Dynamic Transparency in Ghost Metaphor-Based Guidance in Virtual Reality Environments

Cassandra Visser (c.m.s.visser@tudelft.nl)

1. Background

- Skill transfer using Virtual Reality as a medium is applicable to various contexts, including those where users are physically separated. The virtual interface allows for:
  - First-person perspective (1PP) imitation
  - Displaying additional information

- "Just Follow Me" [1]
  - 1PP guidance by a ghost instructor
- Performance drop after the removal of guidance [2]
  - Study comparing: ghost instructor, virtual co-embodiment, and no guidance.
  - Students' focus on following the ghost avatar inhibited learning

- Static transparency vs dynamic transparency
  - Transparency feedback based on how well the student performs

Figure 1: Left: static transparency. Middle: dynamic transparency, high alpha value. Right: dynamic transparency, invisible.

2. Research Question

"How do ***dynamic transparency*** values impact the ***learning and retention of motor skills*** in collaborative virtual reality systems using a first-person perspective in combination with a ***ghost metaphor***?"

H1 : Using a dynamically (instead of statically) transparent ghost instructor leads to a *smaller performance drop between the training and testing phase.*

H2 : Using a dynamically (instead of statically) transparent ghost instructor, leads to a *smaller performance improvement between trials of the training phase.*

H3 : Using a (static or dynamic) ghost instructor leads to an *increase in performance between sequential trials* of the training phase.

6. References

1. U. Yang and G. J. Kim, "Implementation and Evaluation of Just Follow Me: An Immersive, VR-Based, Motion-Training System," *Presence: Teleoperators and Virtual Environments*, vol. 11, no. 3, pp. 304–323, Jun. 2002. DOI: 10.1162/105474602317473240. eprint: https://direct.mit.edu/pvar/article-pdf/11/3/ 304/1623762/1054746023174732 40.pdf.
2. D. Kodama, T. Mizuho, Y. Hatada, T. Narumi, and M. Hirose, "Effects of collaborative training using virtual co-embodiment on motor skill learning," *IEEE Transactions on Visualization and Computer Graphics*, vol. 29, no. 5, pp. 2304–2314, 2023. DOI: 10.1109/TVCG.2023.3247112.
3. Cassandra Visser. "thesis-vr-dynamic-ghost-instructors-2024." (2024), [Online]. Available: https://github.com/C-Hoek/thesis-vr-dynamic-ghost-instructors-2024.

3. Methods

Adjusting the ghost avatar's transparency based on performance

- An error value (∈ [0,1]) is computed based on the *weighted Manhattan distance* between the ghost and the student
  - If any axis-value of the difference in position exceeds the corresponding max. axis value, the error is equal to 1
- An alpha value (∈ [0,1]) is computed based on a linear interpolation between the min. and max. transparency using a transparency modifier
  - Return 0 if the error is below a predetermined threshold
  - Compute the modifier using: $mod = (e^{error} - 1)/e$

Task Representation

- Collection of cubic Bézier curves
  $P = (1-t)^3 P1 + 3t(1-t)^2 C1 + 3t^2(1-t)C2 + t^3 P2$
- Parameter **t**
  - Represents the progress into the curve
  - **t** is reparameterised through piece-wise linear approximation of the curve using line segments to allow for constant speed movement

The code and models (student, and ghost) are available in a public Github repository [3].

5. Discussion & Conclusion

- Hypotheses H1 and H2 hold; hypothesis H3 does not

Limitations

- Small sample size
- The performance drop (improvement compared to the baseline) between the last training trial and the test trial of 41.1-44.5% of the comparison study [2] is much smaller than the increase in percentage for all groups in Table 1 found in this study
  - Task too complex / added break between training and test trials / difference in task type
- Errors in transparency modifier and error computations

Future Work

- Run experiments with a larger sample size to determine if findings generalise to a larger population
- Compare different tasks with various difficulty levels to determine if ghost instructors are more effective at teaching tasks of a certain difficulty.

4. Evaluation

- 12 participants, divided evenly into two groups
  - Group A was taught by a dynamically transparent ghost instructor
  - Group B (control group) was taught by a statically transparent ghost instructor
- Both groups learnt the same identical task
- The first 3 trials were identical for both groups

Procedure

Objective: trace the same curve as the ghost instructor at the same time as it is showcased while wearing a Head-Mounted Display (HMD). Figure 2 shows the general experiment procedure and the ghost instructor's transparency per trial through the α parameter.

