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ACTIVITY PACING

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ABSTRACT

We implement a strategic behavioral approach, known as pacing, to balance how much time we spend on activities, along with allotted rest periods. Pacing takes place throughout our everyday lives: when we get ready in the morning, when driving, throughout our workday, etc. Existing research primarily investigates pacing in the context of athletics or endurance exercises. This research, however, explores the mechanisms of pacing in the context of a small-scale laboratory task, which aids in understanding how people pace themselves through decision-making processes. The purpose of this paper is to shed light on cognitive effort distribution, and whether experiencing symptoms of Attention-Deficit/ Hyperactivity Disorder (ADHD) affect pacing behavior. This paper addresses the ways in which students with and without self-reported symptoms of ADHD adopt certain pacing strategies when faced with a laboratory search task. This research is significant, as it uncovers how people with Attention-Deficit/ Hyperactivity Disorder approach various activities compared to the general population of students, and if they have particularly unique pacing behaviors. This research ultimately furthers our understanding of how the human brain categorizes and prioritizes activities throughout our everyday lives

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INTRODUCTION

A rather impactful decision we make in our daily lives is how we pace ourselves. Being faced with countless mental and physical tasks every day, the art of pacing allows us to cycle between high and low levels of activity to avoid burnout. Instances in which we pace ourselves can include conscious thoughts, such as deciding when you should wake up, how long you should be getting ready, or what time you need to be on the road to work by, just to name a few. Pacing may also be subconscious and include biological processes, such as our circadian rhythm or breathing rate. The ways in which we distribute our time and energy dictate the entirety of our lives.

A substantial body of research has examined pacing in the context of athletics and endurance exercises. Such research includes that of Simon (2014), which investigates optimal pacing strategy in the field marathon. More recent research also supports evidence of pacing strategies aiding in performance among elite athletes (Casado et al., 2021). The focus of these studies examines pacing among runners, although research in the context of various other athletics has also been conducted (e.g. skating, cycling, rowing, swimming) (Abbiss et. al, 2008). This research has established various prominent pacing strategies among athletes.

Little attention has been paid to the investigation of pacing on a smaller and less physically demanding scale. Relevant research does, however, include that of Van der Linden et. al (2003), which explored the effects of mental fatigue on task planning and preservation. This study was conducted by using the Wisconsin Card Sorting Task (WCST). The WCST is a task in which participants sort a card through pressing a button on a keyboard that represents a certain target card (Van der Linden et. al, 2003). The Tower of London (TOL) was also used, consisting of three pegs on which colored beads must be configured in the same way as in a given model state (Van der Linden et. al, 2003). Both tasks were used to measure preservative activity errors and planning (Van der Linden et. al, 2003). The participants worked on the cognitively demanding tasks for a total of 2 hours (Van der Linden et. al, 2003). Compared to a control group, which is a non-fatigued group faced with only a simple memory task, the fatigued participants displayed a loss of regulation in perceptual and motor processes for goal-oriented behavior (i.e., planning) (Van der Linden et. al, 2003). These findings are significant because they indicate that pacing in the context of small-scale activities varies based on mental fatigue and prolonged engagement.

Another relevant study that may aid understanding of smaller scale pacing through mental tasks (i.e., how we pace ourselves through daily work tasks) investigates a phenomenon known as the rate of perceived exertion (RPE). Tucker (2009) defined RPE as a system of conscious feedback integration, which is generated by an individual during activity and allows for a decision regarding the best pace to use (Tucker, 2009). Understanding how the mind develops a RPE is significant in explaining how individuals choose appropriate amounts of effort with the goal of balancing energy and activity levels.

Despite these foundational findings, research on mental pacing of small-scale activities, like the kind encountered daily, is scarce. This leads to the ultimate purpose of this study: to investigate how individuals pace themselves when faced with decision-making tasks. This research is unlike most in that it did not involve a physically exhausting component, and focuses primarily on mental or cognitive pacing, which is classified in the context of this study as the ability to focus attention on work activities and stay on task at a sustained rate.

