Condition 3

surgical tool blocks
line-of-sight

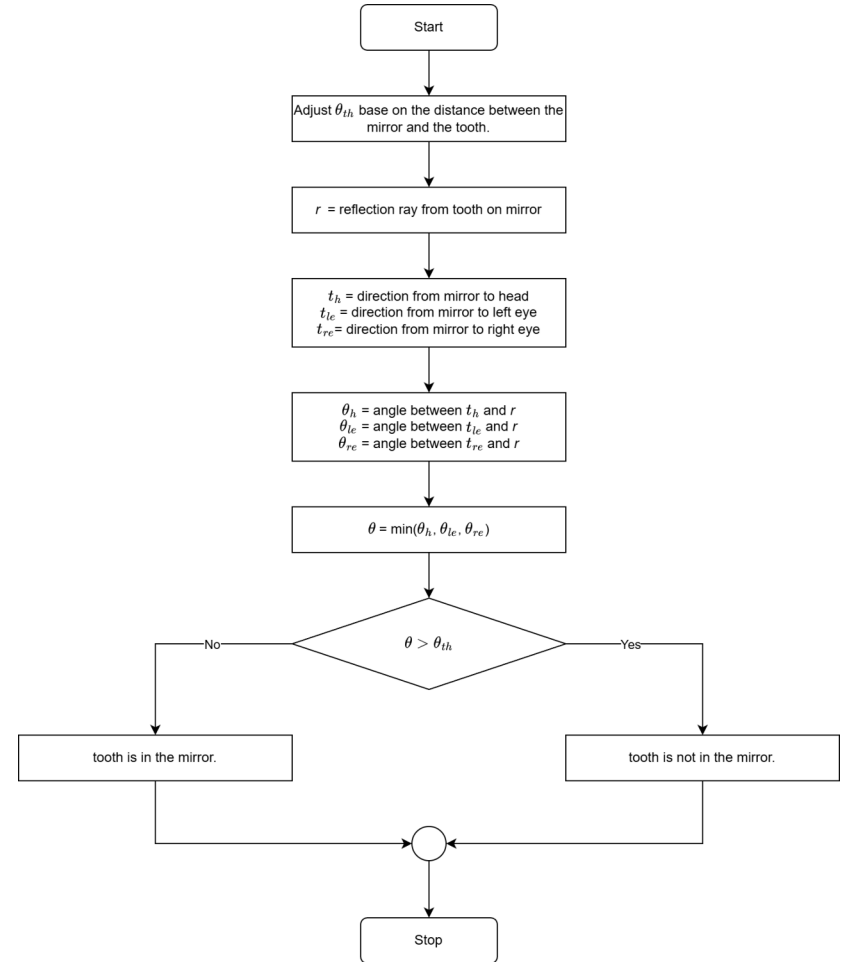
Mirror Correction - Condition 1 - Optimal Area



