INVESTIGATING DOPAMINE- AND NOREPINEPHRINE-LINKED VARIABILITY IN COGNITIVE CONTROL IN LAB AND IN LIFE

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REBECCA DIANE CALCOTT

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Student: Rebecca Diane Calcott

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This dissertation has been accepted and approved in partial fulfillment of the requirements for the Doctor of Philosophy degree in the Department of Psychology by:

Dr. Elliot Berkman	Chairperson
Dr. Ulrich Mayr	Core Member
Dr. David Unsworth	Core Member
Dr. Santiago Jaramillo	Institutional Representative

and

Scott L. Pratt	Dean of the Graduate School

Original approval signatures are on file with the University of Oregon Graduate School.

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DISSERTATION ABSTRACT

Rebecca Diane Calcott

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A series of experiments investigated the relationship between locus coeruleus-norepinephrine (LC-NE) function and striatal dopamine (DA) tone and the flexibility of stability of cognitive control. Across 4 experiments, participants completed an attention shifting task, in which they had to periodically switch the focus of their attention while avoiding distraction. In 3 of the 4 experiments, participants' eyes were tracked to collect eye blink rate and pupil size, indices of striatal dopamine and LC-NE function respectively. A second aim of this project was to determine whether DA- and NE-linked variability in cognitive control was predictive of more ecologically valid real-world behaviors. To this end, participants in Experiment 4 also completed an additional lab session, in which they performed an internet search task, designed to be similar to what a student might experience in their everyday life. Participants then completed 2 weeks of follow-up questionnaires to provide a self-report of their daily experience of distractibility and flexibility. We hypothesized that observable indices of flexibility and distractibility during the internet search task would mediate the relationship between attention task performance and real-world experiences.

Results indicated that EBR is related to attentional flexibility; however the

specific shape of the effect was inconsistent across studies, with one showing a linear effect on the ability to update the attentional set, and the other showing a quadratic effect. There were large, consistent main effects of both tonic and phasic pupil measures on attention task performance, with longer latencies, larger phasic responses, and larger baseline pupil sizes all tending to predict slower responding and a higher error rate. There was no clear pattern of pupil effects across conditions, however, and so it is not clear whether pupil-linked changes in task performance are related to specific effects on cognitive control processes, or rather a more general arousing effect on performance. Finally, there were also no clear links suggesting that observable behaviors on our internet search task could be used to bridge between attention task performance and real-world behavior.

CURRICULUM VITAE

NAME OF AUTHOR: Rebecca Diane Calcott

GRADUATE AND UNDERGRADUATE SCHOOLS ATTENDED:

University of Oregon, Eugene, OR
University of Toronto, Toronto, ON

DEGREES AWARDED:

Doctor of Philosophy, Psychology, 2017, University of Oregon
Master of Science, Psychology, 2012, University of Oregon
Bachelor of Science, Psychology and Human Biology, 2010, University of Toronto

AREAS OF SPECIAL INTEREST:

Cognitive Neuroscience
Cognitive Control
Attention
Motivation

PROFESSIONAL EXPERIENCE:

Research Assistant, The Hospital for Sick Children, April 2010-August 2011

GRANTS, AWARDS, AND HONORS:

Research Grants for Doctoral Candidates and Young Academics and Scientists (more than 6 months), Dissociating dual mechanisms of conflict adaptation by examining reward effects and neurotransmitter correlates, German Academic Exchange Service (DAAD), 2017-2018

Dissertation Research Award, Cognitive Control: A bridge between the brain and real-world behavior, American Psychological Association (APA), 2016

Postgraduate Scholarship – Doctoral Level, Natural Sciences and Engineering Research Council of Canada (NSERC), 2013-2016

Postgraduate Scholarship – Master's Level, Natural Sciences and Engineering Research Council of Canada (NSERC), 2011-2012

Certificate of Academic Excellence, The effects of induced mood on attentional control sets, Canadian Psychological Association (CPA), 2010

PUBLICATIONS:

Calcott, R.D. & Berkman, E.T. (2015). Neural correlates of attentional flexibility during approach and avoidance motivation. *PLoS ONE*, *10*, e0127203-19.

Calcott, R.D., & Berkman, E.T. (2014). Attentional flexibility during approach and avoidance states: The role of context in shifts of attentional breadth. *Journal of Experimental Psychology: General*, *143*, 1393-1408.

Giuliani, N., Calcott, R.D., & Berkman, E.T. (2013). Piece of cake: Cognitive reappraisal of food rewards. *Appetite*, *64*, 56-61.

Chakravarty, M.M., Steadman, P., van Eede, M.C., Calcott, R.D., Gu, V., Shaw, P., Raznahan. A., Collins, L.D., and Lerch, J.P. (2012). Performing label-fusion based segmentation using multiple automatically generated templates. *Human Brain Mapping*. doi 1002/hbm.22092

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CHAPTER I

INTRODUCTION

Delineating the neurocognitive mechanisms that underlie our ability to exert cognitive control is a key to understanding how we are able to pursue goal-directed behaviors, and on the other hand, why we sometimes fail to do so. Solving this puzzle will involve attaining a mechanistic understanding of the processes that facilitate versus undermine the translation of an abstract goal into concrete sequence of thoughts and behaviors. A challenge inherent in this aim is that the methods and timescales leveraged to measure the neural and cognitive processes of interest are often necessarily far-removed from the consequential real-world behaviors of interest.

Here, we discuss a framework that uses cognitive control as a central construct through which we can begin to bridge this gap between the brain and complex goal-directed behaviors. Cognitive control, also known as executive function, describes processes that organize and regulate our thoughts and actions, allowing us to act in accordance with internally-held goals. Cognitive control operates, in part, by regulating attention and working memory (WM). Attention can be thought of as an informational filter, which selectively enhances processing of certain information (external or internally-generated) and filtering out other information. WM refers to the capacity to temporarily store and manipulate a limited amount of information within conscious awareness. Because we can attend, maintain, and respond to only a fraction of the information from our environment at any given time, cognitive control over attention and working memory plays a central role in ensuring that thoughts and stimuli that are relevant to our goals reach conscious awareness, while irrelevant or potentially distracting stimuli do not. The neural mechanisms of attention, working memory, and cognitive control are relatively well-characterized, and although there are clear hypotheses that can be drawn regarding how cognitive control in the moment contributes to complex behaviors, these links are not often tested empirically.

One route to explicitly establishing links between variability in cognitive control and variability in real-world behaviors involves breaking the behavior down into its component parts. Complex behaviors and thought patterns can be represented hierarchically, with a higher-level, abstract goal promoting specific behaviors, which can be further decomposed into a series of nested sub-tasks (Figure 1) . Much empirical work supports idea that complex tasks are represented hierarchically, at the level of overt, real-world behaviors (Wilkowski &

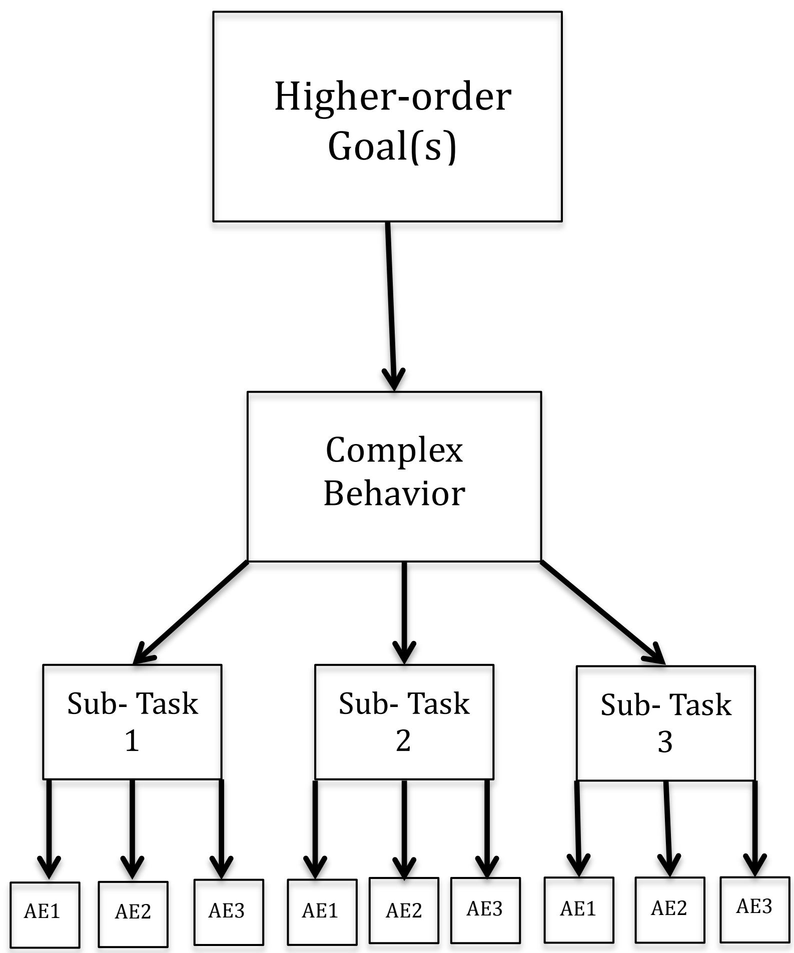

Figure 1. Schematic depicting the hierarchical structure of goal-directed behavior. Complex, goal-directed behaviors can be broken down into a series of hierarchically-nested sub-tasks, with an attentional episode (AE) constituting the briefest subcomponent.

Ferguson, 2016), in the execution of tasks in a laboratory setting (Reimer, Radvansky, Lorsbach & Armendarez, 2016), and in patterns of neural activity (Farooqui, Mitchell, Thompson & Duncan, 2013; Badre & D'Esposito, 2009).

Within this hierarchical structure, our experience can be conceptualized as a series of brief-timescale attentional (or WM) episodes, which are strung together as we proceed through time (Duncan, 2013). Although our capacity for attention and WM is limited, we are able to accomplish complex, longer-term behaviors because, in any given moment, we need to focus only on a smaller subcomponent of the behavior. The upshot of this attentional episode frame is that understanding how the brain regulates the contents, stability, and organization of these attentional episodes can provide insight into the longer-term complex behaviors that they comprise. Westbrook and Braver (2016) introduced the concept of a control episode, which describes the processes involved in coordinating these moment-by-moment attentional episodes, by maintaining the higher-order goal in mind, while continuously updating contents of WM as each sub-goal is accomplished. An additional piece of the puzzle is that control episodes are effortful, and we often opt to avoid them (Westbrook, Kester & Braver, 2013). Thus, our ability to successfully pursue self-directed behaviors depends on both our decision to engage in a control episode, and the effectiveness with which we can implement the control episode.

In this introductory chapter, we will highlight research on how dopamine (DA) and norepinephrine (NE), two neurotransmitters with key roles in cognitive control, contribute to the decision to engage in effortful cognitive control processes and the implementation of cognitive control over WM and attention. Finally, we will introduce the experiments carried out with the aims of both clarifying DA and NE's influences on cognitive control, and linking DA- and NE-mediated variability in cognitive control with real-world behaviors.

DA and Evaluation of the Control Episode

An emerging consensus suggests that the extent to which we exert cognitive control in the service of goals depends on a value-based decision making process that assesses whether the effort required for control is worth its costs (Shenhav et al., 2017; Berkman Hutcherson, Livingston, Kahn & Inzlicht., *in press*). The outcome of this valuation process is proposed to determine not only which cognitive tasks we engage in, but also the intensity with which we engage (Shenhav et al., 2017; Shenhav, Cohen & Botvinick, 2013). Thus, understanding this decision process is an integral component to understanding our capacity to exert control in the service of our goals. Here, we will briefly comment on the neural processes involved in learning and making decisions about cognitive control, with an emphasis on the role of DA (for comprehensive review, see Westbrook & Braver, 2016).

The decision to engage cognitive control depends, in part, on the learned costs and benefits of exerting control in a particular context. Striatal DA prediction error signals play a critical role in this learning process, by binding actions and their outcome states. Specifically, actions that produce better-than-expected outcomes (positive prediction error) lead to phasic DA firing in striatum, which binds the action with contextual information and increases the likelihood that the action will be repeated in the future, whereas worse-than-expected outcomes (negative prediction error) suppresses striatal DA release, producing the opposite effect (Hazy, Frank, & O'Reilly, 2007; O'Reilly & Frank, 2006). Learning about the current context can be either reflexive and model-free, in which decisions are made solely based on the past reward history of an action or context, or deliberative and model-based, in which potential outcomes are prospectively simulated based on knowledge of the task structure (Daw, Niv & Dayan, 2005; Doll, Duncan, Simon, Shohamy & Daw, 2015). In addition to acting as a reinforcement signal, DA also influences learning strategy, with higher overall and PFC DA associated with the tendency to use a deliberative model-based strategy (Wunderlich, Smittenaar & Dolan, 2012; Doll, Bath, Daw & Frank, 2016). Both model-based and model-free decisions, however, appear to be reinforced via striatal prediction error signals (Daw, Gershman, Seymour, Dayan & Dolan, 2011).

Any learned benefits of exerting cognitive control in a given context must overcome its costs. Exerting cognitive control feels subjectively effortful and aversive (Dreisbach & Fischer, 2015), and when given the choice, people often avoid it (Kool, McGuire, Rosen & Botvinick, 2010). Indeed, people will forego monetary rewards to avoid performing a more cognitively demanding task (Westbrook, Kester & Braver, 2013). Several proposals have been put forth to explain *why* cognitive control is costly (Shenhav et al., 2017), and one influential proposal is that the subjective experience of effort during cognitive control is caused by opportunity costs (Kurzban, Duckworth, Kable & Myers, 2013). Engaging in cognitive control has particularly high opportunity costs because it requires the use of our limited WM and attention resources, and so we are unable to engage in other tasks simultaneously.

The decision to exert control depends not only on the learned costs and benefits, but also on an individual's current state, and here, too, DA plays a critical invigorating role, to overcome the costs of cognitive control and facilitate effort expenditure towards goal attainment (Westbrook & Braver, 2016). Collins and Frank's (2014) Opponent Actor Learning (OpAL) model clarifies the distinction between DA's role in these learning and incentive choice components of decision-making. Specifically, they propose that higher DA levels at choice will increase the weighting of the benefits, whereas lower DA at choice leads to increased weighting of costs.

The remainder of this chapter will focus on how DA and NE contribute to the implementation of cognitive control, rather than these learning and valuation processes. It is important to note, however, that these processes are tightly intertwined. The extent to which an individual is motivated to exert cognitive control has consequences for their ability to implement cognitive control effectively, in part via changes in neural DA functioning, which plays a critical role in the implementation of cognitive control, as well a learning and choice.

DA- and NE-Linked Variability in Cognitive Control

Cognitive control is characterized by extensive variability, both within and between individuals. Two dimensions for understanding variability in cognitive control are stability, the ability to maintain WM representations with fidelity in the face of potential distraction, and flexibility, the ability efficiently update WM representations in order to attend a new stimulus or perform a new task. Much research suggests that these qualities are in an antagonistic balance with each other, such that states or traits that enhance one often undermine the other (Armbruster, Ueltzhöffer, Basten & FIebach, 2012; Dreisbach & Goschke, 2004; Cools & Robbins, 2004). Although the relative benefits of flexible versus stable cognitive control vary depending on the task at hand, both qualities are essential for effectively executing self-directed behavior. Understanding how some states and traits promote or interfere with effective cognitive control while others undermine it is critical for understanding human behavior in both healthy and patient populations. The brain's neuromodulatory neurotransmitters are one source of neuronal variability that have been extensively investigated as mechanisms that can explain variability in cognitive control. Here, we will focus on the roles of two neurotransmitters that have been implicated in modulating the flexibility versus stability of cognitive control: dopamine and norepinephrine.

As outlined above, DA plays important roles in in learning and evaluating the costs and benefits of cognitive effort (Westbrook & Braver, 2016), and acts as a signal to maintain versus update the contents of WM. Inter- and intra-individual differences in brain DA function, are also a source of much variability in the stability versus flexibility of cognitive control.

In the PFC, WM representations are maintained by neuronal assemblies that can sustain their activity, or pattern of activity, in the absence of a physical stimulus (D'Esposito & Postle, 2015), and DA acts on these neuronal assemblies to modulate the relative stability of WM representations. In particular, D1-type receptors enhance the recurrent activity of currently-active (e.g. task-relevant) neuronal assemblies, while simultaneously inhibiting spontaneous neural activity, or background noise, by increasing both NMDA- and GABA-mediated currents (Durstewitz & Seamans, 2008). The end result is more stable WM representations, but at the cost of inflexibility, because the energy requirements for a novel representation become greater. On the other hand, activated D2 receptors in the PFC reduce GABA-ergic inhibition of spontaneous neuronal activity, which increases the amount of noise, leading to less stable representations and greater flexibility. The relative influence of D1 versus D2 receptor activation in PFC may depend on the concentration of DA in a non-linear manner, with intermediate DA levels promoting stable D1-dominant states, and very high or very low DA levels promoting noisier D2-dominant states (Durstewitz & Seamans, 2008).

The basal ganglia, on the other hand, play the complementary role of selectively gating relevant representations into PFC to update the contents of WM (O'Reilly, 2006). Phasic DA bursts in the striatum trigger activation of the D1 receptor-mediated GO pathway, which increases the likelihood that new information from the environment will be gated into PFC (O'Reilly & Frank, 2006; Hazy et al., 2007). Lower DA levels in striatum reinforce the D2-mediated NO-GO pathway, which inhibits PFC gating and promotes maintenance of current WM representations in PFC. Unlike the global, slower PFC DA-mediated modulation of WM representations, this BG mechanism can act rapidly, and because PFC-BG connectivity is characterized by a series of parallel loops, is able to gate specific representations while maintaining others (O'Reilly & Frank, 2006; Hazy et al., 2007). This adaptive gating role of the BG is supported by neuroimaging work showing that BG activity during set-shifting modulated connectivity between PFC and posterior cortices responsible for processing task-relevant stimuli, by enhancing connectivity with newly-relevant brain regions and suppressing connectivity with newly-irrelevant brain regions (van Schouwenburg, den Ouden & Cools, 2010; 2015). Although this striatal gating mechanism relies on phasic DA bursts, tonic striatal DA levels can also modulate the sensitivity of the system to these phasic bursts, by altering the threshold for a phasic signal to produce updating, with higher tonic DA levels facilitating updating (Maia & Frank, 2011). Thus, via tonic and phasic signaling onto distinct receptor subtypes in different brain regions, DA is involved in both the global stability and flexibility of WM representations as well as the updating of WM in response to specific cues.

