Two lingering delays in a go/no-go task: mind wandering and caution/uncertainty slow down thought probe response times

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In a go/no-go task, changes to the inter-trial interval (ITI) or the press percentage (PP) are known to have decelerating effects on both reaction time and on thought probe response time. The mental causes of these delays remain obscure. We performed an 18-minute online experiment with 60 participants who each performed 8 versions of an attention task (Test of Variables of Attention, ToVA) with different ITIs and PPs. After each block there were mind wandering (MW) thought probes and rating scales for subjective effort and awareness. A version of the ToVA with zero no-go-stimuli spontaneously and implicitly accelerated mean reaction time significantly. That version also quickened three subsequent response times for rating tasks by hundreds of milliseconds, which suggests that the basis of this effect is a lingering mental state. None of the subjective ratings measured were strongly related to the reaction time delay, although MW seems to delay the thought probe response. We conclude that there may be another lingering state besides MW. To perform different tasks participants make mental speed-accuracy trade-offs whereby the participant adopts a lingering mental strategy that speeds up thinking by reducing caution/uncertainty, quickening both reaction times and thought probe response times.

CCS Concepts: • **Applied computing → Psychology**; • **Human-centered computing → Laboratory experiments**; **User studies**.

Additional Key Words and Phrases: mental strategy, mind wandering, attentional resources, caution, effort, awareness, speed-accuracy tradeoff

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1 INTRODUCTION

1.1 Performance Decrement: Mind Wandering during Go/No-Go Tasks

Mind wandering (MW) is a family of states similar to daydreaming in which the thoughts stray from the task at hand [17, 21]. Mind wandering is known to lead to performance decrement and accidents in a variety of work and vehicular contexts [24]. MW may contribute to increased accidents when supervising automated tasks [9], and paradoxically more automation may lead to worse human performance when the automation fails [5]. A laboratory system for observing performance decrement over time and fatigue or accidents with computers is Go/No-Go tasks. In a go/no-go task the computer user must make a very simple decision and then respond as quickly and as accurately as possible. By doing these simple tasks repeatedly over a longer time, go/no-go tasks allow experimenters to test users' ability to sustain their attention and to resist boredom or mental fatigue.

In each trial of a go/no-go task, an image appears on screen and the participant must press a response button as quickly as possible whenever one kind of image appears on the screen (the 'Go-stimulus'), but they must not press (i.e. inhibit) their response if a different kind of image appears (the 'No-Go-stimulus'). This means that these go/no-go tasks require both attention and arousal to detect the stimulus plus executive control to inhibit their instinctive actions during the no-go stimuli. Therefore, go/no-go tasks are linked with three types of performance decrement: slow responses, commission errors (pressing during a no-go-trial), and omission errors (failing to press when the go-stimulus appears). Two well-known examples of go/no-go tasks used to test participants' ability to sustain attention are the Sustained Attention to Response Task (SART) [14, 16] and the similar Test of Variables of Attention (ToVA) [13].

The traditional SART has an inter-trial interval (ITI, time between experimental trials) of 1150-3000 milliseconds (ms) and a press percentage (PP, the probability that in a given trial the participant will have to respond as opposed to withholding any action, i.e. the % of go-trials divided by the total number of trials) of 89% [16, 20]. Under these circumstances, healthy participants make many commission errors, an error type where a participant responds when they should have withheld any response. Such commission errors have been proposed to represent risks to innocent victims when law officers must make split second decisions between shooting at a perpetrator versus recognising an innocent bystander [23]. Commission errors have a well-established link to mind wandering [14].

However, the relationship between mind wandering and reaction time in go/no-go tasks remain controversial. Initially MW was shown to speed up responses to SART [20], presumably due to truncating serial mental processes, i.e. scanning the environment (perception) and executive/decision control (see Figure 1A at right). An alternative view is that MW will slow down responses due to perceptual decoupling (see Figure 1A at left); in this view a parallel (executive) process is linked to paying attention, and this additional process either helps scanning the environment, or works purely at an executive level to maintain goal focus. At an experimental level, the direction of change of go/no-go reaction times during MW is not agreed, and may depend on which of the two processes above is dominant in a given individual [18].

