Pacing - Slowing Phenomenon in Varying Length Tasks

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ABSTRACT

Pacing is a critical mechanism for regulating effort over time to achieve optimal performance. While commonly associated with sports, pacing can be seen in individuals' everyday lives. For example, students can pace their studying habits to retain information effectively and avoid last-minute studying. Current pacing literature lacks empirical testing in less physically demanding tasks. The team sought to study pacing, using a task analogous to running different-length events. In two preliminary experiments, undergraduate students pressed the enter key N = [8, 16, 32, 64] times. Running and key presses involve prolonged repetitive activities that require sustained performance. Participants were instructed to complete the task rapidly and exceed the specified number of taps, similar to runners sprinting through the finish line. Our main method of measurement was the mean interresponse interval (IRI) which is the average elapsed time between consecutive taps. Our main question was if participants would tap slower when N is large versus when N is small, just like runners. Surprisingly, participants did not change their performance based on N and slowed dramatically as they approached N. The premature slowing effect was indicated by an appreciable difference between IRI values for Experiment 2 where $F(3,656) = 3.83$, $p = .0097$. We varied the count feedback between experiments: either counting up from 1 or down from the total number of key presses required. The slowing effect before the trial ended was not extinguished. This premature slowing suggests that as people approach the end of a task, they slow their performance.

KEYWORDS: pacing, meta-cognition, learning process, slowing effect

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INTRODUCTION

Homeostasis, the body's equilibrium of internal conditions, is essential for health and well-being (Billman, 2020). Maintaining this equilibrium is done through various methods, one of which is the pacing of one's performance. Pacing in daily activities allows the body to sustain its internal balance throughout the day and prevent excessive depletion of resources. Thus, as individuals engage in tasks throughout the day, they adjust their efforts to optimize performance while conserving energy (Menting, 2022).

Folklore and Pacing

Pacing has been seen in folk knowledge and many well-known idioms, emphasizing its prevalence, such as "haste makes waste," "take it a day at a time," and "fools rush in." The most famous idiom, "slow and steady wins the race," comes from Aesop's famous fable "The Tortoise and The Hare." The tortoise, pacing itself throughout the race, won despite the hare being a speedy animal.

The concept of pacing is not limited to specific timeframes—it involves spreading performance out over time and condensing it into shorter bursts within time intervals (Gersick, 1994). For instance, when studying for an exam, pacing might mean spreading out study sessions over several weeks to avoid cramming. Pacing could also entail focusing intensely for shorter periods, such as using the Pomodoro Technique, where an individual may work for 25 minutes and then take a 5-minute break. By alternating between periods of focused work and brief breaks, the Pomodoro Technique helps individuals pace themselves effectively, manage their energy, and maintain productivity throughout the day (Cirillo, 2013).

A study focusing on the impact of massed versus spaced learning revealed that spaced studying resulted in better test performance compared to massed studying (Kornell & Bjork, 2008). Thus, pacing oneself during learning tasks might also lead to better understanding and retention of information.

Similarly, pacing strategies can be manifested in the athletic world. Spreading out study sessions over several weeks is similar to how marathon runners approach pacing. But working intensely in short bursts, such as by using the Pomodoro Technique, is similar to how sprinters approach their races.

Pacing studies predominantly focus on athletics, where it guides athletes' strategies and performances. From sprinters to marathoners, a mastery over pacing is essential for optimizing energy expenditure and achieving peak results (Abbiss, 2008). There is a distinction between pacing as a rate and pacing through decisions. For example, compare sprinting to long-distance running: in sprinting, the focus is on maintaining a high pace for a short duration, while in long-distance running, it is about sustaining a consistent pace over a longer period by making strategic decisions about energy expenditure and effort allocation. In a 1992 study, van Ingen Schenau et al. noticed that sprinters running the 1000m versus the 4000m adopted different pacing strategies.

Our project delves into the pacing behavior in every day, less physically demanding tasks. We aim to understand whether similar pacing strategies manifest in daily task contexts compared to pacing seen in the athletic world. Specifically, we want to investigate whether participants modulate their performance as the length of a task changes. By exploring pacing behavior in everyday tasks, we aim to contribute to a deeper understanding of human behavior, productivity, and well-being.