The locus coeruleus-norepinephrine (LC-NE) system also modulates the relative stability of cortical representations and plays a critical role in WM functions (Arnsten, 2011). In contrast to the more anatomically-targeted DA system, NE projections from LC reach a wide range of cortical and subcortical targets, with the exception of the BG (Sara, 2009). The LC-NE system acts by modulating the relative responsivity of relevant cortical representations, and varies continuously, between different modes (Aston-Jones & Cohen, 2005). Optimally-focused on-task performance occurs in when background LC-NE tone is moderate, but phasic responses of the system are large (phasic mode). Large phasic NE signals are theorized to enhance activity of currently-activated representations via a positive feedback loop between NE and glutamate, and suppress the activity of less active representations (Mather & Harley, 2016). On the other hand, when background LC-NE tone is high, phasic responses are smaller, resulting in noisier cortical representations that are less differentiated from each other (tonic mode). Additionally, very low levels of baseline LC-NE activity reflect low arousal or drowsiness. Thus, optimally-focused task performance occurs at an intermediate level of background LC-NE activity.

The Adaptive Gain Theory of LC-NE function (Aston-Jones & Cohen, 2005) posits that the LC-NE system adjudicates the evolutionary tradeoff between exploitation of a current resource (phasic mode; stable cognitive control) and exploration of alternatives in the tonic mode, based on signals from ACC and OFC, which communicate the relative value of the current task compared to potential alternatives. This model of NE function is supported by behavioral work showing that tonic and phasic LC-NE mode promote exploratory and exploitative decision-making respectively (Jepma & Nieuwenhuis, 2011; Gilzenrat, Nieuwenhuis, Jepma & Cohen, 2010), and by neuroimaging work that links NE tone with the precision of neural representations (Warren et al., 2016). This ability of the NE system to alter the exploration-exploitation tradeoff has clear relevance to our understanding of the flexibility and stability of cognitive control.

Although much is known about the brain's DA and NE systems, their empirical link with behavior is not always straightforward. The relevance of brain DA levels to cognitive control is very clear; for example, striatal DA synthesis positively predicts WM capacity (Cools, Gibbs, Miyakawa, Jagust & D'Esposito, 2008). On the other hand, DA's influence on cognitive control is often observed as non-linear, and numerous studies have demonstrated that increasing DA system activity improves stability and flexibility of WM in subjects or groups that typically have poor performance or low DA levels, but has a negative or null effect on subjects who already have good performance or high DA levels (Cools, Sheridan, Jacobs & D'Esposito, 2007; van Holstein et al., 2011). Taken together, these findings suggest that optimal DA levels promote effective WM function, but DA tone that is too high or low interferes with WM (Cools & D'Esposito, 2011), and underscores the importance of examining non-linear relationships between DA and cognitive performance.

Additionally, DA's relationship with cognitive control varies across different task contexts. One robust finding is that individuals with higher striatal DA tone, as indexed by spontaneous eye blink rate, show reduced perseverative switch costs when shifting to a novel target and inhibiting a previously-relevant stimulus, but larger switch costs when the task requires switching to a previously-irrelevant target and inhibiting a novel stimulus (Dreisbach et al., 2005; Müller et al., 2007). This finding has multiple interpretations. First, it is possible that higher EBR is predictive of a novelty bias, so that it becomes easier to shift attention towards a novel stimulus, but more difficult to avoid attending a novel stimulus and attend an old stimulus. Alternatively, this finding could indicate enhanced inhibition of irrelevant information in those with high EBR, which would facilitate inhibition of previously-relevant stimuli, but also make it more difficult to overcome inhibition to attend previously-irrelevant stimuli. Other studies that have linked higher DA levels with improved inhibition of irrelevant stimuli (e.g. Zhang et al.'s, 2015) may lend support to this latter explanation.

NE has also been empirically linked with stability and flexibility of WM. Administration of modafinil, a drug that increases NE levels, leads to improvements in WM maintenance and manipulation, with the largest benefits in lower-ability individuals (Müller, Steffenhagen, Regenthal & Bublak, 2004). With respect to flexibility, few studies have directly addressed this question in humans. Higher tonic pupil size has been linked with increased voluntary task switching (Katidioti, Borst & Taatgen, 2014), which is consistent with the Adaptive Gain Theory which suggests that higher baseline NE supports exploration of other activities (Aston-Jones & Cohen, 2005). Additionally, numerous studies in rodents have demonstrated that prefrontal NE depletion interferes with flexible attention shifts, whereas increases in prefrontal NE lead to improvements in shifting (Newman, Darling & McGaughy, 2008; McGaughy, Ross & Eichenbaum, 2008; Tait et al., 2007; Lapiz, Bondi & Morilak, 2007; Lapiz & Morilak, 2006). Increasing extracellular NE levels also increases behavioral flexibility and reduces perseveration in rodents and monkeys (Seu, Lang, Rivera & Jentsch, 2009). This work highlights the key role of NE in flexibility; however it can be difficult to draw conclusions about how experimental manipulations of NE in animals might translate to naturally-existing variability in NE levels in humans. Currently, no studies have directly examined the link between brain LC-NE activity and cued attention shifting in humans.

An additional open question concerns the respective roles of DA and NE in modulating cognitive control. In many respects, DA and NE appear to perform similar functions, as both alter the stability of WM representations by regulating the cortical signal-to-noise ratio, and have an inverted U-shaped relationship with WM performance. It is likely that DA and NE act synergistically or complementarily to facilitate cognitive control (Chandler, Waterhouse & Gao, 2014); however their specific roles have not been fully teased apart. Based on the anatomical distribution of DA, which is restricted to prefrontal areas of the neocortex, it is possible to make some predictions - namely that NE plays a role in sharpening representations in posterior cortices which could increase the precision of WM representations and task sets being maintained. The PFC, however, receives both DA and NE. One proposal is that in the dorsolateral PFC, a critical region for WM, DA is involved in suppressing task-irrelevant neuronal assemblies, whereas NE in PFC amplifies the activity of relevant representations (Arnsten, 2011; Arnsten, Wang & Paspalas, 2012). No studies have directly examined the interaction between measures of naturally-arising DA and NE and cognitive control in humans.

Most research on DA, NE, and cognitive control has enlisted relatively simple lab-based tasks. An additional gap in our knowledge concerns how DA- and NE-mediated influences on cognitive control manifest in more complex, ecologically-valid behaviors. By extending the attentional/control episodes framework, we can predict that the degree to which an individual has flexible or distractible cognitive control in the lab should relate to their flexibility and distractibility in their real-world behavior; however, this link has never been explicitly tested.

The Present Studies

The present studies have two broad goals. First, we aim to clarify specifically how DA and NE influence the flexibility versus stability of cognitive control. Second, we attempt to bridge the gap between DA- and NE-mediated influences on cognitive control in the lab and actual, consequential behaviors in the real world.

Aim 1: DA, NE, and Cognitive Control

To accomplish the first aim, we assessed the relationship between indices of brain DA and NE and the flexibility and stability of cognitive control in the context of an adapted attention shifting task. Across 4 experiments, participants completed a task in which they maintain an attentional set in order to attend stimuli of a particular color while ignoring distractors. Periodically, participants are cued to update their attentional set. Thus, the stability of one's attentional set can be operationalized by examining participants' susceptibility to distraction, while their ability to flexibly shift attentional set is indexed by switch costs. This paradigm is similar to the task used by Dreisbach et al. (2005), but with one critical modification: target and distractor letters will not differ in the degree to which they are novel. In one condition, attentional shifts will involve the target and distractor colors trading roles, so that the previous target color becomes the new distractor color and vice-versa. In the other condition of interest, target and distractor colors will both switch to completely novel colors. This adapted task will allow us to index DA and NE's role in a pure WM updating process, independent of an influence on inhibitory processes.

DA and NE will be indexed using spontaneous eye blink rate (EBR) and pupil size respectively. EBR has been established as a reliable measure of striatal DA tone (Jongkees & Colzato, 2016), and may specifically reflect D2 receptor activity (Groman et al., 2014). Pupil size reliably predicts both tonic and task-evoked phasic LC-NE activity (Joshi, Li, Kalwani & Gold, 2016).

Although EBR and pupil size have been established as correlates of DA and NE tone in the brain, they do have several limitations. First, the anatomical pathways underlying the relationships between EBR and pupil size with striatal DA and LC-NE activity are still the subject of investigation, and are likely to be indirect. Striatal DA levels are hypothesized to influence EBR via indirect connections between the basal ganglia and spinal trigeminal complex, which contributes to spontaneous eye blink rate (Kaminer, Powers, Horn, Hui & Evinger, 2011). Similarly, there are no direct anatomical connections between LC and the sympathetic and parasympathetic nervous system nuclei that regulate pupil size. The paragigantocellularis nucleus (PGi), which receives inputs from many cortical and subcortical areas, may mediate both LC and sympathetic nervous system activity, and has been proposed as the link between pupil size and NE levels (Nieuwenhuis, De Geus, & Aston-Jones, 2011); however this hypothesis has not yet been systematically investigated. In addition to the lack certainty about these anatomical pathways and underlying physiological mechanisms, another limitation of EBR and pupil measures is that they are noisy, and factors other than DA and NE also affect them. For example, tiredness and dry eyes increase the eye blink rate, and ambient light levels influence pupil size. Overall, EBR and pupil size have the important advantage of being inexpensive and non-invasive, and can help establish relationships between DA, NE, and cognitive processes; however, any EBR- or pupil-linked effects on cognitive control would ideally be corroborated by research using other methods to measure and/or manipulate DA.

A specific goal of Studies 1 and 4 is to determine the relationship between individual differences in striatal DA, as indexed by EBR, and the ability to flexibly shift attention and avoid distraction across different task contexts. In a pilot study (N=61) that contained only the Perseveration-Inhibition condition, we found that higher EBR predicted slower switching. Taken alongside the findings of Dreisbach et al. (2005) and Müller et al. (2007), who found a similar relationship when participants shifted attention to a previously-ignored stimulus, this finding suggested that participants with higher EBR may more strongly inhibit irrelevant stimuli, which takes more time to overcome, resulting in slower RTs. We expected to replicate this finding in the Perseveration-Inhibition condition. In the Pure Updating condition, on the other hand, we hypothesized that higher EBR would predict improved performance on Switch trials, because higher striatal DA levels should lower the threshold for gating an updated representation into PFC. With respect to distractibility, there were two possible hypotheses. If higher striatal DA is contributing to enhanced inhibition, we would expect that participants with higher

EBR would have smaller incongruence costs across both block types. If, on the other hand, higher striatal DA is reducing the threshold for WM updating, it is also possible that higher EBR could predict larger incongruence costs. Because the effects of DA on performance are often non-linear, with intermediate levels leading to optimal performance, we will also test for quadratic relationships between EBR and subjects' ability to shift attentional set and inhibit distraction. Prior studies (e.g. Müller et al., 2007) have also found evidence of gender differences in the relationship between EBR and cognitive control, with males showing stronger effects than females, so we additionally examined the influence of gender in our analyses.

A second goal, is to assess the effect of LC-NE activity on flexibility and stability of cognitive control, both within- (Studies 1, 2, and 4) and between-subjects (Studies 1 and 4). Given the link between the phasic mode and focused on-task attention, we expect that trials and individuals with moderate baseline pupil size and large task-evoked pupil responses to be less distracted, as indexed by smaller RTs and error rates on Incongruent trials. As outlined above, the effects of LC-NE activity on the flexibility of cognitive control have not been studied extensively in humans, and there were multiple plausible hypotheses. On one hand, in the tonic mode, cortical representations are noisier, and thus it may require less energy for a novel representation to become active. If this were the case, we would expect to observe relatively faster switch RTs and lower error rates when subjects have high baseline pupil size. On the other hand, the high degree of on-task focus afforded by the phasic mode may facilitate efficient set-shifting. In this case, we would expect that subjects would perform better on switch trials when their baseline pupil size is moderate and their task-evoked change in pupil size is large. Work in rodents finding that intermediate brain NE levels promote optimal set-shifting (Newman, Darling & McGaughy, 2008) suggests that this latter prediction may be more likely.

An additional goal is to use eye tracking methods to determine the gaze patterns that underlie neurotransmitter-linked effects on cognitive control. To this end, we examined the relationship between EBR (Studies 1 and 4) and pupil (Studies 1, 2, and 4) measures and the time it takes for subjects to fixate on the target, as well as the likelihood of fixating on a distractor. Given the hypothesis that higher DA levels strengthen inhibition of irrelevant distractors, we expect that in the Perseveration-Inhibition blocks, subjects with high EBR will be less likely to fixate on distractors, but that they will be slower to fixate on the new target. Additionally, because high tonic NE indicates than an individual is in an exploratory mode, we expect that when subjects have a large tonic pupil size they will be more likely to fixate on both the distractor letter and a never-relevant non-letter distractor stimulus.

A final exploratory goal Studies 1 and 4 is to examine whether our measures of DA and NE have an additive or an interactive effect on performance. To this end, analyses will test the interaction between EBR and pupil measures as a predictor of performance across different trial types and task contexts.

Aim 2: Linking DA- and NE-mediated variability in cognitive control to ecologically valid and real-world behaviors

To accomplish this second aim, we will leverage individual differences in cognitive control, in order to link behavior in the lab-based attention shifting task to performance on a more ecologically valid lab task, as well as to self-reported real-world experiences. We will additionally test whether variability in the more ecologically-valid and real-world assessments can be linked back to individual differences in our indices of striatal DA tone and LC-NE function.

To this end, student participants were recruited, in order to assess cognitive control in the context of real-world academic goals. In addition to completing the attention shifting task, participant in Study 4 also performed an in-lab task that required them to use the internet to find information, while they were video recorded and their computer use was monitored. Measures of participants' distractibility and flexibility while completing this task was then extracted from the video and computer use patterns, to determine whether they are linked with performance on the attention shifting task. Participants then self-reported on their daily experience of distraction and flexibility while pursuing academic tasks for two weeks, to determine whether self-reported real-world experience was linked with performance on the attention shifting task. The rationale for this three-component approach was that any link between our measures of cognitive control on the attention shifting task and real-world experiences should be mediated by observable behaviors in the lab. Thus, we expected that observed flexibility and distractibility on the internet search task would mediate the relationship between flexibility and distractibility on the attention shifting task and real-world experiences. Furthermore, we hypothesized that relationships between measures of flexibility and distractibility during the different study components would be at least partly explained by variability in our indices of DA and NE. Such a result could allow for clear empirical links between DA and NE's influences on cognitive control and consequential real-world behaviors.

CHAPTER II

STUDY 1

Method

Participants

A power analysis based on pilot data indicated that data from 100 participants was necessary to obtain statistical power of .8 for the relationship between EBR and switch cost (r =.28). To reach this target, 123 students at the University of Oregon participated in the study for partial course credit. Eligible participants were between 18-30 years old and had normal or corrected-to-normal color vision. Data from 13 participants were excluded prior to data analysis because of task presentation failure (2), participant withdrawal or lack of time to finish task (5), inability to track eye (1), file corruption (1) and not meeting the eligibility criteria (4). The remaining 110 participants had a mean age of 19.98 (SD=2.33) and included 69 females (62.7%), 40 males (36.4%), and 1 (<1%) individual who did not report being male or female. All procedures were approved by the Committee for the Protection of Human Subjects at the University of Oregon.

Procedure

After providing informed consent, participants completed a brief demographic questionnaire. Participants then received instructions for the attention shifting task and completed 3 short practice blocks (8-12 trials each). Prior to the beginning of the task, the eyetracker was calibrated to ensure accurate eye gaze measurements. Calibration was repeated every 2 blocks, for a total of 4 calibrations. After the first calibration and after the final task block, participants completed the EBR baseline period. When the task was completed, participants responded to several questionnaires, and were then debriefed about the purpose of the experiment. The entire procedure lasted approximately 1 hour.

Materials and Apparatus

Attention shifting task. The attention shifting task was designed to independently measure participants' ability to update and maintain an attentional set. To this end, participants were instructed to attend and respond about whether a letter in a target color is a consonant or a vowel, while ignoring a distractor letter in an irrelevant color (maintenance). Periodically, the target color shifted (updating).

Each set of trials began with the presentation of one of 6 possible color words (e.g. BLUE) for 2000 ms in black text on a grey background, to indicate the target color in the upcoming set of trials (Figure 2). A fixation cross then appeared for 4000 ms, after which the first trial of the set began. At the beginning of each trial, the fixation cross disappeared to encourage eye movements, and the stimulus array appeared 100 ms later. Each stimulus array consisted of three characters: the target-colored letter, the distractor letter in a second color, and an irrelevant symbol in a third color. Characters were positioned at 3 evenly-spaced locations of 12 possible locations at a distance of 4.45 degrees from the center of the screen. The positions of the letters were never repeated on back-to-back trials. Letter stimuli were randomly selected from 5 consonants (D, F, H, L, V), 5 vowels (A, E, I, O, U), and symbols were one of 5 non-letter characters (&, %, ?, #, @). The color of the irrelevant symbol was randomly selected from a different set of 6 colors, to avoid overlap with the letter stimuli. On a given trial, there was a 50% chance that the distractor letter would be in the same category as the target (Congruent trials, e.g. both vowels), and a 50% chance that the distractor would be Incongruent (e.g. a consonant when the target letter is a vowel). Target and distractor letters were never identical on a given trial. As quickly as possible, participants indicated with a key press whether the target letter was a consonant or a vowel. The stimulus array remained on the screen until participant response, and was then replaced by a fixation cross for a 3500 ms inter-stimulus interval (ISI). This longer ITI was chosen to give the delayed phasic pupillary response sufficient time to return to baseline between trials. Each set of trials consisted of a randomized number of between 4-6 trials. Switch trials were defined as the first trial in a set, except for the first set in a block, and Non-Switch trials were all other trials.

