THE EFFECTS OF GOAL SETTING AND AUGMENTED FEEDBACK ON SUSTAINED ATTENTION AND PSYCHOMOTOR VIGILANCE TASK PERFORMANCE

by

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The present study aimed to examine the effect to which augmented feedback affects task performance, task engagement, and effort mobilization as seen through pupil dilation. Participants (N = 127) from the University of Oregon completed a Psychomotor Vigilance Test (PVT) designed to test an individual's ability to sustain attention. After a row of 0s appeared on-screen, participants were instructed to press the spacebar as quickly as possible once they noticed the numbers begin to count upwards (stimulus). Participants were randomly assigned to one of three conditions: Control, Goal, and Goal + Augmented Feedback. The two Goal conditions had the same target of 0.325 s, however, the Augmented Feedback condition received messages on-screen after each trial based on whether their performance achieved the goal or not. During this 30-minute PVT, we measured participants' pupil dilations in response to the stimulus. Our results suggest that the addition of augmented feedback does not translate into higher performance (faster RTs), increased effort mobilization (larger pupil dilations), or minimize off-task thoughts. However, participants who were assigned a goal (Goal & Goal + Augmented Feedback) had significantly quicker RTs as well as larger pupillary responses to the stimulus.

Acknowledgements

First and foremost, I want to thank my Mom and Dad for everything that you've ever done to get me to the position I am in right now. I do not express enough how grateful I am for all your sacrifices—your time and energy spent—just to see me succeed and realize my potential. You both have been nothing but supportive of me in everything that I do, pushing me to realize my potential. You two are amazing and I love you so much. I can't forget my sister, Riley, for shaping me into the person I am today. You have had such a significant impact on my life, I truly do not know who I would be without you. Keep doing your thing, I'll always be right beside you.

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Introduction

Darting across the racetrack at speeds over 200 mph, Formula 1 drivers must communicate to their teams any inconsistencies or issues with the car. If this feedback is not given, the car could lock up, potentially ending in catastrophic damage. Much like in this high-speed example, it is increasingly important for individuals in today's fast-paced world to set goals and receive feedback on their progress towards achieving them. Whether in a personal or professional setting, the ability to effectively set and achieve goals is a vital skill that can lead to improved performance, increased motivation, and greater satisfaction with one's achievements. Similarly, receiving feedback is essential in identifying areas for improvement and making necessary adjustments to achieve desired outcomes.

However, several internal and external factors can impact an individual's ability to maintain focus on a task. The vigilance decrement, referring to the decline in a person's ability to maintain attention and detect stimuli accurately over prolonged periods of time, highlights the challenges of sustained attention. As the duration of the task increases, individuals tend to experience a decline in their ability to detect and respond to stimuli, resulting in decreased vigilance and increased errors. There are several theories about its causes—some believe that attention is a limited resource that dwindles over time, some believe that the vigilance decrement is due to a shift in attention from the task to expected results, and others believe that signal detection abilities become more laxed with increased time spent on a task (Robison et al., 2021). Understanding the vigilance decrement is important for developing effective strategies to maintain attention and performance during prolonged tasks—particularly when errors can have serious consequences, such as driving.

The ability to control attention and maximize our productivity and responsiveness is critical, but people vary significantly in this regard (Unsworth and Engle, 2007; Fried et al., 2014; Unsworth & Robison, 2017; Unsworth et al., 2021). Goal setting is one established way to increase task performance and effort (Locke & Latham, 2002; Robison et al., 2021). Feedback is another hypothesized way for individuals to increase engagement, commitment, and performance across a variety of aspects of life including school, work, and personal health (Adam et al., 2016; Young et al., 2020; Morrison et al., 2014; Abrahamse et al., 2007). This study proposes the idea that augmented feedback, when paired with a specific, challenging goal, can enhance sustained attention and improve task performance.

The results of this study will contribute to the existing literature and provide additional information about what factors contribute to high levels of sustained attention. Individuals that are aware of these factors can enjoy greater successes, focus on difficult activities for longer durations, and achieve more of their goals. Expanding on this topic, future research on the effects of augmented feedback may lead to insights about effective communication and optimizing efficiency.

Background

LC-NE system

Understanding arousal assists our understanding of goal setting and feedback. To do so, having background information on the neural region responsible—the locus coeruleus system—is key. The locus coeruleus system is in the brainstem, is responsible for the release of most of the norepinephrine in the brain and is closely associated with the frontal parietal network and substantia nigra. This LC-NE (Locus Coeruleus Norepinephrine) system is related to attentional states, as it influences the effectiveness of tuning out irrelevant information and focusing on relevant stimuli (Unsworth et al., 2021). LC-NE activity is believed to be a modulator for the signal-to-noise ratio of neurons, allowing for more selective responses to stimuli while ignoring irrelevant information. In other words, the LC-NE system is responsible for attentional states and arousal.

Neurons in the LC-NE system have two modes of activation: tonic and phasic. Tonic relates to the baseline activity level, while phasic refers to the increase in firing rate in response to an important stimulus. The Yerkes-Dodson curve (Figure 1) is a good way to visualize the relationship between tonic LC levels and task performance.

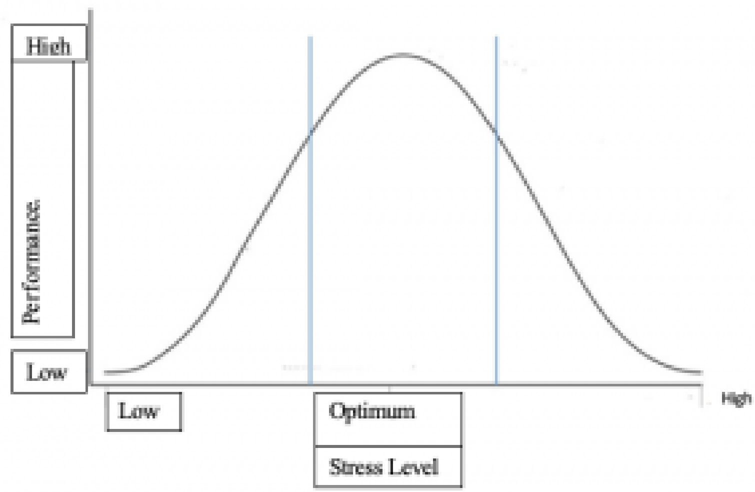

Figure 1. The Yerkes-Dodson Law Bell Curve (Source: Kariuki, 2021).

