http://dx.doi.org/10.14236/ewic/BCSHCI2025.40

Strategic Pausing in Digital Reading: A Pilot Evaluation of SmartPause on Cognitive Performance

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Digital reading environments are prone to premature disengagement, which can impair comprehension and cognitive performance. This pilot study introduces a simplified version of SmartPause—a lightweight, timing-sensitive intervention that encourages readers to continue until a natural breakpoint. Unlike earlier conceptual designs that included reflection prompts and note-taking, this version isolates the effect of exit timing alone, offering a more minimal and scalable interaction. By removing additional scaffolding and controlling for individual variability, we test whether timing cues by themselves support cognitive performance. Fourteen participants read two digital passages in a fixed order: one passage ended at a natural breakpoint, while the other was exited partway through. Exit timing was counterbalanced across participants to compare cognitive outcomes associated with early versus full completion. Measures included selective attention, free recall, perceived workload, engagement and affective state. Preliminary results suggest directional benefits in favour of natural breakpoint-aligned exits, particularly for memory, attentional control, and affective tone. These trends tentatively support the role of cognitively aligned pausing in enhancing digital reading outcomes without adding user burden. This exploratory pilot offers early evidence for context-aware disengagement as a design principle and motivates future development of adaptive reading systems aligned with cognitive rhythms.

Digital reading, Strategic pausing, Cognitive-aware interaction design, Cognitive performance

1. INTRODUCTION

Digital reading has transformed how people consume information, yet it remains cognitively demanding and often less effective than print. Research has linked digital formats to reduced comprehension, visual fatigue, and fragmented attention (Liu, 2005; Jian, 2022; Froud *et al.*, 2024). These effects are often exacerbated by interface-driven features such as scrolling, hyperlinking, and multitasking. Given the dominance of screen-based reading, there is a growing need to optimise digital interfaces for sustained engagement and information retention.

Recent research in human-computer interaction has explored how the timing of interruptions impacts task performance. Studies show that breaks introduced at natural task boundaries—such as between subtasks or reading segments—are significantly less disruptive than those that occur mid-task (Adamczyk and Bailey, 2004; Bailey and Iqbal, 2008). These findings highlight opportunities for interface designs that align with cognitive rhythms, offering support without introducing additional friction.

This pilot study forms part of a broader design exploration of strategic disengagement in digital reading. It introduces and evaluates a minimal version of SmartPause, a context-sensitive digital reading intervention that prompts users to continue reading until a nearby semantic breakpoint before disengaging. While informed by an earlier conceptual between-participants study on a full version of SmartPause with reflective prompts and note-taking (Hacioglu *et al*., 2025), this pilot evaluates a minimal version that isolates exit timing alone. The goal is to explore whether simple, non-intrusive timing cues can support cognitive performance in digital reading.

SmartPause was designed to encourage readers to pause intentionally when attempting to exit a passage prematurely, particularly before a natural breakpoint. To explore this, we conducted a within-subjects pilot that controlled for individual differences known to moderate responses to interruption—such as multitasking style and

cognitive control—both of which influence how users manage competing demands and recover attention following disruption (Ophir, Nass and Wagner, 2009). Fourteen participants read two digital passages in a fixed sequence, with one passage ended at a natural breakpoint and the other exited partway through. Exit timing was counterbalanced across the sample to isolate the impact of disengagement timing. Outcome measures included free recall, perceived workload, affective state, and engagement. Although results were not statistically significant due to the small sample size, promising trends emerged, suggesting that exit timing alone may influence memory and attentional outcomes in digital reading. These findings help isolate the role of task boundaries, informing future designs for adaptive reading support.

2. RELATED WORK

Interruptions have long been a central concern in HCI, particularly in the context of multitasking, notifications, and attention-aware systems (Cutrell, Czerwinski and Horvitz, 2001; Bailey and Konstan, 2006). Prior work has primarily examined externally triggered disruptions in the context of productivity tasks such as list evaluation, interface navigation, and information retrieval. For instance, Cutrell et al. (2001) demonstrated that interruptions negatively affect task performance and memory, especially when they occur early in a task. Similarly, Bailey and Konstan (2006) found that interruption timing significantly influenced error rates**,** task completion time**,** and users' affective state**,** with early-stage interruptions producing the most detrimental effects.