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Relevant Research and Implications

A relevant study hypothesis that may aid in our understanding of pacing is the goal gradient hypothesis. The goal gradient effect refers to the phenomenon where an increase in efforts is seen as the goal is approached. This study was done on rats and noticed that as the rats get closer to reaching a goal, they tend to work harder and more efficiently (Hull, 1932). In addition, pacing patterns in activities like running, swimming, and cycling are influenced by a psychological mechanism called "perceived impact." This means that athletes push harder toward the end of a task when they feel their efforts have a bigger impact on their advancement (Emmanuel, 2019). Perceived impact enhances the goal gradient hypothesis by elucidating how individuals increase their effort as they approach a goal, driven by the belief that their actions have a greater impact on their progress.

The goal gradient hypothesis suggests that as individuals get closer to a reward, they expend more effort to reach it. Other studies have built on this idea, proposing new insights into how humans respond to rewards. Through various experiments and analyses, they found that participants in a café reward program increased their coffee purchases as they neared a free coffee reward (Kivetz et al, 2006).

The "labor-in-vain" effect suggests that individuals may pace themselves differently depending on the difficulty or intensity of a task (Nelson, 1988). For example, they might slow down or take breaks during more challenging activities to conserve energy. This suggests a modulation of activity depending on the task length and difficulty.

The goal gradient hypothesis suggests that as participants near the end of a trial, they may ramp up their efforts, echoing findings from studies by Kivetz et al. (2006) and Emmanuel (2019). Various potential explanations for this hypothesis exist in varying fields of psychology. One of these explanations revolves around prospect theory, which employs the concept of diminishing sensitivity to argue that the value of each action increases as the goal draws nearer (Heath et al., 1999). According to Koo and Fishbach (2012), goal outcomes hold greater value when they are in proximity to the goal's end state, as the value function becomes steeper near this point. Gestalt psychology also contributes to understanding this phenomenon, suggesting that motivation increases as individuals strive to achieve closure (Zeigarnik, 1938). Lastly, another perspective in social psychology posits that each step towards goal attainment is perceived as a success, with the value of each success increasing as it contributes further to reaching the goal (Förster, 1998).

Additionally, insights from Nelson (1988) regarding the labor-in-vain effect indicate that participants may adjust their pacing based on the length of the trial. Considering the implications of the Pomodoro Technique by Cirillo (2013) and the results from massed and spaced learning by Kornell & Bjork (2008), we observe that pacing strategies can effectively influence participants' performance across various tasks and learning contexts.

Research Question

Unlike most pacing studies, this research doesn't involve physical exhaustion. Instead, it focuses on the modulation of performance in a sustained task. This study aims to investigate whether pacing strategies observed in physically demanding tasks, such as running or cycling, are similar in a less physically demanding task, specifically keypressing. We vary the duration of the task to attempt to answer the question: does the pacing mechanism seen in physically demanding tasks work similarly in non-physically demanding tasks? If so, then similar variations in performance given the distance of the event, so to speak, should result. We sought to test this with the simplest task we could devise, a button-pressing task. Both running and keypressing share similarities as they both involve constant repetitive activity over a duration of time.

METHODOLOGY: EXPERIMENT 1

Participants

A total of 45 undergraduate students participated in this research study from the University of California, Riverside (UCR). All participants were obtained from the undergraduate research pool using the Sona platform for psychology courses PSYC001 and PSYC002.

Procedure

We sought to study pacing using the simplest task we could. Participants in our study were instructed to press the enter key of a standard computer keyboard a specified number of times in each trial (N = 8, 16, 32, 64). There were a total of 32 trials with each N value being seen a total of 8 times each. For each event or value of N, participants were directed to continue tapping past the trial length, akin to a runner sprinting through the finish line. Additionally, participants were told there would be no penalty for tapping beyond the N required taps. Real-time countdown feedback regarding the number of taps was provided until each participant reached zero responses left, eliminating the need for them to keep count of their responses. Feedback, including the average response time per trial and the best overall time of any trial was given to encourage participants to go as quickly as possible. MATLAB software administered the experiment and recorded the data. Inter-response intervals (IRIs), measured as the elapsed time between successive taps, were the variable of interest and represented the speed of the performance.