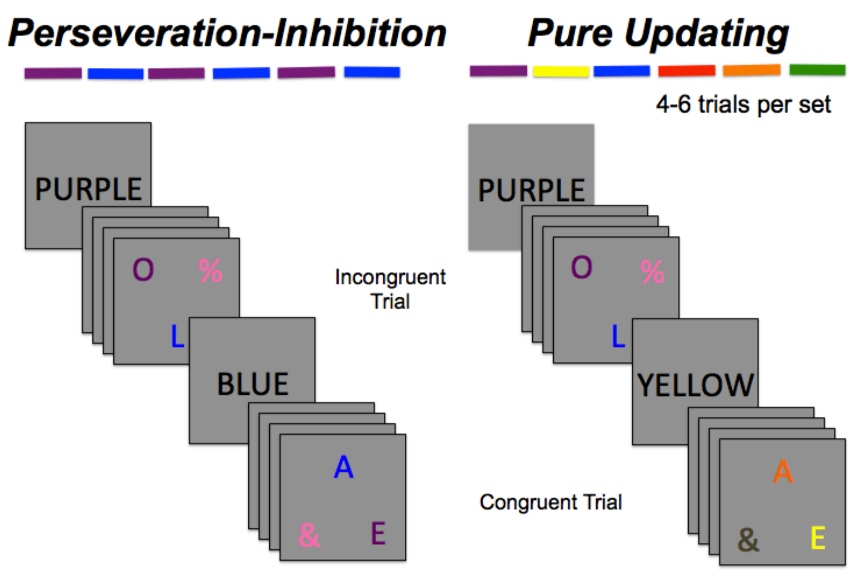

Figure 2. Attention shifting task set and trial sequence.

Participants completed sets of trials within each of 3 block types: Perseveration-Inhibition, Pure Updating, and Non-Switch. During Perseveration-Inhibition blocks, the target and distractor colors would trade roles at each switch, with the former target color becoming the new distractor color and vice-versa. On Pure Updating blocks, on the other hand, both target and distractor colors become novel colors (different from the two colors in the previous set). Participants completed 3 blocks of 12 sets of both Perseveration-Inhibition and Pure Updating tasks in a randomized alternating order (e.g. either ABABAB or BABABA). During Non-Switch blocks, the target color remained the same from set to set. Non-Switch blocks each contained 6 sets and were the first and last blocks completed in the session. These blocks were included to account for global effects of switch on performance. In total, participants completed 8 blocks of the attention shifting task, containing approximately 420 trials.

EBR baseline. EBR baseline periods took place immediately after the first calibration, and following the final task block. Participants were instructed to relax and look at a fixation cross in the center of the screen for 2 minutes.

Questionnaire measures. Prior to the task, participants provided their demographic information. Following the task, participants completed the Behavioral Activation and Inhibition Scales (BIS/BAS; Carver & White, 1994), Sensitivity to Punishment and Sensitivity to Reward Questionnaire (SPSRQ; Torrubia, Avila, Molto & Caseras, 2001), and the Barratt Impulsivity Scale (Patton, Stanford & Barratt, 1995). These measures were chosen because of the relevance of behavioral activation, reward sensitivity, and impulsivity to dopamine function (Cools et al., 2007). Finally, participants responded about their caffeine consumption for the day and the number of hours of sleep during the previous night.

Apparatus. The attention shifting task was run with Psychtoolbox in Matlab (Brainard, 1997; Pelli, 1997; Kleiner, Brainard & Pelli, 2007). Stimuli were presented using a Mac Mini computer and an 18’’ monitor with a resolution of 1024 x 768 pixels. Participants made responses using the left and right arrow keys on a standard QWERTY keyboard.

Participants completed the task while their eyes were tracked using an Eyelink CL infrared eyetracker running Eyelink 1000 software (Version 4.56) with a sampling rate of 1000 Hz. Participants' heads were stabilized with a chin rest, located 50 cm from the eyetracker.

Data Processing and Analysis

Behavioral data. All participants performed the task with an error rate less than 25% (mean error rate = 4.4%, SD = 3.7%), and so the full sample of 110 was kept for the behavioral RT analyses. To correct for non-normality, RTs were transformed using the natural log (lnRT). All RTs less than 100ms or greater than either 3 standard deviations from the participant's mean lnRT or 2000ms were removed from RT analyses (3.97% of trials). Error trials were also excluded from RT analyses. In cases where participants' error rate for a particular condition was 3 standard deviations from the group mean, the value was winsorized to the next closest value within 3 standard deviations from the group mean.

EBR data. All eye data were processed in R (R Core Team, 2016) using the itrackR package (Hubbard, 2015). For the EBR analyses, the number of blinks during the EBR baseline was determined by calculating the number of missing data intervals during the 2-minute EBR baseline periods that lasted between 50-500ms. Although other studies (e.g. Aarts et al., 2012; Pas, Custers, Bijleveld & Vink, 2014) have used a higher threshold (100ms), manual inspection of the recorded pupillometry data prior to statistical analyses demonstrated that with the equipment used to collect this dataset, a large number of blinks are between 50-100ms in duration. Additionally, other work has estimated that 50ms is the lower limit for the amount of time an eyelid is closed in a blink (Stern, Walrath & Goldstein, 1984). In a subset of the first 10 participants collected, there was a strong correlation between a blink count from manual inspection of pupillometry data and the count produced by the 50-500ms criterion ($r > .99$, $p < .001$). EBR was then calculated by dividing the blink count by 2, to obtain the average number of blinks per minute. Because EBR is often related to cognitive control in a non-linear manner, both EBR and EBR^2 were of interest for this study. In order to keep as many participants as possible in between-subjects analyses while limiting the influence of outliers, values of EBR or EBR^2 that are outside of 3 standard deviations from the mean (*Mean*=19.71, *SD*=13.95) were winsorized. After this process, 4 subjects with EBR^2 values greater than 780 were removed from analyses (range of EBR^2 for remaining subjects: 0-421).

Pupil data. Prior to pupillometry analyses, blinks or other data loss that occurred during the attention shifting task were corrected using linear interpolation. Trials that were missing more than 30% of pupillary data (15.59% of trials) or participants who were missing more than 30% of their pupil data (14 participants) were excluded from pupil analyses. One participant was excluded because although they had less than 30% missing data overall, all trials of one condition were excluded due to excessive missing data. An additional participant was excluded from analyses for having phasic pupil dilations were more than 3 standard deviations from the group mean.

For within-subjects analyses, the tonic pupil size on each trial was operationalized as the average pupil size in the 200 ms prior to the fixation offset (e.g. from -300 to -100ms prior to stimulus onset). In order to control for baseline individual differences in pupil size, trial-by-trial tonic pupil size was normalized within each subject using Z-scores. Two separate indices of the phasic pupil response were examined: Phasic magnitude was defined as the peak percent change in pupil size from pre-trial tonic pupil size in the first 2500 ms after stimulus onset, whereas phasic latency was the amount of time from stimulus to stimulus onset and peak, within this same interval. Because non-linear relationships between both tonic and phasic pupil measures and cognitive control have been observed, models included both measures as well as each measure squared. Trials with tonic or phasic pupil measures that were greater than 3SDs from each subject's mean, as well as those that were greater than 3SDs from the overall group mean were excluded from analyses (5.12% of trials).

For between-subjects pupil analyses, each subject's mean and standard deviation of each pupil measure across all trials (tonic pupil size, phasic magnitude, phasic latency) was calculated, in order to test how both mean estimates and variability in pupil measures are related to individual differences in flexibility and distractibility. Tonic pupil measures were z-scored across the sample. Values for individual differences in pupil measures outside 3 standard deviations from the group mean were winsorized. After these procedures, data from an additional 5 subjects with very large values for EBR^2 were excluded from EBR analyses (greater than 400 difference from next-nearest value of EBR^2; see histogram), and were driving the effects in EBR analyses.

Consistency of the cleaned pupil data was checked by estimation of split-half reliability. Here, trials were randomly divided in half and the correlation between pupil measures in each half was computed, both for each subject, and for each condition within each subject, to obtain estimates of both by-condition and by-subject reliability. By-condition analyses estimated reliability of mean-level pupil measures (phasic Magnitude, phasic Latency, tonic Pupil Size), and the by-subject analyses additionally estimated reliability for the variability (*SD*) of each pupil measure.

Eye tracking data. Prior to processing fixation data, elliptical regions of interest (ROIs) were defined, with an x radius of 45 and a y radius of 90 pixels, centered on each of the potential target locations. Each block of data was then drift corrected with itrackR's drift_correct() function using a threshold of 15 pixels. Thirty-one participants were excluded because they fixated on the target on fewer than 75% of trials, in order to ensure that included participants' were making saccades to the target reliably. For each participant across each experimental condition, the probability of first fixating on the target, distractor, and task-irrelevant symbol was calculated. Probability values more than 3 standard deviations from the group mean were winsorized. Additionally, separate models examined the time for participants to fixate the target. These analyses examined only those trials in which participants did fixate the target while the stimulus array was visible. Fixation times occurring after 2000ms were automatically excluded, and then any fixations that were outside of 3 standard deviations from each participant's mean fixation time were additionally removed (2.1% of trials).

Strategy for statistical analyses. Statistical analyses used linear mixed models (LMMs) to control for random subject-level variability. Observations were single trials in RT analyses, and condition-based aggregation of trials in Error Rate analyses. Observations were nested within subjects, which were modeled as random factors with fixed slopes and variable intercepts. All analyses were carried out in R using the lme4 package to compute LMMs (Bates, Maechler, Bolker & Walker, 2015) and the lmerTest package to compute statistical significance (Kuznetsova, Brockhoff & Christensen, 2016). Dependent variables were RT and Error Rate. Independent variables were Switch (Switch, Non-Switch), Congruence (Congruent, Incongruent), Block Type (Perseveration-Inhibition, Pure Updating, and Non-Switching), EBR, EBR^2, Tonic Pupil size, Tonic $Pupil^2$, Phasic Magnitude, Phasic $Magnitude^2$, and Phasic Latency, Phasic $Latency^2$. The first set of each block was excluded from analyses. Because of the strong link between phasic magnitude and latency, these predictors were entered into separate models. All continuous predictor variables were centered prior to being entered into the models. As was noted in detail above, outliers were removed from analyses when they were at the single-trial level. When outliers were at the level of subject (i.e., individual difference measures) or condition (i.e., mean within a task condition), they were winsorized to the next furthest value from the mean, in order to reduce the effects of outliers in our models while also retaining as many subjects as possible in the analyses.

Results

Behavioral Analyses (N=110)

Prior to hypothesis testing about the effects of EBR and pupillary correlates on performance, we first determined the how performance varied across task conditions.

RT. Behavioral effects of the task performance were estimated by entering trial-by-trial RTs nested within subjects into an LMM. The null model with no predictors had an intra-class correlation (ICC) of .38, indicating a sufficient amount of within-subject clustering in RT to justify the use of a mixed model analyses. The full model tested the effects of Switch, Congruence, Block Type and their interactions on RT. As expected,

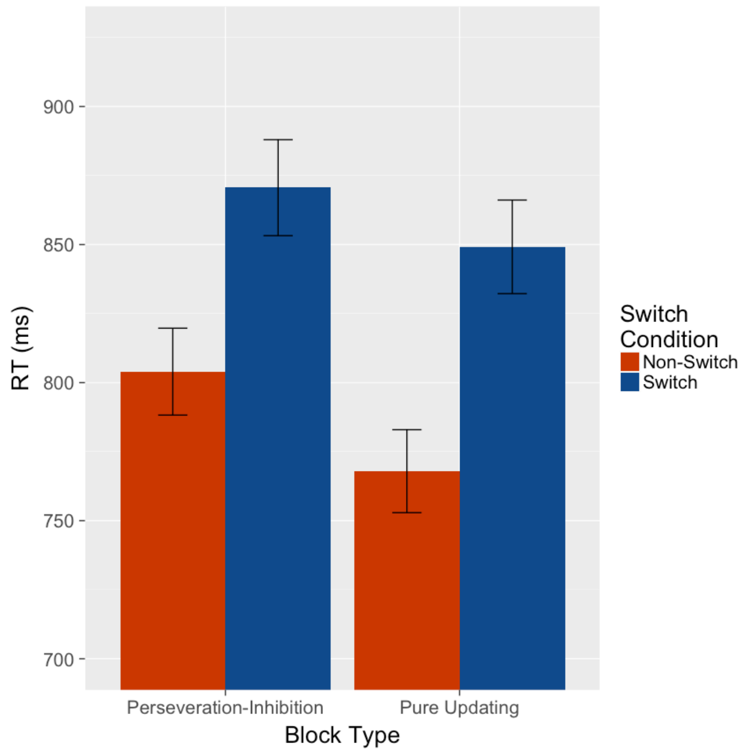

Figure 3. Reaction time (RT) as a function of Switch Condition and Block Type. Switch costs are smaller on Perseveration-Inhibition blocks than on Pure Updating Blocks. Error bars represent +/- 1 *SE*.

there was a significant main effect of Switch, with participants responding on average 89.47ms more slowly on Switch trials (β=.11, *SE*=.0069, *t*(32690)=16.18, *p*<.001). There were also significant main effects of Congruence and Block Type - participants responded 9.25ms more slowly on Incongruent trials (β =.012, *SE*=.0044, *t*(32690)=2.77*, p*=.006) and 39.45ms more slowly on Perseveration-Inhibition blocks (β =.050, *SE*=.0044, *t*(32690)=11.58, *p*<.001). Switch also interacted significantly with Block Type (β =-.032, *SE*=.0098, *t*(32690)=-3.29, *p*=.001). This interaction can be explained by smaller switch costs on Perseveration-Inhibition blocks, and is driven by smaller Non-Switch RTs on Pure Updating blocks, rather than by faster switching on Perseveration-Inhibition blocks (Figure 3). Additionally, the interaction between Switch and Congruence was significant (β =-.021, *SE*=.0098, *t*(32690)=-2.13, *p*=.033), and indicated smaller switch costs on Incongruent trials. Neither the Congruence by Block Type nor the 3-way interaction approached significance (*t*s<1.7, *n.s.*). Overall, the RT findings indicate that this task produces robust RT switch costs, which can be used as an index of flexibility, as well as a smaller effect of Congruence, which can be used to index distractibility.

In order to investigate the relationships between RTs across task conditions, we additionally tested correlations between Switch and Incongruence costs, overall and for each Block Type (Table 1). These correlations suggest that there was a positive correlation between switch costs on Perseveration-Inhibition and Pure Updating blocks. The correlations between switch and incongruence costs, and between incongruence costs across block types, did not reach significance. Table X also shows the split-half reliability of Switch and Incongruence costs, which was low, for Incongruence costs in particular. Thus, these correlations should be interpreted with caution.

Table 1
Correlations between switch and incongruence costs across Block Types.

	1.	2.	3.	4.	5.	Reliability	95% CI
1. Switch Cost	-					.56	.42-.68
2. Switch Cost - Pure Upd	.89 ***	-				.38	.21-.53
3. Switch Cost - PersInhib	.88 ***	.58 ***	-			.45	.29-.59
4. Incongruence Cost	.02	.06	-.06	-		.12	-.07-.30
5. Incongruence Cost - PureUpd	.02	.02	-.02	.76 ***	-	.01	-.18-.19
6. Incongruence Cost - PersInhib	-.04	.04	.12	.67 ***	.08	-.06	-.24-.13

Note: *** p<.001, ** p<.01, * p<.05, . p<.10

Error rate. Error rates were examined using a linear mixed model to predict error rate in each task condition nested within subjects. The null model had an ICC of .28, indicating that the use of a mixed model is appropriate. Participants made 1.3% more errors on Incongruent trials, as evidenced by a significant main effect of Congruence, (β =.013, *SE*=.006, $t(763)=2.16$, $p=.031$). Additionally, there was a significant interaction between Congruence and Block Type (β =.034, *SE*=.009, $t(763)=3.97$, $p<.001$), which was driven by a higher error rate on Incongruent trials in Perseveration-Inhibition blocks

(Figure 4). On Perseveration-Inhibition blocks, participants are more likely to accidentally attend and respond to the distractor letter, because they have recently been attending the same color, which is consistent with the finding of more errors on Incongruent trials in that context. All other main effects and interactions did not reach significance (*t*s(763)<1.1, *n.s.*).

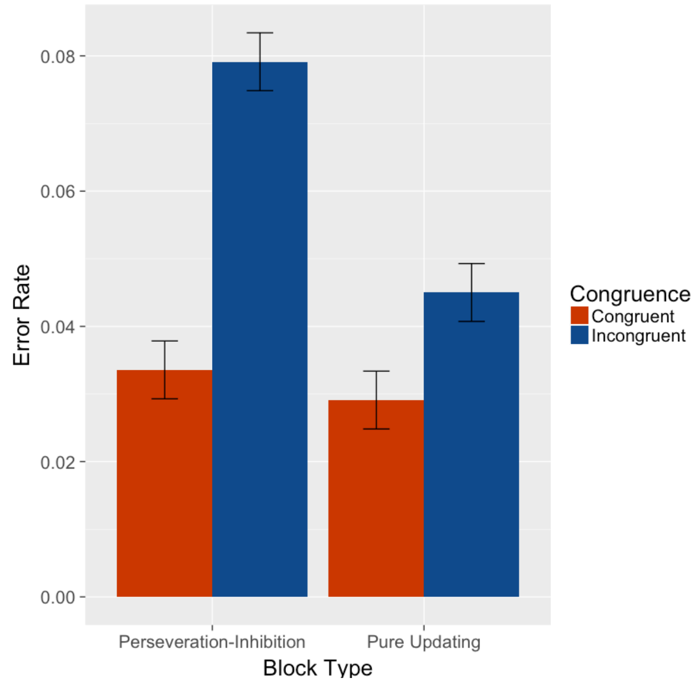

Figure 4. Error rate as a function of Congruence and Block Type. Participants had larger incongruence costs on Perseveration-Inhibition blocks compared to Pure Updating blocks. Error bars represent +/- 1 *SE*.