With low tonic LC levels, individuals tend to be inattentive and easily distracted, there's little phasic LC activity, and overall poor task performance. As tonic LC levels increase to an intermediate level, individuals become more attentive, phasic LC activity increases, and task performance reaches its peak. However, if tonic LC levels continue to increase past intermediate levels, individuals again become easily distracted, leading to low task engagement, decreased phasic LC activity, and suboptimal task performance. The ability to overcome these distractions and automatic tendencies engages our working memory.

Phasic LC levels refer to the change in neural firing and the release of norepinephrine (NE) within the brain. Research suggests that phasic LC levels are a reliable and valid measure of cognitive effort and intensity of attention (Unsworth et al., 2020b). Phasic responses peak right after the stimulus occurs, meaning that measuring these responses can indicate arousal levels (Unsworth et al., 2020b). When phasic levels are low, arousal is also minimal. However, if phasic responses are high, this indicates an increased release of NE and subsequently higher level of arousal.

Working Memory Capacity

Broadly speaking, working memory is our ability to maintain and manipulate information for short periods of time. The LC-NE system is intricately linked with working memory capacity (WMC) and is essential for effective attentional control. Unsworth and Engle (2007) identified three key functions of working memory: the ability to inhibit automatic response tendencies, to maintain new information in an active or distracted state, and to retrieve maintained information while disregarding irrelevant information. However, some individuals—such as individuals with ADHD—can struggle with voluntary attentional control, particularly over extended periods (Fried et al., 2014). These individual differences in attentional control have been linked directly to differences in WMC (Unsworth & Robison, 2017). Individuals with higher WMC can control their attention more effectively than those with lower WMC. Additionally, these individuals are thought to have superior regulatory control of the LC-NE system, with optimal levels of tonic LC and high phasic responses. Thus, higher WMC individuals are better able to resist distractions and maintain attention on task-relevant information. These findings highlight the crucial role of the LC-NE system in regulating attentional control and the importance of WMC in effectively utilizing this system.

Sustained Attention & Pupillometry

For individuals with lower WMC, the LC-NE system is unable to regulate attentional states effectively, leading to decreased task-related attention and increased distractibility. One reliable way to measure the level of attention of participants is through thought probes, which involve asking the participant if they are thinking about the task or if their thoughts are off task (task-unrelated thoughts or TUTs). However, recent research has shown that pupillary responses can also provide valuable information for determining lapses and fluctuations of attention associated with the function of the LC-NE system (Unsworth, Miller & Aghel, 2021; van de Beek et al., 2016).

Unsworth and Robison (2016) found that pupil diameter correlates with the attentional state of the participant measured through thought probes. This research also suggests that pupil diameters during "off-task thoughts" can be further categorized into external distractions, internal distractions, and mind-wandering. Pupil diameters were larger than on-task levels when participants were externally distracted, and smaller than on-task levels when mind-wandering or intrinsically distracted. Research from van de Beek et al. (2016) also suggests that consistent with the Yerkes-Dodson relationship, task performance is worse when baseline pupil diameters are higher or lower than typical, as seen through false alarms and long RTs. This supports the notion that both high and low tonic LC levels indicate suboptimal arousal levels and performance.

Our pupils dilate in response to the cognitive demands of a task, dilating more when effort mobilization is higher (Unsworth & Robison, 2016). Task-evoked pupillary responses (TEPRs) are defined as the change in pupil diameter from baseline levels when a stimulus occurs. Consistent with current understanding of the vigilance decrement, TEPRs steadily decrease throughout the task (Unsworth & Robison, 2016, van de Beek et al., 2016). Prior research has indicated that the phasic LC response correlates with TEPRs (Unsworth et al., 2020b). When TEPRs are smaller, phasic responses are smaller and performance tends to decrease (Unsworth et al., 2020b). This suggests that poor performances are correlated with a lower intensity of attention.

The ability to control intensity attention is related to lapses and fluctuations of attention. When these fluctuations and lapses of attention occur, task performance suffers, either through fast reflexive errors or significantly slower than normal response times (Unsworth & Robison, 2016; Unsworth et al., 2020b). The ability to sustain attention refers to an individual's ability to minimize these fluctuations and lapses of attention. Individuals with higher sustained attention exhibit fewer off task thoughts as well as fluctuations and lapses of attention. Higher sustained attention should therefore be seen when TEPRs remain elevated. These findings altogether suggest that pupillary responses are a promising alternative or supplementary measure to thought probes for determining attentional states.

Goal Setting

Motivation and goal setting has been researched since the 1950's, stemming from the original premise that goals affect action (Locke & Latham, 2002). Task performance must be analyzed to understand the effects of goal setting. Research shows that unlike the LC-NE system, the Yerkes-Dodson inverse, curvilinear relationship does not apply to the relationship between goal setting and task performance. It has instead been found that there's a strong positive relationship between goal difficulty and task performance where the most difficult goals elicited the highest task performance (Locke & Latham, 2002). Higher goals lead to greater effort than low goals, seen in tasks that require physical effort, tasks regarding simple and repetitive cognitive effort, and tasks that include measurements of subjective effort (Locke & Latham, 2002). In situations when attention is focused on the goal, performance will be both fast and accurate (Unsworth & Robison, 2016). Goal setting also has the capability to sustain attention—when individuals are work for a self-set period, they work longer when they give themselves a goal (Locke & Latham, 2002). Additionally, when people are made aware that they're behind their goal, their effort mobilization generally increases (Locke & Latham, 2002). This increased effort directs attention away from goal-irrelevant activities and towards goal-specific activities, a core feature of WMC.

Another conclusion that goal-setting research has found is that goals must be specific in addition to being difficult. For ambiguous goals, such as “try your best”, people tend to hold themselves less accountable as a wider range of results are deemed acceptable. When specifically asked to “try hard” on certain trials, prior research shows no additional ramp in performance was seen (Unsworth et al., 2021). However, goal specificity doesn’t inherently improve task performance either, since individuals can have specific goals that significantly range in achievement difficulty. It has been shown that setting a specific goal reduces variability in performance, since the ambiguity of task performance is reduced (Locke & Latham, 2002; West et al., 2005). A difficult, specific goal is the gold standard for optimal task performance.