We sought to understand mental pacing by administering a visual search task, where participants touched one line segment on the computer screen whose length differed from the other line. Participants were given either 8 or 24 trials in a specific block. Each block contained either search tasks in which the unique line segment was easy to identify, or search tasks in which the unique line segment was not so apparent (Figure 1). These conditions are referred to as “easy” and “hard” search discriminations. The time from when the trial began to when participants touched the correct line segment was recorded. The next trial would not appear on the screen until the participant touched the correct line segment from the previous trial. It is also important to note that participants could touch as many line segments as they wanted and would not be penalized for touching the wrong one (or the one that is not the “unique” segment). The task would only proceed if the participant successfully tapped the correct line segment. The time between when the participant began a trial until they correctly touched the line segment is known as the inter-response time (IRT), which measures, in seconds, the time between the trial start and correct response. In this way, the inter-response times revealed how long an individual took to complete the visual search tasks: a key component in investigating mental pacing trends across blocks.

Not all individuals are likely to display the same, or even similar, attentive patterns. This research includes another variable, which is designed to understand pacing mechanisms in both attentive and inattentive individuals.

Attention/Deficit-Hyperactivity Disorder (ADHD) is a chronic condition marked by patterns of inattention and/or hyperactivity-impulsivity that interferes with daily functioning (NIMH, 2022). Attention/Deficit-Hyperactivity Disorder diagnoses have climbed more than 30% in the past eight years (CDC, 2022). The prevalence of this diagnosis drives the question of whether mental pacing mechanisms differ among people with and without symptoms of ADHD. Since inattention is a prominent symptom of ADHD, it is important to address whether inattentive tendencies correlate with mental pacing. Research in this field is more important than ever, considering the growing prevalence of this condition. Since individuals with ADHD experience major interference with their activities of daily living, mental pacing may in fact be a major component at play. Ultimately, the findings of this study may help improve the understanding of some of the impairing symptoms of ADHD.

Research Question:

What are the mechanisms of mental pacing and do the patterns change among students with and without self-reported symptoms of Attention/Deficit-Hyperactivity Disorder (ADHD)?

Hypotheses:

Hypothesis 1: If students with self-reported symptoms of Attention-Deficit/ Hyperactivity Disorder have difficulty staying on task at a sustained rate, one will observe different inter-response times (IRT) in longer, more difficult, tasks compared to students who do not report symptoms of ADHD.

Hypothesis 2: If students with self-reported symptoms of Attention-Deficit/ Hyperactivity Disorder experience inattention only when they are not mentally stimulated by a task, one will observe fast and consistent inter-response times (IRT) in the longer, more difficult task trials compared to students who do not report symptoms of ADHD.

Hypothesis 3: If students with self-reported symptoms of Attention-Deficit/ Hyperactivity Disorder do not pace themselves differently than students who do not report symptoms, one will observe consistent inter-response times (IRT) among both groups.

METHODS

Under the aegis of the UCR Psychology Department's Laboratory for Cognition and Action, undergraduate students were given an anonymous web-based survey evaluating self-reported symptoms of Attention-Deficit/ Hyperactivity Disorder (ADHD), followed by a laboratory task designed to assess pacing. An additional set of questions pertaining to gender, age, and race/ethnicity were given to the participants to better understand the population demographic. Among these questions were assessments of the participants' condition for participating in the study (e.g., any reports of neurological conditions, whether they are left or right-handed). The undergraduates in this study were all recruited from the University of California, Riverside.