Hypotheses

The primary question of this study was whether participants would modify their performance as the length of the task changed. We hypothesized that if pacing is a cognitive mechanism that works irrespective of a task's physical demands, then participants' IRIs should change as a function of N (the required number of responses). Alternative predictions were guided by the previous literature mentioned in the introductions and we propose those predictions below.
Based on the goal gradient hypothesis, we posit that participants will tap faster as they approach the end of each trial due to an end-of-trial speed-up phenomenon. It is also plausible that participants will exhibit a gradual increase in speed as the length of each trial progresses, as referred to by the perceived impact mechanism. The final prediction is based on the scenario of the "labor-in-vain" effect where participants will exhibit a consistent tapping pace but may slow down, particularly in trials that require lots of taps and not in shorter events.

Measures

In this study, we employed several measures to assess participants' performance in response to varying trial lengths but primarily cover one in this article. Firstly, the total number of responses (N) served as our key independent variable, with trial lengths ranging from 8, 16, 32, and 64. Concurrently, the number of between-response intervals (n) was recorded and represented the speed at which participants performed. Smaller response intervals mean quicker taps and, if sustained, shorter overall times. The study recorded the mean inter-response intervals (IRIs) which is the average elapsed time between consecutive taps for that event. Events were pseudo-randomly ordered, ensuring that no event was tested twice before completing all four N values.

RESULTS: EXPERIMENT 1

The main question for this study was whether or not participants would modify their performance when the length of a trial varied. If the mechanism of pacing is the same regardless of the physical demands of the task, then we expect to see different average speeds depending on the length of the events. In Figure 1 we show the average between tap time, or speed, for each of our 4 events. Noticeably there is little difference between each of the bars. The lack of difference between events was confirmed using a one-way analysis of variance (ANOVA) for each of the 4 events, $F(3,176) = 0.04, p = 0.988$.

This omnibus data helps to answer our question regarding changes in performance by event length but does not speak to our alternative predictions. Showing the data another way, in Figure 2 the mean inter-response time for each of the intervals of an event was averaged across participants and blocks. We see that

We see that participants did not perform differently in each of the 4 events, with no appreciable difference between the lines of different colors. However, we do see a change in the performance across the event. IRIs quickly shrink after the first response or two and then gradually increase as more responses are required. This was confirmed by an ANOVA for the first 4 IRIs by the 4 events where the interaction between event and response number could have occurred by chance, $F(3,704) = 0.3, p = .83$. Additionally, the main effect of the event was not appreciable, $F(9,704) = 0.1, p = 0.99$, which also confirms the previous figure's result. However, there was an appreciable difference between the average time for the first 4 intervals, $F(3,704) = 3.45, p = 0.016$. A multiple comparison test revealed that the difference was between the first IRI and both