Goal achievement and optimizing performance would be incomplete without discussing goal commitment. Naturally, goal performance is highest when people are more devoted to achieving their goals. Having a high level of self-efficacy naturally encourages goal commitment (West et al., 2005), but there are several ways for someone to further increase goal commitment. One of these ways is by increasing the importance of the goal, often done through public commitments, authoritative influence, or collaboration (Locke & Latham, 2002). Another method found to increase goal commitment is to add incentives. In certain situations, money can be a powerful incentive for performance (Locke & Latham, 2002), however, this is not always the case. A task-and-bonus situation, in which payout is only received after success, can hinder performance (Locke & Latham, 2002; Robison et al., 2021).

Feedback

Feedback has been shown to have an impact on working memory performance. In a study which used weighted "streak" points as a form of positive feedback (Adam et al., 2016), participants scored bonus points for consecutive good-performance trials. This condition resulted in a 27% reduction in poor-performance trials and a 37% increase in good-performance trials from baseline tests. This indicates that the "streak" points administered as feedback were useful in sustaining attention and increasing overall working memory performance.

Augmented feedback is often seen in other areas of life, including weight loss & exercise, school, and at home (Young et al., 2020; Morrison et al., 2014; Abrahamse et al., 2007). Across the board, augmented feedback evokes more positive responses, higher levels of engagement with the material or program, and higher goal achievement. West et al. (2005) found that individuals are more likely to increase the difficulty of their goals after succeeding in the task and receiving feedback. It's hypothesized that augmented feedback, in comparison with standard or objective feedback, elicits different perceptions of the task or objective at hand. When people look at tasks differently, they rely on prior knowledge and experience and can apply new and useful tactics (Locke & Latham, 2002).

An expanded relationship between goal setting, task performance, and task engagement has been previously examined. The measure of task performance in this study uses a Psychomotor Vigilance Test (PVT) in which individuals perform a simple reaction time test by pressing the spacebar once they notice a change on a computer screen. Combined with feedback, goal setting was found to reduce the range of RTs (Robison et al., 2021). This is consistent with prior research (Locke & Latham, 2002) where goal-setting concentrates energy and effort towards a standard. There was also strong evidence of a relationship between feedback and task unrelated thoughts (TUTs), where individuals receiving feedback reported fewer TUTs. This relationship suggests that the presence of feedback sustains and focuses attention on the given task.

The Present Study

Prior research laid the groundwork for this study by first providing evidence that goal setting improves sustained attention and increases engagement. Setting a goal—both specific and challenging—has been shown to increase task performance and effort mobilization. One reliable measure of effort mobilization has been pupil dilation. The more a pupil dilates, the more effort is being directed towards the stimulus. Research analyzing the effect of feedback has also shown that augmented—or personalized—feedback increases engagement, goal achievement, and overall performance. In this study, we aim to add to the existing literature by examining the effects of augmented feedback, that of which is tailored to an individual's performance, on task performance and measures of sustained attention.

We predicted that individuals receiving augmented feedback will be able to increase their sustained attention. This would be reflected in larger peak pupil dilations after the stimulus is presented on-screen. Increased sustained attention should also improve task performance, measured by having quicker RTs. Lastly, participants should have fewer off-task thoughts when receiving augmented feedback, measured by using thought probes intermittently throughout the task. This experiment has participants complete the psychomotor vigilance test—a standard task measuring sustained attention—while simultaneously measuring pupil diameters using an eye tracker.

Methods

Participants

A sample of 127 participants was recruited from the subject pool at the University of Oregon. All participants completed the Psychomotor Vigilance Task (PVT), but complete pupillometry data was available for 111 participants and used for analysis. Participants were compensated with course credit for their voluntary participation in the laboratory. During the one-hour session, each participant completed two tasks, including the task of interest, which lasted approximately 30 minutes each.

Materials

Task

A reaction time task built upon work from Dinges and Powell (1985) was used as a reliable measure of attention vigilance. Each trial began with a 2-s fixation screen (+++++). Then, a row of blue zeroes appeared at the center of the screen (00.000). After a random interval (2–10 s in 500-ms intervals), the numbers began counting like a stopwatch. The participants' task was to stop the numbers from counting as quickly as possible by pressing the spacebar. After the participant pressed the spacebar, the numbers stopped counting, and the RT (e.g., 00.369) remained on-screen for 1 s. The next trial began after a 1 s blank screen.

