Evaluating Pan and Zoom Timelines and Sliders Supplementals: Behaviour Graphs, Pan and Zoom Compatibilities, and Interaction Techniques and Settings

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1 Demographic Details

A total of 318 participants from the United States of America successfully completed the studies. Of the 318 participants, 135 identified as female, 178 as male, 4 as other gender, and one participant did not wish to disclose their gender. 21 participants' age was 18–24, 147 participants were 25–34, 93 participants were 35–44, 38 participants were 45–54, and 19 participants were 55 years or older. One participant on average spent 0–2 hours per day on PCs, 25 participants 2–4 h, 123 participants 4–8h, 112 participants 8–12 h, 54 participants 12 h or more, and 3 participants did not wish to disclose how much time per day they spent on PCs.

2 Behaviour Timelines

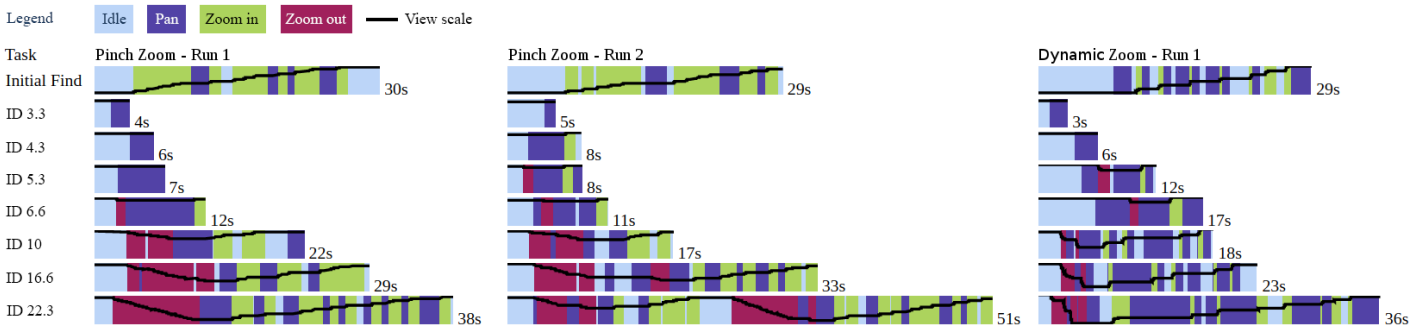

Figure 1: Three example timelines showing navigation behaviour for one participants. Each row represents one task distance, or a target with a specific distance from the current position. The black line denotes the scale of the view over time: When the line is at the top, the target is large on the screen; at the bottom, all 20.000.000 numbers (40 years) are visible. *Left:* In "Pinch Zoom - Run 1", the participant shows typical behaviour. *Middle:* In "Pinch Zoom - Run 2" ID 22.3, a 'desert fog' issue is visible. After zooming out by about 30%, the participant thinks the target is within view and zooms back in all the way to select the target. After short inactivity, the participant realized that they navigated to the wrong number and starts zooming out. In the first attempt, the participant did not zoom out far enough, whereas this time the participant zooms out much farther and finally succeeds in zooming in to the target. *Right:* Using a different interaction technique in "Dynamic Zoom - Run 1", different behaviour is visible with faster zooming and longer panning periods.

Figure 3 allows us to derive characteristics for each interaction method. We draw attention to three main attributes: First, the **angle** of the distribution shows the variability in performance among a real world population. Second, the **speed of the fastest performers** is visible at the top of each interaction, provides us an indication of relative peak performance of a technique. Third, the amount of **time spent idle** (light blue) helps us see potential for improvement, either through training or through better visualization to minimize cognitive load.

Angle: The greater the variation among participants' task times, the shallower the angle of the right edge of each plot. Easier to use interactions have a steeper angle because they induce more even performance across participants. Looking at these angles reveals that pinch, double click, and hold zoom are easier to learn, while rub, brush, and dynamic zoom are harder to learn.