In contrast, relatively little work has examined how interruptions impact deep reading or sustained cognitive engagement with text. Yet digital reading introduces new dynamics: readers often self-interrupt or disengage due to interface-driven distractions, affective fluctuations, or cognitive fatigue (González and Mark, 2004; Yeykelis, Cummings and Reeves, 2014). While González and Mark (2004) documented frequent task-switching across work spheres, including during reading; Yeykelis et al. (2014) observed high-frequency, self-initiated application switching and affective engagement loops during online media use. Studies focused specifically on digital reading show that scrolling, hyperlinking, and multitasking interfaces can undermine attention and comprehension (Liu, 2005; Benedetto *et al.*, 2013; Jian, 2022; Froud *et al.*, 2024), yet few explore how or when to intervene without adding friction. While these studies emphasise the cognitive cost of digital reading environments, our work isolates reading as the primary activity and experimentally tests how the timing of disengagement affects cognitive and affective outcomes—offering both empirical insight and a design prototype for attention-supportive reading systems.

The timing of interruptions is critical. Interruption literature shows that breaks aligned with natural task boundaries—such as between subtasks or cognitive chunks—are less disruptive than those that occur mid-task (Adamczyk and Bailey, 2004; Altmann and Trafton, 2004; Bailey and Iqbal, 2008). These studies demonstrate that task structure, resumption cues, and working memory dynamics play a key role in how people resume tasks after an interruption. However, most systems still lack proactive, user-facing mechanisms to scaffold such timing, with interruptions often occurring arbitrarily or in response to external events, thereby disrupting user flow and degrading performance (Yuan and Zhong, 2024).

Efforts to design digital environments that support attentional control and minimise cognitive disruption such as those addressing mobile interruptions have gained prominence within the context of digital well-being (Mehrotra *et al.*, 2016). Such systems aim to scaffold attention without enforcing rigid behavioural constraints, instead encouraging self-awareness, break-taking, and healthy interaction rhythms. For instance**,** *MyTime* (Hiniker *et al.*, 2016) supports mindful transitions between apps on smartphones, allowing users to reflect on their intent without restricting access. Similarly, the "Reflective Design" approach introduced by Sengers et al. ((Sengers *et al.*, 2005) advocates for systems that make their assumptions visible and support user agency in moments of decision or disengagement.

Together, these strands converge on a shared design goal: helping users pause meaningfully in ways that align with their cognitive state and task structure, rather than through arbitrary or externally imposed interruptions. However, most existing interventions have been developed for general productivity or attention management—not for reading, where cognitive continuity, semantic memory, and narrative immersion are especially critical (Liu, 2005; Froud *et al.*, 2024). The SmartPause concept contributes to this underexplored area by proposing lightweight, context-sensitive prompts that align with natural breakpoints in reading. It extends prior work on interruptibility, reflection, and cognitive scaffolding into the domain of digital reading. This study builds on these insights by examining how exit timing—aligned or misaligned with task boundaries—affects recall and post-task cognitive control in digital reading.

3. SMARTPAUSE DESIGN OVERVIEW AND WITHIN-PARTICIPANT STUDY RATIONALE

SmartPause is a lightweight, context-sensitive intervention developed to support intentional

disengagement in digital reading, originally introduced as a conceptual prototype in prior work (Author, in press). It was designed to promote cognitive continuity in digital reading by encouraging users to disengage at semantically meaningful points and, in its original form, to externalise thoughts through lightweight note-taking.

The earlier study used a between-subjects design to evaluate this full SmartPause experience. While that version demonstrated improved recall outcomes, it included multiple features—timing cues and reflection scaffolding and did not control for individual variability. The current pilot evaluates a simplified version that isolates one core variable: exit timing. By removing all reflective elements and using a within-subjects design, this study explores whether timing cues alone can influence memory, workload, attention, and affect.

The SmartPause system treats user-initiated exit behaviour, such as closing the reading task or attempting to navigate away, as a proxy for disengagement. When such an action is simulated, the system delivers a nudge encouraging the reader to continue until a nearby natural breakpoint (e.g., the end of a section). In the original prototype, this breakpoint was followed by an optional summarisation prompt and visual bookmarking. In the present study, these elements were removed to assess the isolated effects of context-sensitive nudges without additional user burden.