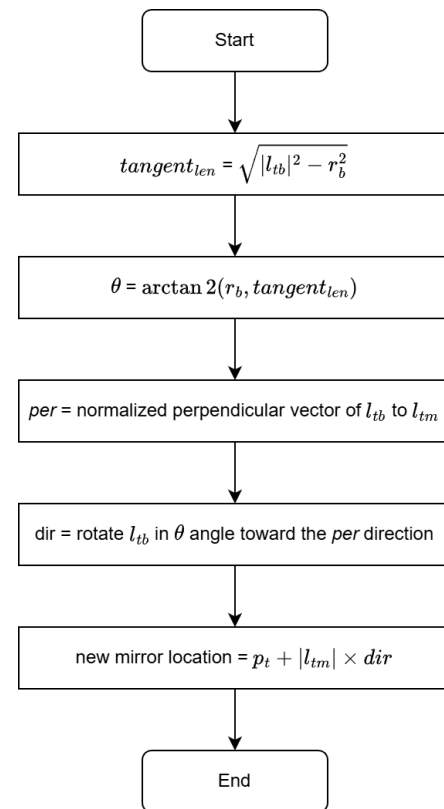
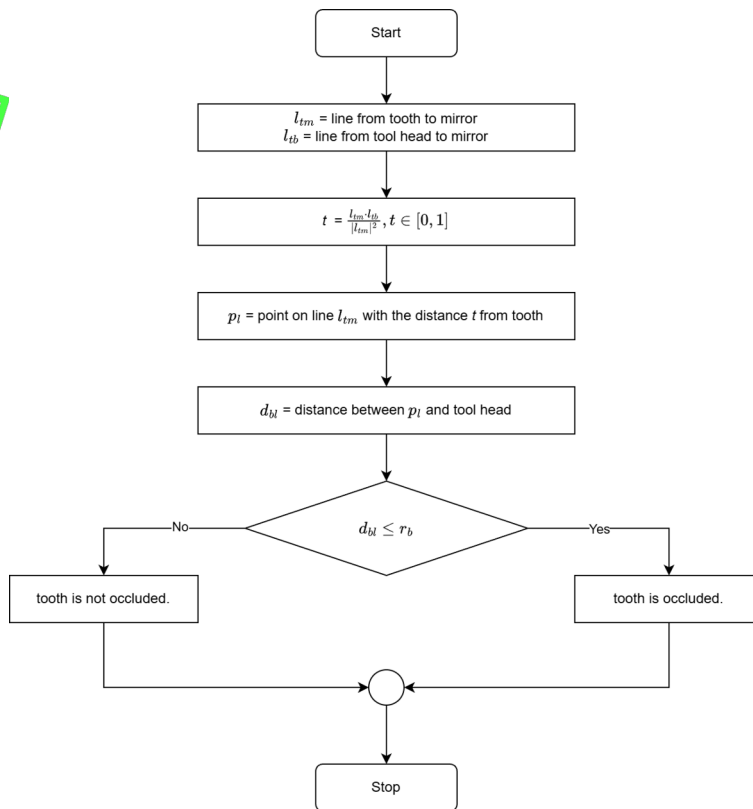
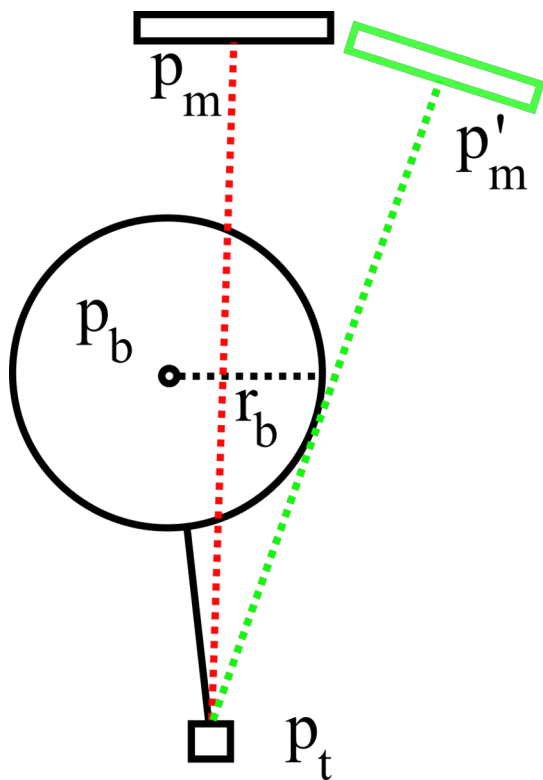
Mirror Correction

Condition 2

Incorrect Mirror Orientation

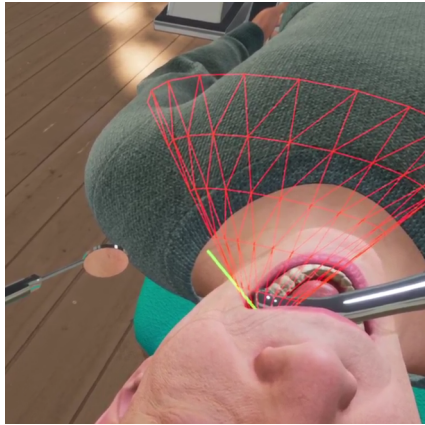


Mirror Correction - Condition 3 - View Blocked



Guidance Implementation

Visual Guidance



Condition 1

mirror is outside of
the optimal area



Condition 2

mirror oriented
incorrectly



Condition 3

surgical tool blocks
line-of-sight

Verbal Guidance

Conditions	mirror is outside of the optimal area	mirror oriented incorrectly	surgical tool blocks line-of-sight
Messages	move mirror to the mouth	adjust mirror	tooltip not visible