Global switch effects. In addition to the effects of switching on performance at cued switch points (local switch costs), we also examined global switch costs, by comparing performance on Non-Switch trials on Switch blocks versus Non-Switch Blocks. Here, Pure Updating and Perseveration-Inhibition blocks were pooled to create a general Switch condition, and only Uncued trials (e.g. trials that are not first in a set) were examined. LMMs estimated the effect of Switch Condition (Switch versus Non-Switch) on RTs and error rates. The trial-by-trial model predicting RT indicated a significant main effect of Switch Condition (β =.057, *SE*=.0041, *t*(30290)=13.81, *p*<.001), with participants 43.08ms slower on Switch blocks, confirming the presence of global switch costs in this task. The error rate analysis also indicated a main effect of Switch Condition (β =.017, *SE*=.0035,

$t(109)=4.78$, $p<.001$), demonstrating that participants made 1.7% more errors on Switch blocks than on Non-Switch blocks.

EBR Analyses

EBR analyses aimed to determine the effects of striatal DA tone on flexibility and distractibility. Based on our previous findings and the work of others, we predicted that the results for flexibility would be context-dependent, with higher EBR would predicting larger switch costs on Perseveration-Inhibition blocks, and smaller switch costs on Pure Updating blocks. With respect to distractibility, there were plausible explanations for higher EBR to lead to either increased distractibility, because increased striatal DA levels may reduce the threshold required for updating (e.g. Frank & Maia, 2011), or alternatively to reduced distractibility, because of an improvement in inhibition of irrelevant stimuli (e.g. Zhang et al., 2013).

RT (N=105). To examine the effects of EBR on RT across task conditions, both EBR and EBR^2 were included as predictors in an LMM, which also included all of the main task effects (Switch, Congruence, Block Type). First, there was no main effect of either EBR or EBR^2 on RT (ts(105)<.5, *n.s.*). With respect to flexibility, there was a marginally significant interaction between Switch and EBR ($\beta=8.19\text{x}10^{-4}$, $SE=4.48\text{x}10^{-4}$, $t(31240)=1.83$, $p=.067$). In this task, higher EBR predicted slower responding on Switch trials, but not on Non-Switch trials (Figure 5). The only other EBR-linked effect that approached significance was a trend-level interaction between EBR and Block Type ($\beta=5.14\text{x}10^{-4}$, $SE=2.84\text{x}10^{-4}$, $t(31240)=1.81$, $p=.070$), which demonstrated that higher EBR predicted faster RTs on Pure Updating blocks, but slower RTs on Perseveration-

Inhibition blocks. Of note, the predicted 3-way interaction between EBR, Switch, and Block Type, which would suggest context-dependent effects of DA on switching, did not approach significance for either EBR or EBR^2 (*t*s<.5, *n.s.*). Additionally, EBR did not interact with measures of distractibility.

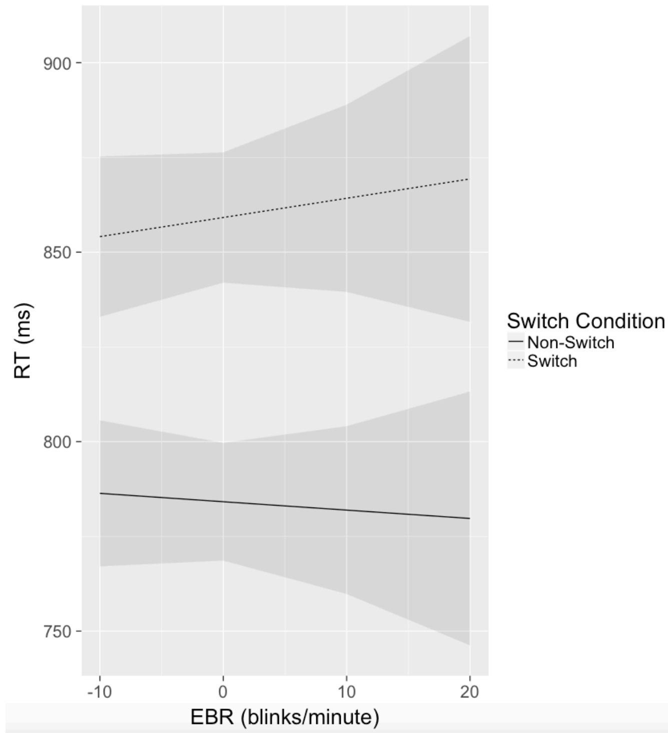

Figure 5. RT as a function of Switch Condition and EBR. Higher EBR was predictive of larger switch costs. Shaded regions represent +/- 1 standard error.

Gender effects on RT (N=104). Because previous research (e.g. Müller et al., 2007) has found that females have a higher EBR than males, and furthermore, that the relationship between EBR and cognitive control is moderated by gender, we added gender to the above model, to examine its interaction with EBR and task factors in predicting performance. First, gender differences in EBR were replicated in our sample, with females (*Mean*=21.66, *SD*=10.86) having a significantly higher EBR than males (*Mean*=12.00, *SD*=9.62; $t(85.10)=-4.70$, $p<.001$). In the LMM with gender, there was a marginally significant main effect of gender on RT (β =.11, *SE*=.064, $t(99)=1.78$, $p=.078$), with males responding on average 90.42ms more slowly than females. There was also a significant 3-way interaction between Switch, Gender, and EBR (β =.0027, *SE*=.0013, *t*(30980)=2.15, *p*=.032). This interaction (Figure 6) suggests that the relationship between Switch and EBR is stronger for males than for females. Specifically, in males, RT switch costs became larger with increasing EBR; however in females, switch costs were not modulated by EBR. Additionally, there were 3-way interactions between Block Type, Gender, and both EBR (β =-.0022, *SE*=8.10x10^{-4}, *t*(30980)=-2.76, *p*=.006) and EBR^2 (β =-4.05x10^{-4}, *SE*=7.22x10^{-5}, *t*(30980)=-5.61, *p*<.001). Whereas EBR did not affect the relative costliness of Perseveration-Inhibition blocks in females, males with higher EBR predicted slower performance, on Pure Updating blocks in particular (Figure 7a). Higher EBR^2, on the other hand, predicted faster RTs in males, most strongly on Perseveration-Inhibition blocks (Figure 7b). Although these findings do not support our hypothesis that the relationship between EBR and flexibility will vary across Block Types, these findings do

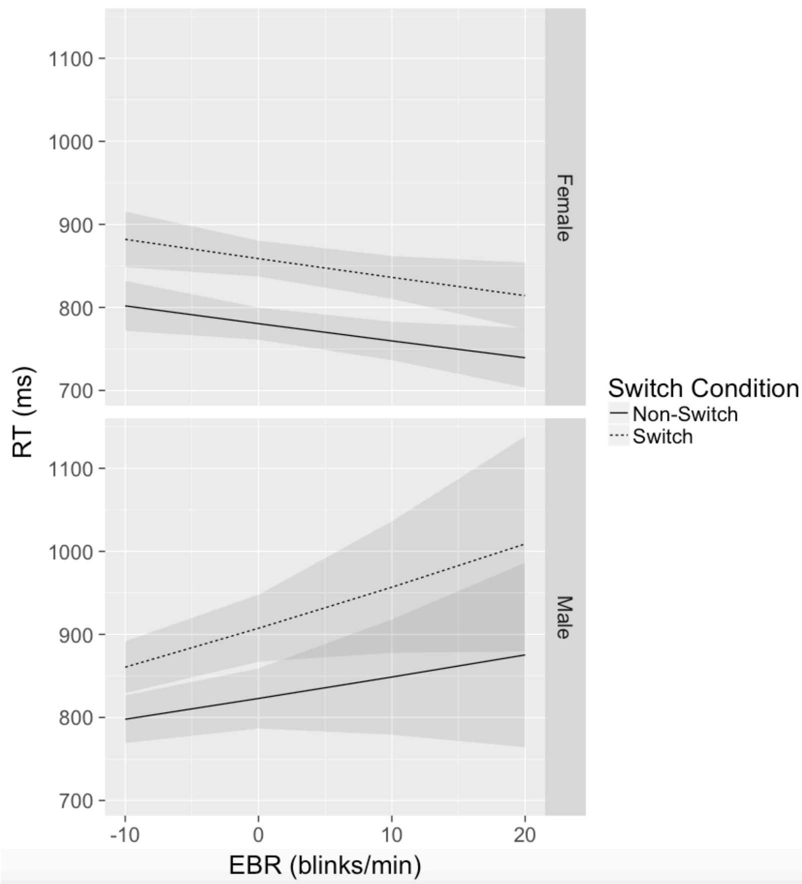

Figure 6. RT as a function of EBR, Switch Condition and Gender. Higher EBR was predictive of larger switch costs in males. Shaded regions represent +/- 1 standard error.

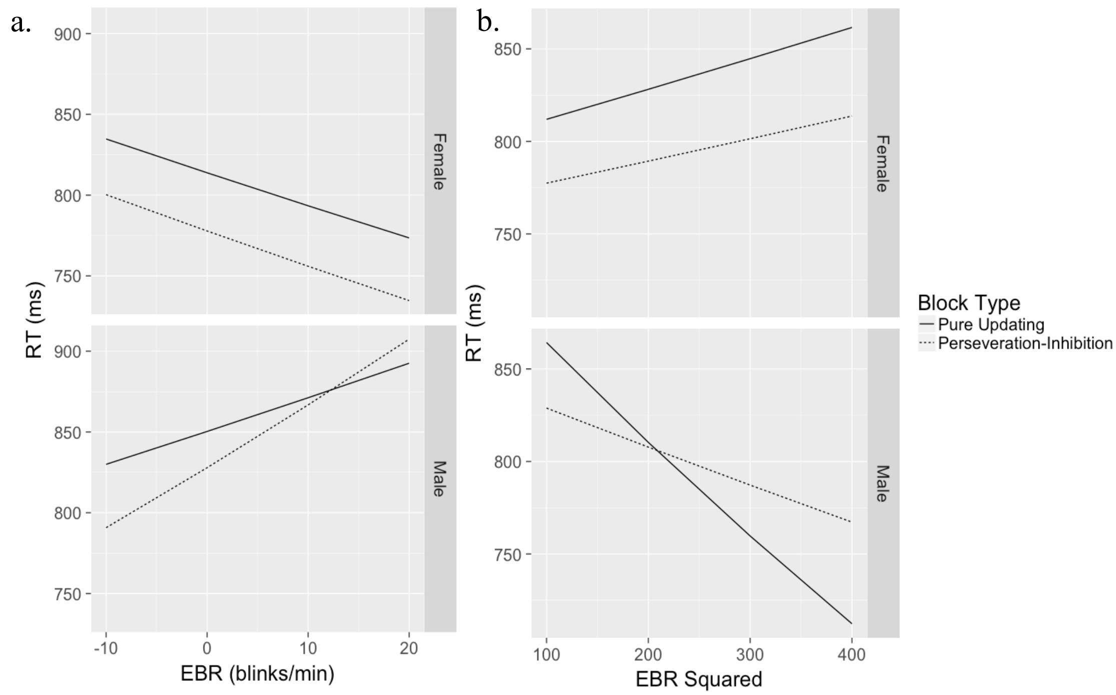

Figure 7. RT as a function of Switch Condition, Block Type, Gender, and EBR (a) or EBR^2 (b).

suggest that EBR is relevant to flexibility, with higher EBR predicting slower switching particularly in males.

Error rate (N=105) . To determine the effect of EBR on error rate across task conditions, EBR and EBR^2 were included in an LMM, which also included effects of Switch, Congruence, and Block Type. No EBR-linked effects approached significance (*t*s<1.3, *n.s.*).

Gender effects on error rate (N=104). When gender was added to the above model, the neither the main effect of gender nor its interaction with other factors reached statistical significance (*t*s<1.3, *n.s.*).

Global switch effects. Addition of EBR and EBR^2 to the global switch effects model revealed no main or interactive effects of either measure on either RT or error rate (*t*s<1.3, *n.s.*).

Gender and global switch effects. When gender was added to the above model for RT, there was a significant interaction between Switch Condition and Gender (β =.033, *SE*=.014, *t*(28720)=2.36, *p*=.019), indicating that females had larger global switch costs than did males. Additionally, there was a significant 3-way interaction between Switch Condition, Gender, and EBR^2 (β =-3.70x10^{-4}, *SE*=9.56x10^{-5}, *t*(28720)=-3.87, *p*<.001), indicating that in Females, having a high or low EBR predicted slower RTs, especially on Switch blocks, whereas in Males, high or low EBR predicted faster responding, especially on Switch blocks. There was additionally a marginally significant 3-way interaction involving EBR (β =-.0019, *SE*=.0011, *t*(28720)=-1.78, *p*=.075). This interaction suggests that in females, larger EBR predicted faster RTs overall, whereas in males higher EBR predicted slower RTs, especially on Non-Switch blocks.

When gender was added to the global switch effect model predicting error rate, there was a marginally significant interaction between Gender and EBR^2 (β =1.49x10^{-4}, *SE*=8.31x10^{-5}, *t*(155.3)=1.80, *p*=.074), in the context of a marginally significant 3-way interaction with Switch Condition (β =-1.55x10^{-4}, *SE*=8.21x10^{-5}, *t*(98)=-1.88, *p*=.063). These findings suggest that in females, larger EBR^2 predicts fewer errors on Non-Switch trials, but has no effect on Switch trial performance. In males, on the other hand, increasing distance from the EBR mean predicts more errors on Non-Switch trials, while also not affecting Switch error rates.

Overall, these results suggest that EBR has both linear and quadratic effects on both local and global switch costs. Furthermore, in this sample, gender moderated the EBR-linked effects, with males often having stronger EBR-linked effects than females, which is consistent with prior work (e.g. Müller et al., 2007). From these results, EBR did not appear to relate strongly to indices of distractibility.

Reliability of Pupil Measures (N=94)

The split-half reliability for the by-condition and by-subject pupil measures are shown in Table 2. By-condition reliability of pupil measures was low, particularly for tonic pupil size. The by-subject reliability, on the other hand, was very high for both phasic measures, and both mean- and variability estimates; however the reliability of the tonic measures was still low. These findings suggest that our index of individual differences in phasic pupil measures are consistent and meaningful, whereas, in this experiment, our index of tonic pupil size was not meaningful, and thus any results should be interpreted with caution.

One potential explanation for this low reliability of by-subject tonic pupil measures is that the tonic pupil size was systematically larger on cued (Switch) trials compared to uncued (Non-Switch), which could have introduced variability when aggregating all trials across conditions. In order to explore this cause of low reliability in tonic pupil size, we estimated the split-half reliability of tonic pupil measures for Switch and Non-Switch trials separately. Here, the reliability of mean-level tonic pupil size was .57 (95% *CI*=.42-

Table 2. *Reliability of Pupil Measures*

	By Condition		By Subject	
	r	**95% CI**	***r***	**95% CI**
Magnitude	.60	.55-.64	.96	.93-.97
Latency	.52	.47-.57	.90	.85-.93
Tonic	.33	.27-.39	.25	.05-.43
Magnitude *SD*			.93	.89-.95
Latency *SD*			.92	.89-.95
Tonic *SD*			.18	-.03-.37

Note: *** p<.001, ** p<.01, * p<.05, . p<.10

.69) and .22 (95% *CI*=.02-.40) for Switch and Non-Switch trials respectively. Reliability of *SD* measures was -.03 (95% *CI*=-.23-.17) and .18 (95% *CI*=-.02-.37), for Switch and Non-Switch trials respectively. Thus, the poor reliability of tonic measures cannot be explained by variability related to baseline pupil differences for Switch versus Non-Switch trials.

Task Effects on Pupil Measures (N=94)

Prior to investigating the relationship between LC-NE activity and task performance using pupil measures, it was first necessary to establish how the pupil response varied across task conditions. A key aim of this research is to directly examine the relationship between pupil measure and flexibility by comparing Switch and Non-Switch trials. However, in this version of the task, the direct comparison was not possible, because all Switch trials were preceded by a cue and all Non-Switch trials were not preceded by a cue. The presence of a cue represents a pupillary confound, we chose to examine the effects of the pupil measures on Switch and Non-Switch trials separately.

Overall, phasic pupil responses had mean magnitude of 7.91% (*SD*=6.33%) and mean latency of 1322.31ms (*SD*=737.61). Also, the magnitude and latency of the pupil response were significantly positively correlated (r=.40, $t(24423)$=68.78, p<.001). Separate LMMs were used to predict the magnitude and latency of the phasic pupil response on Switch and Non-Switch trials from the task factors Congruence and Block Type and their interaction. None of the main or interactive effects in the models reached significance (ts<1.3, *n.s.*), indicating that the magnitude and latency of phasic pupil responses did not differ based on trial Congruence or Block Type.

Within-Subjects Pupil Effects on Task Performance (N=94)

Next, tonic and phasic pupil measures were entered as predictors of task performance. Because of the aforementioned confound, these analyses address only the effects of pupil size on distractibility across contexts, as indexed by the Congruence and Block Type factors. The models included all pupil measures (phasic Magnitude, Magnitude^2, Latency and Latency^2, as well as Tonic Pupil, and Tonic Pupil^2), Congruence, Block Type, and their interactions. Magnitude and Latency measures of the phasic pupil response were examined in separate models.

Here, we expected that trials with relatively small tonic pupil size and large phasic pupil responses would be characterized by less distractibility, whereas participants would be more distractible when tonic pupil size was large and phasic responses were small.

The correlation between the tonic and phasic centered variables was .53 for phasic magnitude and .26 for latency, and the variance inflation factor (VIF) was 1.31 and 1.07 respectively, indicating that collinearity is sufficiently low to maintain model validity.