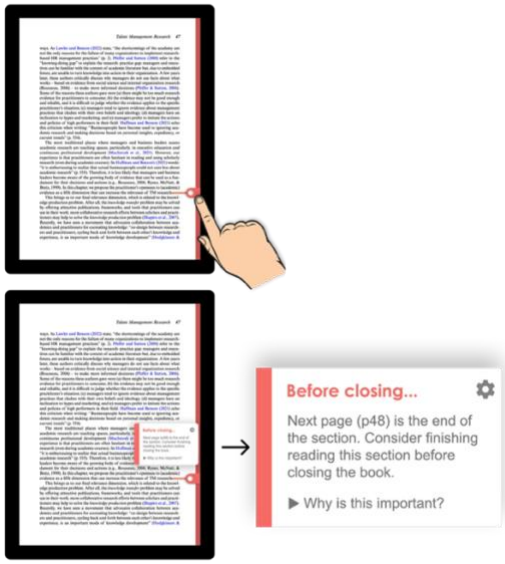

Figure 1: *SmartPause nudge at point of disengagement. When users attempt to exit mid-section, the system prompts them to continue until a natural breakpoint, highlighting the benefits of cognitively aligned pausing.*

The conceptual approach is inspired by three complementary cognitive and HCI frameworks. Event segmentation theory describes how people naturally break down an activity into meaningful units, and interruptions at event boundaries are less disruptive. The Zeigarnik Effect (Zeigarnik, 1927) explains that activities remain cognitively active when they are quit mid-task, i.e., high cognitive load moments. This creates tension, which can enhance recall but also creates cognitive overload or impaired performance. According to goal resumption theory (Altmann and Trafton, 2002), the mental representation of this task is gradually lost from memory when a task is interrupted. Resuming the task depends on reactivating this goal, which can be supported by external cues such as the visual layout of materials or the context in which the task was performed. In digital reading, these theories can be leveraged for improved cognitive performance. Pausing at the end of a section or chapter (event segmentation) may help readers encode the content more effectively, while finishing a text (Zeigarnik effect) can reduce the tension that interferes with comprehension. Resuming after a pause would also be smoother when contextual cues such as section boundaries or headings are available (goal resumption theory).

In the earlier between-participants study, we found that participants in the intervention groups showed significantly better recall than the control group. To investigate individual differences in these outcomes, we included the Big Five Personality Inventory but found no significant effect. As it captures only a limited number of high-level personality dimensions reading (Smederevac *et al.*, 2024), the Big Five may lack the specificity needed to explain nuanced behaviours related to attention regulation and disengagement during reading. The current study therefore adopts a within-subjects design, allowing each participant to serve as their own control—reducing noise from individual variability in cognitive style, multitasking habits, or attentional flexibility (Ophir, Nass and Wagner, 2009)

In this pilot, we isolate exit timing as the key design element. By comparing cognitive outcomes when readers disengage before versus after a natural breakpoint, without note-taking, we examine whether timing alone affects memory, perceived workload, and attention, as well as emotional state.

4. METHOD

4.1 Participants

This study served as a pilot to evaluate the feasibility and sensitivity of a within-subjects design focused on exit timing during digital reading. A total of 14 participants (aged 20–38, M = 30.1; 10 male, 4 female) took part in the study. All participants had advanced or native-level English proficiency (see Appendix A). Participants represented diverse cultural backgrounds (e.g., Irish/German, Chinese, Italian, Japanese, Iranian, Bangladeshi, Sudanese, Vietnamese) and held varying levels of education (2

Bachelor's, 8 Master's, 4 Doctoral). Inclusion criteria included fluent English, no diagnosed cognitive impairments, and normal or corrected-to-normal vision. Ethical approval was granted by the university's Research Ethics Committee.

4.2 Experimental Design and Procedure

This within-subjects pilot tested whether exit timing—disengaging before versus after a natural reading breakpoint—affects recall, attention, and workload. Participants experienced both control (early exit) and intervention (completion at natural breakpoint) conditions in counterbalanced order to mitigate individual variability.

While informed by an earlier between-subjects study that examined the full SmartPause interface, this pilot focused solely on isolating exit timing. The previously used Big Five Personality Inventory yielded inconclusive moderation effects and may lack granularity in explaining attentional disengagement. Thus, a within-subjects design was adopted here to control for individual differences and explore feasibility with a minimal design. To accommodate advanced but non-native English speakers, two texts of ~800-1000 words were selected, each with a relatively easier readability level (Flesch–Kincaid Reading Scores of 66.33 and 65.05; Kincaid *et al.*, 1975). The texts were selected from Secrets of the Octopus (Montgomery, 2024) and The Guest Cat (Hiraide and Selland, 2014) (see Appendix B for details).