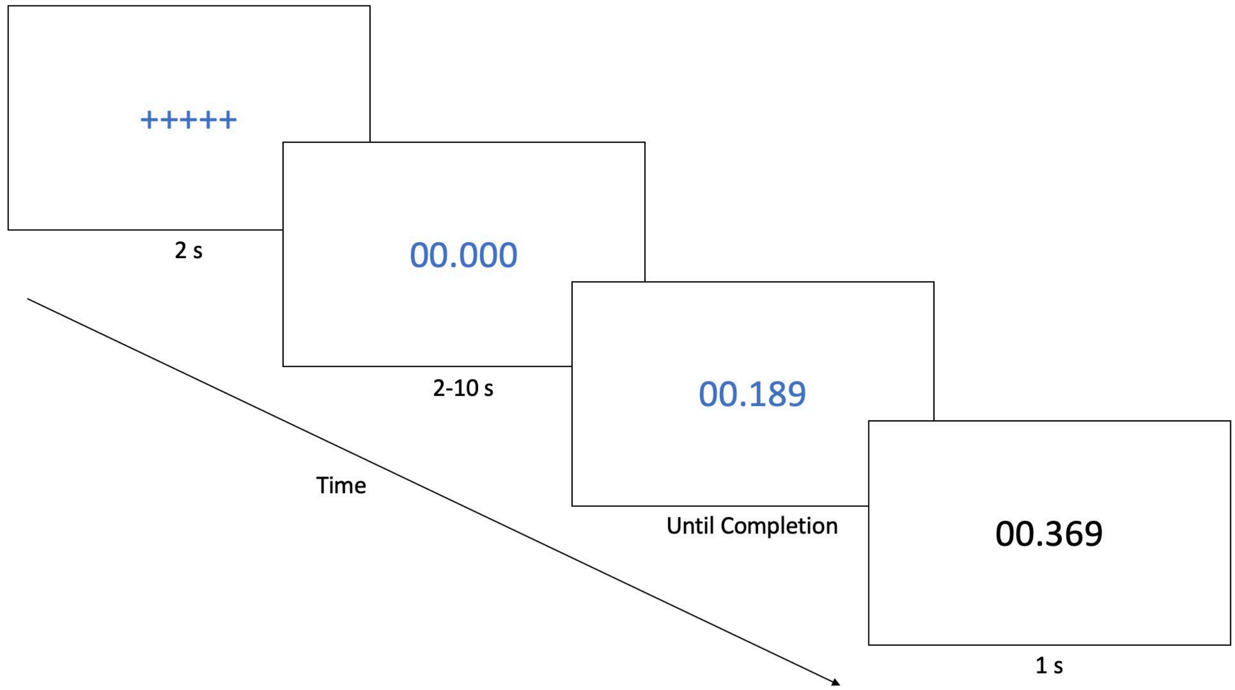

Figure 2: Psychomotor Vigilance Task Progression

Thought Probes

Periodic thought-probe screens asked the participants to indicate their momentary attentional state. At 14 random times during the task, a screen appeared saying, “Press the key that best describes what you were thinking about *just prior* to this screen appearing.” Participants were given five response options: (A) I was totally focused on the current task, (B) I was thinking about my performance on the task, (C) I was distracted by sights/sounds in my environment, (D) I was thinking about things unrelated to the task, and (E) My mind was blank. We recorded response A as on-task, response B as task-related interference, and responses C, D, and E as task-unrelated thoughts (TUTs).

Conditions

Participants were randomly assigned to either a Control, Goal, or Goal + Augmented Feedback condition. Variance between each condition relies on different presented screens after each trial, however, participants in all conditions see their score for 1 s immediately after each trial. For participants in the Control condition, that was their only form of feedback. Those in the Goal condition were given the goal of keeping their responses below 0.325 s. The Goal + Augmented Feedback condition received one of two possible messages directly under their reaction time, depending on their score. After successful trials (< 0.325 s) following message appeared on screen: “You hit your goal. Keep it up!”. Following unsuccessful trials (> 0.325 s), the following message appeared: “You missed your goal. Pick it up!”.

Figure 3: Feedback in Goal + Augmented Feedback Condition

Pupillometry

Binocular pupil diameter was continuously recorded at 120 Hz using a Tobii T120 eye tracker. Participants were seated 60 cm from the monitor, and their heads were fixed with the use of chinrest. Stimuli were presented on the Tobii T120 eye tracker 17 in monitor with a 1,024 x 768 screen resolution. Data from each participant’s left eye was used for the final data analysis. Missing data points due to blinks, off-screen fixations, and/or eye tracker malfunction were removed.

Results

3 Conditions

Our hypothesis was that the Goal + Augmented Feedback condition would increase performance and sustained attention more so than the Goal condition. Both Goal conditions were also believed to yield better performances, larger pupillary responses, and fewer task-unrelated thoughts than the Control.

RTs

A one-way ANOVA was performed to compare the effect of augmented feedback on reaction times. Results reveal a nonsignificant main effect of condition; Control (M = 366.31 ms, SD = 64.74), Goal (M = 346.86 ms, SD = 33.48), and Goal + Augmented Feedback (M = 344.59 ms, SD = 37.70), $F(2, 124) = 2.69$, $p = 0.072$. Tukey's HSD Test for multiple comparisons found that the mean RTs were not significantly different between the Control and Goal conditions (p = 0.147). Additionally, there was no statistically significant difference between the Control and Goal + Augmented Feedback conditions (p = 0.093).

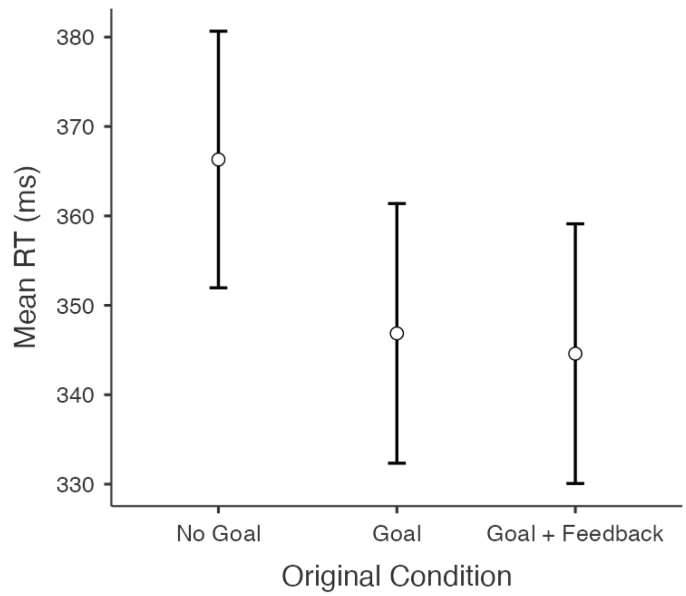

Figure 4: Mean RTs in the Control, Goal, and Goal + Augmented Feedback Conditions

Pupillary Responses

A second one-way ANOVA was performed to compare the effect of augmented feedback on pupillary responses. This analysis revealed that there was a statistically significant difference between the Control (M = 0.09 mm), Goal (M = 0.12 mm), and Goal + Augmented Feedback (M = 0.10 mm) conditions, ($F(2, 108) = 4.01$, $p = 0.021$). Surprisingly, Tukey's HSD Test for multiple comparisons found that the mean pupillary responses were significantly different between the Control and Goal conditions ($p = 0.016$), but the difference between Control and Goal + Augmented Feedback conditions ($p = 0.519$) was nonsignificant.