RT

Switch Trials. In the models examining Switch trials, there were main effects of Phasic pupil measures (Magnitude: β =.34, *SE*=.14, $t(4505)=2.37$, $p=.018$; Latency: β $=9.33\text{x}10^{-5}$, *SE*$=1.21\text{x}10^{-5}$, $t(4500)=7.69$, $p<.001$), suggesting that larger phasic magnitude and longer latency predicted slower RTs overall. There was additionally a main effect of Latency^2 (β $=1.24\text{x}10^{-7}$, *SE*$=1.51\text{x}10^{-8}$, $t(4503)=8.19$, $p<.001$). Tonic pupil size also exhibited a main effect on RT in the magnitude model (β =.020, *SE*=.0096, $t(4501)=2.13$, $p<.033$); however this effect did not reach significance in the latency model ($t(4499)=1.35$, $p=.18$). There was also an interaction between Block Type and Phasic Latency ($\beta=4.76\text{x}10^{-5}$, $SE=1.66\text{x}10^{-5}$, $t(4490)=2.86$, $p=.0043$), which was marginally significant for Magnitude as well ($\beta=.36$, $SE=.20$, $t(4489)=1.81$, $p=.071$), which demonstrated that the slope of the positive relationship between phasic pupil measures and RT was steeper on Perseveration-Inhibition blocks.

Non-Switch Trials. Similar to the Switch models, Non-Switch models found a main effect of phasic pupil response on RT (Magnitude: $\beta=.39$, $SE=.072$, $t(19740)=5.36$, $p<.001$ Latency: $\beta=2.72\text{x}10^{-5}$, $SE=4.74\text{x}10^{-6}$, $t(19720)=5.74$, $p<.001$), as well as an main effect of Latency^2 ($\beta=2.71\text{x}10^{-8}$, $SE=6.46\text{x}10^{-9}$, $t(19730)=4.20$, $p<001$). Also similarly, the main effect of tonic pupil size also reached significance in both models (Magnitude model: $\beta=.028$, $SE=.0044$, $t(19720)=6.28$, $p<.001$; Latency model: $\beta=.015$, $SE=.0039$, $t(19720)=3.93$, $p<.001$). There was additionally a significant interaction between Block Type and Latency ($\beta=3.05\text{x}10^{-5}$, $SE=6.74\text{x}10^{-6}$, $t(19720)=4.52$, $p<.001$), indicating a stronger positive relationship between Phasic Latency and RT on Perseveration-Inhibition blocks, which mirrors the effect in the Switch trials. Finally, there was a there was a marginally significant interaction between Block Type and Tonic Pupil^2 in the latency model ($\beta=.0087$, $SE=.0050$, $t(19720)=1.75$, $p=.080$) although it did not reach significance in the magnitude model ($\beta=.0087$, $SE=.0050$, $t(19720)=1.74$, $p=.083$), which suggested that trials with early or late peaks were slower on Perseveration-Inhibition blocks compared to trials with intermediate peak latency.

Overall, these findings suggest that, aside from any condition-specific influences, pupil measures have general effects on RT, with larger phasic dilations, longer latencies, and larger tonic pupil size generally predicting slower RTs. There was also a quadratic effect of latency, suggesting the presence of a non-linear effect, as trials with both early and late latencies were slower. Interestingly, pupil measures also interacted with Block Type, which also suggests a more general effect on performance, with later pupil dilations being especially predictive of slower RTs on Perseveration-Inhibition block contexts. Based on the involvement of the LC-NE system in modulating the gain of currently-active representations, we had hypothesized that trials with low or intermediate tonic pupil size as well as large phasic dilations would be characterized by less distractibility; however these RT data do not support that hypothesis: There was no interaction between Congruence and any pupil measures (*t*s<1.5, *n.s.*). We were not able to directly test our question about the relationship between flexibility and LC-NE function with these data, because switch trials are confounded with the

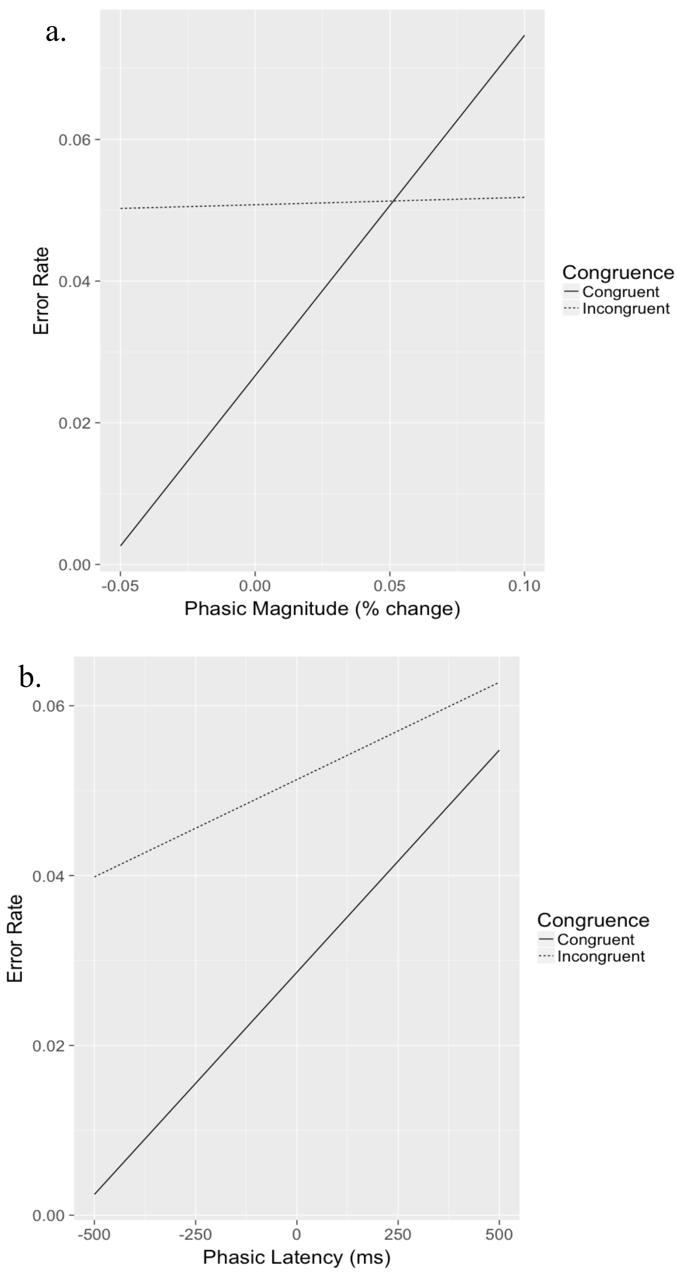

Figure 8. Error rate as a function of Congruence and phasic Magnitude (a) or Latency (b) on Switch trials.

presence of a cue (a limitation that is addressed in a subsequent study).

Error Rate

In the behavioral analysis, Congruence appeared to have a greater effect on error rate than on RT; thus, it is possible that pupil measures will be more predictive of error-related measures of distractibility. Here, too, we will report the results for Switch and Non-Switch trials separately.

Switch Trials. On Switch trials, there were main effects of phasic pupil magnitude (β =.55, *SE*=.21, $t(353.2)=2.58$, p=.010) and latency (β =6.97x10^{-5}, *SE*=1.92x10^{-5}, $t(352.0)=3.63$, $p<.001$), with both positively predicting error rates. Relevant to distractibility, both phasic measures interacted significantly with Congruence (Magnitude: β =-.58, *SE*=.28, $t(288.4)=-2.08$, p=.038; Latency: β =-5.59x10^{-5}, *SE*=2.55x10^{-5}, $t(289.4)=-2.19$, p=.029), which indicates that larger phasic dilations and longer latencies predicted smaller incongruence costs (Figure 8a-b). This finding may reflect a speed-accuracy tradeoff, with trials that take longer to reach peak phasic response being more accurate on the more difficult incongruent trials. Tonic pupil size was also relevant to distractibility, as indicated by a significant 3-way interaction between Congruence, Block Type, and Tonic Pupil Size (Magnitude model: β =-.087, *SE*=.031, $t(287.4)=-2.77$, p=.006; Latency model: β =-.063, *SE*=.031, $t(288.0)=-2.04$, p=.042). On Perseveration-Inhibition blocks, larger tonic pupil size reduced error rates on Incongruent trials, but increased them for Congruent trials. On the other hand, large tonic pupil size on Pure Updating blocks predicted reduced error rates on Congruent trials, and unchanged error rates on Incongruent trials (Figure 9).

Non-Switch Trials. On Non-Switch trials, there were no main effects of pupil measures on error rates; however there were significant and marginally significant 3-way interactions involving both tonic and phasic pupil measures. First, there was a significant 3-way interaction between Congruence, Block Type, and Tonic pupil size (magnitude model: β =-.081, *SE*=.038, *t*(289.9)=-2.13, *p*=.034; latency model: β =-.073, *SE*=.037, *t*(292.6)=-1.98, *p*=.049). Similar to the interaction observed for Switch trials, large tonic pupil size on Perseveration-Inhibition blocks predicted fewer errors on Incongruent trials and more errors on Congruent trials, whereas on Pure Updating blocks, large tonic pupil size predicted fewer errors on Congruent trials, but had no effect on Incongruent trial error rates. There was additionally a significant 3-way interaction between the task factors and Tonic Pupil^2, although it was only marginally significant in the magnitude

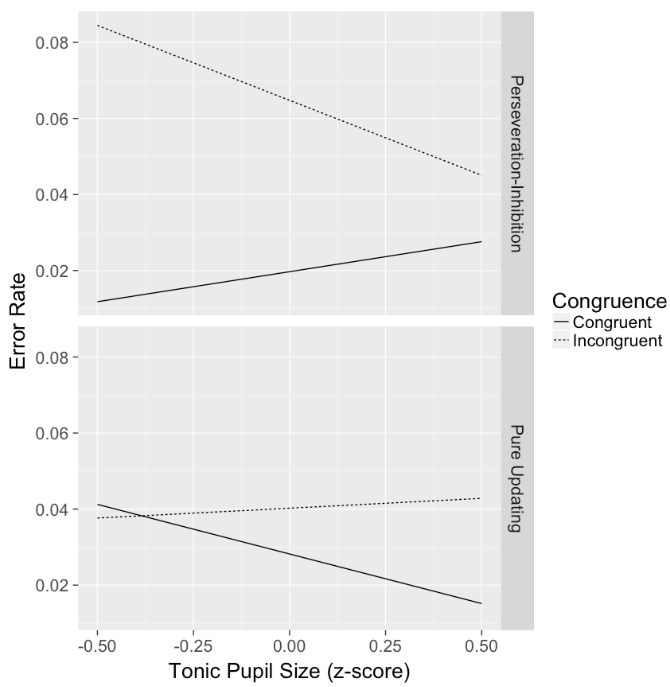

Figure 9. Error rate as a function of Congruence, Block Type, and Tonic Pupil Size on Switch trials.

model (latency model: β =-.080, *SE*=.039, *t*(320.3)=-2.07, *p*=.039; magnitude model: β =-.074, *SE*=.039, *t*(320.1)=-1.90, *p*=.059). This interaction suggests that having large or small tonic pupil size was predictive of smaller incongruence costs on Perseveration-Inhibition blocks, but larger incongruence costs on Pure Updating blocks (Figure 10). With respect to phasic pupil measures, there were marginally significant 3-way interactions involving both Phasic Magnitude (β =-.61, *SE*=.32, *t*(277.6)=-1.88, *p*=.061) and Phasic Latency^2 (β =6.81x10^{-8}, *SE*=3.69x10^{-8}, *t*(272.9)=1.85, *p*=.066). This first interaction demonstrated that large phasic pupil dilations predicted smaller error rate incongruence costs on Perseveration-Inhibition blocks, but larger incongruence costs on Pure Updating blocks. The second interaction suggests that increasing distance from the mean phasic latency (early and late) was predictive of larger error rate incongruence costs on Perseveration-Inhibition blocks, but had little effect on incongruence costs in Pure Updating blocks.

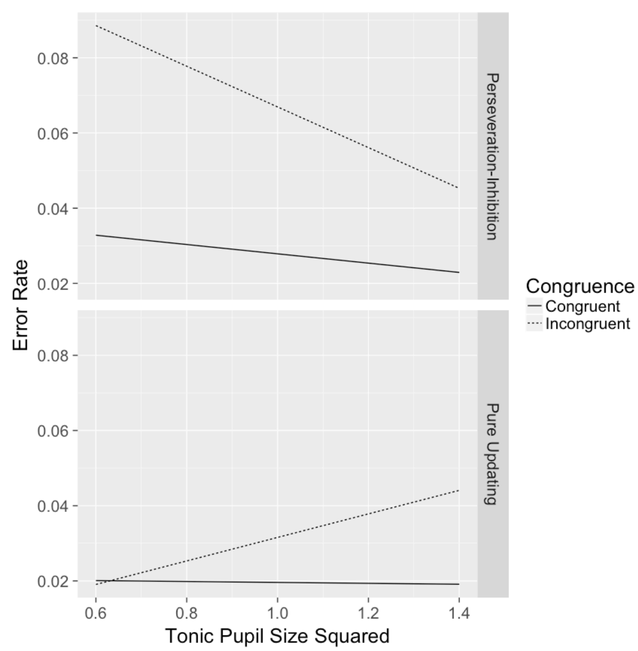

Figure 10. Error rate as a function of Congruence, Block Type, and Tonic Pupil Size Squared on Non-Switch trials.

Overall, the effects of Congruence, which index distractibility, were more evident on error rate analyses than on RT analyses. We had initially hypothesized that smaller tonic and large phasic pupil measures would predict less distractibility. The results on Switch trials suggest that large phasic dilations did predict smaller incongruence costs; however this effect did not generalize to non-switch trials. Other effects of pupil measures on performance were highly context-dependent. Across all trial types, larger tonic pupil size on Perseveration-Inhibition blocks predicted fewer errors on incongruent trials, whereas on Pure Updating blocks predicted fewer errors on Congruent trials. Additionally, on Switch trials, phasic magnitude and tonic pupil size had context-dependent, non-linear effects on distractibility. Particularly because these effects were not hypothesized, it will be important to replicate these effects in other experiments.

Global Switch Effects

To explore the relationship between LC-NE function and global switch effects, pupil measures were entered into the RT and Error Rate models comparing performance on non-cued trials in Switch versus Non-Switch blocks. In RT models, there were significant interactions between Switch Condition and both Phasic Pupil measures (Magnitude: β =.27, *SE*=.090, $t(22740)=2.98$, $p=.002$; Latency: β =$2.73\text{x}10^{-5}$, *SE*=$6.31\text{x}10^{-6}$, $t(22740)=4.33$, $p<.001$), and Tonic Pupil (Magnitude model: β =.026, *SE*=.0056, $t(22740)=4.67$ $p<.001$; Latency model: β =.020, *SE*=.0052, $t(22740)=3.78$, $p<.001$). These interactions indicate that larger tonic pupil size, larger phasic dilations and longer peak latency all predict larger global switch costs. In the magnitude model, there was additionally a marginally significant interaction between Switch Condition and Phasic Magnitude^2 (β =-1.81, *SE*=.96, $t(22740)=-1.89$, $p=.059$), which suggests that large and small phasic pupil responses predicted reduced global switch costs, as a result of slower RTs on Non-Switch blocks.

In the Error Rate analysis, both phasic Latency and Latency^2 interacted with Switch

Condition with at least marginal significance (Latency: $\beta = 2.94 \times 10^{-5}$, $SE = 1.59 \times 10^{-5}$, $t(98.9) = 1.85$, $p = .067$; Latency^2: $\beta = 4.99 \times 10^{-8}$, $SE = 1.59 \times 10^{-8}$, $t(96.6) = 2.88$, $p = .005$). These interactions demonstrate that both later phasic latencies and latencies that are farther from the group mean (I.e. early and late) predicted larger global switch costs in error rate.

Overall, both tonic and phasic pupil measures were predictive of global switch costs in this experiment. It is interesting that tonic pupil size had opposite influences on global switch time in RT and error rate, increasing costs in RT and reducing them in error rate. Thus, it is possible that having large tonic pupil size leads to slower performance particularly on Switch blocks, but that this slowing leads to reduced error rates.

Between-Subjects Pupil Effects on Task Performance (N=94)

The following analyses were carried out using aggregate measures of each subject's mean of each pupil measure (Tonic, Tonic^2, Phasic Magnitude, Phasic Magnitude^2, Phasic Latency, and Phasic Latency^2), as well as the standard deviation of each non-quadratic measure, as predictors. Magnitude and Latency measures, as well as mean and standard deviation measures, were entered into separate models. Because predictors were aggregated at the subject level, rather than single trials or by-condition aggregates, we were able to examine Switch and Non-Switch trials in the same models. Our hypotheses for individual difference-level pupil measures paralleled those for the within-subjects effects. We expected that participants with larger tonic pupil size would be more distractible, whereas those with large phasic pupil dilations would be less distractible. We did not have strong hypotheses about the effects pupil measures on flexibility, or about the effects of variability in pupil measures.