One way to elicit a change in mental strategy in a go/no-go task results from changing the press percentage. When the press percentage in a go/no-go task is increased, there is a change in strategy that speeds up reaction times by up to 100 ms as well as increasing error rates. [23]. In addition to reaction times, we have shown previously [1] that when increasing the press percentage during a go/no-go task (from 20% to 80%), participants would unequivocally speed up (by nearly one second) their subsequent thought probe response time (to the question, "In the moment that just passed, were you focused on the task, mind wandering deliberately, or mind wandering spontaneously (without meaning to)?") [22]. The tentative conclusion from this extraordinary result is that MW leads to a lingering state of delay and lapsed attention that has an even greater effect on complicated tasks such as thought probes than it does on

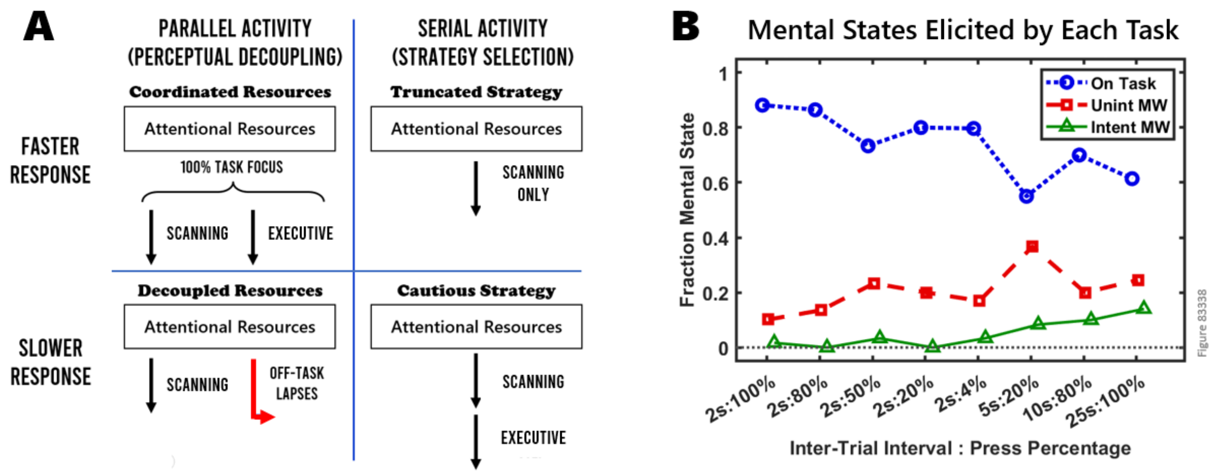

Fig. 1. Panel A: Schematic of parallel vs. serial attentional resources relating to Mind Wandering (MW). Executive = verification + goal upkeep, and may be related to subjective effort. Scanning is more perceptual and may be related to subjective awareness. Panel B: Responses to thought probe during different versions of the task. Unint = unintentional, Intent = intentional.

simple go/no-go tasks. Note that the compliant activity did not have clear effects on the reaction time element of the go/no-go task. If the *lingering state* hypothesis is true, then this implies that MW has an effect on parallel processing during complex tasks (see Figure 1A, left). The observation that MW leads to far greater delays during a complicated task would mean that supposed short lapses occurring during go/no-go task, like a momentary break for looking away, cannot fully explain the much longer MW-induced delay of the thought probe. A momentary break during a go/no-go task would imply a serial process (see Figure 1A, right), where the delay would be an extra step of reorientation, and in a serial process model, that reorientation would be a constant time, irrespective of the following step. By contrast, in a parallel processing model of reorientation, where the reorientation step requires several attentional resources simultaneously, then a more complex task (such as task switching or introspection) could be much more delayed by the previous deployment of resources to the mind wandering thought than a simple button pressing task would be.

The main critique of the conclusion from this extraordinary result (i.e. MW causes longer delays in complex tasks) is that the thought probe decision itself may have led to unequal response times, in the absence of a previously lingering state of MW. The thought probe in [22] gave a choice of three options: on-task, deliberate mind wandering, and spontaneous mind wandering. One can easily imagine a situation where a person who has no thinking delays would answer with the on-task option instantly, but if they had actually been mind wandering, this undelayed person may have spent a moment thinking, "Okay, I was mind wandering, but was I doing it deliberately? And what is deliberate mind wandering, anyway?" To address this criticism, we needed a thought probe where the mind wandering option required no more introspection than the on-task option, such as a binary choice, where you were either mind wandering or not.

Another result from [22] is that increasing compliant activity (without changing stimulus presentation rate) also reduced intentional MW (but this was supplanted by unintentional MW rather than being on-task). This implied that the compliant activity was hijacking parallel resources, possibly executive control, that were used for feeling "in control", such that the MW could no longer be believed to be intentional. This meant that there were potentially three processes fighting for the same resources: the go/no-go task, the executive control that led to having a strategy, and the mind wandering. Because compliant activity *reduced* subjective ratings of detachment [22], which is much more strongly related to intentional MW than unintentional MW, we suspect that the additional compliant activity triggers a change to a more cautious cognitive strategy. The detachment feeling may be an explicit parallel process of performing the task while introspecting ("I am bored but I still see it"). A test for this is to ask the participant subjective questions about awareness, or even about meta-cognition [2]; if they maintain awareness during MW, then it is probably parallel processing. If so, compliant activity would reduce divergent parallel thinking and focuses limited mental resources.