Participants

A total of 52 undergraduate students at the University of California, Riverside, participated in this study. 83% of the participants (*n* = 43) were recruited via SONA in the Introductory psychology courses PSYC001 and PSYC002. The remaining 17% (*n* = 9) were recruited as volunteers by asking around in common areas on the UCR campus. Of these 52 college students, 4 of them were excluded due to incomplete data; thus, only 48 students were assessed. The age range was 18 to 23 years. 69% (*n* = 33) of the participants were female and 31% (*n* = 15) were male. The participants were ethnically diverse: 15.4% were Caucasian, 38.5% were Hispanic/Latino/a, 13.5% were Black/African American, 21.8% were Asian/Pacific Islander, 10.8% were Other. All of the participants in the study were right- hand dominant. .08% of the participants (*n* = 4) reported previous concussion with loss of consciousness and .02% of participants (n = 1) reported a history of seizures. These neurological conditions did not disqualify the subjects from the study.

Measures

Attention-Deficit/ Hyperactivity Disorder Self-Reporting Scale

Students completed an online Qualtrics survey asking questions based on symptoms of Attention-Deficit/ Hyperactivity Disorder (ADHD). These questions correlate with the DSM-5 Diagnostic Criteria for ADHD (e.g., "How often do you find yourself troubled to follow through on instructions and failing to finish coursework, chores, or other duties, "How often do you have difficulty getting things in order when you have to do a task that requires organization," "how often do you have trouble concentrating on what people say to you during a conversation," "how often do you find yourself troubled to follow through on instructions and failing to finish coursework, chores, or other duties," etc.). Students responded to questions on a 5-point scale from never (1) to always (5). Participants were classified as having self-reported symptoms if they scored often (4) or always (5) to ≥ 5 questions. Thus, a score of 20 points or higher classified students in this study as having self-reported symptoms of Attention-Deficit/ Hyperactivity Disorder. 34 students scored below 20 points, meaning that they were not classified as having self-reported symptoms of ADHD. On the other hand, 14 students scored 20 points or more, classifying them as having self-reported symptoms of ADHD. The Attention-Deficit/ Hyperactivity Disorder Self-Reporting Scale did not offer any feedback or diagnoses to the participants. It only served as a way for us to understand whether personal experiences with inattention or other ADHD symptoms correlate with a different style of mental pacing. No diagnoses or medical advice was given.

Procedure

Participants were recruited starting in Fall Quarter of 2022 until Week 5 of Winter Quarter 2023. All participants were required to read and complete a consent form before beginning the study. The participants were then given the Attention-Deficit/ Hyperactivity Disorder Self-Reporting Scale, along with a second survey. After completing the survey, the participants were told how to complete the Visual Search Pacing laboratory task. To ensure understanding of the task, all participants were required to repeat the instructions in their own words before the start of the task.

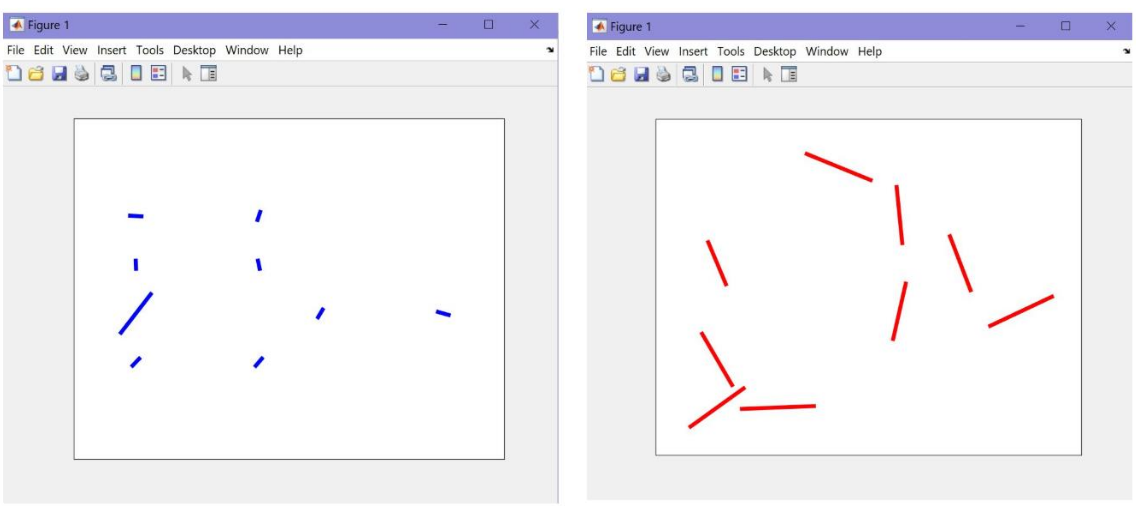
The Visual Search Pacing laboratory task is a program written in MATLAB by the principal investigator of the lab, Dr. David Rosenbaum. Dr. Rosenbaum has extensive experience with MATLAB and is the author of *MATLAB for Behavioral Scientists*, which details computer programming for the use of experimental psychology and behavioral science. The program was designed so any given subject alternated between blocks of trials with either 8 (short) or 24 (long) trials, which required easy or hard visual search tasks (Figure 1). The visual search tasks contained either easy or hard line-length discriminations. The task in each trial was to touch the one line segment on the computer screen whose length differed from the other line segments. An illustrative display is shown in Figure 1.