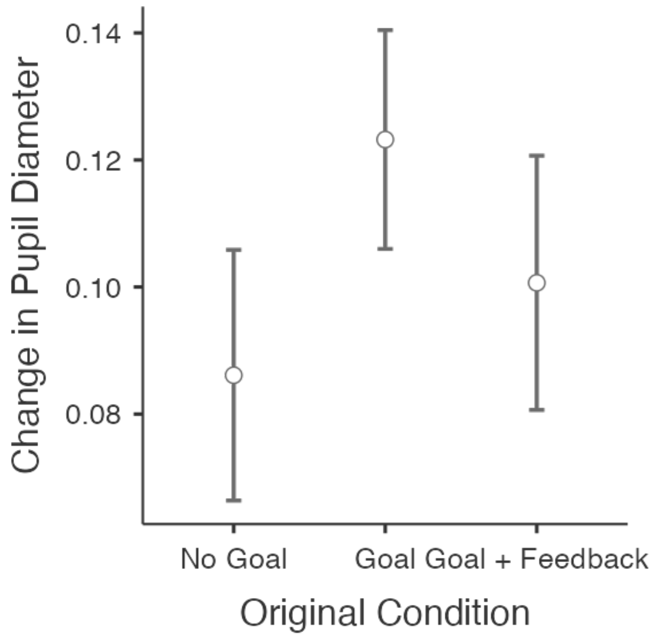

Figure 5: TEPRS in the Control, Goal, and Goal + Augmented Feedback Conditions

Task-Unrelated Thoughts

Lastly, a one-way ANOVA was conducted to examine the effect of augmented feedback on task-unrelated thoughts. However, this analysis shows no difference in the proportion of TUTs between No Goal (*M* = 0.44, *SD* = 0.23), Goal (*M* = 0.44, *SD* = 0.26), and Goal + Augmented Feedback (*M* = 0.41, *SD* = 0.28) conditions, $F(2, 81.91) = 0.16$, p = 0.854. This suggests that neither the presence of a goal nor the type of feedback received had any impact on whether individuals were thinking about the task at any given point in time.

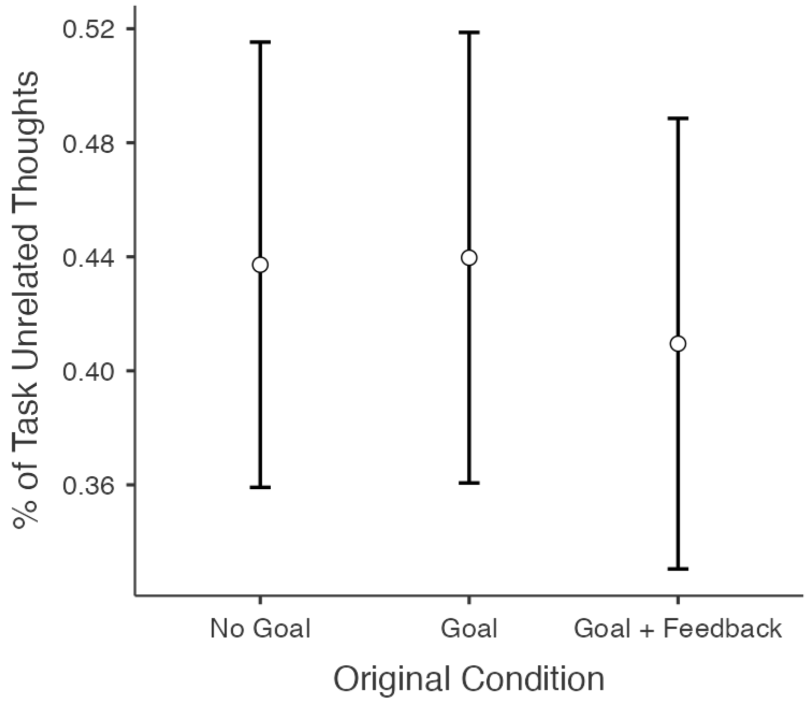

Figure 6: Task-Unrelated Thought % in Control, Goal, and Goal + Augmented Feedback Conditions

2 Conditions

After finding that augmented feedback had a nonsignificant main effect on any of our dependent variables, we decided to consolidate the Goal and Goal + Augmented Feedback conditions to examine main effects and interactions of goal setting. These modified conditions will henceforth be referred to as No Goal (*N* = 43) and Goal (*N* = 84) conditions.

RTs

An independent samples t-test found that RTs in the No Goal condition (*M* = 366.31 ms, *SD* = 64.74) were significantly higher than the new Goal condition (*M* = 345.73 ms, *SD* = 35.46), t(125) = 2.32, p = 0.022. The effect size was medium, with a Cohen's d of 0.43. The standard deviation of the Goal condition was significantly smaller than the standard deviation of the No Goal condition, indicating that having a goal promotes consistency of responses.

However, this sample failed Levene's test ($p < 0.05$), violating the assumption of equal variances. After condensing two conditions into one larger condition, the two variances and number of participants significantly differ from one another.