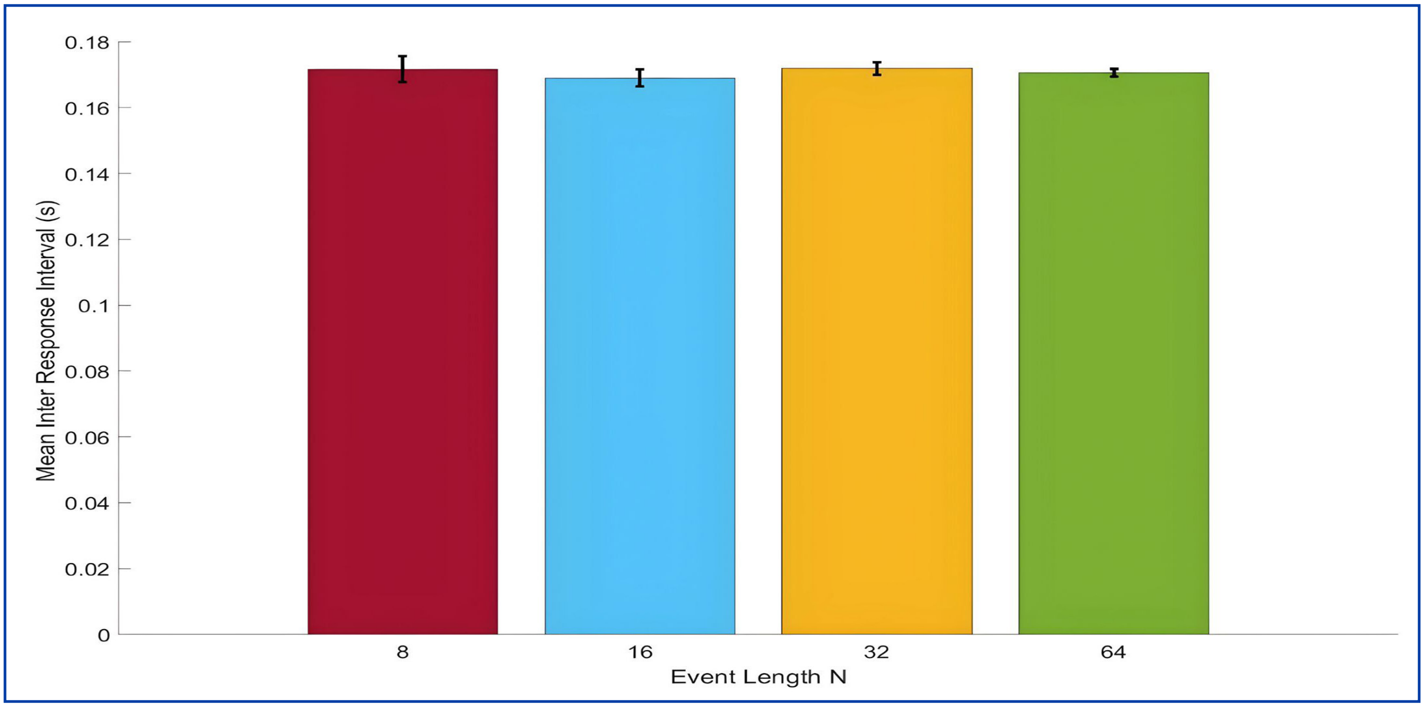

Figure 1: Mean Inter-Response Intervals by Event

Note. Mean Inter-Response Interval (± 1 SEM) in seconds for each of the 4 events averaged over the 8 blocks, all intervals (n), and overall 45 participants. The number of required taps distinguishes each event and is not only shown in different colors in this and all figures following but is also denoted by the value on the x-axis.