1.2 Aim and Hypotheses

Our aim was to extend our previous data [22] showing that a latent state (that is, a substrate, e.g. caution) could linger from a go/no-go task (where it was elicited purposefully) to a subsequent rating task, where this state would no longer be strategically relevant. Our hypotheses were: (H1) a PP% of 100% would lead to elimination of a cautious state or to a mental strategy that would be detectable as a faster reaction time, (H2) this mental substrate would still be detectable later as a faster response time on subjective rating scales, (H3) this response would not be related to MW, but would instead be due to a reduction in caution and monitoring, and (H4) any combination of lowering the press percentage, increasing the ITI, and MW would have additive effects on delaying reaction times and thought probe response times.

2 METHODS

2.1 Experimental Participants

Sixty online volunteers were recruited via Prolific and received £2.50 for their time. This study was carried out in accordance with the approval of BSMS's Standard Risk Ethics Protocol. Prolific allows for specifying and pre-selecting participants; we specified: English speaking, UK based, aged 18-70, using a laptop/desktop computer (i.e. not using a mobile phone or a tablet). All participants gave explicit informed consent (by pressing the letter "A", signifying "I agree") in accordance with the Declaration of Helsinki.

2.2 Protocol

Once recruited by advertising on Prolific, participants were sent to Pavlovia; this web platform allowed presentation of the stimuli on the participant's local computer and then uploaded the anonymised results to the platform. The online protocol had the following steps: open text for participant number (provided by Prolific) and simple demographic data, informed consent including description of how to withdraw instantly and button press for "I agree", detailed instructions for both the experimental task (Test of Variables of Attention, ToVA) and for the subjective ratings that they would make, an explicit practice block (4 trials), announcement that the experiment would begin, a rehearsal block (50 seconds) that was never included in the analyses, 8 experimental blocks (50 seconds each) presented in a pseudo-random order, and the thank you screen that sent participants back to Prolific for confirmation and payment. The entire experiment would take approximately 18 minutes, although it could be longer if the participant delayed during the subjective responses.

2.3 Stimuli and Subjective Rating Scales

The online go/no-go task (ToVA visual stimulus) was as described [13, 22], in which all responses were gathered by keyboard (i.e. not via mouse). For each trial, one of two easily distinguished images were presented: a go-stimulus (small box uppermost) and a no-go-stimulus (small box lower). See Figure 2.

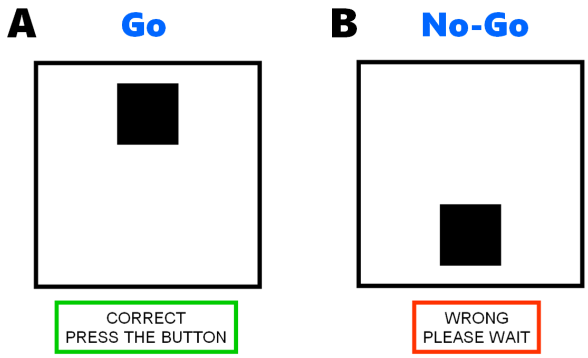

Fig. 2. The two stimuli used in ToVA. Panel A: The go-stimulus image. Panel B: The no-go stimulus image.

The entire trial (including the participant's response) was set to be the inter-trial interval (ITI). The combination of ITI and the ratio of go-stimuli (sometimes referred to as "non-target" in the literature) versus total stimuli (Press Percentage = go-stimuli ÷ (total go- plus no-go- stimuli)) were set differently for each block (see Results). The number of trials in a block was set to be approximately 50 seconds. Each block ended with a series of 3-4 subjective tasks. The first rating task was a forced-choice, binary thought probe, "In the moment just preceding this thought probe were you:" and the choices were "On Task" (spacebar) or "Mind Wandering" (any other letter). If, and only if, the participant answered "Mind Wandering", the next part of the thought probe was presented, "Was your mind wandering:", and the choices were "Intentional" (spacebar) or "Unintentional" (any other letter). The next subjective task was the meta-awareness rating: "How aware were you of whether or not you were paying attention? Press one key 1-6". The final subjective task was the mental effort rating: "How much mental effort were you making to do the task correctly? Press one key 1-6" where 1 had an anchor "minimum effort" and 6 had an anchor of "maximum effort". The instructions described maximum effort as "compared to what is possible in an experiment like this. Mental effort means you are using your willpower to press the button as FAST as you can, whilst being CAREFUL to only do so when the correct square is shown. It is possible to fail at a task when making a lot of effort, particularly if the task is difficult or if you are fatigued. It is also possible to succeed with very little mental effort, particularly if the task seems easy."

2.4 Analysis and Pre-determined Data Exclusion Criteria

Pavlovia files were read into Matlab using a specially designed script, and all statistics were performed in Matlab. Individual trials were dropped if the reaction time > 0.9 seconds. Individual subjective ratings were capped at 15s if the response time (e.g., thought probes and subjective ratings) > 15 seconds. A block was dropped if the block had more than 4 omission or commission errors. The entire participant was dropped if a participant's data included more than 3 dropped blocks. The entire participant was dropped if the participant did not complete the experiment or if the participant's experimental duration was greater than 30 minutes (i.e. they took a break in the middle of the experiment).

