Could the Stylus Be Mightier Than the Controller? An Investigation Into the Heisenberg Effect of Spatial Interaction for 3D Tracked Styluses

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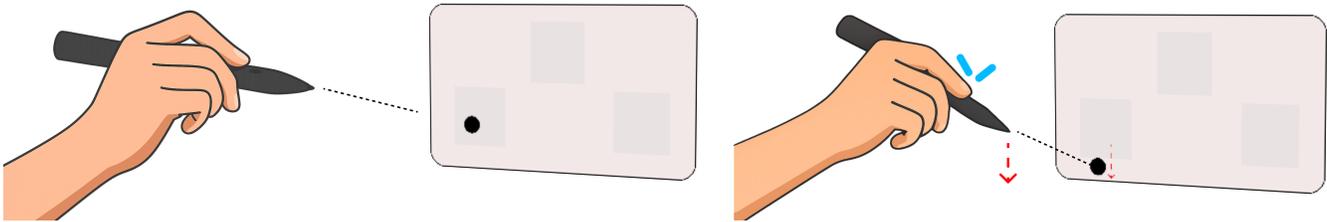Aidan Kehoe
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Figure 1: The Heisenberg Effect of Spatial Interaction occurs when the physical act of pressing a button changes the position or orientation of the device, often resulting in missed targets.

Abstract

Recent advancements in extended reality have enabled new peripheral types beyond standard controllers. Devices such as 3D-tracked styluses emulate the feel of traditional pens, offering a more familiar interaction style and higher precision. However, these spatial input devices are susceptible to the Heisenberg Effect of Spatial Interaction, where involuntary cursor movement is caused by the physical act of selection (e.g., button pressing), reducing selection accuracy. We present an exploratory investigation into the Heisenberg Effect using a 3D-tracked stylus (Logitech MX Ink) and a standard controller (Meta Quest Touch Plus). Through selection tasks across varying target widths, amplitudes, and actuation fingers, results indicate that styluses are less susceptible to the Heisenberg Effect than controllers. However, choice of actuation finger matters: thumb-based input produces significantly more unintended movement than index. We present these findings to open a discussion on the future of XR peripheral design to enable both fast and precise input.

CCS Concepts

• **Human-centered computing** → **Pointing devices**; **Mixed / augmented reality**; **Usability testing**; **Pointing devices**.

Keywords

Mixed Reality, Virtual Reality, Stylus, Heisenberg Effect

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1 Introduction

Pointing and selection in extended reality (XR) are commonly supported by controllers or hand-tracked input, but these techniques often lack the precision required for fine-grained tasks. As a result, there has been growing interest in stylus-based input for XR, particularly for activities such as sketching, annotation, and precise manipulation [8, 9, 19, 23, 24]. Recent consumer devices such as the Logitech MX Ink [16] exemplify this trend, offering pen-like interaction that builds on users' familiarity with traditional pen-and-paper workflows [5, 15, 21]. Styluses are often assumed to provide higher precision [10] and have demonstrated faster and more accurate input in XR compared to other modalities [22], positioning them as a promising input device for spatial computing [21].

However, spatial input introduces challenges that are less prominent in 2D interaction. One such challenge is the *Heisenberg Effect of Spatial Interaction* [32], in which the physical act of selection (e.g., pressing a button) induces unintended device movement and reduced precision. While this effect has been studied for controllers and hand-tracking [30, 32], it remains under-explored for stylus input. This paper investigates the Heisenberg Effect in 3D stylus interaction, examining how the stylus's light, precision-oriented grip [4, 26, 27] influences stability during selection. Understanding this behaviour is critical for the design of high-precision XR interfaces that rely on stylus-based input.

We present an exploratory study comparing the precision of a spatially tracked stylus (Logitech MX Ink; see Figure 2) to that of a

standard 6DoF controller (Meta Quest Touch Plus) in pointing and selection tasks. Our preliminary results identify a critical trade-off between device design, input stability, and selection precision. We present these findings to open a discussion on alternative devices for XR input and to identify increasingly more precise ways to interact within these environments.

2 Background

Spatial input is critical for effective interaction in 3D XR environments [1, 28] where pointing and selection are among the most fundamental tasks supported by these input modalities. Currently, tracked controllers remain the industry standard due to their precision and haptic capabilities [17], relying on a virtual pointer for distant raycasting [20]. As the focus of this work, virtual pointing requires users to align a ray with a target for selection. Since accurate pointing is central to XR, characterising the stability and limitations of these inputs is essential for improving user experience.