Haptic Guidance

save the last location where the tooth is visible in the mirror

Condition 1 - mirror is outside of the optimal area

- Apply haptic force toward the previously seen tooth location inside optimal area

Condition 2 - mirror oriented incorrectly

- Distance is more than threshold, apply haptic force toward the previously seen location
- Distance less than threshold, apply haptic noise

Condition 3 - surgical tool blocks line-of-sight.

- Apply haptic force toward the suggested mirror position

Video Demo

Mirror Guidance Feedback Demonstration

User Study

Study Design

Randomized Balanced 4x4 Latin
Square Crossover Design

Sample Size: 20
(G*Power version 3.1.9.2)

Requirements:

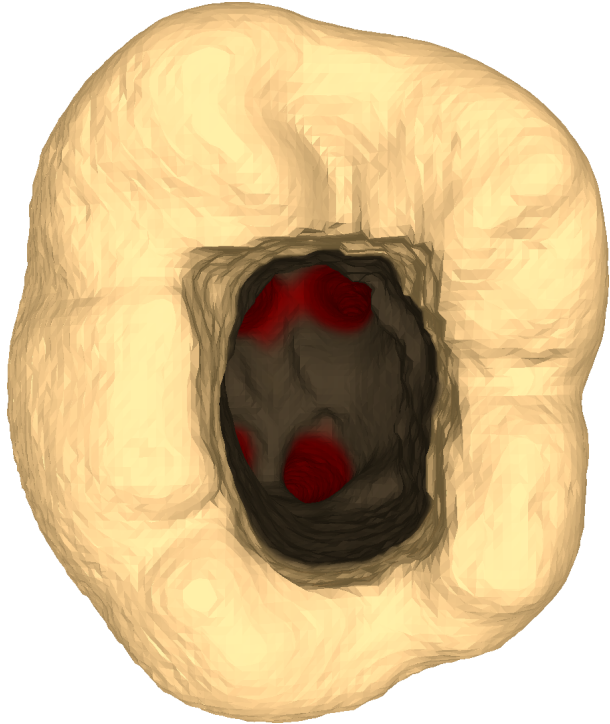
- fourth-year undergraduate dental students
- completed the endodontic course
- no prior experience with the VR dental simulator

Study Design

	Day 1	Day 2	Day 3	Day 4
Group A	Verbal Guidance	Visual Guidance	Haptic Guidance	No Guidance
Group B	Visual Guidance	Haptic Guidance	No Guidance	Verbal Guidance
Group C	Haptic Guidance	No Guidance	Verbal Guidance	Visual Guidance
Group D	No Guidance	Verbal Guidance	Visual Guidance	Haptic Guidance

(48 hours washout period between each day)

Study Design - Task



- Perform drilling task on the second innermost tooth on the upper left side of the jaw
- Goal: 3 root canals of the tooth become visible

Data Collection

Performance Outcome

- Outcome error score
- Task completion time (sec)

Mirror Handling Outcome

- Tooth visibility duration(sec)
- Incorrect mirror orientation: amount (n) and duration (sec)
- Mirror occlusion: amount (n) and duration (sec)

Questionnaire Results

- Virtual Reality System Usability Questionnaire (VRSUQ)
- Participants' comment

Other

- Incorrect posture: amount (n) and duration (sec)