3 RESULTS

3.1 Mind Wandering

There were a total of eight versions of the go/no-go task that this cohort experienced (ToVA). Of the 474 non-excluded blocks, 122 (25.74%) were reported as mind wandering. Figure 1B shows the breakdown by task. There were subtle increases in mind wandering when more false alarms appeared (i.e. when press percentage was lower, as tested among the blocks with 2s inter-trial intervals). There were slightly larger increases in MW when ITIs were longer (compare 2s:80% to 10s:80%), but substantially larger increases in MW appeared when there was a co-occurrence of both slow ITI and many false alarms (5s:20%).

3.2 Mean Reaction Times

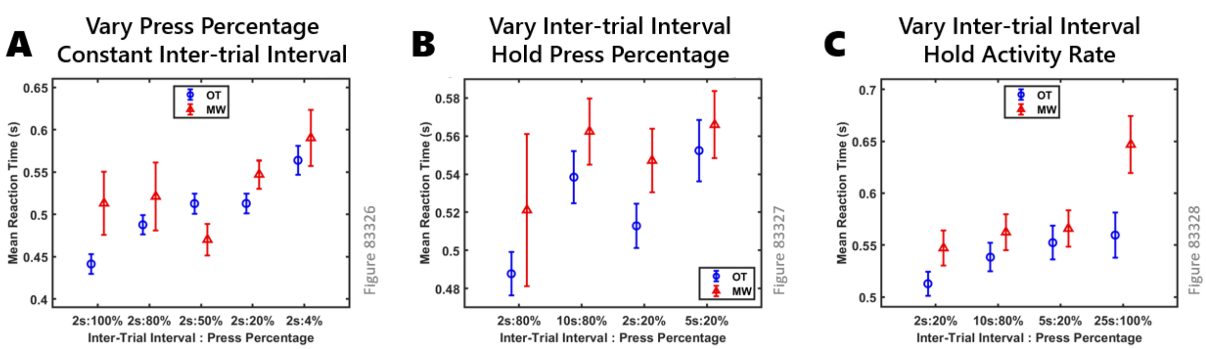

Fig. 3. Reaction times are slowed by longer Inter-Trial Intervals and Lower Press Percentages. Panel A: As press percentage is decreased, reaction times slow down. Panel B: Two pairs of tasks showing that when inter-trial interval is lengthened, reaction times are slowed down. Panel C: Two pairs of tasks with the same activity rate (10 seconds and 25 seconds) despite having altered both press percentages and inter-trial intervals. Error bars are SEMs. OT = on-task (blue circles); MW = mind wandering (red triangles).

Figure 3 shows how mean reaction times (not including the first trial) varied when both the ITI was made longer and the PP was lower. Panel A shows that mean RT0 slowed down when the PP was lower for four versions of the task that all had an ITI = 2s. In an LME model for mean RT0 in these tasks, the effect of PP was highly significant ($t = -10.56, P = 2.6 \times 10^{-22}$) but the effect of mind wandering was not ($P = 0.29$). Panel B shows for two examples that when ITI is lengthened (i.e. the task becomes slower, but not longer), reaction time increases. Again this effect was significant ($t = 4.90, P = 2.13 \times 10^{-6}$) and the effect of mind wandering was not ($P = 0.18$). Panel C attempts to change the two features oppositely (to determine if one effect dominates) by maintaining a stable expected activity rate (button presses per minute). At left 2s:20% and 10s:80% both expect presses approximately once every 10s. The effect of the task was significant ($t = 2.75, P = 0.007$) while the effect of MW was not ($P = 0.40$). At right 5s:20% and 25s:100% both expect a button press every 25s. The effect of the task was significant ($t = 24.1, P = 6.40 \times 10^{-31}$) and so was the effect of MW ($P = 0.013$). The implication is that ITI has a slightly stronger effect on slowing reaction time than does PP, and that MW has only a weak slowing effect unless it is combined with another factor that slows down reaction times (in this case, an ITI of 25s).