Participants were randomly assigned to two groups. In group 1, participants were given 24 trials of hard discrimination and 8 trials of easy discrimination. In group 2, participants were given 24 trials of easy discrimination and 8 trials of hard discrimination. Each subject was assigned a total of 16 blocks with either condition of alternating trials. Thus, each participant would have 8 easy blocks and 8 hard blocks of alternating nature. In repeating the visual search task in alternation of trials, the data obtained was mean search time (or inter-response time) as a function of trial number for trials of different lengths (either 8 or 24) and different difficulties (easy or hard discrimination) The subjects were explicitly told the amount of required blocks they must complete and how many trials were within said block (8 or 24) (Figure 2).

Additionally, the program contained an incidental feature, color, which was counterbalanced over subjects to implicitly cue blocks as either easy or hard discriminations. In subject A, for instance, the color blue represented an easy discrimination trial, while the color red represented a hard discrimination. This scenario is represented in Figure 1, for reference. In subject B, however, now red is what represented easy discrimination and blue was hard. This occurred in an alternating pattern among subjects to implicitly cue participants about difficulty level. This incidental feature is important in understanding whether or not participants pace themselves differently when they anticipate an activity to be easy or hard, for instance.

Figure 1

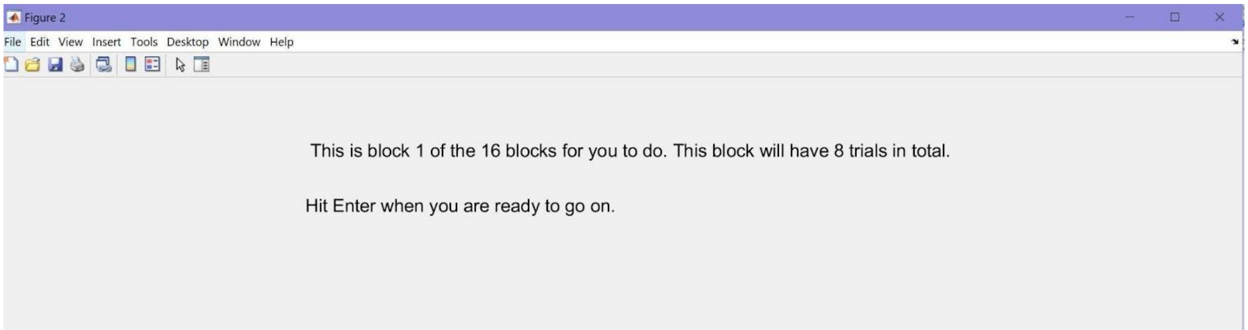
Easy and Hard Visual Searches



Note. In the Visual Search Pacing laboratory task, a subject alternated between easy discrimination (right side in blue) and hard discrimination (left side in red).