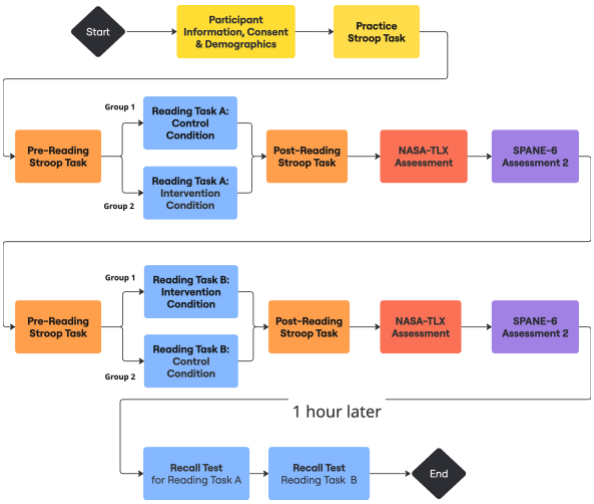

Figure 2: *Experimental design flow: participants experienced both reading conditions in counterbalanced order, with cognitive and affective measures collected across blocks.*

Participants were randomly assigned to one of two counterbalancing groups. All participants read both Reading Task A and Reading Task B, but the order of control and intervention conditions was counterbalanced. Group 1 completed the control condition with Task A and the intervention condition with Task B, while Group 2 experienced the reverse order of conditions.

After consent and a demographic questionnaire, participants completed a practice Stroop task to reduce learning effects. Each reading block then followed this sequence illustrated in Figure 2 (see Appendix C for full Stroop specifications):

(i) Pre-reading Stroop (baseline attention)
(ii) Reading task (control or intervention)
(iii) Post-reading Stroop
(iv) NASA-TLX workload questionnaire
(v) SPANE-6 affective questionnaire

To assess selective attention and processing speed, a computerised Colour-Word Stroop task was administered using Inquisit Lab 6 software . This keyboard-based task was conducted both before and after the reading task, enabling comparison of attention and processing speed across conditions. After completing each reading task, participants filled out the NASA-TLX (Hart and Staveland, 1988) to gauge perceived mental workload, and a shortened version of the Scale of Positive and Negative Experience (SPANE; Diener *et al.*, 2010) to assess affective state . This abbreviated "SPANE-6" included three positive and three negative items, selected for their relevance and brevity. The 6-item format reduced participant burden while preserving a balanced snapshot of emotional tone. Although the full 12-item SPANE is psychometrically validated, this compact version was used to capture key affective signals efficiently without overloading participants. A recall test, consisting of 12 questions across multiple formats (multiple-choice, true/false, fill-in-the-blank, matching, and short-answer), was administered one hour after the second reading block. This delay was designed to assess longer-term memory consolidation more robustly than the 10–15 minute interval used in previous work.

In this experimenter-led protocol, the interaction logic was simulated through conceptual interfaces and structured walkthroughs, not a live application. All forms and questionnaires were developed using an online survey platform (Qualtrics, 2024), hosted on an institution-managed account at the university. A consistent setup was used for all tasks, with participants working on a MacBook Air laptop (M2, 2022, 16GB RAM) in full-screen mode to minimise distractions. The study was conducted in a controlled, quiet environment with only the participant and the two researchers present.

4.3 Hypotheses

Based on findings from the prior between-subjects study and relevant literature in cognitive psychology we tested the following hypotheses in the current within-subjects design:

H1: Exiting at a natural breakpoint will improve Stroop response time and accuracy, reflecting better attentional control and reduced interference

H2: Perceived workload (NASA-TLX) will be lower in the intervention condition.

H3: Time-on-task will be higher in the intervention condition due to the longer reading segment. We interpret this increase as a proxy for deeper engagement.

H4: Delayed recall will be higher in the intervention condition, reflecting improved encoding and memory consolidation.

H5: Affective balance (SPANE-B) will be more positive in the intervention condition, reflecting a more satisfying disengagement experience.

These hypotheses reflect our underlying assumption that aligning task exits with natural cognitive boundaries supports better performance and experience than premature disengagement.

4.3 Data Analysis

We used paired-samples t-tests to compare control and intervention conditions on six dependent variables:

- Stroop response time change (post – pre): Speed of attentional processing
- Stroop accuracy rate change (post – pre): Control over attentional interference
- NASA-TLX: Perceived mental workload
- Time-on-task: Reading duration (engagement proxy)
- SPANE-B: Affect balance (positive – negative)
- Recall score: Delayed memory retention

We report means, confidence intervals, Cohen's d effect sizes**,** and p-values (one-tailed where directional). Given the small sample size, interpretation focuses on effect size trends and exploratory patterns rather than statistical significance**.** Outlier sensitivity was qualitatively assessed. All analyses were conducted using Jamovi (Version 2.3.28; The Jamovi Project, 2023) with emphasis on effect size trends over statistical significance due to the small sample size.