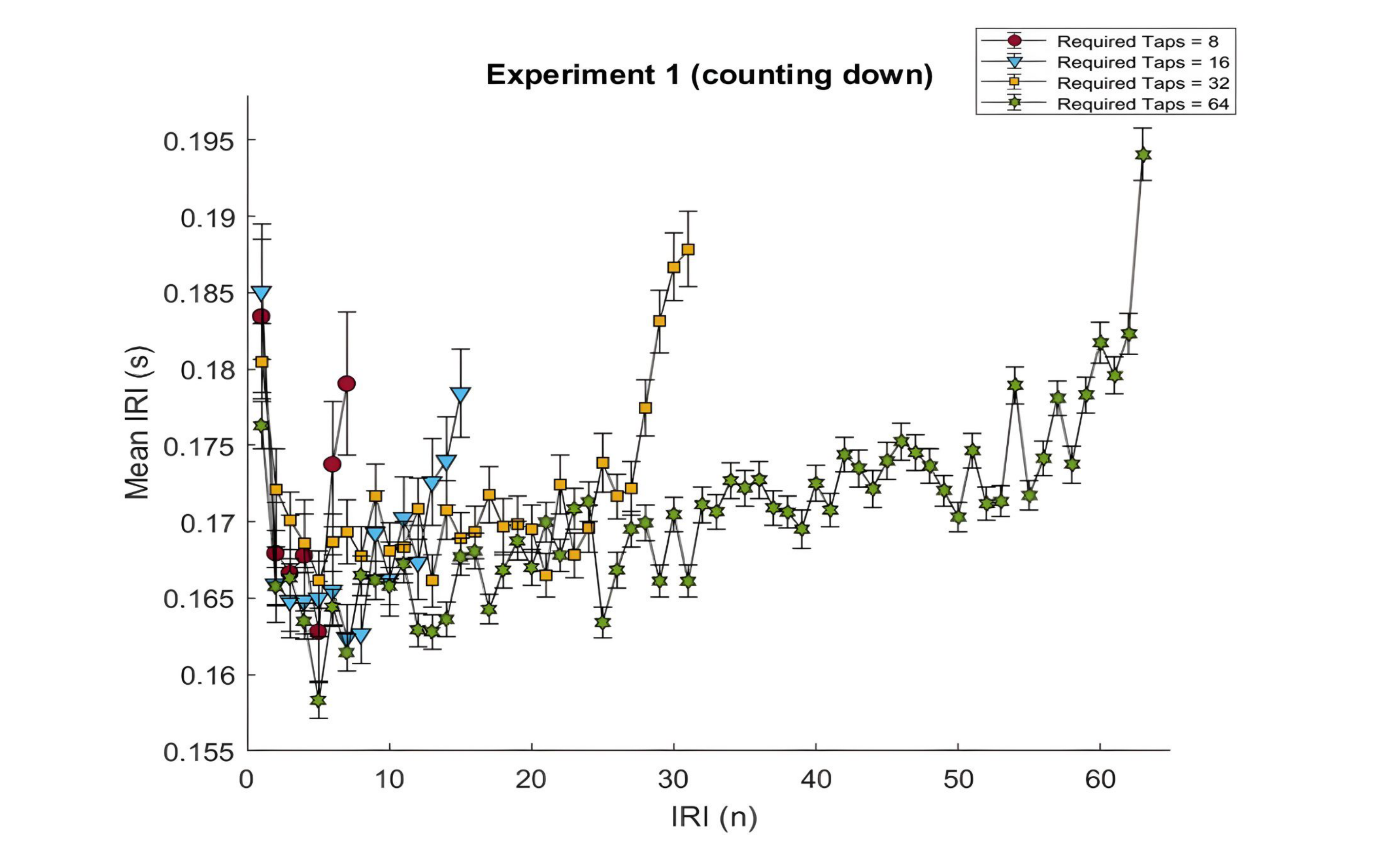

Figure 2: Mean Inter-Response Intervals

Note. Mean (± 1 SEM) inter-response intervals (IRI) as a function of which interval (n) for each of the 4 number of required taps or events. Both the marker color and the marker shape represent the event length.

the third and fourth intervals. This shows that there is an appreciable increase in speed during the first few taps of an event. Lastly, and most surprising was the sharp decrease in speed (increase in response intervals) toward the end of the trial. This feature of the data was not hypothesized or expected and so we respectfully chose not to perform hypothesis tests like those covered above.

DISCUSSION: EXPERIMENT 1

In this experiment, we looked at the effect of trial length on participant performance when asked to tap a computer key as quickly as possible. Our question was whether participants would change their tapping rate when the number of required taps changed. We hypothesized that if pacing one's performance is done irrespective of the physical demands of the task then key pressing should work similarly to running. Our data showed that participants did not modify their performance as a function of N. However, they did show increases in speed and dramatic slowing as the trial began and ended, respectively. We did not hypothesize the dramatic slowing that participants showed at the end of each event, thus no significant data for it was collected in Experiment 1. However, this slowing effect goes directly against the goal gradient effect popularized by Hull (1932) and others. We believe this end-of-trial slowing could be an artifact of the feedback provided to the participants. In each trial, participants saw the number of required taps count down from N to 0 as they submitted more and more key presses. We speculated that this counting down to 0 inhibited participants from sprinting through the finish line as instructed thus not maintaining their previously set level of performance. We sought to test this theory in the experiment to be covered next.

METHODOLOGY: EXPERIMENT 2

Participants

For Experiment 2, 42 undergraduate students participated for partial course credit. We recruited participants using the same recruiting system, Sona.

Procedure

In Experiment 2, we aimed to address the observed end-of-trial slowing by altering the count feedback provided to participants. Instead of having a countdown method, participants were shown feedback that counted up during each trial, beginning from "1" and incrementing with each tap. Participants were given the same instructions as Experiment 1 of tapping the enter key as fast as they could for a predetermined number of times in each trial, with N values set at 8, 16, 32, and 64. Each N value was tested 8 times across 32 trials, and the experiment's events were pseudo-randomly ordered. Real-time feedback on the number of taps was provided to participants, although differently than before. End-of-trial feedback with the current time and best overall time was also provided. All aspects of the study were the same except for the performance feedback regarding the number of taps submitted (n) out of how many were due (N). The study again recorded the inter-response intervals (IRIs), which was the elapsed time between two consecutive taps.