Results

Results - Participants Demographics

Age

- range: 22-30 years
- mean: 23.2 years
- SD: 1.85

Vision

- 17 with myopia
- 3 with normal vision

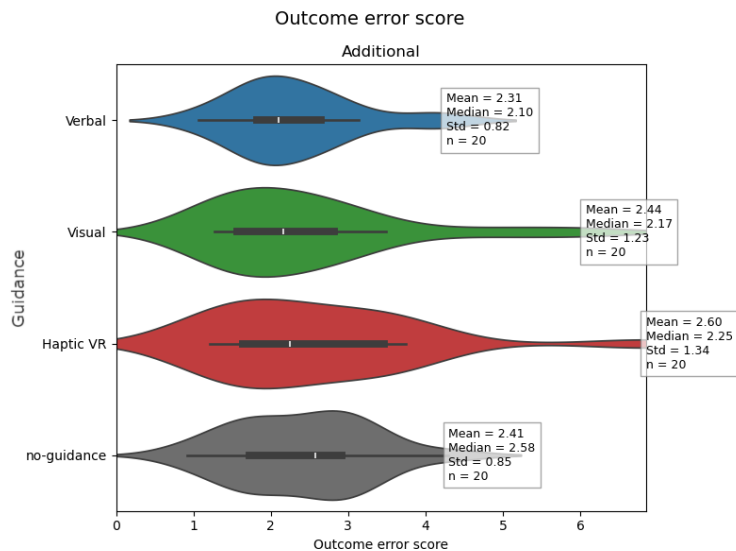
Gender

- 15 female
- 5 male

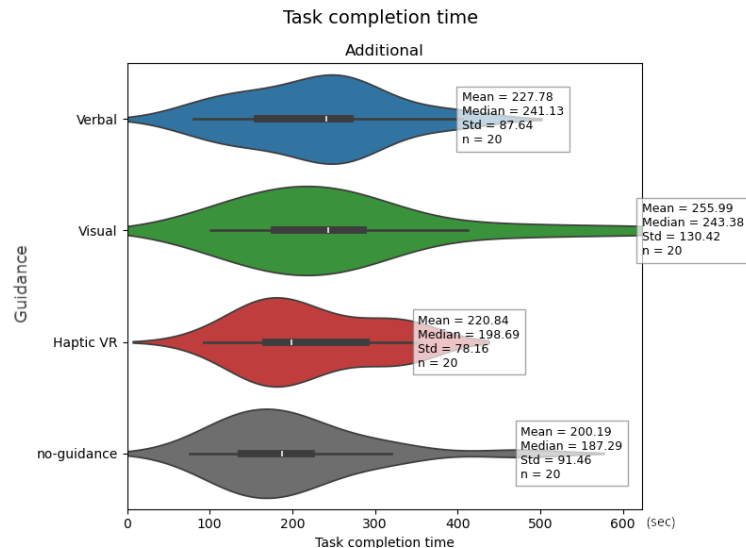