5. RESULTS

To evaluate how exit timing influenced cognitive performance, we conducted paired-samples t-tests across six dependent variables: Stroop accuracy and response time, perceived workload (NASA-TLX), time-on-task, affective balance (SPANE-B), and delayed recall. The intervention condition involved exiting at a natural breakpoint, while the control condition simulated disengagement mid-section. Full descriptive statistics and effect sizes are presented in Table 1. While not statistically significant, as typical in small pilot samples, several measures revealed moderate effect sizes in the expected direction, offering preliminary support for the intervention's cognitive and affective benefits.

Figure 3 summarises mean scores across all dependent variables, highlighting directional differences between control and intervention conditions. Notably, Stroop accuracy, time-on-task, and delayed recall all favoured the intervention condition, lending tentative support to hypotheses H1–H5. These trends are explored in the subsections that follow.

5.1 Attentional Processing (Stroop Task)

Participants demonstrated improved Stroop accuracy following the intervention condition (M = 0.01, SD = 0.06) but a decline after the control condition (M = –0.04, SD = 0.07), $t(13) = -1.90$, $p = .080$, $d = -0.51$. This moderate, trend-level effect aligns with H1, suggesting that exiting at a natural breakpoint may help preserve attentional control. These results echo findings from the earlier between-subjects study, where the intervention group similarly showed improved accuracy compared to control. The within-subjects design strengthens this interpretation by controlling for individual variation in attention and multitasking resilience.

In contrast, Stroop response time did not differ meaningfully between conditions (Intervention: M = 40.55 ms, SD = 159.43; Control: M = 3.13 ms, SD = 254.13), $t(13) = -0.50$, $p = .627$, $d = -0.13$. Response time appeared highly variable across participants, consistent with previous findings suggesting that accuracy may be a more reliable marker of attentional modulation in this task context.

5.2 Perceived Mental Workload and Time-on-Task

Participants reported slightly lower mental workload (NASA-TLX) in the intervention condition (M = 38.45, SD = 12.79) than in the control condition (M = 42.62, SD = 15.74), $t(13) = 1.25$, $p = .234$, $d = 0.33$. This small effect supports H2, suggesting that readers may experience less mental strain when allowed to complete a semantically coherent unit before disengaging. This mirrors a similar non-significant pattern in the earlier study, where SmartPause prompts were associated with numerically lower workload scores.

Significantly higher time-on-task was observed in the intervention condition (M = 470.21s, SD = 141.36) versus control (M = 408.29s, SD = 125.25), $t(13) = -2.25$, $p = .042$, $d = -0.60$. While this increase is partly attributable to passage length, it also supports H3, indicating greater engagement when

Table 1: *Paired-sample t-tests for intervention vs. cont= 14)*

Measure	Control (M ± SD)	Intervention (M ± SD)	*t*	*p*	Cohen's *d*
Stroop RT Δ (ms)	3.13 ± 254.13	40.55 ± 159.43	-0.498	0.627	-0.133
Stroop Accuracy Δ	-0.04 ± 0.07	0.01 ± 0.06	0.06	-1.896	0.080
NASA-TLX	42.62 ± 15.74	38.45 ± 12.79	12.79	1.247	0.234
Time-on-task (s)	408.29 ± 125.25	470.21 ± 141.36	141.36	-2.253	0.042
SPANE-B	1.07 ± 5.72	2.86 ± 4.94	4.94	-1.181	0.259
Recall Score (%)	40.27 ± 23.98	50.81 ± 23.00	23	-1.162	0.266

users are encouraged to read to a natural breakpoint. Notably, the increased duration was not accompanied by increased perceived workload, suggesting deeper involvement rather than cognitive overload.

5.3 Delayed Recall Performance

Participants scored higher on the delayed recall test following the intervention condition (M = 50.81%, SD = 23.00) compared to control (M = 40.27%, SD = 23.98), $t(13) = -1.16$, $p = .266$, $d = -0.31$. Though exploratory, this moderate effect aligns with H4 and extends findings from the earlier between-subjects study, where recall significantly improved under SmartPause. Here, even without note-taking prompts, simply exiting at a natural breakpoint appeared to support better memory retention—consistent with theories of task segmentation and semantic closure (Zeigarnik, 1927; Zacks *et al.*, 2007).