Hypotheses

If pacing is a cognitive mechanism that works independently of the physical demands of a task, then participants' IRIs should change as a function of N, the required number of responses. The slowing seen in Experiment 1 may or may not have been due to feedback given to participants, thus we presume changing the feedback provided might eliminate the end-of-trial slowing. Our hypotheses align with those proposed in Experiment 1, except for the aforementioned end-of-trial slowing. In Experiment 2 we are replicating the test regarding event length and performance changes and extending to test whether the end of trial slowing was due to an artifact of the design. interval which was averaged to varying degrees.

Measures

Quantitative measures remain the same from Experiment 1 where (N) represents the number of total responses required for the trial our independent variable, (n) represents one of N-1 inter-response intervals. The dependent variable is the inter-response interval which was averaged to varying degrees.

RESULTS

Figure 3 shows an omnibus graph model depicting the event length (N) on the x-axis and the mean inter-response interval in seconds on the y-axis. Based on the omnibus comparison across different trial lengths, there is no significant variation observed in the Mean Inter-Response Interval (IRI) as trial lengths increase. A one-way ANOVA showed no appreciable difference between the four events for Experiment 2, $F(3,164) = 0.27$, $p = 0.85$. We again chose to look at the mean interval data for each (n) in Figure 4, displaying the mean IRI changes across different trial lengths.

Figure 4 also shows that participants performed similarly, with no appreciable difference, in each of the 4 events. A 4x4 analysis of variance uncovered a

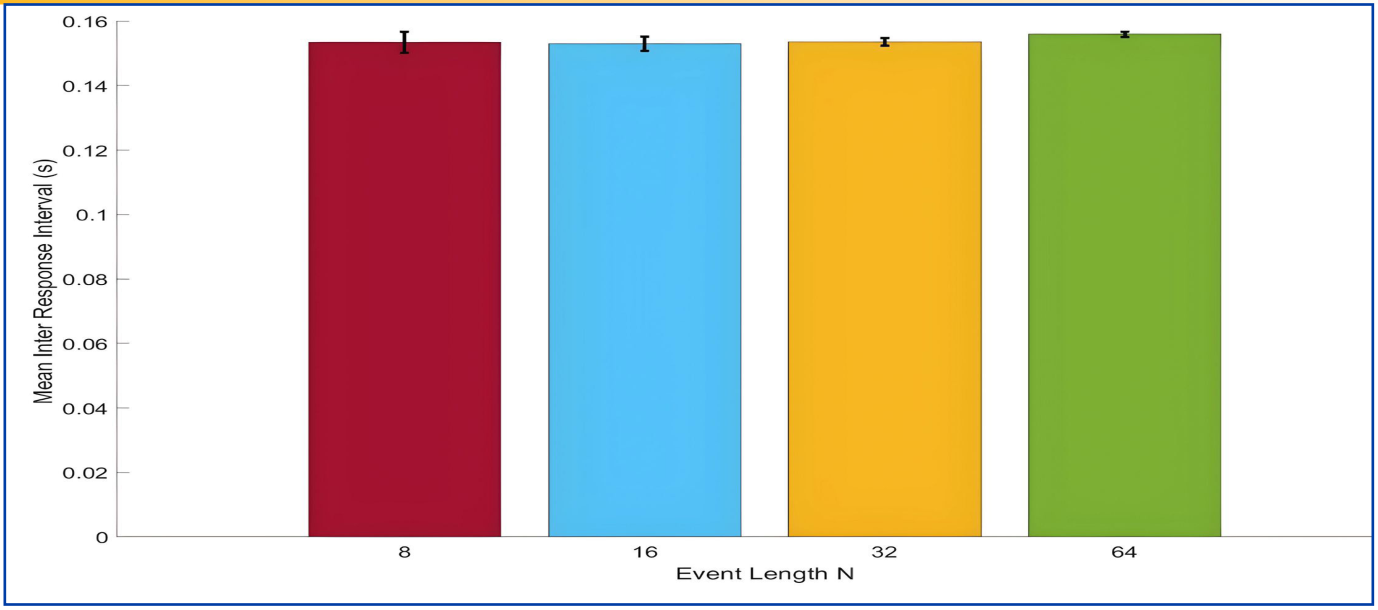

Figure 3: Mean Inter-Response Intervals by Event

Note. Mean Inter-Response Interval (± 1 SEM) in seconds for each of the 4 events averaged over the 8 blocks, all intervals (n), and overall 42 participants. The number of required taps distinguishes each event and is not only shown in different colors in this and all figures following but is also denoted by the value on the x-axis.