2.1 Stylus Input

Styluses are a well-established input modality in computing due to their high precision and familiar pen-like form factor [3, 7, 19]. Traditionally, stylus use has been limited to 2D touchscreens on tablets and mobile devices [3, 13], Recently, in XR, styluses have been adopted for 3D sketching [8, 24], precise manipulation [2, 23], and annotation [11, 33]. Commercial devices such as the Logitech MX Ink [16] now offer fully tracked 6DoF stylus input, combining the spatial expressiveness of VR controllers with the fine-grained control of pen-based input while also enabling on-surface interactions.

Compared with conventional controllers, styluses can have higher precision in pointing tasks while maintaining a familiar interaction style [5, 22]. However, their compact form imposes design constraints: the stylus body's limited surface area restricts the number and placement of buttons [29]. However, unlike traditional controllers, styluses invite users to grasp them in a variety of different ways, whereas the affordances of a controller are more prescriptive in how users hold them [25, 27], changing how the device is used by each person. Grip style and finger choice affect not only comfort and control, but also the amount and direction of force applied to the stylus during interaction [12, 18]. These variations can influence device stability and may amplify or reduce displacement effects (such as those introduced by the Heisenberg Effect) highlighting the importance of evaluating ergonomics alongside input performance.

2.2 The Heisenberg Effect

A unique challenge for spatial input is the *Heisenberg Effect* [6], where the physical act of selection (e.g., pressing a button) unintentionally displaces the input device, often causing target slips (See Figure 1). Distinct from sensor jitter or hand movements, this effect is solely user induced at the moment of selection.

Wolf et al's. [32] formal investigation (controllers ray-based pointing) introduced two key metrics to quantify its impact: *Heisenberg Error*, the proportion of selection errors caused by device displacement during a click, and *Heisenberg Magnitude*, the angular or spatial offset between the cursor's position before and after the button press.

Research surrounding the Heisenberg Effect has focused almost exclusively on standard VR controllers. Styluses, by contrast, differ significantly in both form factor and interaction dynamics. They are typically held with a lighter, precision grip and are used for tasks requiring high spatial accuracy [22, 23]. These characteristics suggest styluses may exhibit different sensitivity to press-induced motion. Styluses' compact form factor often limits the placement of additional input mechanisms, potentially amplifying the impact of even small involuntary movements.

**Figure 2: Logitech MX Ink - 3D Tracked XR Stylus made in partnership between Logitech and Meta.**

3 Experiment

3.1 Study Design

The aim of this exploratory experiment was to quantify the impact of the Heisenberg Effect on selection performance when using a 3D-tracked stylus in XR (Logitech MX Ink, Figure 2)[1]. For comparison, we included the Meta Quest 3 Touch controller, given its widespread use and role as a standard input device in consumer XR systems. As highlighted in section 2, factors such as grip and the finger used for selection can influence the amount of force exerted on the device, and thus the degree of unintentional displacement. To account for this, we evaluated multiple button placements and fingers across conditions to examine how these variables influence Heisenberg-induced movement.

We adopted two tasks from Wolf et al. [32] to isolate distinct aspects of the effect. **Task 1**, a standard ISO 9241-9 multi-directional task requiring rapid, accurate selections (Figure 3a), **Task 2**, a stabilised task (Figure 3b) requiring maintaining a stable cursor (500ms) before selecting upon a visual cue, isolating displacement caused solely by confirmation. Targets appeared at Amplitudes of 1.5 and 3.5m and Widths of 0.3, 0.4, and 0.5m at a fixed distance of 8m from the participant [32]. We employed a randomised, 2 (Device: Stylus, Controller) × 2 (Finger: Index, Thumb) × 2 (Amplitude) × 3 (Width) within-subjects design. As the controller affords grip in a specific manner, we followed conventions, mapping the index finger to the trigger and the thumb to the A button. For the stylus, the front and middle buttons were tested with both the index finger and the thumb. Pointing was facilitated using the standard Meta Quest raycast from the top of the controller and the nib of the stylus.