RT

Individual differences in mean pupil measures on RT. In the analyses examining the relationship between mean pupil measures, task performance, and RT, individual differences, effects were observed largely for phasic pupil measures. First, phasic Latency interacted with Block Type ($\beta = 1.15 \times 10^{-4}$, *SE*=$2.47 \times 10^{-5}$, *t*(25600)=4.66, *p*<.001), which suggests that subjects with longer phasic latencies tended to be slower, particularly on Perseveration-Inhibition Blocks. Additionally, there was a significant interaction between Block Type and phasic Magnitude^2 (β =-17.44, *SE*=7.02, *t*(25600)=-2.49, *p*=.013), which indicates that phasic pupil dilations that were farther from the mean (large or small) predicted slower RTs, and that this relationship was stronger for Pure Updating Blocks. There was additionally a marginally significant interaction between Congruence and Phasic Magnitude (β =-.31, *SE*=.17, *t*(25600)=-1.77, *p*=.076), in the

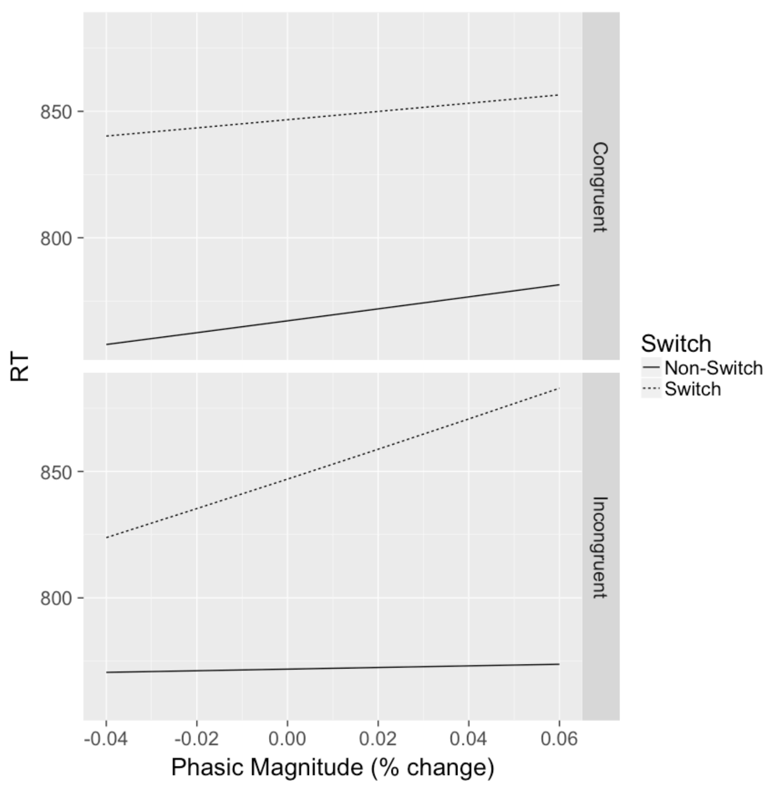

Figure 11. RT as a function of Switch, Congruence, and individual differences in mean phasic Magnitude.

context of a significant 3-way interaction between Switch, Congruence, and phasic Magnitude (β =1.03, *SE*=.40, *t*(25600)=2.56, *p*=.010). Here, larger phasic pupil dilations were predictive of smaller incongruence costs on Non-Switch trials, but larger incongruence costs on Switch trials (Figure 11). With respect to tonic pupil size, there was a marginally significant interaction between Congruence and Tonic Pupil[2] (Magnitude model: β =-.0095, *SE*=.0050, *t*(25600)=-1.88, *p*=.060; Latency Model: β =-.0084, *SE*=.0050, *t*(25600)=-1.67, *p*=.095). This interaction indicates that increasing distance from mean tonic pupil size predicts faster RTs, especially on Incongruent trials.

The correspondence between these findings and our hypotheses is mixed. On the one hand, we might have expected that large and small tonic pupil size, which is believed to reflect restlessness and drowsiness respectively, would predict greater distractibility; however here, we observed the opposite. On the other hand, large phasic pupil dilations did predict reduced incongruence costs on Non-Switch trials, as we had hypothesized. It is important to note, however, that large phasic pupil dilations predicted greater distractibility by incongruent distractors on Switch trials.

Individual differences in pupil variability on RT. Next, models examined the effect of variability in pupil measurements, by entering the standard deviation in tonic, phasic magnitude, and phasic latency as predictors. Here, variability in both tonic and phasic pupil measures was predictive of task performance. In this analysis, there was a main effect of Latency SD (β =8.13x10^{-4}, *SE*=1.36x10^{-4}, *t*(97)=5.96, *p*<.001, which indicated that participants with greater variability in phasic latency tended to respond more slowly overall. In the latency model, there was also a significant main effect of Tonic pupil SD (β =2.67x10^{-4}, *SE*=1.34x10^{-4}, *t*(97)=1.99, *p*=.050); however it did not approach significance in the magnitude model ($t(95)=1.19$, *n.s.*), and so will not be discussed further here. There was additionally a significant 3-way interaction between Switch, Congruence, and Phasic Magnitude SD ($\beta=1.22$, $SE=.60$, $t(25610)=2.02$, $p=.043$). In this interaction, greater variability in the magnitude of the phasic response predicted slower RTs on Incongruent Switch trials more strongly than other trial types (Figure 12). There was also a marginally significant 3-way interaction involving Tonic SD , Switch, and Congruence in the latency model $\beta=2.10\times10^{-4}$ $SE=8.47\times10^{-5}$, $t(24660)=2.48$, $p=.013$); however this effect is difficult to interpret alongside null results in the magnitude model (ts<1, *n.s.*). Thus, there appears to be a general trend suggesting that greater variability in the latency and magnitude of phasic pupil responses predicts slower performance.

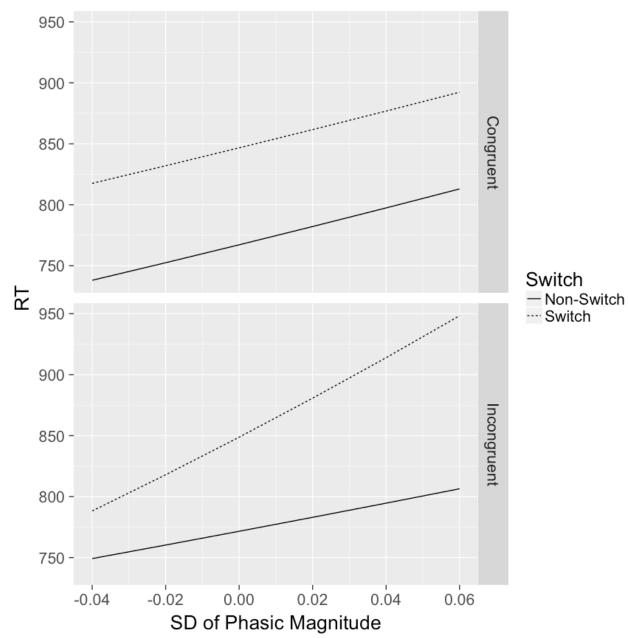

Figure 12. RT as a function of Switch, Congruence, and individual differences in the standard deviation of phasic Magnitude.

Error Rate

Individual differences in mean pupil measures and error rate. The only pupil-linked effects that reached significance in the models predicting error rate involved phasic Latency. Specifically, there was a 2-way interaction between Switch and Latency ($\beta=7.34\times10^{-5}$, $SE=3.06\times10^{-5}$, $t(623)=2.40$, $p=.017$), as well as a 3-way interaction

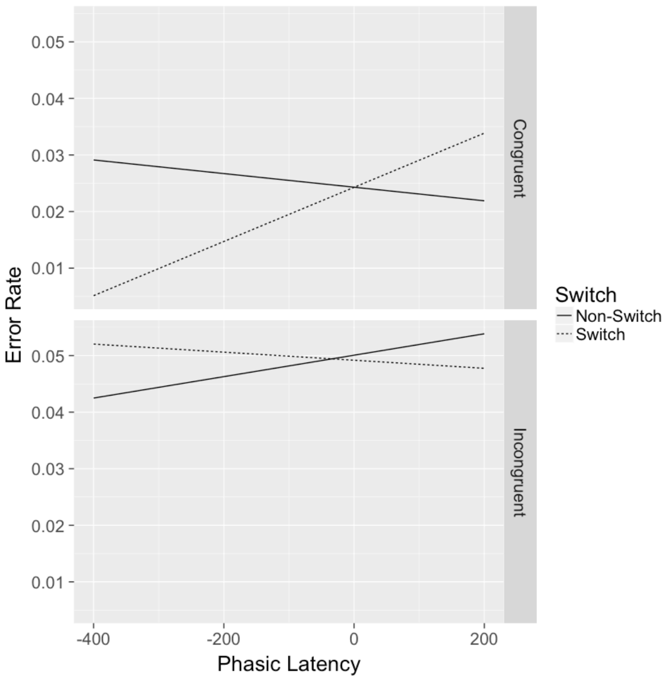

Figure 13. Error rate as a function of Switch, Congruence, and individual differences in mean phasic Latency.

between Switch, Congruence, and phasic Latency (β =-1.29x10^{-4}, *SE*=4.33x10^{-5}, *t*(623)=-2.97, *p*=.003). As shown in Figure 13, this effect demonstrates that individuals with longer latencies tended to have larger error rate switch costs on congruent trials, but smaller error rate switch costs on incongruent trials. There was additionally a marginally significant interaction between Congruence and Tonic Pupil (Magnitude Model: β =-.013, *SE*=.0069, *t*(623)=-1.81, *p*=.071; Latency Model: β =-.012, *SE*=.0069, *t*(623)=-1.75, *p*=.082), which indicated that participants with larger tonic pupil size tended to have smaller incongruence costs in error rate. This finding is in contrast to our hypotheses, which would have predicted more errors on trials with large tonic pupil size.

Individual differences in pupil variability and error rate. In the model predicting error rate from all indices of pupil variability, there were no significant pupil-linked effects (*t*s<1.4, *n.s.*).

Global Switch Effects

Individual differences in mean pupil measures and RT global switch effects.

These models examined the extent to which mean-level individual differences in pupil measures predicted the tendency to exhibit slowing on Non-Switch trials in switching contexts. Here, both phasic Magnitude and Phasic Latency interacted with Switch Condition (Magnitude: β =.42, *SE*=.16, $t(24060)=2.57$, $p=.010$; Latency: β =6.23x10^{-5}, *SE*=2.34x10^{-5}, $t(24060)=2.66$, $p=.0078$). These effects suggest that individuals with larger phasic responses and longer latencies tended to have larger global switch costs. There was additionally a marginally significant interaction between Switch Condition and Tonic Pupil Size (magnitude model: β =.0089, *SE*=.0053, $t(24060)=1.67$, $p=.095$; latency model: β =.010, *SE*=.0053, $t(24060)=1.91$, $p=.057$). This trend-level effect suggests that participants with larger mean tonic pupil size had larger global switch costs.

Individual differences in pupil variability and RT global switch effects. Individual variability in tonic pupil size influenced global switch costs (Magnitude model: β =1.11x10^{-4}, *SE*=4.53x10^{-5}, $t(24070)=2.45$, $p=.014$; Latency model: β =1.14x10^{-4}, *SE*=3.51x10^{-5}, $t(24070)=3.24$, $p=.001$). Specifically, participants with greater variability in tonic pupil size showed larger global switch costs than those with lower variability in tonic pupil size.

Individual differences in mean pupil measures and error rate global switch effects. There were no significant effects of individual mean-level pupil measures and global switch costs in error rate (*t*s<1.4, *n.s.*).

Individual differences in pupil variability and error rate global switch effects. Variability in phasic Latency did interact significantly with Switch Condition (β =6.23x10^{-5}, *SE*=2.45x10^{-5}, $t(91)=2.54$, $p=.013$. This effect indicates that that participants with more variable phasic latencies tended to have larger global switch costs, which was driven by both reduced errors in Non-Switch contexts and increased errors in Switch contexts.

Overall, individual differences in both mean-level pupil indices were significant predictors of flexibility and distractibility in both RT and error rate, and also appear to be relevant for global switch costs.

Eye Tracking Analyses

Finally, we examined the participants' eye movements, with the goal of understanding the behavioral gaze patterns that underlie the observed effects of task condition, EBR, and pupil measures on performance.

Task Effects on Fixations (N=76)

Probability of fixating on target and distractors. First, we examined how participants' tendency to fixate on the distractors varies across task conditions (Switch, Congruence, Block Type). In the sample included here, participants first fixated on the target on 77.5% of trials (*SD*=12.0%), on the distractor on 11.8% of trials (*SD*=8.2%), and on the irrelevant symbol on 5.1% of trials (*SD*=5.1%). Separate LMMs predicted the probability that participants would fixate first on the target letter, distractor letter, and irrelevant symbol.

In the target probability model, there was a main effect of Block Type (β =-.036, *SE*=.014, $t(525)$=-2.60, p=.010) and a marginally significant main effect of Switch (β =.023, *SE*=.014, $t(525)$=1.65, p=.10), with participants 3.6% less likely to fixate on the target on Perseveration-Inhibition blocks, and 2.3% more likely to fixate on the target on Switch trials.

Consistent with the Block Type result in the target probability model, in the distractor model there was also a main effect of Block Type, with participants 3.9% more likely to first fixate on the distractor letter on Perseveration-Inhibition blocks (β =.039, *SE*=.010, *t*(525)=3.73, *p*<.001). In the distractor model, there was additionally a significant interaction between Switch and Block Type (β =-.029, *SE*=.015, *t*(525)=-1.97, *p*=.049), in the context of a 3-way interaction that also included Congruence (β =.045, *SE*=.021, *t*(525)=2.14, *p*=.033). Interestingly, this 3-way interaction (Figure 14) indicates that there was an increased probability of fixating on the distractor on Congruent Non-Switch trials on Perseveration-Inhibition blocks, and to a lesser extent on Incongruent Non-Switch trials on Pure Updating blocks.

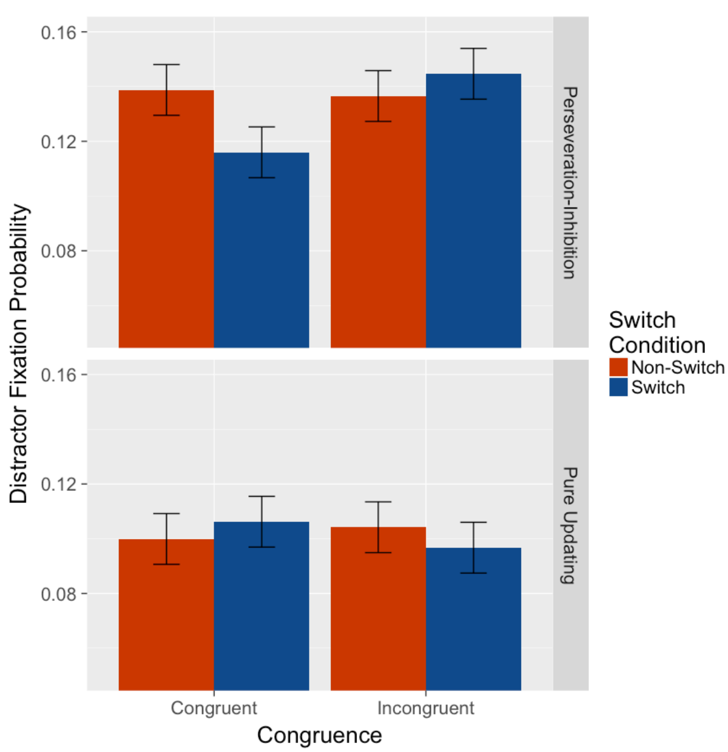

Figure 14. Distractor fixation probability as a function of Switch, Congruence, and Block Type.

In order to assess general distractibility, we were also interested in variability in attending the always-irrelevant symbol. In this model, there was a significant effect of Switch, with Switch trials leading to a 1.5% reduction in probability of fixating the irrelevant symbol (β =-.015, *SE*=.0067, *t*(525)=-2.25, *p*=.025). There was also a marginally significant interaction between Switch and Congruence (β =.017, *SE*=.0094, $t(525)=1.79$, $p=.074$), in the context of a 3-way interaction that also included Block Type (β =-.027, *SE*=.013, $t(525)=2.05$, $p=.041$). This interaction (Figure 15) suggests that on Incongruent trials in Pure Updating blocks, there is no difference between the probability of fixating the irrelevant symbol between Switch and Non-Switch trials; however, in all other conditions, there is a greater probability of fixating the symbol on Non-Switch trials compared to Switch trials. Overall, the finding that people are more likely to first fixate on the target and less likely to fixate on distractors on Switch trials is somewhat counterintuitive, given other work (Dreisbach & Wenke, 2011) suggesting that people are more vulnerable to distraction when switching. In this task, however, it is possible that because Switch trials are closer in proximity to a cue, the target color is more salient. It will be important to determine in the subsequent study whether this pattern is replicated when both Switch and Non-Switch trials are cued.

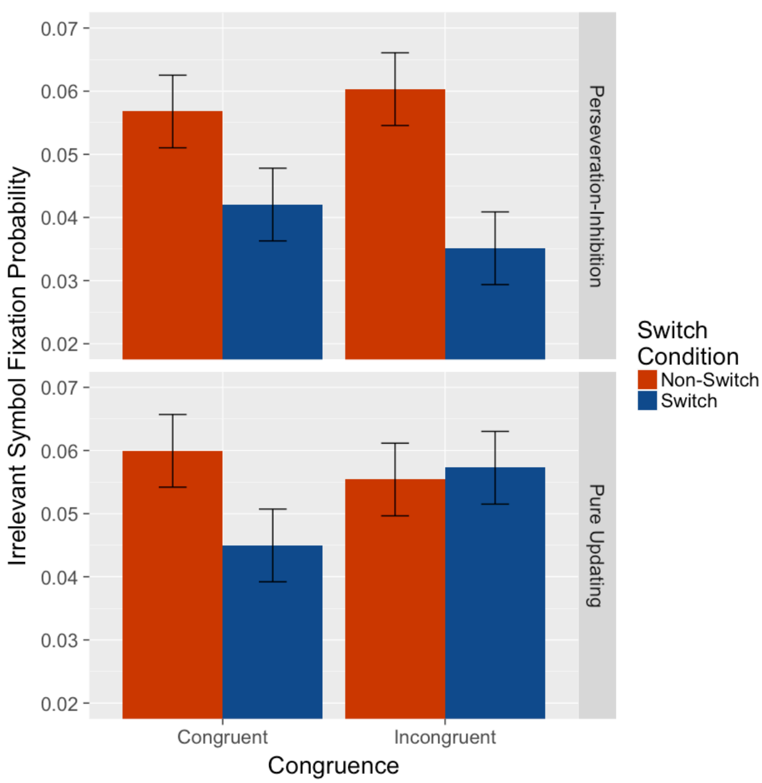

Figure 15. Probability of first fixating the always-irrelevant distractor signal, as a function of Switch, Congruence, and Block Type.