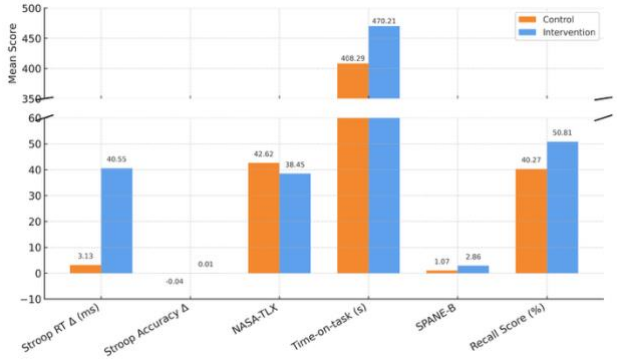

Figure 3: *Mean performance across cognitive and affective outcomes by condition.. A broken y-axis is applied only to Time-on-Task to enhance visibility of lower-value measures. Intervention reflects reading to a natural breakpoint; control reflects early exit mid-section.*

5.4 Affective Response (SPANE-B)

Affective balance (SPANE-B) was more positive following the intervention (M = 2.86, SD = 4.94) than control (M = 1.07, SD = 5.72), $t(13) = -1.18$, $p = .259$, $d = -0.32$. This trend is consistent with H5 and prior qualitative feedback from the between-subjects study, where participants described SmartPause-style transitions as smoother and less frustrating. These results suggest that even subtle design changes in disengagement timing may influence users' emotional experience of digital reading.

6. DISCUSSION

This pilot study explored whether the timing of disengagement from digital reading—specifically, exiting mid-section versus at a natural breakpoint—affects cognitive outcomes including attention, memory, perceived workload, affect, and task engagement. While informed by a prior conceptual study evaluating the full SmartPause experience, this pilot study aimed to better isolate causal effects while accounting for individual differences. The earlier study suggested that traits like multitasking resilience or attentional style may moderate how readers respond to interruption timing. By adopting a within-subjects design, the present study reduced between-participant variability, allowing clearer insight into how exit timing alone shapes cognitive outcomes. Although not statistically robust, several directional effects emerged that align with cognitive theory and support the rationale behind the SmartPause design.

6.1 Cognitive Outcomes and Trends

The findings of this pilot study offer preliminary support for the idea that cognitively aligned disengagement can mitigate the disruptive effects of interruption in digital reading. Participants exhibited improved Stroop accuracy after completing a full reading section compared to exiting partway through— consistent with H1 and with the principle that transitions are less mentally taxing when they occur at meaningful semantic boundaries. Although this difference was not statistically significant, the moderate effect size indicates that attentional control may be more readily preserved when users disengage at structurally coherent points. These trends mirror prior HCI work showing that interface interruptions introduced at natural breakpoints are less disruptive and allow for smoother task resumption (Altmann and Trafton, 2002; Adamczyk and Bailey, 2004).

Recall performance also improved in the intervention condition, supporting H4, although the effect size was modest. This aligns with our earlier findings, where participants showed stronger recall when the intervention included reflective features. The fact that recall remained higher here despite the absence of note-taking**,** suggests that timing cues alone may support semantic consolidation, possibly through the closure of cognitive schemas or narrative structures. This pattern resonates with the Zeigarnik Effect, which proposes that when tasks are interrupted before reaching a point of perceived completion, they remain cognitively active, potentially interfering with memory integration. In contrast, disengaging at natural breakpoints may allow for cognitive closure, reducing residual tension and enabling more effective encoding.

The results for perceived workload and time-on-task provide further insight into cognitive experience. As predicted in H3, participants spent significantly more time reading in the intervention condition, reflecting deeper engagement with the material. Yet despite the longer duration, they reported slightly lower NASA-TLX workload scores (H2), suggesting that completing a coherent section may be cognitively smoother than disengaging mid-flow. This aligns with theories of cognitive fluency and cognitive control, which propose that well-structured, semantically coherent tasks are perceived as less effortful and more manageable than fragmented or disjointed ones (Gray *et al.*, 2006; Kahneman and Frederick, 2007).

This study also introduced affective outcomes via SPANE-B, extending the scope beyond what was measured in the earlier SmartPause evaluation. Participants reported a higher positive affect balance after completing a full section, suggesting that smoother cognitive transitions may also influence emotional state. While this supports H5, the result should be interpreted with caution, as passage-to-condition assignment was fixed**,** and emotional tone or topic familiarity may have influenced scores independently of the intervention.