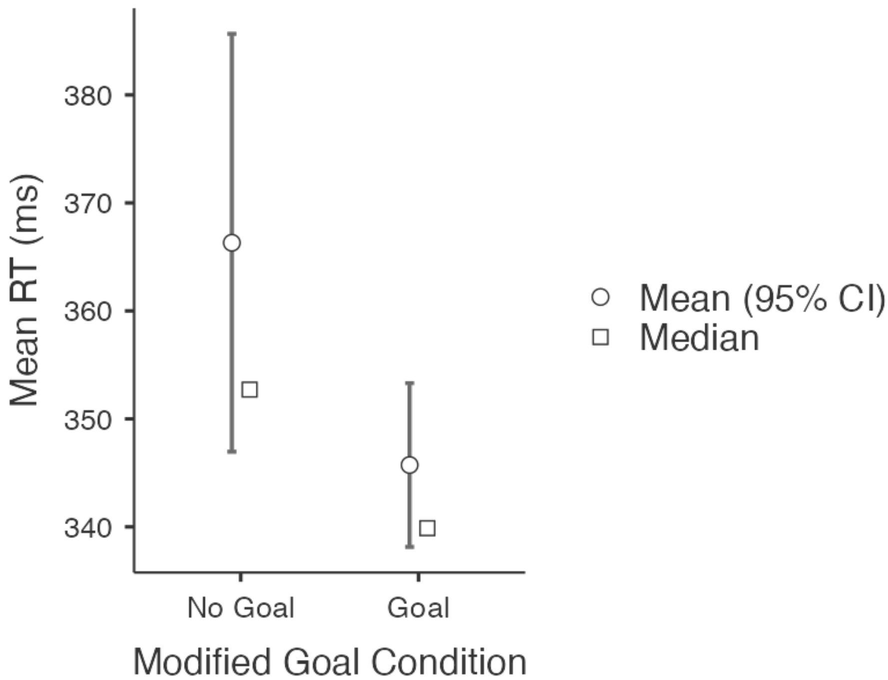

Figure 7: Mean RTs in No Goal and Goal Conditions

Goal Interactions

It's useful to see that goal setting influences performance, but to better understand the nuance and complexity of this relationship, we need to examine the interactions between goal setting and other variables. We conducted a 2 (Modified Goal Condition) x 5 (Time Bin) repeated measures ANOVA to determine if there was an interaction between goal condition and quartiles of performance. Our analysis indicated a small interaction, $F(4, 500) = 3.99$, $p = .003$, partial $n^2 = 0.03$ was present. The fastest 20% of RTs (Bin 1) for the No Goal ($M = 280.04$ ms, $SD = 23.44$) and Goal ($M = 274.61$ ms, $SD = 17.29$) conditions were not significantly different. However, the slowest 20% of RTs (Bin 5) within the No Goal condition ($M = 521.47$ ms, $SD = 208.15$) and Goal condition ($M = 464.96$ ms, $SD = 80.41$) are significantly different. Figure 8 demonstrates this Condition x Bin interaction and Table 1 shows correlational strengths and significance.

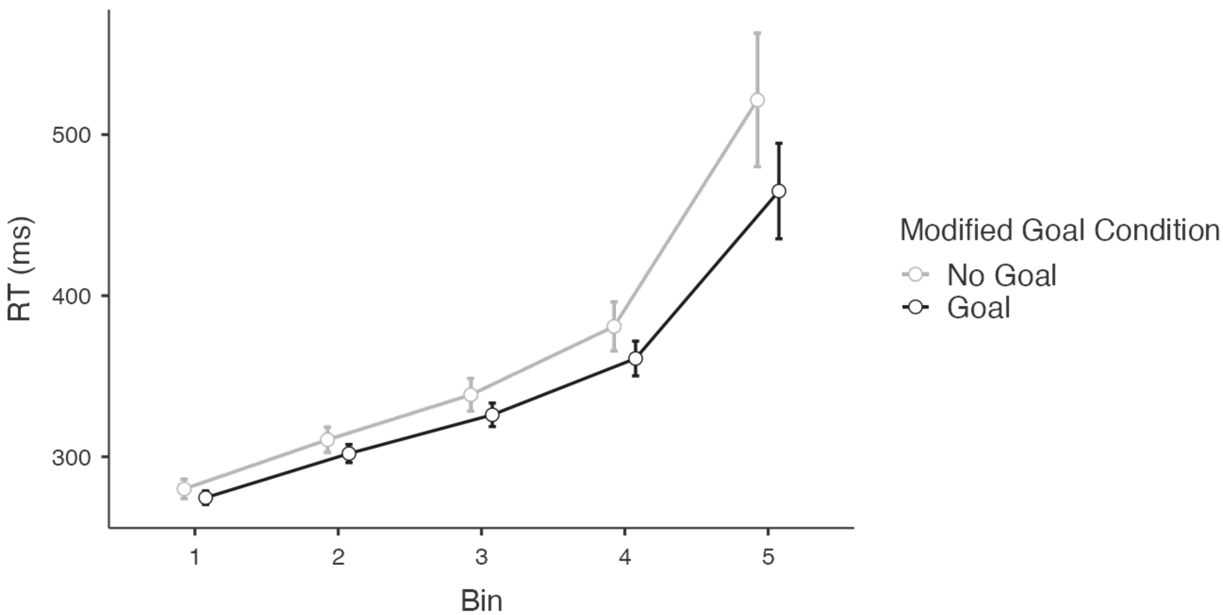

Figure 8: RTs by Quartile in No Goal and Goal Conditions

Independent Samples T-Test

		Statistic	df	p
Bin 1 Mean RT	Student's t	1.48 [a]	125.00	0.142
Bin 2 Mean RT	Student's t	1.76 [a]	125.00	0.081
Bin 3 Mean RT	Student's t	1.97 [a]	125.00	0.051
Bin 4 Mean RT	Student's t	2.13 [a]	125.00	0.035
Bin 5 Mean RT	Student's t	2.20 [a]	125.00	0.030

Table 1: Correlations by Quartile between No Goal and Goal Conditions

Another 2 (Modified Goal Condition) x 5 (Trial Block) repeated measures ANOVA revealed a significant interaction between Goal condition and block, $F(4,500) = 8.98$, $p < .001$, partial $n^2 = 0.07$. When just starting the task (Block 1), RTs between the No Goal ($M = 324.14$ ms, $SD = 30.79$) and Goal ($M = 323.71$ ms, $SD = 30.84$) conditions were nearly identical. However, RTs in the No Goal condition in Block 4 ($M = 398.47$ ms, $SD = 117.31$) and Block 5 ($M = 400.66$ ms, $SD = 98.39$) were significantly slower than Goal condition RTs in Block 4 ($M = 354.21$ ms, $SD = 38.03$) and Block 5 ($M = 361.97$ ms, $SD = 51.42$). Figure 9 highlights this Block x Condition interaction and Table 2 shows correlational strengths and significance.