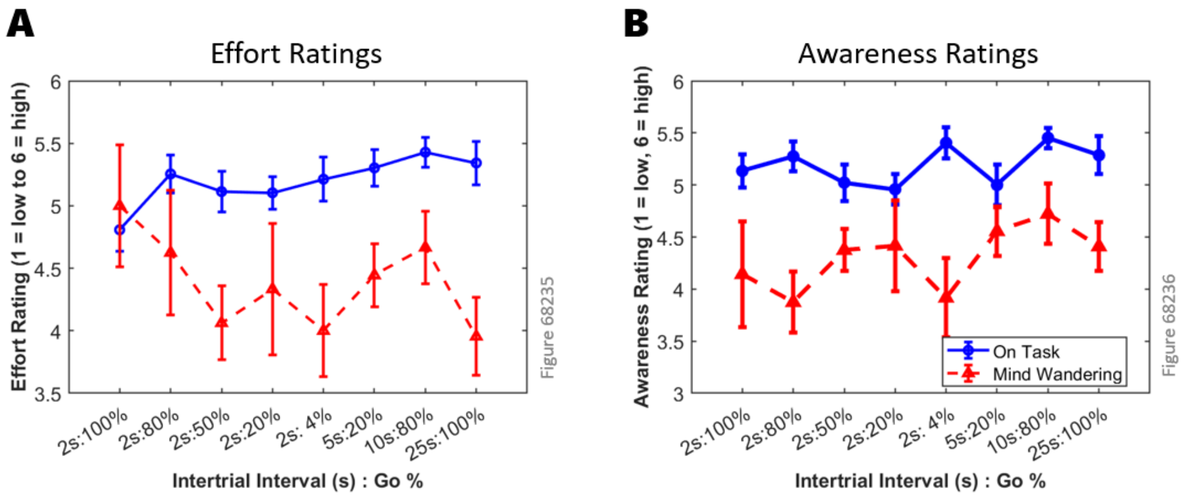

Fig. 4. Mean Effort and Awareness Ratings elicited by each task. Error bars are SEMs

3.3 Subjective Responses

Figure 4 shows the combined effects of mind wandering, ITI and PP on the the subjective ratings of effort and awareness. Panel A shows that mind wandering was associated with a fairly clear drop in subjective effort (LME $t = -6.21, P = 1.15 \times 10^{-9}$), and that compared to the reference of 2s:100%, the two tasks with 80% PP elicited significantly more effort (LME $t > 2.75, P = 0.0062$ for both), but the effects of the other tasks were not significant. Panel B shows that mind wandering was associated with a fairly clear drop in subjective awareness (LME $t = -7.15, P = 3.40 \times 10^{-12}$), and that compared to the reference of 2s:100%, 10s:80% PP elicited significantly more awareness (LME $t > 2.28, P = 0.023$), but the effects of the other tasks were not significant. The implication is that participants subjectively described themselves as on-task, highly aware, and making an effort all at the same time. It is common in experiments like these that the various subjective ratings are related to one another, and there is always a question among the limitations as to how able lay participants are to discriminate between various subjective ratings [19, 22].

To test for this subjective coupling, Figure 5A shows the relatedness for the effort and awareness responses, and they are fairly clearly on the diagonal. In an LME for awareness rating as an outcome, with effort rating and task design as predictors, this relationship between effort an awareness was statistically unequivocal (LME $t = 14.8, P = 6.01 \times 10^{-41}$). Panel B of Figure 5 shows the relationship between effort and on-task states. Above effort ratings of two, the relationship is fairly clearly diagonal and statistically significant (LME $t = 6.21, P = 1.15 \times 10^{-9}$). Panel C shows the relationship between subjective awareness and on-task states. Above effort ratings of four, the relationship is fairly clearly diagonal and statistically significant (LME $t = 3.40, P = 1.15 \times 10^{-12}$).

Although these results suggest that all three subjective responses (effort, awareness and on-task states) are locked in a coupled relationship, there are differences when looking at statistics for the type of mind wandering. Intentional MW is strongly related to effort (LME, $t = -4.55, P = 6.74 \times 10^{-6}$), but not significantly related to awareness (LME, P = 0.13). Unintentional MW is strongly related to both awareness (LME, $t = -6.70, P = 6.16 \times 10^{-11}$) and effort (LME, $t = -5.08, P = 5.39 \times 10^{-7}$), and if they are both in a model all the relationship is partitioned to awareness (LME, $t = -4.36, P = 1.58 \times 10^{-5}$), and not effort (P = 0.32).