As a pilot, the aim of this study was not to statistically confirm hypotheses, but to explore the viability of the SmartPause intervention and identify promising cognitive effects. While significance was not achieved, the convergence of trends across H1–H5, moderate effect sizes, and consistency with cognitive theory suggest that lightweight, timing-sensitive disengagement cues may support attention, memory, and emotional experience. These findings establish a foundation for further evaluation in more naturalistic contexts.

6.2 Implications for Design and Interaction

The SmartPause concept contributes to an emerging design agenda in HCI that seeks to scaffold attention, memory, and task continuity without enforcing rigid behavioural control. Unlike productivity tools that rely on timers, blocks, or fixed usage modes, it engages only when the user signals intent to disengage—prompting them to consider pausing at a more cognitively aligned point, such as the end of a section. This approach preserves autonomy while gently encouraging behaviour that supports semantic closure and long-term recall.

Rather than introducing new interruptions, SmartPause responds to moments of natural disengagement and reframes them as opportunities for reflection. In doing so, it draws on the principle of seamful interaction, not by hiding disruptions, but by recognising seams as potentially useful interaction points that can support appropriation, understanding, or empowerment (Chalmers, MacColl and Bell, 2003). It also aligns with the values of reflective design (Sengers *et al.*, 2005), offering lightweight scaffolding at moments of cognitive drift without requiring prior setup or sustained user effort. Because the prompt is brief, contextual, and easily dismissible, it strikes a balance between guidance and autonomy, surfacing cognitive transitions without undermining control.

These findings extend prior conceptual work on SmartPause, suggesting that even without reflective elements, timing cues alone may support memory and attention. The results offer preliminary evidence that encouraging readers to complete semantically meaningful units before disengaging can lead to improvements in attention, engagement, and affect, even in the absence of deeper reflective mechanisms.

From a design perspective, SmartPause represents a shift from preventing disengagement to guiding it strategically. This opens up new opportunities for digital reading, learning, and work environments to better support users as they transition in and out of cognitive tasks. For example, embedding SmartPause-like mechanisms into academic readers, e-learning platforms, or document review tools could help users pause more meaningfully and resume more effectively—without burdening them with effortful planning or rigid system constraints.

More broadly, these results suggest that managing how users leave a task may be as important as managing how they stay engaged. Designing for disengagement, not just sustained focus, can be key to better cognitive wellbeing. The SmartPause concept invites a rethinking of cognition-aware interaction design by taking timing, context and task structure into consideration. While promising as a concept, real-world deployment requires addressing practical challenges, including reliable breakpoint detection and supportive nudges rather than intrusive ones.

6.3 Limitations and Future Direction

This study, while informative, was designed as a small-scale pilot with 14 participants and is therefore limited in its statistical power and generalisability. Most findings remained below conventional significance thresholds, and the primary aim was exploratory—to assess the viability of the SmartPause concept and identify promising trends in cognitive and affective outcomes. While the within-subjects design helped control for individual variability, several methodological limitations should be acknowledged.

First, the reading passages used in the intervention and control conditions differed slightly in length and complexity. This may have confounded time-on-task and workload comparisons, as longer passages naturally take more time to complete. Although participants did not report increased mental workload in the intervention condition, future studies should equalise or adaptively segment reading content to ensure structural and semantic equivalence across conditions.

Second, the reading materials were not counterbalanced across participants. As a result, the assignment of specific texts to each condition may have influenced affective responses (SPANE-B) and memory performance due to differences in content familiarity, emotional tone, or personal relevance. To address this, future studies should randomise or counterbalance text assignment and reading order. Incorporating valence-specific measures or open-ended reflections may also help disentangle content-driven effects from those attributable to the intervention itself. Moreover, affective responses may have been influenced by differences in the texts' emotional tone, which could act as a confounding factor independent of the intervention.

The SmartPause system was not implemented as a functional prototype. Instead, participants followed researcher-led instructions to simulate the system's logic, depending on the assigned condition. No real-time detection of disengagement or interface-level prompting was included. While this approach enabled tight experimental control, it limits ecological validity. In naturalistic settings, user behaviour and responses to SmartPause cues may differ based on interface design, timing precision, and task context.

Additionally, the cognitive and affective measures relied on self-report and performance-based metrics (e.g., Stroop accuracy, delayed recall). While informative, these offer only a partial view of user experience. Future research could benefit from richer behavioural or physiological data, such as eye-tracking, pupillometry, or engagement telemetry, to better capture attention dynamics and cognitive load in real time.