Time to fixate on target. We additionally examined the effects of task condition on the time it takes for participants to first fixate on the target, on those trials in which they did fixate on the target. There was a main effect of Block Type, with participants fixating on the target 10.31ms more slowly on Perseveration-Inhibition blocks (β =10.31, *SE*=2.81, $t(21363)=3.67$, $p<.001$). This effect is consistent with behavioral results showing that participants were slower to respond on Perseveration-Inhibition blocks. No other effects approached significance (*t*s <1.5, *n.s.*).

EBR Effects on Fixations (N=72)

Probability of fixating on target and distractors. To determine whether EBR, our index of striatal DA tone, has linear or quadratic relationships with fixation patterns, the above analyses were repeated with EBR and EBR^2 included. In the model predicting the probability target fixation, there was a significant interaction between Switch, Block Type, and EBR (β =-.0040, *SE*=.0019, $t(483)=-2.05$, $p=.041$). This interaction suggests that on Perseveration-Inhibition blocks, higher EBR predicts greater likelihood of fixating on the target on Non-Switch trials, and has no effect on the probability of target fixation on Switch trials. On Pure Updating blocks, on the other hand, higher EBR predicts increased likelihood of first fixating on the target on both trial types,

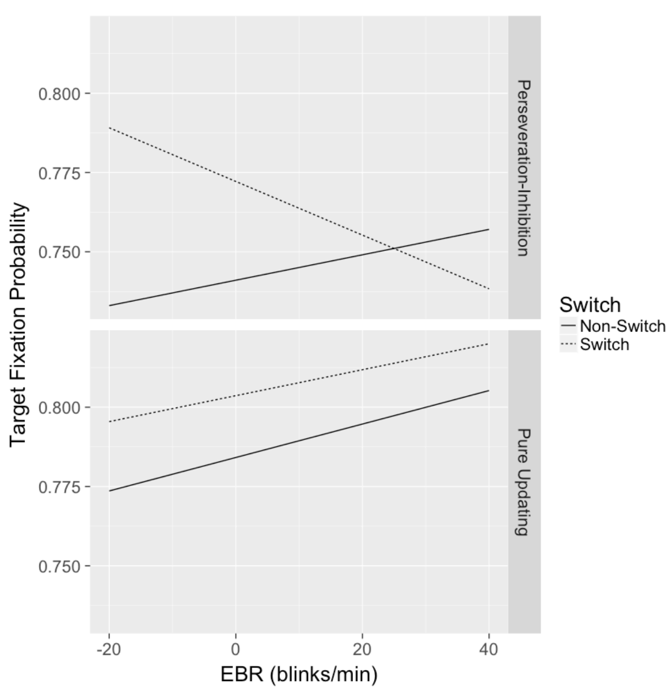

Figure 16. Target fixation probability as a function of Switch, Block Type, and EBR.

although the slope is steeper for Switch trials (Figure 16). This finding is the first evidence to support our hypothesis of context-specific effects of EBR on flexibility. In particular, if high EBR facilitates updating of the attentional set, but also increased inhibition, we would expect to see higher probability of target fixation on Switch trials in Pure Updating blocks, but not in Perseveration-Inhibition blocks.

Additionally, there was a significant interaction between Switch, Block Type, and EBR^2 (β =-3.88x10^{-4}, *SE*=1.71x10^{-4}, *t*(483)=-2.27, *p*=.024), in the context of a 4-way interaction that also included Congruence (β =5.68x10^{-5}, *SE*=2.42x10^{-4}, *t*(483)=2.35, *p*=.019). As shown in Figure 17, this interaction suggests that having low or high EBR was predictive of an increased target fixation advantage for Switch trials on Incongruent trials in Perseveration-Inhibition blocks and on Congruent trials on Pure Updating Blocks. In the other conditions, however, we observed a reduction in the Switch trial advantage for target fixation.

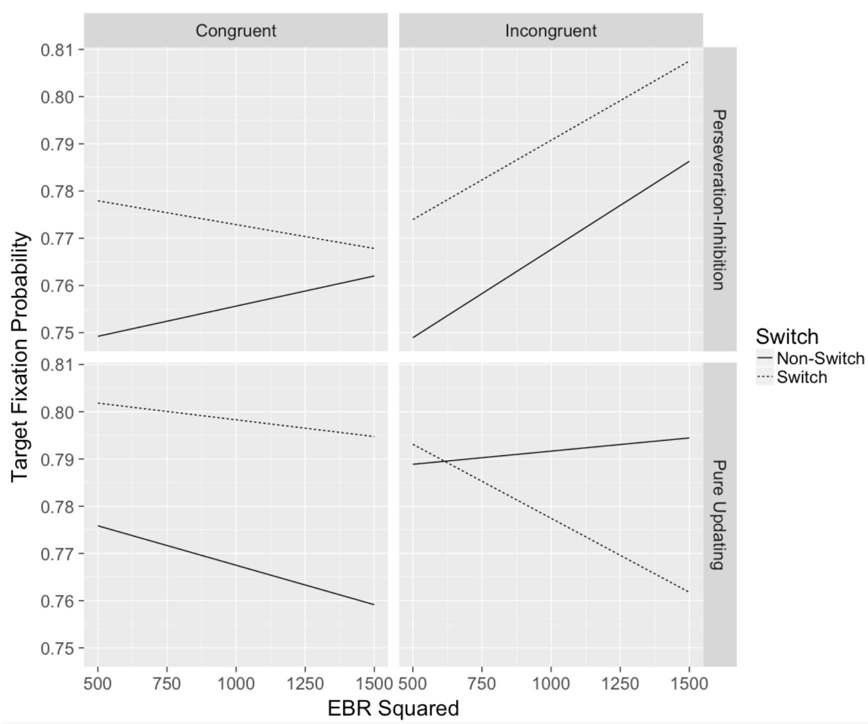

Figure 17. Target fixation probability as a function of Switch, Congruence, Block Type, and EBR^2.

In the model predicting the probability of distractor fixation, there was a marginally significant interaction between Switch and EBR^2 (β =-1.54x10^{-4}, *SE*=9.26x10^{-5}, *t*(483)=-1.66, *p*=.098), in the context of a significant 4-way interaction between Switch, Congruence, Blocktype, and EBR^2 (β =-3.87x10^{-4}, *SE*=1.85x10^{-4}, *t*(483)=-2.09, *p*=.037). This effect echoed the EBR^2 finding from the target fixation analysis. Specifically, although Switch trials tended to show advantage, with reduced probability of distractor fixation, having a high or low EBR was predictive of an increased Switch advantage on Incongruent trials in Perseveration-Inhibition blocks and Congruent trials in Pure Updating blocks.

In the model predicting fixations on the irrelevant symbol, there was a main effect of EBR (β =-.0012, *SE*=5.63x10^{-4}, *t*(307.3)=-2.06, *p*=.040), with larger EBRs associated with a smaller probability of fixating on the irrelevant distractor letter.

Time to fixate on target. We had originally hypothesized that if higher striatal DA facilitates inhibition, we might expect to see that higher EBR predicts slower target fixations on Switch trials on Perseveration-Inhibition blocks, which would reflect the need for more time to overcome inhibition of a newly-relevant color. This finding would be reflected in an interaction between Switch, Block Type and EBR. In this

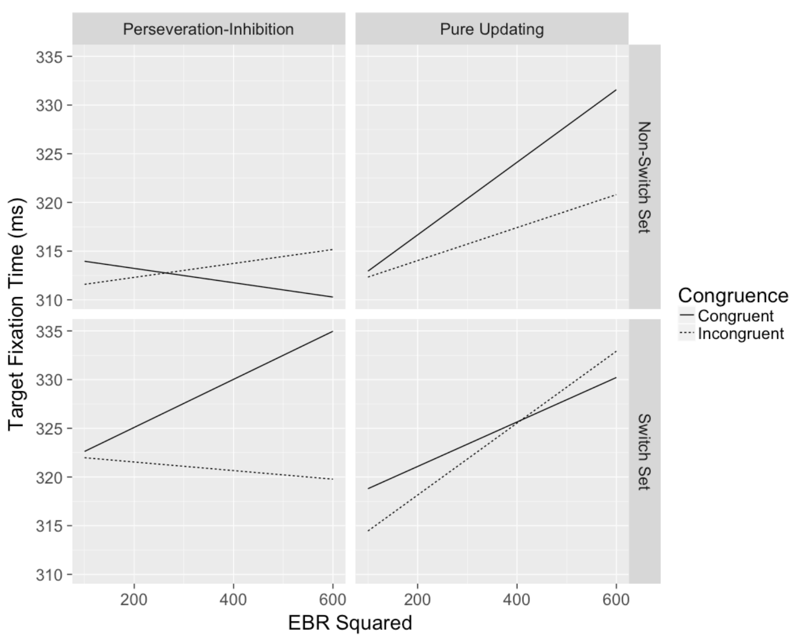

Figure 18. Target fixation time as a function of Switch, Congruence, Block Type, and EBR^2.

model, we did observe marginally significant interactions between Switch and EBR^2 (β =-.087, *SE*=.047, *t*(20610)=-1.86, *p*=.063) and Switch, Congruence, and EBR^2 (β =.12, *SE*=.069, *t*(20610)=1.74, *p*=.082), in the context of a significant 4-way interaction that also included Block Type (β =-.20, *SE*=.099, *t*(20610)=2.00, *p*=.045). As shown in Figure 18, this result indicates that while higher values for EBR^2 (i.e. high or low EBR) predicted faster target fixation times in general, they typically predicted faster fixation on Switch trials compared to Non-Switch trials, in all conditions except for Congruent trials on Perseveration-Inhibition blocks. There was also a significant interaction between EBR and Block Type (β =.91, *SE*=.36, *t*(20610)=2.54, *p*=.011). Here, higher EBR predicted faster target fixation on both Block Types, but the effect was strongest for Pure Updating blocks.

Overall, these effects suggest that in addition to linear effects, there are also important non-linear effects of EBR eye gaze behaviors.

Pupil Effects on Fixations (N=68)

Probability of fixating on target and distractors. Here, we examined whether pupil measures predicted participants' probability of first fixating the target or either distractor. The first analysis examined the probability of fixating the target. On Switch trials, there was a marginal main effect of phasic $Latency^2$ (β =-1.19×10^{-7}, *SE*=6.12×10^{-8}, *t*(237.9)=-1.94, *p*=.053), which suggests that peak phasic latencies that were more distant from the mean (e.g. early or late) tended to be less likely to fixate on the target first when Switching. On Non-switch trials, the only pupil-related effect to approach significance was a marginal main effect of phasic $Magnitude^2$ (β =-7.68, *SE*=4.13, *t*(237.9)=-1.86, *p*=.064), indicating that trials with large or small phasic pupil dilations had a smaller probability of fixating on the target first.

Next, we examined the relationship between pupil measures and the probability of fixating on the distractor letter. We had hypothesized that large tonic pupil size and smaller phasic dilations would be characterized by greater distractibility, and potentially a greater probability of fixating the distractor letter. However, no pupil-related effects approached significance (ts<1.5, *n.s.*).

Finally, we examined the probability of fixating on the always-irrelevant symbol. Here, too, we had predicted that large tonic pupil size should predict general distractibility, and thus higher likelihood of fixating on the always-irrelevant distractor. On Switch trials, there were no significant relationships between pupil measures and probability of fixating the symbol (ts<1.3, *n.s.*). On Non-Switch trials, while there were no significant relationships between tonic pupil size and distraction by the irrelevant symbol, phasic Latency did relate to this index of general distractibility. First, there was a marginally significant main effect of Latency ($\beta = -3.32\text{x}10^{-5}$, $SE=2.00\text{x}10^{-5}$, $t(245)=-1.66$, $p=.098$), which suggested that at the trend level, longer latencies predicted reduced probability of fixating on the target. There was additionally a significant interaction between Congruence and phasic Latency ($\beta = 6.42\text{x}10^{-5}$, $SE=2.39\text{x}10^{-5}$, $t(188.9)=2.69$, $p=.008$), which illustrates that on Incongruent trials, increasing phasic latency predicted a greater probability of fixating on the symbol, whereas latency had little effect on distractibility on Congruent trials. There were additionally significant interactions between Block Type and both Latency ($\beta = 7.45\text{x}10^{-5}$, $SE=2.43\text{x}10^{-5}$, $t(189.6)=3.07$, $p=.0024$), and Latency^2 ($\beta = 5.84\text{x}10^{-8}$, $SE=2.86\text{x}10^{-8}$, $t(193.1)=2.04$, $p=.043$). These interactions demonstrate that both late latencies, as well as those that are further from the mean (early and late) tended to have an increased probability of fixating on the irrelevant symbol on Perseveration-Inhibition blocks in particular. Finally, there was a significant 3-way interaction between Congruence, Block Type, and Latency (β =-8.18x10^{-5}, *SE*=3.31x10^{-5}, *t*(187.1)=-2.47, *p*=.014). This 3-way interaction (Figure 19) helps clarify the 2-way interactions involving Latency, and demonstrates that longer peak latencies predicted an increased likelihood of fixating on the symbol across most conditions, with the exception of Congruent trials on Pure Updating blocks. We had not expected that block context or trial congruence would affect probability of fixating this always-irrelevant symbol.

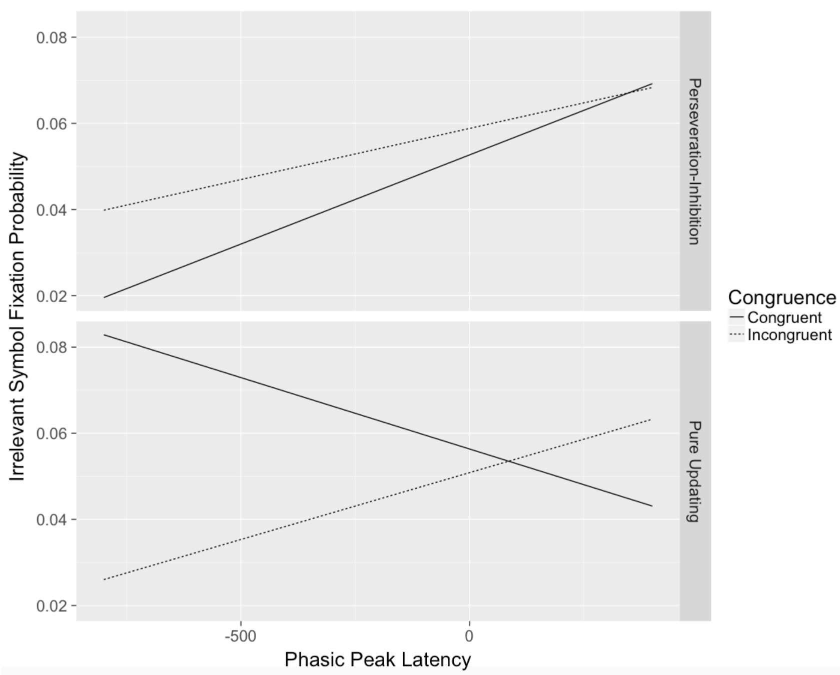

Figure 19. Irrelevant symbol fixation probability as a function of Congruence, Block Type, and phasic Latency on Non-Switch Trials.

Overall, these eye tracking findings are interesting because they suggest that distractor Congruence influence the likelihood of distraction. Thus, it appears that participants are able to gather some information about Congruence prior to making eye movements.

Time to fixate on target. On Switch trials, there were several main effects of phasic pupil measures, including phasic Magnitude (β =169.22, *SE*=79.67,

$t(3140.7)=2.12$, $p=.034$), Magnitude^2 ($\beta=1816$, $SE=763.22$, $t(3120.6)=2.38$, $p=.017$), Latency ($\beta=.014$, $SE=.0066$, $t(3139)=2.19$, $p=.029$), as well as a marginal effect of Latency^2 ($\beta=1.37\text{x}10^{-5}$, $SE=8.24\text{x}10^{-6}$, $t(3143)=1.66$, $p=.097$). Thus, trials with longer latencies, as well as those that had latencies further from the mean (fast or slow) tended to have slower target fixation time. There was additionally a significant interaction between phasic Magnitude^2 and Block Type ($\beta=-2259$, $SE=1108$, $t(3119)=-2.04$, $p=.042$). This interaction indicated that increasing distance of phasic pupil response magnitude from the mean predicted slower target fixation time on Pure Updating blocks, but faster fixation time on Perseveration-Inhibition blocks.

On Non-Switch trials, there were significant main effects of both Latency^2 ($\beta=9.96\text{x}10^{-6}$, $SE=3.71\text{x}10^{-6}$, $t(1327)=2.69$, $p=.007$) and Tonic Pupil Size^2 (magnitude model: $\beta=5.45$, $SE=1.98$, $t(13241)=2.75$, $p=.006$; latency model: $\beta=5.22$, $SE=1.95$, $t(13250)=2.68$, $p=.007$), suggesting that trials with early and late latencies tended to fixate on the target later. Similarly, large and small tonic pupil size was predictive of later target fixation.

EBR-Pupillometry Interaction (N=92)

These exploratory analyses examined how pupillary and EBR measures interact to predict task performance. Because of the aforementioned limitations of the study design, Switch and Non-Switch trials were analyzed separately, and so these analyses focus on the predictors of stability, or lack thereof, through the Congruence factor. Separate models were run for phasic Latency and phasic Magnitude indices. Models tested all possible interactions between a pupil and an EBR factor, as well as their interaction with

Congruence. As shown in Appendix A, there were many significant interactions between pupil and EBR measures predicting RT. Because we had no strong hypotheses about how EBR and pupil measures would interact, and also because of the large number of statistical tests, we are choosing to provide the complete findings in table format, without interpretation. It will be important to continue to investigate interactions between DA- and NE-linked measures to determine which of these effects are consistent across studies.

Discussion

Although our specific hypotheses were, for the most part, not supported, this experiment demonstrated that both EBR and pupil measures are relevant to participants' cognitive control performance on this task. Specifically, participants with higher EBR tended to have higher switch costs, and this effect was most evident in males. Between-subjects pupil measures had both main and interactive effects on distractibility; however their link with flexibility could not be directly tested here. Additionally, individual differences in pupil measures were relevant to both flexibility and distractibility.