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[1]Developed in partnership with Meta, the stylus shares the same tracking protocol and latency characteristics as the standard Quest 3 Touch controller.
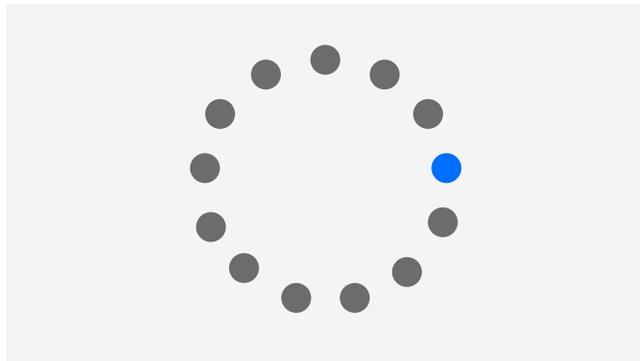
(a) Example task layout. Blue circle denotes the target.
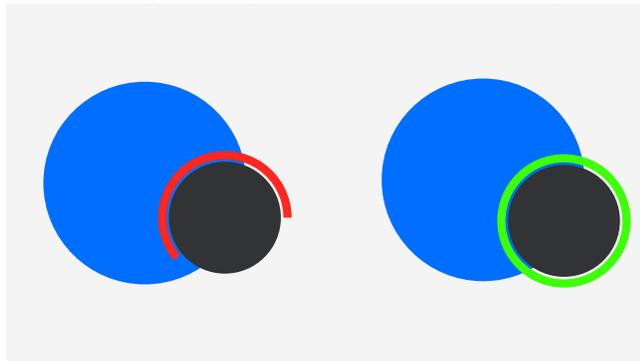
(b) Example of the 500ms wait mechanic used for task 2 (stabilised).

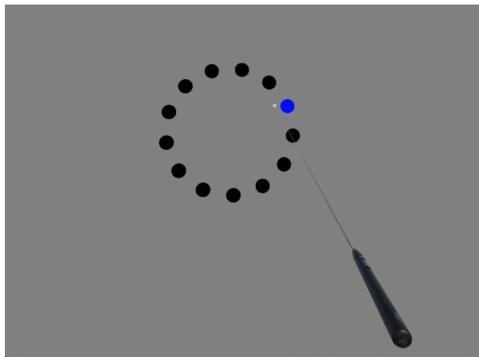Figure 3: Task examples as displayed to the participants.

Figure 4: Screenshot of the participant view.

3.2 Procedure and Measurements

After providing informed consent and demographics, participants practised with the Meta Quest 3, controller and stylus until comfortable. Rest breaks and qualitative feedback were provided after each trial.

We adopted metrics from Wolf et al. [32]: Effective Throughput (ISO 9241-9), Overall Error Rate, and Click Duration. To isolate click-induced instability, we measured Heisenberg Error Rate (errors attributable to actuation movement) and Heisenberg Magnitude (cursor displacement in degrees during the click).

4 Results

We recruited 11 right-handed participants (1 female, age 26–35). Data was analysed using Repeated-Measures ANOVA or Aligned-Rank Transform (ART) for non-normal distributions, followed by ART-C post-hoc comparisons. Significant main effects and interactions for Rapid (Task 1) and Stabilised (Task 2) selection are summarised below.[2]

In summary of Table 1 and Table 2, the key results show that:

- The input *device* influenced overall error rates, with the stylus yielding fewer errors compared to the controller.
- The *thumb* resulted in more overall error on both devices.
- The *device* type influenced Heisenberg error, with the stylus producing fewer errors.
- Both *device* and *finger* significantly influenced the magnitude of unintended movement associated with the Heisenberg effect, with the stylus and index finger resulting in reduced displacement.
- The *stylus* demonstrated superior throughput compared to the controller.
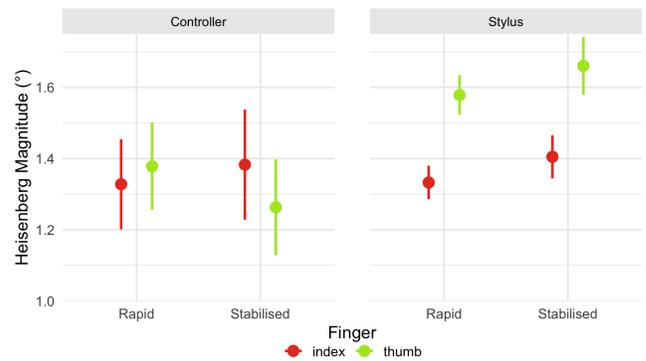
(a) Heisenberg Magnitude (cursor displacement caused by the effect).
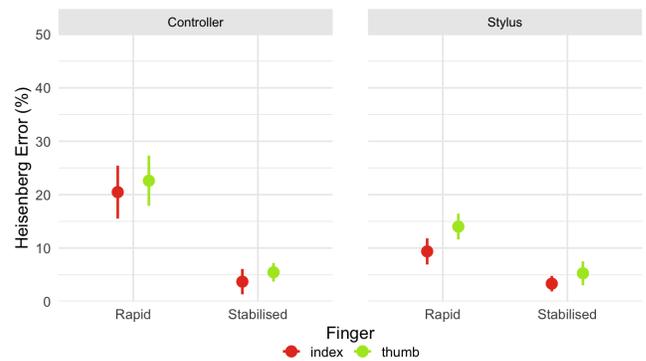
(b) Heisenberg Error (percentage of selection error caused by the effect).