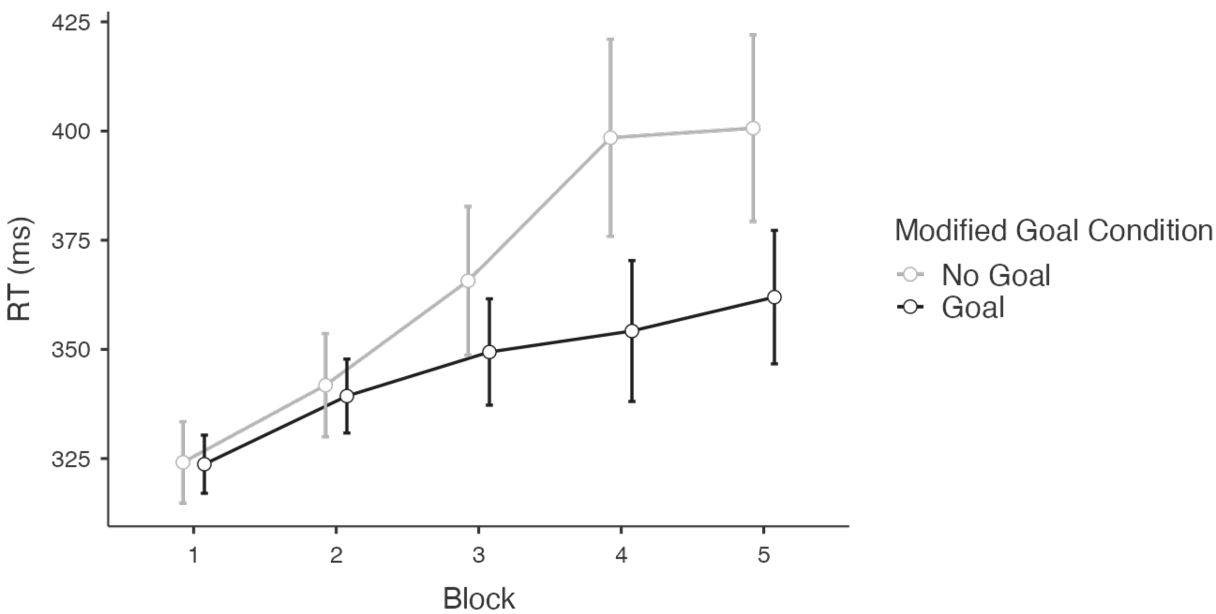

Figure 9: RTs over Time in No Goal and Goal Conditions

Independent Samples T-Test				
		Statistic	df	p
Block 1 Mean RT	Student's t	0.07	125.00	0.941
Block 2 Mean RT	Student's t	0.34	125.00	0.736
Block 3 Mean RT	Student's t	1.54 [a]	125.00	0.125
Block 4 Mean RT	Student's t	3.16 [a]	125.00	0.002
Block 5 Mean RT	Student's t	2.92 [a]	125.00	0.004

Table 2: Correlations by Block between No Goal and Goal Conditions

Pupillary Responses

An independent samples t-test was run on the pupillary response data for the mean difference, revealing a main effect of peak pupil dilation for the No Goal condition (*M* = .09 mm, *SD* = .06) and Goal Condition (*M* = .11 mm, *SD* = .06) (t(109) = 2.26, p = 0.026). The effect size was medium, with a Cohen's d of 0.45. As shown in Figure 10, pupils tended to dilate approximately 400 ms after the stimulus and then ultimately reduce in size. Not only did participants in the Goal condition have a larger pupillary response, but their pupils also remained dilated longer before returning to baseline level. The main effect of goal setting can be seen below in the difference between peak heights, while the condition x time interaction can be seen in the pupillary response after the peak.

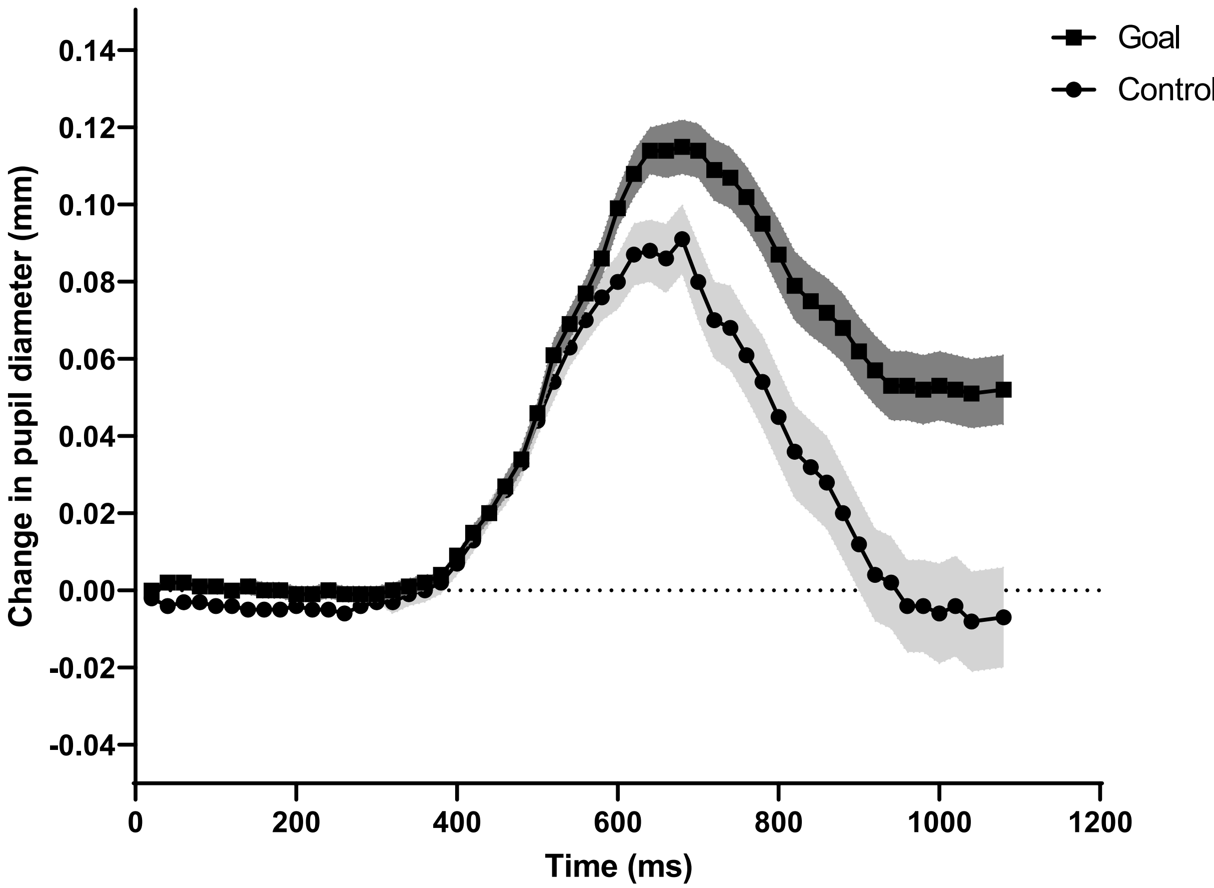

Figure 10: Change in Peak Pupil Dilation for No Goal and Goal Conditions

Data averaged between all participants across each condition, measured at 20 ms intervals.

