Evaluating Gesture-based Desktop Projection Models in a 3D Environment

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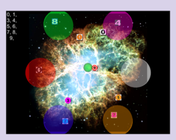
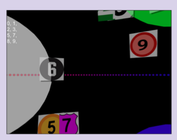
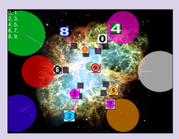
ABSTRACT

We attempted to leverage emerging augmented reality technologies in order to redefine the computer desktop paradigm. Using three desktop projection models (DPMs), participants were asked to complete tasks commonly performed using the standard desktop, such as moving and locating icons.

Participants of our study were able to complete the tasks most quickly and most efficiently when using the pDPM. Although they were receptive to the idea of the iDPM, most preferred the pDPM. Due to hardware limitations, the vDPM was almost unusable and only qualitative data was gathered.

Desktop Projection Models

We evaluate the following DPMs:

	Planar DPM (pDPM)	Immersive DPM (iDPM)	Volumetric DPM (vDPM)
Concept			
Screenshot			
Desktop	A bounded 2D plane in 3D space.	The outer shell of a sphere surrounding the user.	A bounded volume in 3D space. Depth is present.

LITERATURE REVIEW

Spatial Memory
- The ability to remember where items are located.
- Leveraged via continuous perspective, occlusion, landmarks. [Robertson98]
- Better achieved when gestures involve more than just hands, [Jetter12, Rädle13] and tasks are more difficult. [Cockburn07]
- Faster performance with body-centric techniques. [Rädle13]

Natural User Interfaces
- "...feels just as natural to a novice as it does to an expert user." [Wigdor11]
- Applicable via natural hand gestures with projection of interface onto the real world. [Mistry09]

3D Desktop Interaction
- BumpTop: 3D desktop metaphor allows piling. [Agarawala06]
- SpaceTop: implemented switching between 2D and 3D. [Lee13]
- ...Generally studied on a traditional 2D desktop. [Robertson98, Cockburn01]
- Despite decreased performance, feels more "natural". [Cockburn01]

RESEARCH QUESTIONS & HYPOTHESES

R1. Does an immersive space/room metaphor 3D DPM (iDPM) result in optimized user performance?

➔ **H1. Spatial Memory Performance (Time)**
1. Best: iDPM because it's more body-centric, allowing both the arms & head to make faster combined gestures. [Rädle13]
2. Second: pDPM because it's typically found to be fastest. [Cockburn11]

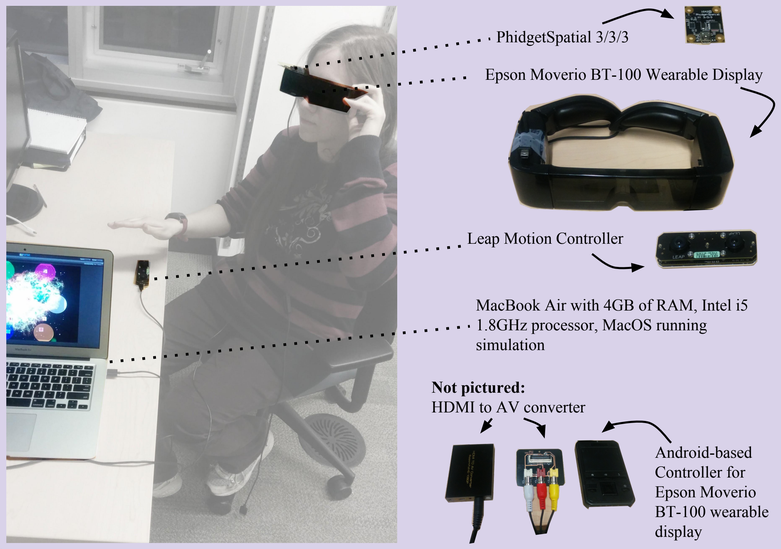
➔ **H2. Navigation Performance (Distance)**
1. Best: pDPM because the 2D plane has the smallest size.
2. Second: iDPM because combined gestures are more efficient [Rädle13]

R2. Does an immersive space/room metaphor 3D DPM (iDPM) result in higher user preference than other DPMs?

➔ **H3. User Preference**
1. Best: iDPM because it's the most natural & intuitive interface.
2. Second: vDPM because it's 3D-aspect is more "natural". [Cockburn01]

EXPERIMENT

Apparatus

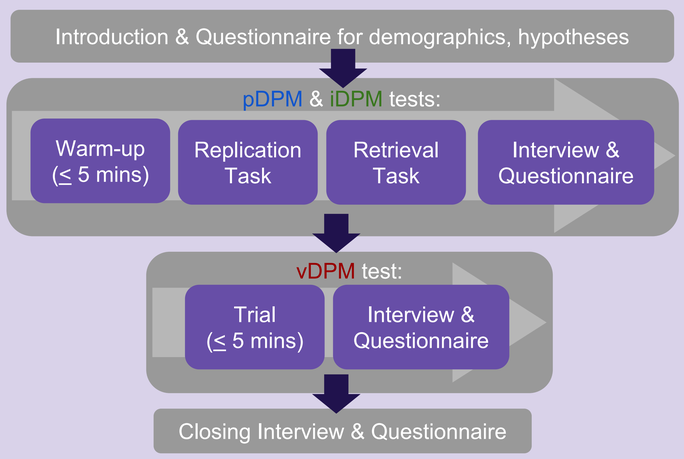


Participants

Six participants between the ages of 18 and 27, recruited on a voluntary basis, required to have average control of their arms and hands, have either 20/20 vision or vision corrected to 20/20, and not be colour-blind.