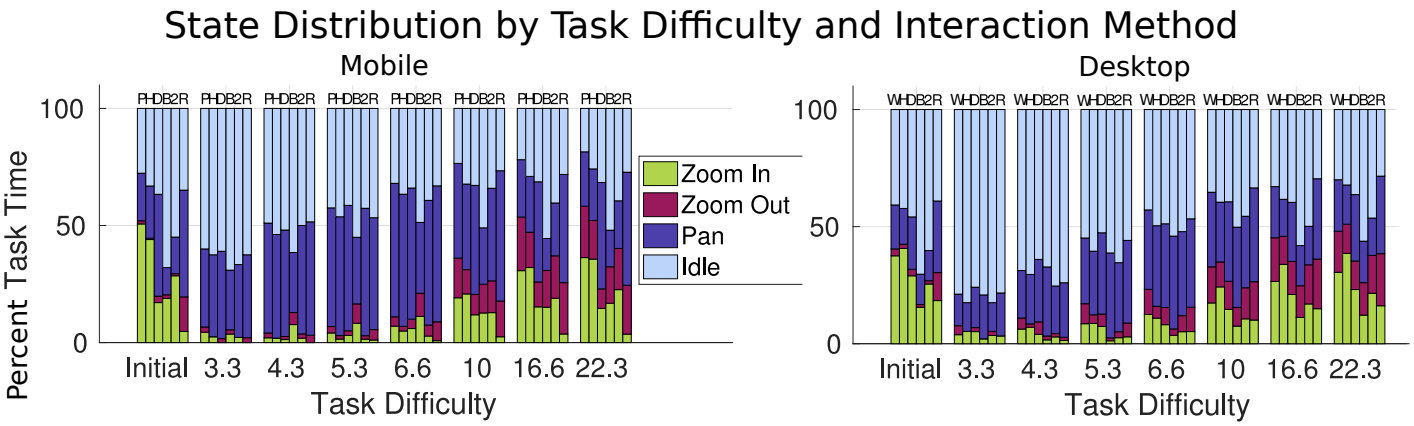

Figure 2: Aggregated subtask interactions across mobile and desktop, for each ID, and for each interaction type, as a percentage of total task time. Here, we can see clearly that brush zoom (B) requires significantly more participant idle time. We attribute this to the rapid change in data view that brush zoom induces, which causes participant to need to reorient. Mobile: P = Pinch Zoom. H = Hold Zoom. D = Dynamic Zoom. B = Brush Zoom. 2 = Double-click Zoom. R = Rub Zoom. Desktop: W = Scroll Zoom.

Speed of fastest performers: Pinch, double click, and hold have relatively worse peak performance, and rub, brush, and dynamic zoom all have participants that perform faster than those of other methods. This suggests that they may be more expert interactions, and that better training would improve the overall population performance.

Time spent idle Pinch, scroll, and hold zoom timelines are packed very densely with manipulation interactions. Brush zoom is packed very sparsely, which suggests that the interaction/visualization may be optimized. Rub zoom is very densely packed as it is a cyclic gesture, though not all of this time. Dynamic zoom and rub zoom have red/green speckling, which is a sign that some users struggled to zoom in to the correct location.

Initial find: An optimal interaction would not include any zooming out (red), and we can see that specially in rub and dynamic zooming, it occurs on many participants' timelines. Again, this may indicate interaction difficulty. For dynamic zoom, we believe that participants may have zoomed in too quickly, and users had to zoom back out to find their path. For rub zoom, the implementation used here allows for very easy switching from zooming in to zooming out, and some participants may have switched accidentally.