Figure 2

Experiment Instructions



Note. In the Visual Search Pacing laboratory task, the subject was explicitly told how many blocks they must complete and the number of trials present in each block (either 8 or 24). In this instance, the participant was at the start of the task, where they were told that they were about to complete block 1 of 16 blocks in the experiment. The subject was told to expect 8 trials in total from this block.

After the completion of each trial, the subject was given feedback generated by the program about the average task completion time. After they pressed “Enter,” they were told once again how many blocks remained and how many trials to expect before they started the next block. At the end of the experiment, the subject went through a debriefing period, where they were informed of the purpose of the study and were given opportunities to ask questions.

An important feature of the program that is important in determining the ability to stay on task at a sustained rate is the block with 24 trials of difficult search tasks. Since this block is long and mentally challenging, it may be the case that students with self-reported symptoms of Attention-Deficit/ Hyperactivity Disorder had difficulty with sustained attention. If this is the case, the data will show larger inter-response times and greater variability between trials, when compared to the control group. The control group were students who did not report experiencing symptoms of Attention-Deficit/ Hyperactivity Disorder. Larger inter-response times would illustrate that the trials took more time to complete, which may relate to distractibility and overall inattention.

Alternatively, it may also be the case that students with self-reported symptoms of Attention-Deficit/ Hyperactivity Disorder experience inattention only when they are not mentally stimulated by a task. If this were true, the students would have shown faster and more consistent inter-response times in the long (24 trials) and difficult block. This would entail that in the easier condition, they had greater response times than the control. If this trend is shown, it may be correlated with distractibility and inattention on easier, less mentally engaging activities.

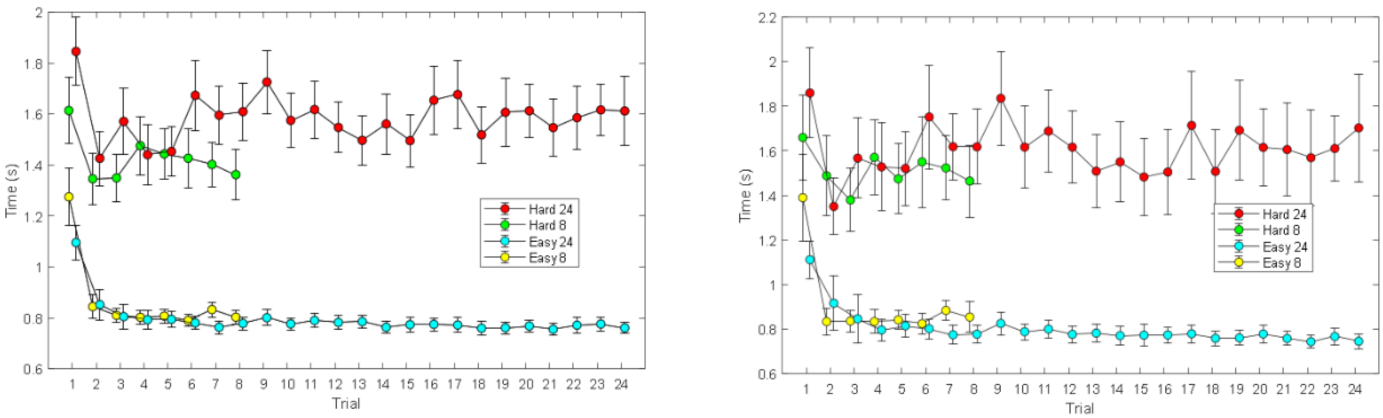
RESULTS

Data Analysis in Subjects with Self-Reported Symptoms of ADHD Verses Without

Data from 52 participants was collected, however, 4 of the participants' data was omitted due to incompletion of the MATLAB experiment. Thus, a total of 48 students were included in the data analysis. 34 students (71%) scored below 20 points on the Attention-Deficit/ Hyperactivity Disorder Self-Reporting Scale, meaning that they did not classify as having self-reported symptoms of ADHD. On the other hand, 14 students (29%) scored 20 points or more, which classified them as having self-reported symptoms of ADHD. The data from these two groups was separated and analyzed.