Experimental Design, Tasks & Procedures

From a pilot study, we found that vDPM was almost unusable, and hence, we only sought to obtain qualitative feedback for its design in this preliminary experiment.



➢ **Within-participant design:** We varied the order of pDPM & iDPM tests to counterbalance potential order effects.

➢ **Independent Variable:** DPMs

➢ **Dependent Variables:** Time, Distance, User preference

➢ **Replication Task:** Based on their color, move 10 desktop objects to the corresponding coloured areas.

➢ **Retrieval Task:** Find & grab 10 desktop objects based on their numbers. Objects are initially located by colour.

Data Measures & Collection Process

➢ **Spatial Memory Performance:** Total time to complete the task.

➢ **Navigation Performance:** Total physical distance to complete the task.

$$\sqrt{(\Delta x)^2 + (\Delta y)^2 + (\Delta z)^2}$$

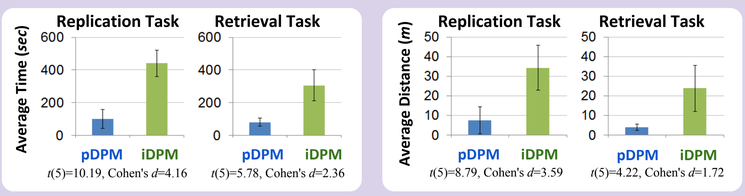
} Collected automatically by the computer as users complete the task.

➢ **User Preference:** Subjective data on each participant's preference -- ease of use, learning, general preference, estimated effectiveness, and stress levels.

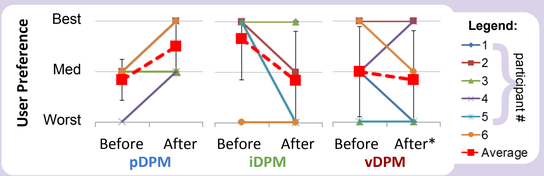
} Collected via computer-based visual & audio recording and questionnaires.

RESULTS

R1: Time & Distance Measures. In paired 1-sided t-tests, time & distance are significantly lower in the pDPM than in the iDPM ($p < 0.05$).



R2: User Preference. Participants' preferences changed during the experiment.



Before the trials, most participants (5 of 6) preferred the iDPM over the other DPMs. However, after tests, only 2 of 6 participants preferred the iDPM.

* Participants are now biased because they're aware of how researchers believe vDPM to be impossible to use.

DISCUSSION

R1. Time & Distance Results

Reasons for pDPM's better performance
- It revealed a larger portion of the desktop; hence, locating desktop icons & colour spheres was easier.
- It resembles a traditional desktop -- used daily by all participants.
- Most people (4 of 6) expected the pDPM to require less time, and all expected it to require less distance.

Reasons for iDPM's worst performance
- It required participants to, while looking away from their hands, make the correct gestures to select objects over the Leap Motion controller
- It induced dizziness in one-third of participants.
- The path to move desktop objects was along the outer shell.

R2. User Preference Results

Before testing...
- iDPM seemed "cool", modern sci-fi, realistic, and was expected to have the same ease-of-use as pDPM.
- pDPM was too similar to the standard desktop & less interesting.
- vDPM seemed like a mixture between iDPM and pDPM.

After testing...
- pDPM allowed for better performance, ease-of-learning, ease-of-use, mental demand, physical demand, and stress level.
- iDPM's & vDPM's concepts were still liked, despite difficulty of use.

Trial Feedback on vDPM
- It was too sensitive for movement over the z-axis, and the hardware failed to detect hand position during grab gesture.
- The depth cues were difficult to learn.
- Some participants (2 of 6) found the input mapping unintuitive, and preferred the input (mouse) mapping used on a normal desktop.

Limitations
- Game engine did not support stereoscopic display.
- Augmented reality glasses perceived image size was relatively small, i.e. 80'' at 5m (equivalent to 16" at 1m).
- Leap Motion prototype controller had a small effective range (1m), and a limited field of view (60º).

CONCLUSIONS

➔ **R1. The pDPM required significantly less time and significantly less distance to complete tasks than the iDPM.**

➔ **R2. Initially, most people prefered the more-3D iDPM to the other DPMs. However, after use, most people prefered the more-2D pDPM.**

Future Work

➢ Determine if vDPM becomes more usable when using a stereoscopic display.
➢ Investigate whether mounting the hand sensor on the glasses results in an increase in performance and user experience.
➢ Consider whether user experience increases when the DPMs have a fixed position in space, rather than having a fixed position on-screen.
➢ Test the effects of iDPM on spatial memory.