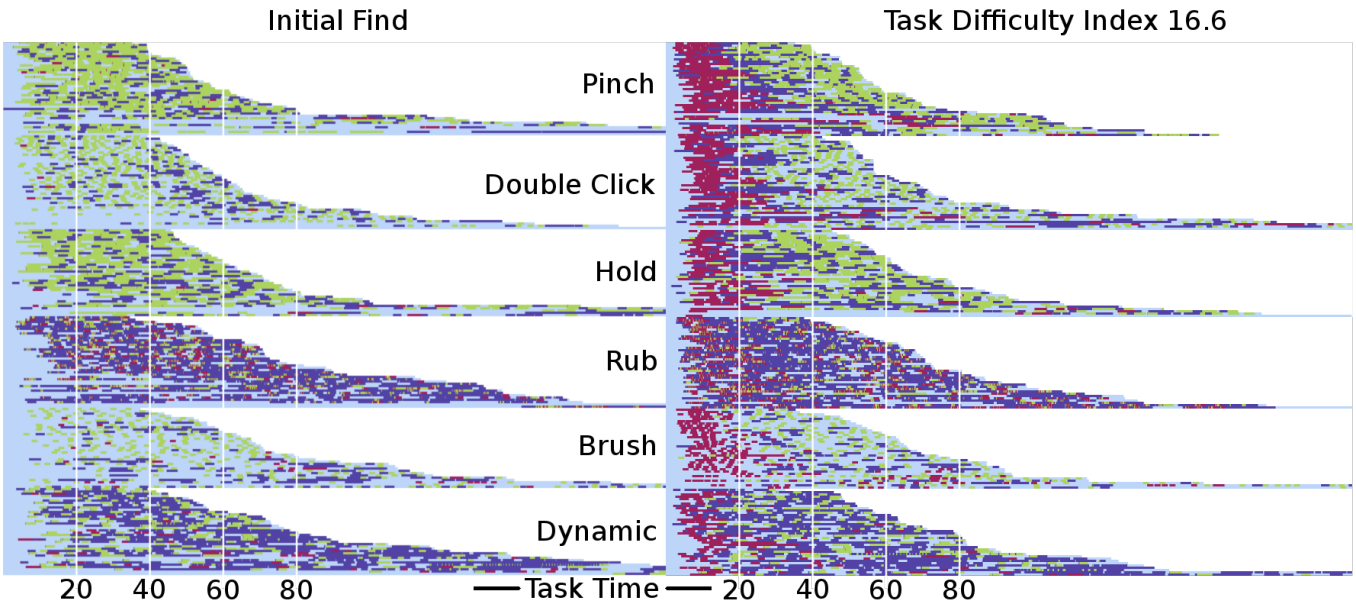

Figure 3: Participant behavior for each of the 39 mobile participants in study 3, sorted by task time. Colors are as in Figure 1. We show a single high ID for each interaction type. Each participant's behavior is visible on zoom; however, the goal of this plot is to see trends across participants by looking broadly at the distributions of colors. For instance, we can see that brush zoom requires significantly less zoom out (less red) *and* less zoom in (less green), but that it requires more idle time to process the zoom operations (more blue).

3 Interaction Techniques Compatibility

Technique Compatibilities are listed in Table 1.

Interaction Method											
2D Drag Pan	✓	✗	✗				●	○			
2D Flick Pan	✓	✗	✗				●	○			
1D Scroll Pan	✓	✗	✗	●							
2D Two-finger Pan	✓	✗	✗								●
2D 2x Click Zoom (prim.)	✗	✓/✗	✗/✓		●						
2D 2x Click Zoom (sec.)	✗	✓/✗	✗/✓			●					
2D Scroll Zoom	✗	✓	✓	●							
2D Pinch Zoom+Pan	✓	✓	✓								●
1D Dynamic Zoom	✗	✓	✓				○		●	●	
2D Brush Zoom	✗	✓	✗				●	○			
2D Hold to Zoom	✗	✓/✗	✗/✓				○	○			
2D Click + Hold Zoom	✗	✓/✗	✗/✓								
2D Rubbing (prim.)	✗	✓/✗	✗/✓					●			
2D Rubbing (sec.)	✗	✓/✗	✗/✓				○			●	

Interaction Key

- Scroll
- Double Click (left click.)
- Double Click (right click)
- Drag (along timeline)
- Drag + Back (along timeline)
- Drag (perpendicular)
- Drag + Back (perpendicular)
- Two Finger Drag

Table 1: Overview of pan and zoom techniques and their compatibility. Methods are identified as working on mobile ( ), and/or desktop( ). 1D methods only work on one-dimensional visualizations such as timelines, while 2D methods can additionally operate on two-dimensional contents such as maps. Methods can support (✓) or not support (✗) panning ( ), zooming in ( ), and zooming out ( ), and some methods can be used for either zooming in or zooming out ( ). Columns 1-10 refer to specific input methods. A ● indicates that an input method is the primary input method for an interaction, while a ○ indicates that an input method is used as additional input for the interaction. Two interactions with ● in the same column are never compatible, while two interactions that have one ● and one ○ or two ○ have limited compatibility. Two interaction methods are fully compatible if there is no overlap between their filled columns.

4 EasyPZ Interaction Implementations

An overview of implemented techniques is shown in Table 2. For more detail, Table 3 shows all techniques implemented in EasyPZ together with their settings as used in our study.