Figure 3

Experimental Results: Control Versus Self-Reported ADHD Symptoms



Controls (n=34)

ADHD (n=14)

Note. The left-hand panel displays the results from the control group, those who did not report symptoms of ADHD. The right-hand panel displays the results of the ADHD group, those who did self-report symptoms.

The graphs in Figure 3 display trial number on the x axis and mean search time on the y axis in units of seconds. The mean search time is the time from when the subject began a given search task (trial) and when they tapped on the correct line segment. The red data points represent the hard visual searches with 24 trials and the green represents the hard visual searches with 8 trials. For the easy visual searches, the light blue indicates the long condition with 24 trials and the yellow represents the short condition with 8 trials. On the left panel are the results from the control group, which are the 34 students who scored less than 20 on the Attention-Deficit/ Hyperactivity Disorder Self-Reporting Scale, indicating no self-reported ADHD symptoms. On the right panel are the results from the participants who scored 20 or higher on the

Attention-Deficit/ Hyperactivity Disorder Self-Reporting Scale, indicating self-reported symptoms of ADHD.

For both groups of participants, the hard conditions have a much greater mean search time than the easy conditions. For both the 8 and 24 trial lengths, the easy search conditions have a consistent mean search time, with small standard error bars. On the other hand, for both the 8 and 24 trial lengths, the hard search conditions exhibit larger variance. This is especially true in the ADHD group on the right of Figure 3, where the standard errors bars are much larger.

In the case of all conditions, for both groups of participants, the first trial starts off with a slower mean search time and in the second trial forward, the search time is much quicker.

Experimental Results: Cumulative Data, All Participants

The second experimental analysis was conducted by analyzing all 48 complete data sets together. The data was no longer separately grouped by categories of self-reporting symptoms of ADHD, but instead analyzed cumulatively (Figure 4).