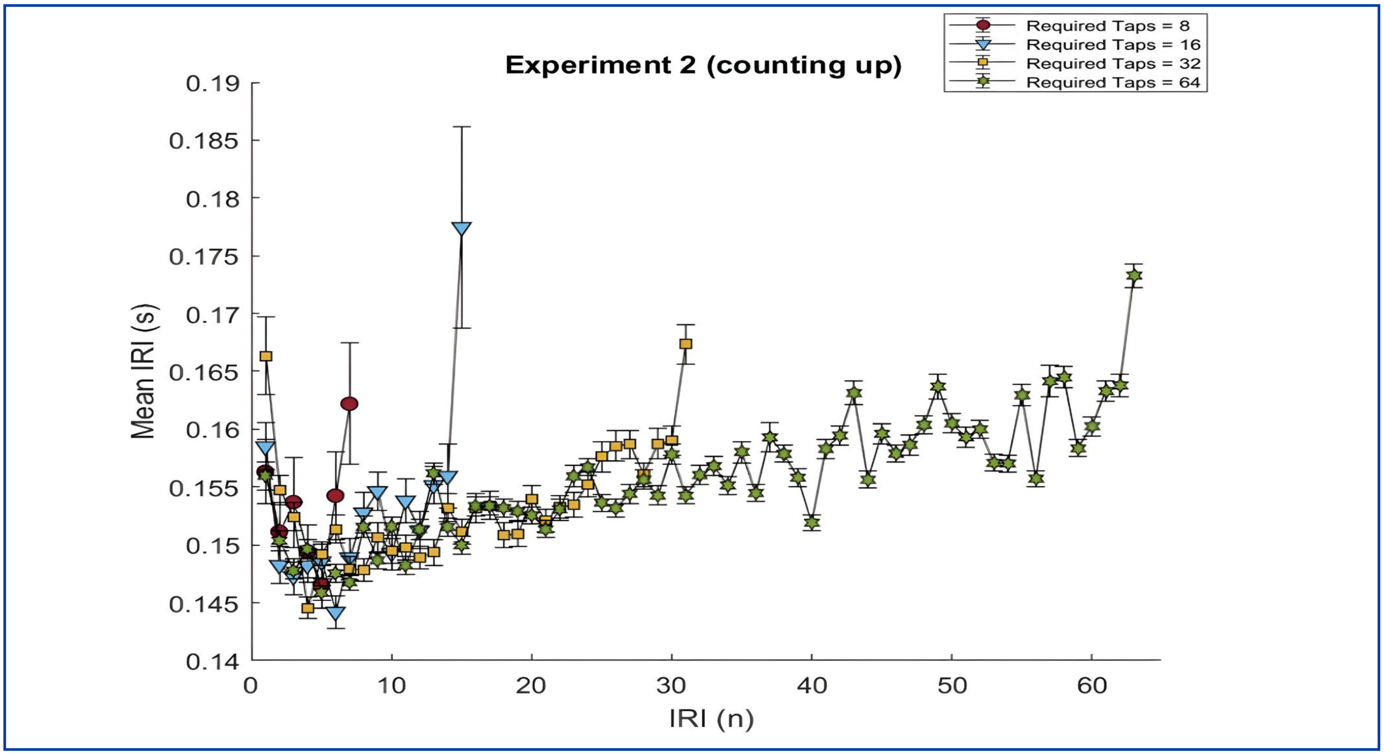

Figure 4: Mean IRI Values for Actual Responses (n) of Each Event in Experiment 2

Note. Mean (± 1 SEM) inter-response intervals (IRI) as a function of which interval (n) for each of the 4 number of required taps or events. Both the marker color and the marker shape represent the event length.