DRAG_PAN WHEEL_PAN_X PINCH_PAN FLICK_PAN	WHEEL_PAN_Y
HOLD_ZOOM_IN CLICK_HOLD_ZOOM_IN,	HOLD_ZOOM_OUT CLICK_HOLD_ZOOM_OUT
DBLCLICK_ZOOM_IN DBLRIGHTCLICK_ZOOM_IN	DBLCLICK_ZOOM_OUT DBLRIGHTCLICK_ZOOM_OUT
WHEEL_ZOOM WHEEL_ZOOM_EASE	WHEEL_ZOOM_MOMENTUM
PINCH_ZOOM PINCH_ZOOM_QUADRATIC	PINCH_ZOOM_MOMENTUM PINCH_ZOOM_POWER_FOUR
BRUSH_ZOOM_X BRUSH_ZOOM_2D	BRUSH_ZOOM_Y
DYNAMIC_ZOOM_X_STATIC DYNAMIC_ZOOM_X_ORIGINAL_PAN DYNAMIC_ZOOM_X_NORMAL_PAN DYNAMIC_ZOOM_X_ADJUSTABLE	DYNAMIC_ZOOM_Y_STATIC DYNAMIC_ZOOM_Y_ORIGINAL_PAN DYNAMIC_ZOOM_Y_NORMAL_PAN DYNAMIC_ZOOM_Y_ADJUSTABLE
RUB_ZOOM_IN_X RUB_ZOOM_OUT_X	RUB_ZOOM_IN_Y RUB_ZOOM_OUT_Y

Table 2: The 12 interactions implemented in EasyPZ thus far, including horizontal, vertical, or 2D mapping, plus behavior variants.

Method Names	**Settings**
SIMPLE_PAN	minDistance: 3, delay: 300
FLICK_PAN	minDistance: 3, delay: 300, friction: 0.005
HOLD_ZOOM_IN, HOLD_ZOOM_OUT, CLICK_HOLD_ZOOM_IN, CLICK_HOLD_ZOOM_OUT	maxDistance: 3, delay: 350, zoomInScaleChangePerMs: -0.0015, zoomOutScaleChangePerMs: 0.003, doubleClickTimeout: 300
DBLCLICK_ZOOM_IN, DBLCLICK_ZOOM_OUT, DBLRIGHTCLICK_ZOOM_IN, DBLRIGHTCLICK_ZOOM_OUT	dblClickTime: 300, zoomInScaleChange: 0.33, zoomOutScaleChange: 3, maxHoldTime: 200
WHEEL_ZOOM, WHEEL_ZOOM_MOMENTUM, WHEEL_ZOOM_EASE	zoomInScaleChange: 0.8, zoomOutScaleChange: 1.2, momentumSpeedPercentage: 0.01, momentumFriction: 0.000004, easeDuration: 300
PINCH_ZOOM, PINCH_ZOOM_QUADRATIC, PINCH_ZOOM_POWER_FOUR, PINCH_ZOOM_MOMENTUM, PINCH_PAN	friction: 0.00001
WHEEL_PAN_X, WHEEL_PAN_Y	speed: 50
BRUSH_ZOOM, BRUSH_ZOOM_X, BRUSH_ZOOM_Y	minDistance: 3, delay: 300, minTime: 150
DYNAMIC_ZOOM_X_STATIC, DYNAMIC_ZOOM_X_ORIGINAL_PAN, DYNAMIC_ZOOM_X_NORMAL_PAN, DYNAMIC_ZOOM_X_ADJUSTABLE, DYNAMIC_ZOOM_Y_STATIC, DYNAMIC_ZOOM_Y_ORIGINAL_PAN ,DYNAMIC_ZOOM_Y_NORMAL_PAN, DYNAMIC_ZOOM_Y_ADJUSTABLE	speed: 0.05, minDistance: 3, delay: 300, minDirectionPercentage: 0.7
RUB_ZOOM_IN_X, RUB_ZOOM_IN_Y, RUB_ZOOM_OUT_X, RUB_ZOOM_OUT_Y	speed: 0.02, minDistance: 15, minDistanceAfterDirectionChange: 10

Table 3: EasyPZ techniques and technique settings as used in the study. For full reproducibility, these settings should be used for follow-up research, or explicitly state how the used settings differ from the ones presented here.