Figure 4

Experimental Results: Cumulative Data

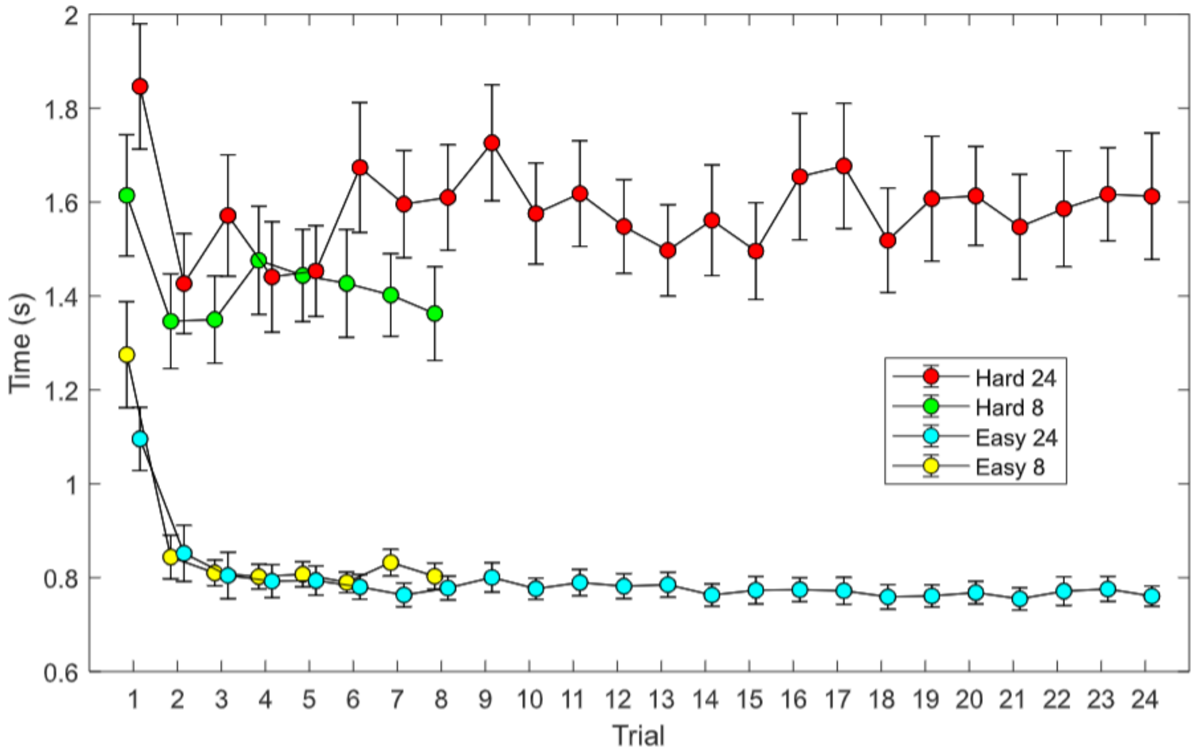


Figure 4 was generated with the same axes: trial number on the x axis and mean search time (or inter-response time) on the y axis in seconds. The colored data points in this figure are consistent with that of Figure 3.

The hard conditions continue to maintain a greater mean search time than the easy conditions. For both the 8 and 24 trial lengths, the easy search conditions remain consistent with low variance. The 8 and 24 trial lengths of the hard search conditions exhibit larger variance.

Additionally, we continue to observe the first trial starting off with a slower mean search time relative to trials 2-8 or 2-24. These patterns are consistent with the patterns in Figure 3.

However, taking a closer look, the sharp increase in speed after trial 1 is greater for the easy 8 condition and the hard 24 condition, compared to the other conditions.

Lastly, the hard 8 condition slows down during the last 3 trials, whereas the same data points in the hard 24 condition do not exhibit any slowing.

DISCUSSION

Pacing Trends in the Control Subjects Versus Subjects with Self-Reported ADHD Symptoms

In the first data analysis, the participants were divided into a control group and an ADHD group (Figure 3). The data trends are generally consistent among both groups of participants. The only dissimilarity between the groups are larger standard error bars, or variance, for the hard search condition of both possible lengths (8 and 24 trials) in the ADHD symptom group. Although, because of the small sample size for the ADHD symptom group (n= 14), further statistical analysis is necessary to make the claim that more variation exists. In the case that the variation is statistically significant, this could potentially indicate distractibility in especially hard mental tasks. Assuming that the increase in variation is not significant, it is likely the case that if there is a difference in pacing behavior between subjects with symptoms of ADHD and subjects with no inattentive symptoms, then the current methodology did not pick it up.

These findings support the following hypothesis: if students with self-reported symptoms of ADHD do not pace themselves differently than students who do not report symptoms, one will observe consistent mean inter-response times (IRT) among both groups.

Pacing Trends in all Subjects (n=48)

Since the pacing trends in both groups of participants proved to be extremely similar, we combined the data into a cumulative set to observe pacing behavior across all subjects (Figure 4). This means that all 48 subjects' data was combined. The first and most noticeable effect is that the hard conditions have a much greater mean search time than the easy conditions (Figure 4). This indicates that the hard discrimination is indeed harder, and thus takes longer, than the easy discrimination condition.

Secondly, an observable trend from the data in Figure 4 is the dramatic increase in mean search time following the completion of the first trial. This is unlikely to be caused by a practice effect, since the program design includes alternating conditions for each participant. So, it may be the case that one participant started out with an easy 24 condition, but after that, they had already familiarized themselves with the task at hand and would thus not show a longer trial 1 search time for the other set of conditions. It is also important to note that the analysis is the mean of all participants of alternating conditions, so it is unexpected that a practice effect would be explanatory of the trend. Rather, this trend may indicate that subjects take the first trial to get to their relative maximum speed for the task, and then maintain that pace for the remainder of the trials. This indeed represents a form of pacing: starting off slow and then speeding up almost instantly, while maintaining that speed for the duration of the trial.