Task-Unrelated Thoughts

An independent samples t-test of the proportion of task-unrelated thoughts revealed that there was no significant difference between the Goal condition (*M* 0.42, *SD* = 0.27) and the No Goal condition (*M* = 0.44, *SD* = 0.23), t(125) = 0.26, p = 0.795. When examined in conjunction with pupillary responses and RTs, increased performance and effort mobilization has no direct effect on minimizing TUTs.

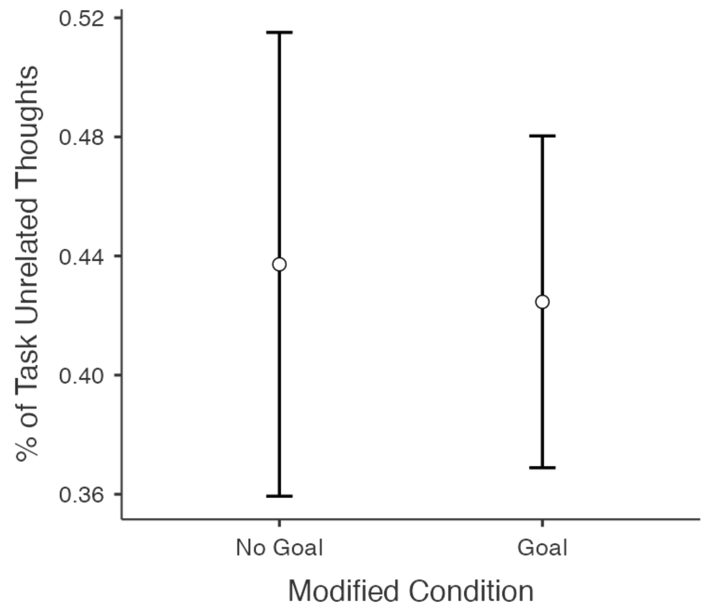

Figure 11: Task-Unrelated Thought % in No Goal and Goal Conditions

Discussion

Our hypothesis was that adding augmented feedback to a Psychomotor Vigilance Test (PVT) would decrease reaction times, increase pupillary responses, and limit off-task thoughts. However, our findings reveal that the addition of augmented feedback to an assigned goal does not significantly decrease reaction times (Figure 4) or limit off-task thoughts (Figure 6). Surprisingly, we found that peak pupil dilation differed between the original three conditions, although the Goal + Augmented Feedback condition did not differ significantly from the Control condition (Figure 5). The similarity in reaction times between the two Goal conditions suggests that receiving augmented feedback on performance does not necessarily lead to better performance. Moreover, since pupillary responses are a reliable measure of effort mobilization (Unsworth & Robison, 2016), the nonsignificant difference between the Goal conditions suggests that augmented feedback does not elicit more effort from an individual.

After we consolidated the Goal & Goal + Augmented Feedback conditions, we saw strong evidence suggesting that having a goal affects performance and sustained attention. Individuals that were assigned a goal (0.325 s) averaged significantly quicker RTs over the course of the PVT. This difference can be better explained when examining results in chronological order as well as comparing the best and worst scores of both conditions.

Participants in the Goal condition were able to better sustain their attention on the task, as seen through the interaction between time and goal condition. Participants in both conditions began the task with similar RTs. However, as time spent on the task increased, RTs for individuals in the No Goal condition increased much quicker than for those with the assigned goal (Figure 9). As the results indicate, the vigilance decrement was certainly a factor, as there was a negative relationship between task performance and time spent on the task.

A similar phenomenon can be seen when comparing quartiles of RTs. Overall, the top performances were similar between the two groups. However, the worst performances in the No Goal Condition were significantly slower than the worst performances in the Goal conditions (Figure 8). Although participants in both conditions had lapses in attention and occasionally exhibited slow RTs, there were significantly more egregious and more abundant lapses by participants in the No Goal condition. These results are in line with prior research, in which goal setting focuses performances on the goal, reduces the overall range of performances, and increases overall performances (Locke & Latham, 2002; Robison et al., 2021).

When examining TEPRS between the Goal and No Goal conditions, we observed a clear difference in the degree of pupil dilation. Approximately 0.4 seconds after stimulus onset, we noted an increase in pupil diameter for all participants. However, the peak response was significantly greater for individuals assigned a goal compared to those in the No Goal condition (Figure 10). Furthermore, pupils for participants assigned a goal remained dilated 1 second after the stimulus, while pupils for individuals in the No Goal condition returned to baseline levels. These TEPRS support our current understanding of the LC-NE system and its correlation to arousal and task performance. Having a goal correlates to higher TEPRS throughout the task. As noted above, having a goal also increases sustained attention. When individuals have a goal, their arousal levels remain and do not drop as quickly as they do when no goal is present. This altogether is evidence supporting the hypothesis that we can manipulate sustained attention by goal setting.

Surprisingly, we found that goal setting had no effect on the overall proportion of reported off-task thoughts. Despite having a goal, individuals were just as likely to report task-unrelated thoughts throughout the task as they would be without a goal (Figure 11). This conclusion is consistent with previous research (Unsworth et al., 2021). The reason why additional effort mobilization does not correlate with more on-task thoughts is not currently understood.

Our results suggest that when paired with a goal, augmented feedback adds no significant benefit. One possible explanation is that participants were focused more on the goal and their score than they were on the augmented feedback. Similarly, participants may have tuned out the feedback after a certain period. Since the form of feedback is the same modality as the task (words/numbers on a screen), the feedback was possibly ignored. Future research could consider if having augmented auditory feedback on a PVT yields similar results as augmented visual feedback. Another limitation of this study was the simplicity and repetition of the augmented feedback. Since we programmed one message for success and one for failure, participants quickly knew what the augmented feedback was going to say. The lack of creativity and variability could've played a part in the lack of significance and possible ignorance altogether by participants. Without a post-test survey, the helpfulness of the augmented feedback is unknown.

Overall, the current results demonstrated that goal setting improves performance in a variety of different ways. Not only does goal setting improve overall performance, but it also reduces the magnitude of poor performances and softens the impact of time on performance. These impacts on performance are seen to correlate with peak pupil dilations, as individuals with set goals have a greater physiological response to the stimuli. Holistically, the data from this study indicates that goal setting sustains our body's attentional capacity, keeping attention and arousal closer to optimal levels.

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