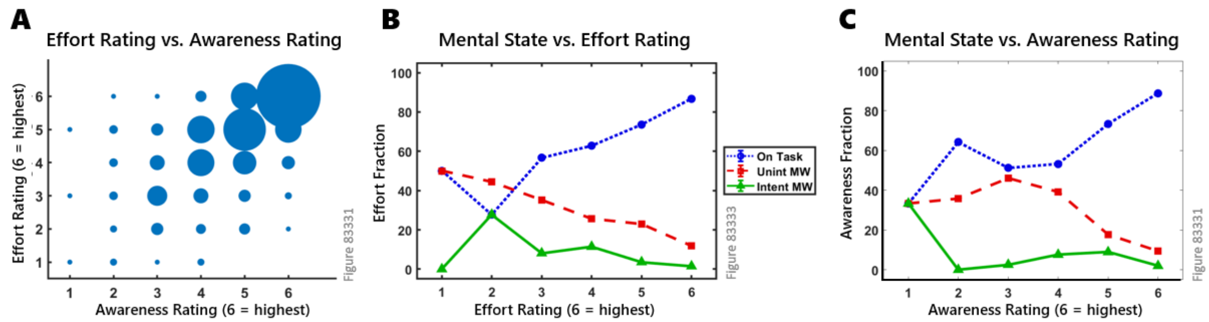

Fig. 5. Relatedness of Effort vs. Awareness vs. On Task. Panel A: Effort vs. Awareness Bubble Plot for all tasks. Panel B: Mental state vs. effort rating (for all tasks combined). Panel C: Mental state vs. awareness rating (for all tasks combined). For Panels B & C On-task = blue circles with dotted line, unintentional MW = red squares with dashed line, and intentional MW = green triangles with continuous line

3.4 Lingering Mental Effects on Thought Probe Response Time

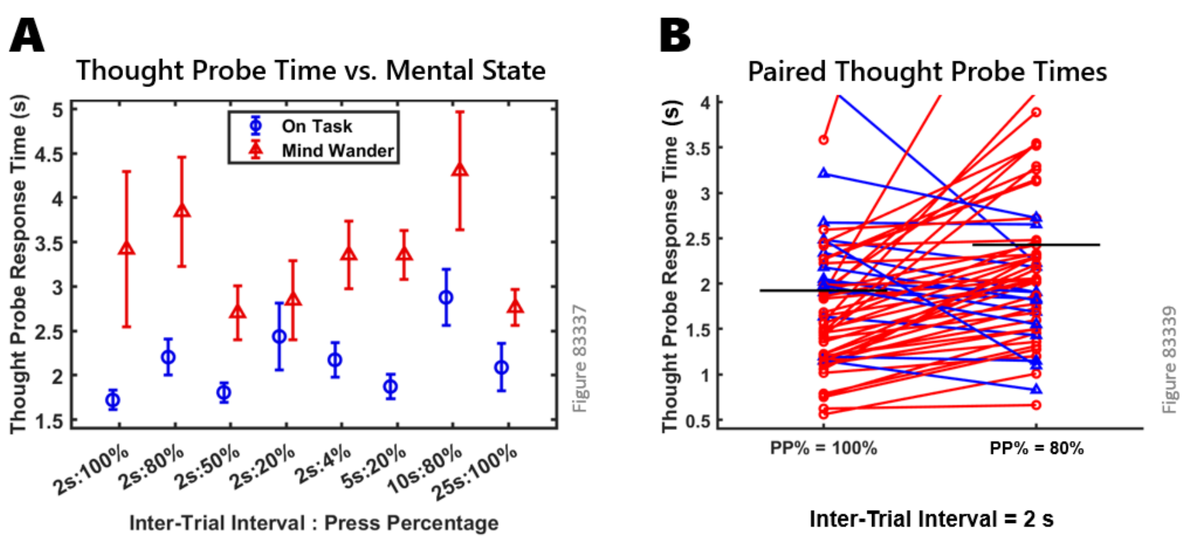

Fig. 6. Slowed response lingers into thought probe response time. Panel A: Comparing on-task (blue circles) to mind wandering (red triangles) for each task version. Panel B: Paired comparison of 100% press percentage to 80% when inter-trial interval = 2s. Black horizontal lines = means. Each participant is one coloured line. Red circles = 80% is slower, blue triangles = 80% is faster.

We previously detected a difference in the thought probe response time between blocks that were on-task versus those that were mind wandering [22], so we looked to see that this result was repeated here. Figure 6A shows that there is a fairly clear delay in thought probe response time elicited by MW for virtually every version of the task (LME, $t = 6.13$, $P = 1.84 \times 10^{-9}$, except 2s:20%, which did not reach significance). The estimate for the additional time needed to respond to the thought probe is 890.5 ms. So MW delays the response to the thought probe by nearly one second, whereas it only delays the mean reaction time (see Figure 3) by 23.5 ms (LME for all blocks together, with predictors task type and MW). Figure 6B shows that 2s:100% speeds up thought probes compared to 2s:80% (see Table 1 for statistics).

3.5 Comparing Two Blocks With and Without False Alarms

To look more deeply at the strategic response to different tasks, we compared one block with no false alarms (ITI = 2s, PP%=100%) to another, more effortful block that had occasional false alarms (ITI = 2s, PP%=80%). The results for the 58 participants who had matching data for ITI = 2s, PP%=100% vs. ITI = 2s, PP%=80% were compared using paired t tests (see Table 1). These two versions of the go/no-go task had nearly identical amounts of button pressing activity, and there was no difference in their instructions (to press as fast as possible when the go-image was shown and to refrain from pressing when the no-go-image was shown). However, over the 50 seconds of the 2s/100% task, participants may have habituated to the total lack of no-go-stimuli by a mental strategy that sped up their responses. Row 1 of Table 1 shows that these participants reacted (simple reaction time = "RT0") to the go/no-go stimuli at 100% by pressing on average 45 milliseconds faster. The effect size for this difference is medium size (Cohen's d = 0.546 [6]).