Examining this pacing trend further, the data in Figure 4 reveals that the sharp increase in speed after trial 1 is greater for the easy 8 condition and the hard 24 condition, compared to the other conditions. Interestingly, these are both conditions of opposite extremes, hard and long vs. easy and short. Perhaps, when faced with tasks of opposite extremes, participants take a small moment longer to mentally prepare themselves for the task ahead.

The last noticeable trend is that the hard 8 condition slows down during the final 3 trials (trials 6, 7, and 8), whereas the same data points in the hard 24 condition do not exhibit any slowing (Figure 4). Since the hard 8 condition is much shorter than the hard 24 condition, participants may be anticipating stopping when they get to trial 6, ultimately slowing their performance. This potentially represents a new mental pacing strategy: slowing toward the end of a particularly short task, as you anticipate finishing the task. This stands true of the short, hard task only. So, it may be the case that task length causes subjects to assume a new pacing strategy, only when the task is mentally challenging.

Limitations and Future Directions

Given the design of the experiment, participants were able to click on as many line segments as they wanted, but the program would not move to the next trial, or search task, until the correct line segment was touched. This poses a new set of questions regarding pacing: did subjects take a long time to complete the search task because they were clicking on as many line segments as possible (as in a trial-and-error approach) or because they were carefully thinking about which line segment was the correct one? This can be understood in the context of signal detection, where "costly" false alarms promote a conservative bias and "costly" misses promote a liberal bias. Whether the participants were deploying conservative or liberal criterion for selecting the unique line segment, this would ultimately affect the mean search time. Thus, the next direction for this research is to run analyses on how many clicks people did on average for each of the four conditions. For instance, if the hard short condition had more clicks than the hard long condition, but appreciable mean search times, then that would indicate a different pacing strategy.

Another main limitation is the sample size when comparing the groups of self-reported symptoms of ADHD. The sample size of the reported symptoms of ADHD (n=14) is less than half of the comparison, or control group (n=34). That said, increasing the sample size is another future direction for this research. In a future experiment, we will aim to run at least 50 participants for both the inattentive and attentive conditions.

Lastly, this research is limited by lack of current statistical analyses. Since many of the data points are extremely close in nature, and it is hard to tell where the error bars start and finish just by visual analysis, the conclusions being made must be backed up by statistical analysis. This is a future direction in the research, which we plan to carry out soon. If we increase the sample size and run accurate statistical analyses, we will be able to make claims about pacing style and differences in participant groups more confidently.

Benefits & Context

Pacing is an art that is implemented into our daily lives, whether that be consciously or subconsciously. Pacing is not only applicable in the context of endurance exercises, but it is what allows us to cycle between high and low levels of activity every single day. Productivity in work or academic settings heavily relies on pacing. Driving, walking, and crossing the crosswalk all rely on pacing. Waking up in the morning and getting ready for the day relies on pacing. Breathing and sleeping also rely on pacing. The real-life implications of pacing are endless, and evidently do not just involve physical activity. Studying pacing in a small-scale laboratory setting where participants must encounter decision-making tasks of different difficulties most closely represents the type of pacing carried out daily. Cognitive pacing requires an individual to move through various conditions, and decide how to pace their mental expenditures. Given this, the visual search pacing task is extremely important in demonstrating how an individual may pace themselves through their every day lives.

Furthermore, research in this field is important in understanding how the human brain categorizes and prioritizes activities or decisions that we constantly make. This gives rise to potential clinical applications; not just in the context of Attention-Deficit/Hyperactivity Disorder, but for all neurological disorders that impact an individuals’ daily task functioning. For instance, research in this field may also be applicable in learning how individuals with learning disabilities perform given activities of daily living. Ultimately, the results of this study can be used to spark new ideas in cognitive pacing research and further initiatives to delve into different avenues and approaches.

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