significant distinction for the first 4 IRI(n) of each event, ($F(3,656) = 6.66, p < .001$), replicating the result from Experiment 2. Additionally, there was no notable difference for the event ($F(3,656) = 0.89, p = .445$), or the interaction between the event and IRI(n) ($F(9,656) = 0.77, p = .645$) just as there was in Experiment 1. Figure 4 displays that, on average, each trial rose by ≥ 0.02 seconds, comparing the start point and the end point of each N value. At the beginning of each event, the IRI rapidly decreases after the first few taps; however, the IRI then gradually increases, and at the very last response, the IRI has a sharp increase. An increase in IRI shows a slow-down in performance and confirms that this effect was not related to the feedback change from counting down to 0 to counting up to N. This was confirmed with an ANOVA test for the last 4 IRIs. The analysis showed that the main effect for Event, $F(3,656) = 3.83, p = .0097$ and IRI(n), $F(3,656) = 8.0, p < 0.001$, indicating statistical significance. However, the Event and IRI interaction was not significant ($F(9,656) = 0.5, p = .875$).

DISCUSSION: EXPERIMENT 2

The results from Figures 3 and 4 show that there was an increase in IRIs as the trial length increased. This could imply a slower pace or a longer pause between taps, as the trial length increased. Our expectation based on previous literature was that participants would increase their pace–lower IRIs–as they approached the end of the trial. Instead, participants slowed down and had much larger IRIs as they approached N. This experiment aligns with the end-of-trial slowing in Experiment 1. Both experiments showed this remarkable phenomenon that is in direct conflict with the goal gradient prediction. In both Experiments 1 and 2, participants may have experienced cognitive and/or motor fatigue as they progressed through longer trial lengths, leading to a natural slowdown in tapping speed as trial length increased but they also showed a drastic slowing increase in the last few taps of an event.

GENERAL DISCUSSION

The Pacing Project aims to explore pacing in everyday tasks. Previous studies done in the athletic world show that individuals have different pacing strategies for different events such as sprints and marathon running. Our primary objective was to see if individuals would modulate their performance as the length of an event changes. Thus, we designed an experiment where participants were to tap the enter key a various number of times, ($N = 8, 16, 32, 64$). We hypothesized that participants would have different pacing strategies for the different trial lengths, and that they would manifest in the intervals of the tapping. In both experiments covered here, participants tapped the enter key as quickly as possible and were asked to maintain that tapping even beyond the required amount, just as runners run through the finish line of a race. The results were replicated in both experiments where participants did not appreciably modify their performance for each event. However, they did speed up and slow down appreciably at the beginning and end of each event. Most surprisingly, as participants approached the end of a trial their tapping slowed drastically.

This discrepancy between instruction and behavior creates a form of cognitive dissonance, where individuals may experience discomfort or conflict due to the inconsistency between what they are told to do and what they actually do. This observation raises questions about the underlying factors influencing participants' pacing behavior and suggests potential complexities in how pacing is executed and understood in this context.

The end-of-trial slowing was directly tested between the two experiments by modifying the during-trial feedback that showed participants how they were performing by visually counting out their taps on the screen. This discovery is in direct conflict with the long-standing goal gradient effect from Hull (1932) and other experiments that support the goal-gradient hypothesis as seen from Emmaneul (2019) and Kivetz et al. (2006). Additionally, our results having no appreciable difference between trial lengths go against the insights from Nelson (1988) regarding the labor-in-vain effect. This end-of-trial slowing will be our main focus to address in future experiments.

FUTURE DIRECTIONS

Following discussions with research assistants and participants, a new hypothesis emerged regarding the feedback provided after each trial regarding participants' performance. It was suggested that participants might experience apprehension about surpassing the required number of taps, fearing they could miss out on feedback. While this concern wasn't applicable due to the program's design, participants' uncertainty about what to expect prompted us to take their feedback into account. Thus, we aimed to address this aspect in subsequent experiments. We believe that encouraging participants to tap at their comfortable pace, rather than as fast as they can, may alleviate this apprehension. By allowing participants to define their own comfortable pace, we aim to observe whether they will naturally increase their speed towards the end of the trial, rather than experiencing a slowdown. This adjustment is intended to eliminate the observed slowing-down effect and provide insights into participants' pacing behavior.

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