Table 1. Paired Comparisons: Press Percentage PP% = 100% versus PP% = 80%, both at ITI = 2 s

Row	Calculation	PP = 100% (*mean* ± *SEM*)	PP = 80% (*mean* ± *SEM*)	Cohen's d	P
1	mean RT0 (task reaction time)	0.445 ± 0.011 s	0.491 ± 0.011 s	0.546	4.6×10^{-8}
2	RT1 (OT vs. MW probe time)	1.913 ± 0.157 s	2.454 ± 0.208 s	0.380	0.0051
3	RT3 (awareness rating time)	2.664 ± 0.200 s	3.512 ± 0.225 s	0.529	0.0013
4	RT4 (effort rating time)	1.909 ± 0.182 s	2.371 ± 0.171 s	0.344	0.0238
5	Awareness Rating (1-6)	5.017 ± 0.160	5.069 ± 0.147	0.044	0.684
6	Effort Rating (1-6)	4.845 ± 0.161	5.155 ± 0.149	0.263	0.023
7	Omission Errors	0.086	0.086	0	1.00
8	Mind Wandering	12.1%	13.8%	–	1.00

Row 2 shows that the differences in response times (RT1) for the thought probe ("In the moment just preceding this thought probe were you on task or mind wandering?") between these two versions of the task was slowed down by the 80% condition by 541 ms. Row 3 shows that the differences in response times (RT3) for the subjective question "How aware were you?" between these two versions of the task was slowed down by the 80% condition by 848 ms. This is an enormous deceleration (20-fold the slowing of the mean RT0 and 30% of the entire time it takes to score the rating at 2s/100%). It makes sense that the rating tasks would be slower than reaction time tasks (because rating tasks include at least one *interpretive step*). However, it is not intuitively obvious why the two identical rating tasks following different versions of the go/no-go task would be different: the mechanics and the answer for the rating task after the 2s/100% task are no different from after the rating task for 2s/80%. The actual ratings provided for the two tasks (see row 5) are almost identical (mean difference = 0.05 of a unit on a 1-6 scale, P = 0.684). The implication is that some mental element (either a state or a strategy) is lingering from the reaction time task all the way to this rating task, despite the fact that there was a thought probe (lasting about 2 seconds) that occurred between these two tasks. The most obvious lingering state to test would be mind wandering, which was subjectively tested with a binary thought probe and statistically tested using a Fisher's exact test (row 8), but we found no difference in MW for these two versions of the task (odds ratio = 1.166, 95% confidence interval 0.3932 to 3.4560).

One possible strategic difference is that participants spent less effort on the 100% task (row 6). There was a small, statistically significant decrease in subjective effort (0.310 units on a 1-6 scale, Cohen's d = 0.263 [6]). Again, the response time for this effort rating (RT4, row 4), which was presented after the awareness rating task, was significantly faster (462 milliseconds) following the 100% version of the go/no-go task than after the 80% version. Although this is nearly half of one second, it is a small effect (Cohen's d = 0.344 [6]) because rating times are so variable. The final state that might be different is that the participants might be clumsier or more sloppy during the 100% version. To test for this, we compared the number of errors of omission (when a go-image appeared and the participant failed to press the button in within 2 seconds) per block (row 7), and there was absolutely no difference. Of course, there were errors of commission (when a no-go-stimulus appeared and the participant made a mistake and pressed the button) in the 80% task, and this was not possible in the 100% version of the task because there were not any no-go-stimuli.

4 DISCUSSION

4.1 Overview of the Effects of a Cautious Strategy

It is well-established that immediately after mistakes on a go/no-go task, participants slow down [7, 12] due to caution, which is often described as a strategic choice. The caution is a substrate (i.e. a latent state that is necessary for the trigger to take effect) and the error is the trigger, and when the substrate and trigger co-occur together, they trigger a cautious delay strategy (see Figure 1A right); the delay is due to additional serial use of attentional resources. Our team has previously found evidence that a three-way thought probe (between on-task, intentional MW and unintentional MW) manifested slower thought probe responses when mind wandering than when on-task [22]. However, this delay could have been due to the nature of the thought probe. Furthermore, even if the delay was due to an ongoing mental state elicited during the go/no-go task (such as after errors), there was no evidence in the literature that this change would linger through additional go/no-go trials and then through three subsequent rating tasks. In this experiment we re-designed the thought probe into a simpler two-way choice to minimise the chance that thought probe delay is due to the thought probe itself. We also used many more versions of the go/no-go task to determine if the delay might be ascribed to a rational, cautious state, as well as adding two rating scales for effort and awareness.