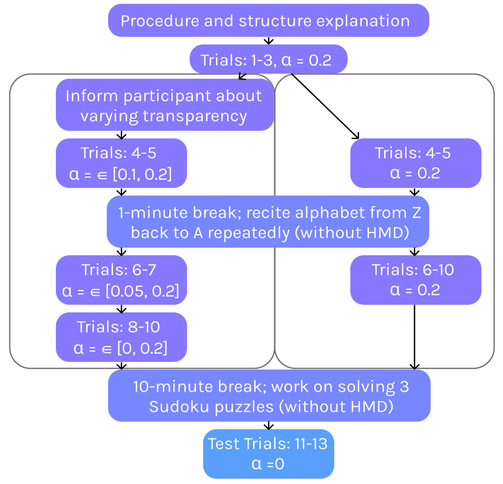

Figure 2: The left path shows the procedure for group A. The procedure for group B is shown on the right.

	Dynamic (Trial 7)	Dynamic	Static
Euclidean	301.0%	154.9%	427.9%
DTW	268.1%	123.7%	424.1%

Table 1: The percentage distance increase between the last training trial and the best test trial. The percentage increase between the 7th trial and the best test trial for the dynamic group can also be seen.

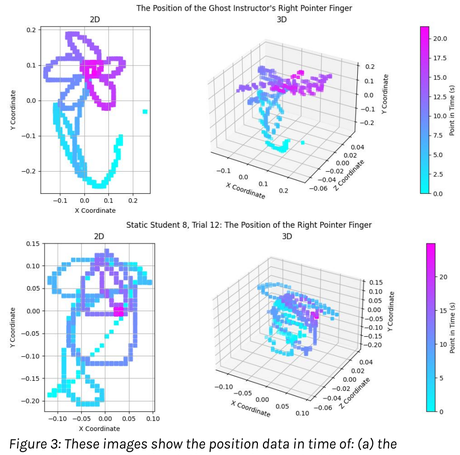

Figure 3: These images show the position data in time of: (a) the ghost, (b) a student in the static group during a test trial.

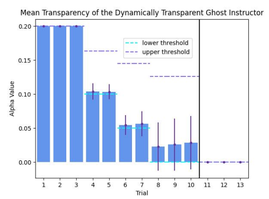

Figure 4: This figure visualises the mean alpha value (1 denotes fully visible, 0 denotes invisible), standard deviation (purple bars), and the lower and upper transparency thresholds.

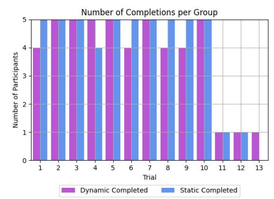

Figure 5: This figure visualises the number of participants that completed each trial.

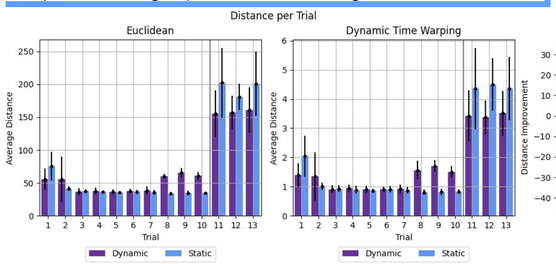

Figure 6: On the left, the average distance per trial computed using Euclidean distance is shown. On the right, the average distance per trial computed using Dynamic Time Warping is shown. For both plots, the standard deviation is shown through black error bars.

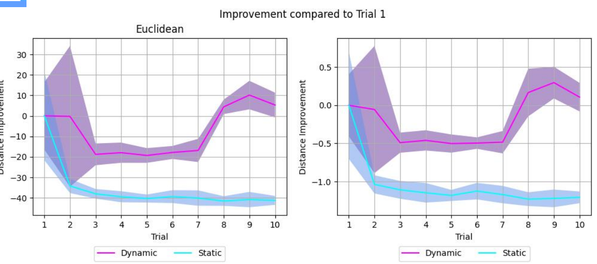

Figure 7: Improvement with regards to the first trial per group per trial, based on the mean distances in Figure 6. Standard deviation is shown as a coloured area around the line. Negative y-values equate to an improvement.

Responsible Professor: Ricardo Marroquim (r.marroquim@tudelft.nl)

Supervisor: Amir Zaidi (a.zaidi@tudelft.nl)