Figure 5: Mean values for Heisenberg Magnitude and Error for each device, finger and task. Error bars show 95% CIs.

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[2]Full statistical tables are available in the supplementary material.

Table 1: Task 1 (rapid) mean values and significant* , ANOVA and post-hoc test results[2].

	Click Time	**Mean 840.42 ms, SD 165.13 ms, 95% CI [824.23, 856.61] ms**			
	ANOVA	*Result*	*p*	η_p^2	*Post-Hoc Comparisons*
1	*Amplitude*	F(1, 367) = 229.78	< .001*	< .001	1.5 < 3.5* (p = < .001)
2	*Width*	F(2, 367) = 45.25	< .001*	< .001	0.3 > all* (p = < .001), 0.3 > 0.5* (p = < .001)
3	*Amplitude × Width*	F(2, 367) = 3.12	.04*	< .001	Lower for higher width/amplitude* (p ≤ .001)
	Error	**Mean 16 %, SD 19 %, 95% CI [15, 18] %**			
4	*Device*	F(1, 368) =21.57	< .001*	.06	Stylus < Controller* (p < .001)
5	*Finger*	F(2, 368) = 6.25	.01*	.02	Thumb > Index* (p = .01)
	Heisenberg Error	**Mean 15 %, SD 18 %, 95% CI [13, 17] %**			
6	*Device*	F(1, 368) = 35.33	< .001*	.09	Stylus < Controller* (p < .001)
	Heisenberg Magnitude	**Mean 1.42 degrees, SD 0.41 degrees, 95% CI [1.38, 1.46] degrees**			
7	*Device*	F(1, 368) = 7.53	.006*	.01	Stylus > Controller* (p = .006)
8	*Finger*	F(2, 368) = 15.42	< .001*	.01	Thumb > Index* (p < .001)
9	*Device × Finger*	F(1, 368) = 6.83	.009*	.01	Thumb > Index* (p ≤ .001)
10	*Device × Amplitude*	F(1, 367) = 3.97	.05*	.01	Stylus < Controller for amplitude 1.5* (p = .005)
	Effective Throughput	**Mean 3.98 b/s, SD 1.12 b/s, 95% CI [3.87, 4.1] b/s**			
11	*Device*	F(1, 368) = 30.34	< .001*	.08	Stylus > Controller* (p < .001)
12	*Finger*	F(2, 368) = 9.16	.002*	.02	Index > Thumb* (p < .003)
13	*Amplitude*	F(1, 367) = 22.39	< .001*	.06	3.5 > 1.5* (p < .001)

Table 2: Task 2 (stabilised), mean values and significant* , ANOVA and post-hoc test results[2].

	Click Time	**Mean 833.94 ms, SD 154.37 ms, 95% CI [818.57, 849.30] ms**			
	ANOVA	*Result*	*p*	η_p^2	*Post-Hoc Comparisons*
1	*Amplitude*	F(1, 355) = 215.73	< .001*	.38	3.5 > 1.5* (p < .001)
2	*Width*	F(2, 355) = 23.92	< .001*	.12	0.3 > all* (p < .001), 0.4 > 0.5* (p = .01)
	Error	Mean 5 %, SD 12 %, 95% CI [3,6] %			
3	*Device*	F(1, 356) = 5.58	.02*	.02	Controller > Stylus* (p = .01)
	Heisenberg Error	**Mean 4 %, SD 12 %, 95% CI [3, 6] %**			
	Heisenberg Magnitude	**Mean 1.47 degrees, SD 0.5 degrees, 95% CI [1.42, 1.52] degrees**			
4	*Device*	F(1, 357) = 14.14	< .001*	.04	Stylus > Controller* (p < .001)
5	*Finger*	F(1, 357) = 7.03	.01*	.02	Thumb > Index* (p < .001)
6	*Device × Finger*	F(1, 357) = 9.18	.01*	.03	Controller Index > Controller Thumb* (p = .05)
	Effective Throughput	**Mean 3.01 b/s, SD .53 b/s, 95% CI [2.95, 3.06] b/s**			
8	*Device*	F(1, 356) = 14.25	< .001*	.04	Stylus > Controller* (p < .001)
9	*Amplitude*	F(1, 355) = 107.49	< .001*	.23	3.5 > 1.5* (p < .001)