Our results were: (H1) A version of the go/no-go task with zero no-go-stimuli spontaneously and implicitly led to a highly significant acceleration in mean reaction time (RT0), as implied by [23]. (H2) The same version of 100% go-stimuli quickened three subsequent response times for rating tasks by over 500 ms, 400 ms and 800 ms, which suggests that the basis of this effect is a lingering state (or substrate, e.g. carelessness). (H3) This is a change in the speed-accuracy trade-off in which the participant adopts a mental strategy that speeds up thinking by reducing caution [11, 16]; the evidence is that PP = 100% causes a modest decrease in subjective ratings of mental effort, although there is no significant change in MW or in awareness ratings. By contrast, MW has a very brittle effect on ToVA reaction times (Figure 3) but causes a strong delay in thought probe response times (Figure 6). (H4) The causes of go/no-go delays are synergistic, and may work in parallel. We propose that the reason the individual effects of ITI and PP on reaction and response times are so inconsistent in our data (see Figures 3 & 6A) is because the timing delays are due to rational (albeit implicit or subconscious) decisions, which will vary by person as well as by mood.

The observations of acceleration at 100% go-stimuli are particularly interesting because this strategy of reduced effort lingers from the go/no-go task (where the strategy has a task-related benefit to performance) to a subsequent series of rating tasks, where this strategy has no task benefit. In addition, the change in response between 80% to 100% was implicit (i.e. we did not openly reveal the change in PP to the participants); this means that in under 50 seconds participants jump to conclusions about risk that alter their mental strategies [3]. The other interesting aspect of this data is that we have seemingly eliminated the possibility that this change is due to a state change in awareness (i.e. increased distraction, see Table 1 rows 5–8). Yet, our controls (Figure 5) showed: (A) mental effort and awareness are very strongly linked, (B) MW is linked to lower mental effort, and (C) MW is linked to lower self-awareness.

Thus, the mechanism for accelerating task responses at PP = 100% seems to break the link between effort and awareness. We propose that many instances of mind wandering involve parallel deployment of unneeded mental resources, which does not impair perceptual awareness (although intense mind wandering like daydreaming can hijack all mental resources and necessitate serial resumption of external tasks). This fits with the observation that increased automation leads to increased mind wandering [9] and unreliable automation when participants supervise an autopilot increases mental demand but without changing the probability of mind wandering [10]. The implication is that certainty, in both our experiments and Gouraud et al.'s supervising automation experiments [10], can make people careless or incautious leading to decreases in a serial deployment of mental resources (i.e. a truncated strategy in the PP = 100% version). Thus, although we found, as expected, that low effort does cause reductions in awareness and an increase in MW, the *subtle* reduction in subjective effort we observed at PP = 100% reduced the *serial* use of mental resources for caution, but not the subjective awareness of the participant during the task; omission errors were no more common when caution was reduced, nor was mind wandering (see Table 1, rows 7 & 8). For human supervisors of automation, there may be complacency [15] in the form of over-confidence that they are doing a good job because their *parallel* awareness and broad performance is not reduced, but in fact their fine-grained performance to cautiously monitor persistently and *serially* for rare automation errors (situational awareness) may be sub-optimal.

4.2 Conclusions and Future Research

There seem to be two different lingering states: MW is one (see Figure 6), but the other is an unidentified low effort state that might be caution/carelessness (see Table 1). Our experiments showed that a task of high certainty (PP = 100%) induces a lingering state that reduces both reaction times and subjective response times via a truncated serial strategy. Our control experiments showed that this truncated strategy is related to decreased effort but not to decreased awareness nor to MW. This short-term cognitive change (low effort and presumably low caution in a context of high certainty and normal awareness) could be an *active complacency without mind wandering* and may even reflect the habitual "yes set" of increased certainty, reduced resistance and reduced caution described in Ericksonian hypnosis [4, 8]. Instead of a gross change in awareness slowing all attentional resources (so-called decoupling, see Figure 1), in this case we saw a truncation in mental strategy that led to decreased monitoring and the quickening of compliant responses. That is, as the participants realised that the go/no-go task was easier at PP = 100%, they rationally (perhaps subconsciously) decided to improve their performance by truncating their serial strategy for using mental resources in a way that is objectively detectable, and this reassignment of resources lingered into a subsequent process in a way that was not rational [11]. The main limitations in this experiment are the reliability of thought probes in representing conscious states, which is described elsewhere [22]. It is possible that the reduced effort strategy we observed is due to less caution or to greater certainty, so future experiments should have subjective measures of both caution and certainty.

5 FUNDING DETAILS

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6 DISCLOSURE STATEMENT

The authors report there are no competing interests to declare.

7 DATA AVAILABILITY

This data is available in a matlab .mat file on github at https://github.com/harry-witchel/LingeringStatesToVA.git

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