Several future directions emerge from this pilot. Larger, more diverse samples are needed to validate the trends observed and to explore potential subgroup differences—for example, based on cognitive style, reading proficiency, or multitasking habits. Beyond lab settings, SmartPause could be deployed in e-learning platforms, workplace dashboards, or knowledge repositories, where memory and focus are mission-critical. Real-time breakpoint detection, powered by natural language processing or gaze-based segmentation, could support adaptive and personalised pausing suggestions. Future versions may also reintroduce lightweight note-taking or compare passive versus interactive resumption aids to explore their respective benefits.

Finally, longitudinal evaluations will be crucial for understanding how SmartPause affects user trust, satisfaction, and long-term reading habits. As reading becomes increasingly screen-based and fragmented, there is a growing need for interface interventions that preserve cognitive continuity while respecting user autonomy. SmartPause offers a promising foundation toward that goal, and this study provides early evidence to support its continued refinement and real-world deployment.

7. CONCLUSION

This study extends previous research on SmartPause by examining whether the benefits of cognitively aligned pausing persist when controlling for individual variability. Using a within-subjects design, we compared outcomes when participants exited partway through a reading section versus after reaching a natural breakpoint. Although based on a small sample, results consistently favoured breakpoint-aligned disengagement across memory, attention, workload, engagement and affect.

These findings underscore the potential of timing-sensitive interventions that align with users' cognitive rhythms. SmartPause provides a lightweight, context-aware approach that supports more intentional transitions without imposing external interruptions. By responding to user-initiated exits rather than enforcing scheduled breaks, the design supports cognitive continuity and more intentional transitions.

Future work should examine how such interventions perform in real-world digital contexts, leveraging adaptive breakpoint detection and testing with larger, more diverse samples**.** As reading becomes increasingly screen-based and fragmented, supporting not only sustained attention but also strategic disengagement may be key to improving comprehension and cognitive performance in digital reading environments.

ACKNOWLEDGEMENTS

This work was conducted with the financial support of the Research Ireland Centre for Research Training in Digitally-Enhanced Reality (d-real) under Grant No. 18/CRT/6224 and the Research Ireland Centre Grant No. 12/RC/2289_P2 at Insight Centre for Data Analytics at Dublin City University. For the purpose of Open Access, the author has applied a CC BY public copyright license to any Author Accepted Manuscript version arising from this submission. The authors would like to thank Dr Brendan Rooney, University College Dublin, for his advice in the planning part of the experiment.

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APPENDIX A. PARTICIPANT CHARACTERISTICS

Table A1: *Sociodemographic and Language Characteristics of Participants*

Characteristic	Value (N = 14)
Age (years)	M = 30.1, Range: 20–38
Gender	10 Male, 4 Female
Highest Degree Completed	2 Bachelor's, 8 Master's, 4 Doctoral
Cultural Backgrounds	Irish/German, Chinese, Moroccan, Spanish, Vietnamese, Bangladeshi, French, Iranian, Japanese, Sudanese, Italian
English Proficiency	2 Native-level (the ability to speak, read, write, and understand this language as fluently as a native speaker) 12 Advanced (the ability to speak, read, write, and understand this language very well, but I am not at a native level)

APPENDIX B. READING MATERIALS

Table B1: *Characteristics of Reading Materials (Tasks A and B)*

Reading Task	Text Source	Excerpt Used	Topic	Length	Flesch-Kincaid Readability
Task A	Montgomery, S. (2023). Secrets of the Octopus.	Introduction (pp. 1–3)	Encounter with a giant Pacific octopus	**Total = 1012 words** Control = 823 words (last 189 cropped) Intervention = full 1012 words	66.33
Task B	Hiraide, T. (2014). The Guest Cat	Chapter 2	Encounters a stray cat	**Total = 995 words** Control = 814 words (last 181 cropped) Intervention = full 995 words	65.05

APPENDIX C. STROOP TASK SPECIFICATIONS

Table C1: *Stroop Task Parameters*

Parameter	Detail
Software Application	Inquisit Lab 6 (Millisecond Software)
Design	Standard colour–word Stroop with keyboard responses
Response Mapping	D = Red, F = Green, J = Blue, K = Black
Trial Types	Congruent (word and ink colour match), Incongruent (word and ink colour differ), Control (coloured rectangles)
Trials per Block	84 total (4 colours × 3 congruency conditions × 7 repetitions)
Stimulus Timing	Displayed until response; 200 ms inter-trial interval
Error Feedback	400 ms
Procedure	One short practice block was administered before the experiment to reduce learning effects. Each experimental block then included two administrations of the Stroop: pre-reading (baseline) and post-reading (after condition).
Outcome Measure	Accuracy, reaction time (correct trials), Stroop interference (Incongruent – Congruent)