5 Discussion

5.1 The Influence of the Heisenberg Effect on Pointing and Selection Using 3D Tracked Styluses

Our results indicate that device type may help mitigate the Heisenberg Effect. The stylus consistently outperformed the controller, exhibiting significantly lower Heisenberg Error (Table 1_6) and Overall Error rates (Table 1_4, Table 2_3) across all amplitudes. While Heisenberg Magnitude was greater for the stylus (Table 1_7, Table 2_4), the smaller associated Heisenberg Error suggests that the pen-grip form factor potentially offers greater resistance to involuntary displacement during actuation than the standard controller grip [22].

The differences between devices were especially pronounced in the rapid selection task, which closer mirror real-world XR interactions. Here, the stylus demonstrated better performance, yielding significantly lower selection (Table 1_4) and Heisenberg Error rates (Table 1_6). Furthermore, Effective Throughput was higher with the stylus (Table 1_{11}), suggesting that its form factor may enable more efficient, stable input during fast-paced tasks compared to the standard controller.

Compared with the stabilised selections, the rapid nature of Task 1 likely amplified the effects of device-induced movement. Here, selections occurred immediately after a fast motion, meaning that any unintended displacement from pressing a button was more likely to misalign the pointer. We can see this contrast in error rates across both tasks, where for Task 2 (Stabilised), both the overall Error and Heisenberg Error rates were lower than the rapid task (Task 1) (Table 1_4 Table 1_7, Table 2_3). These performance differences are particularly meaningful as the rapid task is more akin to a real-world interaction.

5.2 Implications of Finger Choice

Our results indicate that the finger plays a significant role in the Heisenberg Effect. Across both devices, thumb-based selections resulted in significantly higher Heisenberg Error and Magnitude than index-finger selections (Table 1_8, Table 2_5), with the stylus having the greater impact (Table 1_9). This likely stems from biomechanical differences: whereas the index finger applies force linearly against the grip [18], the thumb introduces rotational torque and lateral variance, particularly on top-mounted buttons [12, 18]. These results suggest that incorporating thumb-based interactions into devices may inherently lead to instability due to biomechanical constraints.

5.3 Compensating for the Heisenberg Effect on 3D Tracked Styluses

Our results indicate that while the stylus reduces Heisenberg-induced error compared to a controller, it does not eliminate it. This performance difference suggests peripheral design may benefit from prioritising the familiarity and stability of the precision grip over the traditional controller power grip. However, our findings also indicate that thumb actuation highly increases Heisenberg-related instability, a potential issue with current interaction paradigm design where the thumb is highly used.

While previously proposed solutions like software compensation (e.g., time-shifting [32]) or enhanced targeting methods (e.g., sticky cursors [14], dynamic area cursors [31]) can mitigate the symptoms of displacement, they may be simply masking an underlying biomechanical flaw. As we move away from traditional controller designs an interesting dialogue opens up regarding the permanence of a solution: is software compensation sufficient, or is a fundamental hardware change required?

6 Limitations

This study presents a preliminary investigation of the Heisenberg Effect on 3D stylus input. While 11 participants is consistent with prior exploratory studies [22, 32], a larger and more diverse sample is needed to closer match the real world population. Second, our results are specific to the Logitech MX Ink stylus. Alternative designs, such as relocating the input mechanism along the shaft or reducing actuation force, may alter interaction dynamics and impact the Heisenberg Effect. Additionally, in this experiment, we did not constrain the grip style and allowed participants to hold the stylus however they felt comfortable. By constraining the stylus's grip, the implications of the Heisenberg effect may change.

7 Conclusion

We investigated the Heisenberg Effect of spatial interaction on a 3D-tracked stylus (Logitech MX Ink) and a standard XR controller (Meta Quest Touch Plus) in pointing and selection tasks. This study offers initial insights into how stylus-based input is impacted by the Heisenberg Effect. While the stylus still exhibited the effect during target selection, it produced fewer Heisenberg-related errors and supported more precise, higher-throughput selections. Further, we identify that the actuation finger plays a critical role, with thumb-based input introducing greater unintended movement than index-finger input. This work serves as an exploratory benchmark for XR styluses. Our findings attempt to understand the interaction mechanics of the precision grip of the stylus compared to a traditional controller for pointing and selection. Our results open up further discussion of the interaction mechanics of XR styluses, where the ergonomic convenience of thumb actuation must be reconciled with biomechanical constraints.

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