Dominant hand

- All reported right-handed

Results - Task Execution Performance

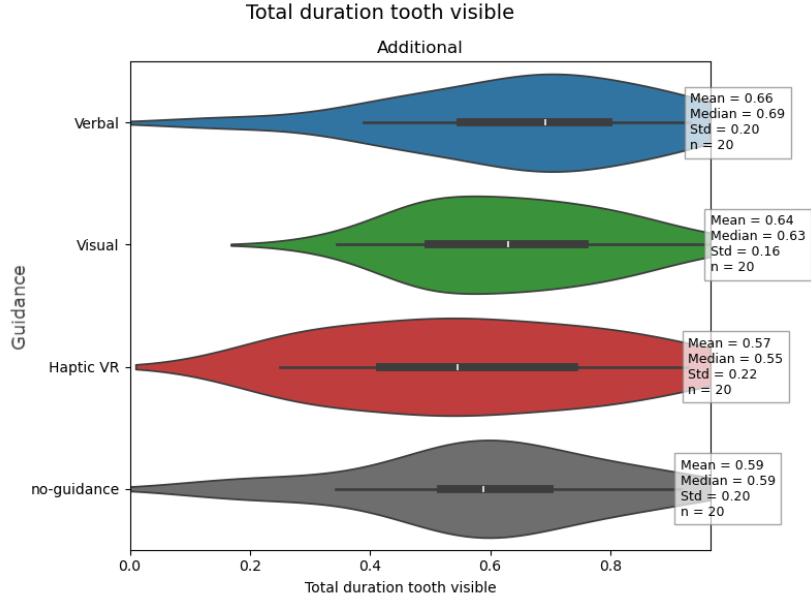


$p > 0.05$



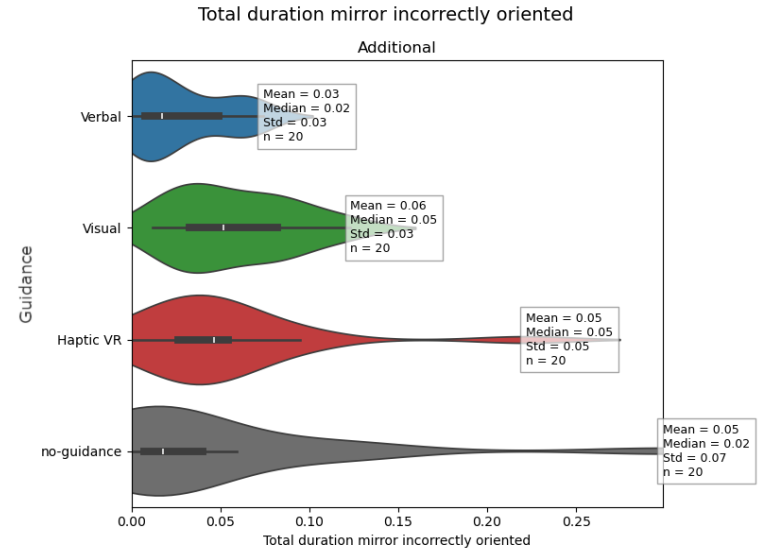
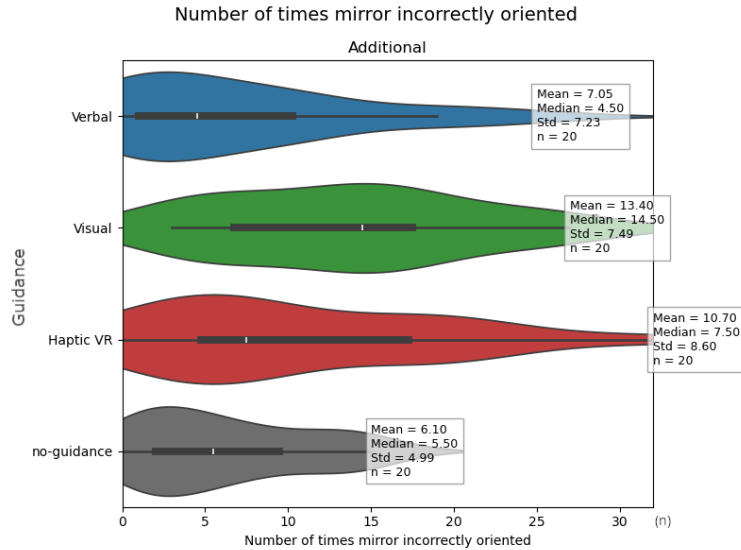
$p > 0.05$

Results - Mirror Handling Outcome - Tooth Visibility



p > 0.05

Results - Mirror Handling Outcome - Mirror Orientation



$p = 0.001$

$p > 0.05$

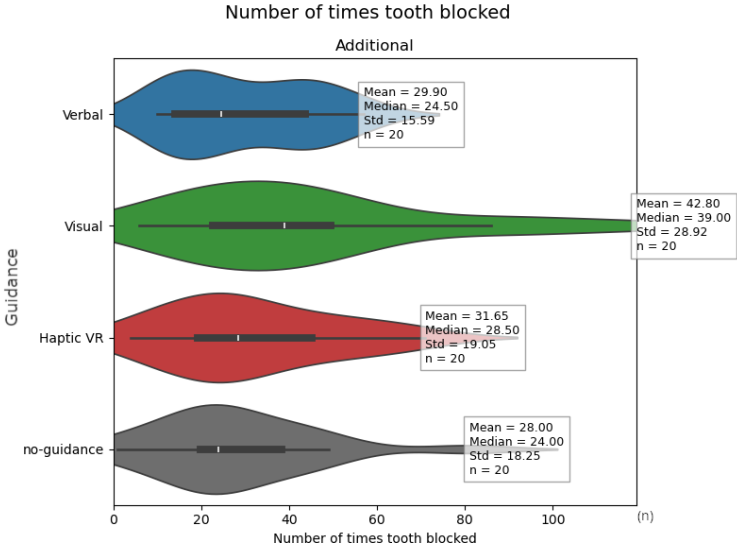
Dunnett's Test

Verbal guidance: $p = 0.537$

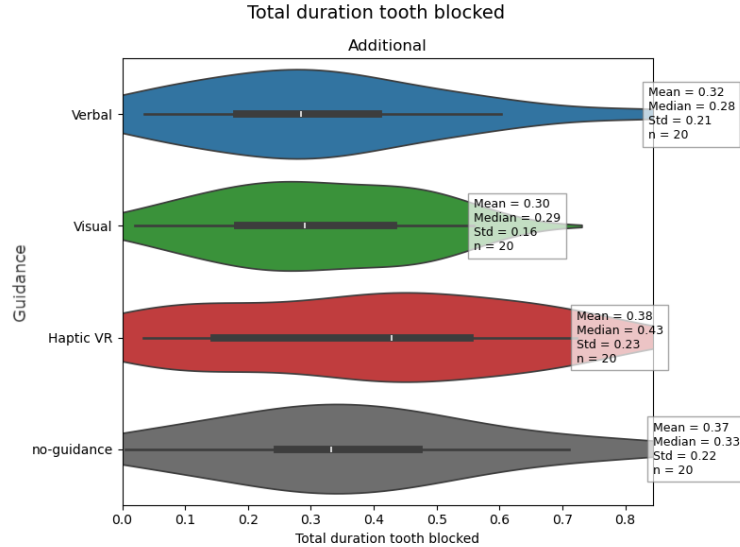
Visual guidance: $p = 0.001$

Haptic guidance: $p = 0.024$

Results - Mirror Handling Outcome - Tooth Blocked

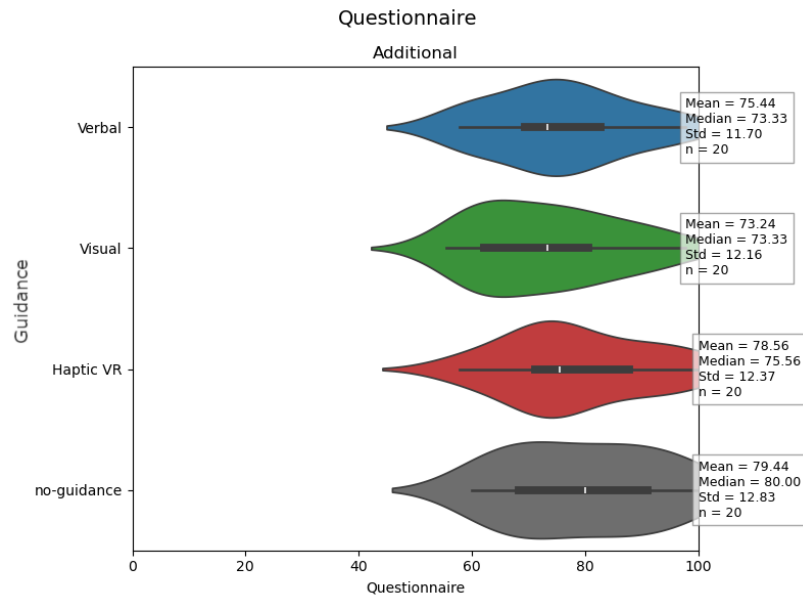


$p > 0.05$



$p > 0.05$

Results - Questionnaire Results



$p > 0.05$

Discussion and Conclusion

Discussion - Result

Task Execution Performance

- None of the guidance produced a clear improvement over the no-guidance condition.

Mirror Handling Performance

- Verbal guidance showed the stable result.
- Visual and haptic guidance may introduce additional challenges to the participants.

User Perception - Quantitative

- No-guidance condition received the highest score.

User Perception - Qualitative

- **Visual guidance:** helpful, but some reported visual obstruction
- **Verbal guidance:** most consistent and helpful
- **Haptic guidance:** mostly negative feedback

Conclusion - Limitations and Future Work

Limitation

- Sample size was to limited.
- Participants only performed one short short term clinical task.
- VR environment might not fully replicate the clinical environment.

Future Work

- Investigate the longer session with multiple trial with retention
- Combine of multiple guidance methodologies
- Explore the effect of various user's expertise

Thank you