One important shortcoming of the design was that switching, our index of flexibility, was confounded with the presence of a cue, because all Switch trials began with a cue, and all Non-Switch trials began without a cue. This issue clearly impacted pupillometry measures, because the presence of a cue affected pre-trial tonic pupil size, which then has an effect on the task-evoked phasic response, and so we were not able to directly compare pupil measures on Switch versus Non-Switch trials. Less obviously, this cue-related confound could also impact other findings as well, because it is possible that the presence of a cue affects task performance, independent of the need to switch, and the current design is not able to disentangle the two processes. The following study will address this issue, by introducing Non-Swich cues.

An additional limitation of the EBR component of our study is that we used a relatively brief 2-minute time window to measure EBR, when typically a 5-minute window is recommended, in order to reduce the impact of high-frequency variability in EBR (Jongkees & Colzato, 2016). In Experiment 4, we address this limitation by expanding the EBR baseline window to 5 minutes.

CHAPTER III

EXPERIMENT 2:

Experiment 2 was designed to directly assess the role of LC-NE function in the flexibility of WM representations, by comparing tonic and phasic pupil measures, as well as their ability to predict performance, on Switch versus Non-Switch trials. To enable this comparison, Non-Switch cues were added to the design, so that half of cues informed participants to continue attending the same-colored target. By directly contrasting pupillary measures on cued Switch versus Non-Switch trials, it was possible to determine the pupillary correlates of effective attentional shifting, while avoiding the potential confound of having a cue present. Furthermore, this design will also allow for an investigation of pupillary responses to the cue itself. Switch cues have greater behavioral relevance, because they signal the need to update attentional sets in WM, thus we expected Switch Cues to lead to a larger phasic pupil responses than Non-Switch cues.

An additional potential pupillary confound in Experiment 1 is that the stimulus array remained on the screen until participant response, and so the visual stimulation varied depending on participants' RTs. To the extent that stimulus duration affects our index of phasic pupil response, it is possible that differences in RT across conditions could have introduced systematic variation in phasic pupil measures that is caused by changes in visual stimulation, rather than by differences in a cognitive process. The use of peak phasic response (vs. mean) reduced the likelihood of this confound influencing our results. Nonetheless, a secondary aim of Experiment 2 was to definitively rule out the possibility that visual stimulation differences are influencing our pupil findings, by standardizing the stimulus duration.

Method

Participants

A power analysis on data from the first 30 subjects in Experiment 1 indicated that 10 participants were necessary to obtain statistical power of 0.8 to find a difference between the phasic response. Because we expected effects to be smaller when both Switch and Non-Switch trials were cued, we aimed to overshoot this target and set a target sample size of 32 subjects. To reach this target, 37 students at the University of Oregon participated in this study. Eligibility criteria were the same as for Experiment 1. Data from 1 participant were excluded from all analyses because of a lack of a good faith effort, and 4 participants were initially excluded from pupil analyses because of eyetracker issues. The 36 participants in the behavioral analyses had a mean age of 19.47 (SD=1.86) and included 21 females (58.3%) and 15 males (41.7%).

Procedure

The procedure was very similar to that of Experiment 1. Participants provided informed consent, and then completed a brief questionnaire about their demographic information, caffeine use for the day, and previous night's sleep. Participants then received task instructions, the eyetracker was calibrated, and then participants completed the EBR baseline and task while their eyes were tracked. Participants were given the option to take a break at calibration points, which occurred every 2 blocks. Following the task, participants were debriefed about the purpose of the experiment. The procedure lasted approximately 2 hours.

Materials and Apparatus

Attention Shifting Task. The attention shifting task was identical to the task used in Experiment 1, with two exceptions. First, Non-Switch cues were added, so that half of sets began with a color word that was the same as previous sets (Non-Switch) and the other half began with a color word that was different than on previous sets (Switch). Each Block still contained 12 sets, and in order to maintain a sufficient number of trials in each condition, the number of Switch Blocks was doubled, so that there were 6 of each Perseveration-Inhibition and Pure Updating Blocks. This change increased the total number of trials to 780.

The second change to the task involved standardizing the duration of the task array stimulus, so that it remained on the screen for 1000ms, regardless of participant RTs. This duration was chosen in order to avoid fundamentally changing the task, while also remaining fairly close to 790.19ms, the mean stimulus duration for Switch Blocks from Experiment 1. Participant responses were still recorded for 1500ms after stimulus offset.

EBR Baseline. Five-minute EBR baseline periods were recorded after the first calibration and at the end of the task. Because this experiment is underpowered to detect EBR effects, this component of the study will not be discussed further.

Apparatus. Apparatus were the same as for Experiment 1, except that the eyetracking was carried out with an Eyelink DM-890 eyetracker running Eyelink 1000 Plus software (Version 5.01).

Data Processing and Analysis

Processing of behavioral and pupil data was identical to that for Experiment 1.

All participants performed the task with an error rate less than 25%, and so the full sample of 36 participants was included in the behavioral RT analyses. The mean error rate was 5.67% (*SD*=3.97%), and error trials were excluded from RT analyses. As in Experiment 1, RTs were log-transformed and trials with RTs greater than 3 standard deviations from a subject's mean, or outside of the 100-2000ms time frame were excluded from analyses (1.18% of trials). One participant was excluded from error rate analyses because on an overall error rate greater than 3 standard deviations from the group mean, to reduce the influence of outliers.

Prior to pupillometry analyses, trials (16.47%) and participants (4) that were missing more than 30% of pupil data were excluded. Thus, when also accounting for those subjects who were initially excluded from pupil analyses, the total sample for pupillometry analyses was 28.

Eye tracking data was processed in the same manner as for Experiment 1. Eleven participants were excluded because they fixated on the target on fewer than 75% of trials overall. An additional 4 participants were excluded from the analyses predicting the probability analyses, because their probability of fixating on one of the stimuli (target, letter, distractor, symbol distractor) was outside of 3 standard deviations from the group mean. For the analyses of target fixation time, fixations that occurred outside the first 1000ms following stimulus presentation were excluded, to limit analyses to those times when stimuli were on the screen. In total, 5.58% of trials were removed for either being outside of this window, or being more than 3 standard deviations from the group mean.

Similar to Experiment 1, statistical analyses were carried out using LMMs. To account for the addition of Non-Switch cues, the task was modeled with 4 factors, with a 2 (Cue: Cued vs. Non-Cued) by 2 (Set Type: Switch Set vs. Non-Switch Set) by 2 (Congruence: Congruent vs. Incongruent) by 2 (Block Type: Perseveration-Inhibition vs. Pure Updating).

Results and Discussion

Behavioral Analyses (N=36)

RT. Trial-by-trial RTs, nested within subjects, were entered into a LMM. The null model had an ICC of .24, indicating a sufficient amount of between-subject variability to justify using a mixed model. Interestingly, the overall mean RT in this task was faster than that of Experiment 1 (742.41ms vs. 810.63ms), suggesting that the time-limited stimulus presentation caused participants to respond more quickly.

The full model included the factors Cue, Set Type, Congruence, Block Type, and their 2-, 3-, and 4-way interactions. Relevant to attentional flexibility, there were significant main effects of Cue (β =.025, *SE*=.010, $t(21450)=2.46$, p=.014), Set Type (β =.029, *SE*=.0064, $t(21450)=4.49$, $p<.001$), as well as an interaction between Cue and Set Type (β =.083, *SE*=.014, $t(21450)=5.74$, $p<.001$). Examination of this interaction suggests that it is driving the main Cue and Set Type effects: On Switch Sets, the RT difference between Cued and Uncued trials was 58.17ms, whereas on Non-Switch Sets, the difference was only 12.55ms. Although the magnitude of the switch cost is smaller than in Experiment 1 (89.47ms), this finding confirms the presence of robust switch costs on this version of the task. There were additionally significant main effects of

Congruence (β =.013, *SE*=.0064, *t*(21450)=2.03, *p*=.043), with Incongruent trials being 9.20ms slower, and Block Type (β =.023, *SE*=.0064, *t*(21450)=3.59, *p*<.001), with RTs on Perseveration-Inhibition blocks 16.23ms slower. Finally, there was a significant 3-way interaction between Cue, Set Type, and Block Type (β =-.058, *SE*=.020, *t*(21450)=-2.85, *p*=.004). This interaction (Figure 20) indicated that there were larger switch costs (e.g. difference between Cued and Uncued trials on Switch Sets) on Pure Updating blocks compared to Perseveration-Inhibition blocks, which was driven by both smaller Switch RTs and larger Non-Switch RTs. This interaction is broadly consistent with the Switch by Block Type interaction from Experiment 1, except in that case the smaller switch costs on Perseveration-Inhibition blocks was specifically driven by slower Non-Switch RTs, rather than faster Switch RTs. Overall, the direction of these RT effects closely parallel those for Experiment 1, with the exception that switch costs did not vary across congruent and incongruent trials here.

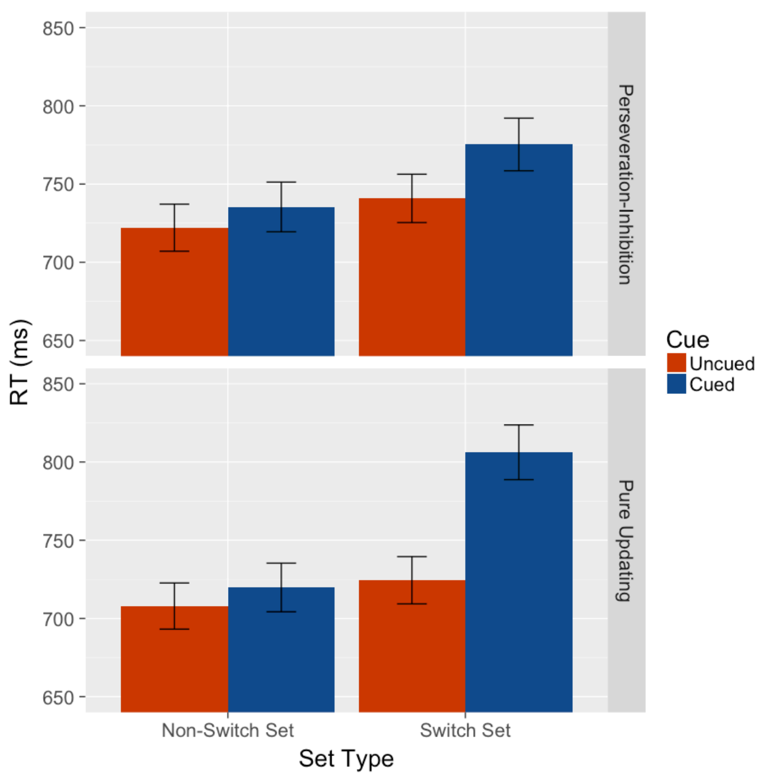

Figure 20. RT as a function of Cue, Set Type, and Block Type.

As in Experiment 1, we then computed correlations between switch and incongruence costs across Block Types. It is important to note that here, switch costs were computed as the difference between Cued Switch and Cued Non-Switch trials, which is different than in Experiment 1, in which switch costs were the difference between Switch (Cued) and Non-Switch (Uncued) trials. The switch costs computed here are thus a more pure index of switch costs, because they are disentangled from potential cue costs.

The correlational analyses (Table X) indicated that switch costs on Pure Updating blocks and Perseveration-Inhibition blocks were positively correlated, which is consistent with the findings of Experiment 1. Also similar to Experiment 1, there was no relationship between incongruence costs in the two Block Types. Switch costs were not related to incongruence costs, with the exception that overall switch costs were positively correlated with incongruence costs on Perseveration-Inhibition blocks. Although these correlational results are largely consistent with those from Experiment 1, they should be interpreted with caution because of the very low reliability of the switch and congruence cost measures (Table 3).

Table 3
Correlations between switch and incongruence costs across Block Types

	1.	2.	3.	4.	5.	Reliability	95% CI
1. Switch Cost	-					.21	-.13-.51
2. Switch Cost - Pure Upd	.86 ***	-				.22	-.12-.52
3. Switch Cost - PersInhib	.85 ***	.45 **	-			.01	-.32-.34
4. Incongruence Cost	.22	.23	.12	-		.07	-.27-.39
5. Incongruence Cost - PureUpd	-.01	.10	-.14	.75 ***	-	.08	-.26-.40
6. Incongruence Cost - PersInhib	.35 *	.25	.33 .	.75 ***	.12	.09	-.25-.41

Note: *** p<.001, ** p<.01, * p<.05, . p<.10

Error rate. The null model for error rate had an ICC of .34. In the full model, none of the main effects reached significance, including the main effect of Congruence, which had been significant in Experiment 1 (t(510)=1.55, p=.12). Here, the interaction between

Cue and Set Type was significant (β =.053, *SE*=.016, $t(510)=3.24$, $p=.001$). This interaction echoed the findings of the RT analysis, with a large difference between Cued and Uncued trials on Switch Sets, but no difference on Non-Switch Sets. Also similar to the RT analysis, there was a marginally significant 3-way interaction between Cue, Switch Set, and Block Type (β =-.045, *SE*=.023, $t(510)=-1.94$, $p=.053$), showing that Perseveration-Inhibition blocks had smaller error rate switch costs, but that this was driven by an increased error rate on Uncued trials on Perseveration-Inhibition Blocks, rather than an improvement on Cued (I.e. Switch) trials (Figure 21). Finally, there was a marginally significant interaction between Set Type, Congruence, and Block Type (β =.052, *SE*=.023, $t(510)=2.22$, $p=.027$), which was driven by a larger incongruence cost on Switch Sets for Perseveration-Inhibition blocks than for Pure Updating blocks. This effect suggests that participants were more distractible on Switch sets in Perseveration-Inhibition blocks, perhaps because they had more recently needed to update their attentional set, and is similar to the Congruence x Block Type interaction from Experiment 1, in which all sets were Switch Sets. All other effects in the model did not reach significance (*t*s<1.2, *n.s.*). In sum, these findings demonstrate that in this version

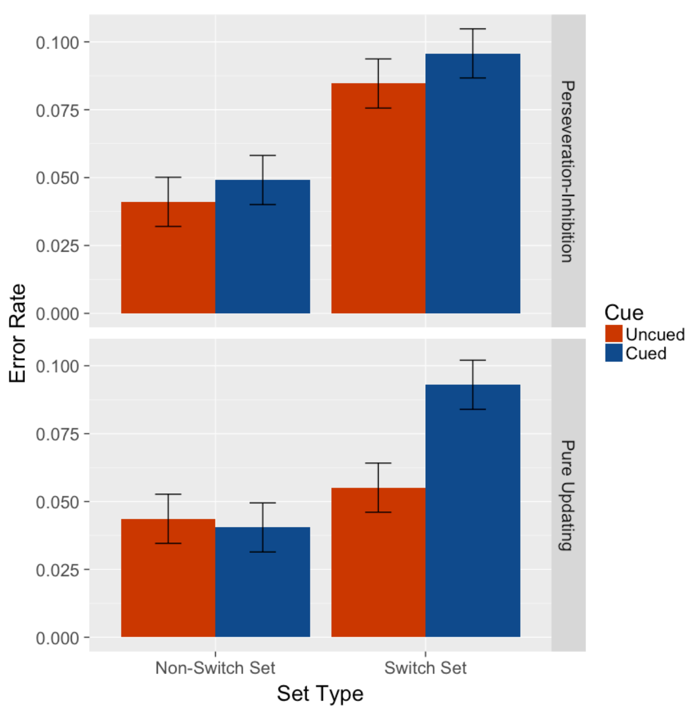

Figure 21. Error Rate as a function of Switch, Congruence, Block Type, and EBR^2.

of the task, task-related changes in both flexibility and distractibility were evident in error rates, whereas in Experiment 1, the error rate findings were restricted to distractibility-related effects.

Global switch effects. Assessment of global switch costs involved comparing performance on Non-Cued trials from Non-Switch blocks and Switch Blocks (Perseveration-Inhibition and Pure Updating pooled together). The RT analysis indicated no effect of Switch Condition ($t(18560)=.63$, *n.s.*). The error rate analysis, however, did show a main effect of Switch Condition, with participants making 1.9% more errors on Switch Blocks than on Non-Switch Blocks ($\beta=.019$, $SE=.0061$, $t(34)=3.09$, $p=.004$). Thus, although the error rate analysis parallels the findings for Study 1, there were no global switch costs for RT in this experiment. It is possible that the lack of a global switch effect in RT occurred because switches happened with half the frequency in this version of the experiment, or because of changes linked with the fixed stimulus duration.

Reliability of Pupil Measures (N=28)

The reliability of both mean-level and *SD* pupil measures is shown in Table 4. We additionally included estimates of the by-subject reliability of tonic pupil measures for Cued trials (Switch and Non-Switch separately), and Uncued Trials. The reliability values here were similar to those found in Experiment 1, with generally low by-condition reliability, and higher reliability for by-subject measures, with the exception of tonic measures, which showed low reliability, even by subject. Interestingly, reliability of mean-level tonic pupil size on Cued Non-Switch trials was somewhat higher than for other tonic pupil measures; however separating trials into cue condition does not fully explain the poor reliability of the tonic pupil measures.

Table 4
Reliability of Pupil Measures

	By Condition		By Subject	
	r	**95% CI**	***r***	**95% CI**
Magnitude	.48	.40-.54	.96	.92-.98
Latency	.42	.34-.49	.94	.87-.97
Tonic	.25	.17-.34	.44	.08-.70
Switch Cues			.40	.04-.68
Non-Switch Cues			.69	.42-.85
Uncued Trials			.49	.14-.73
Magnitude *SD*			.95	.90-.98
Latency *SD*			.95	.89-.98
Tonic *SD*			.21	-.17-.54
Switch Cues			.25	-.14-.57
Non-Switch Cues			-.06	-.43-.32
Uncued Trials			.14	-.24-.49

Note: *** $p<.001$, ** $p<.01$, * $p<.05$, . $p<.10$

Task Effects on Pupil Measures (N=28)

First, we examined how phasic magnitude and peak latency were affected by the task. In this experiment, phasic pupil responses had a mean magnitude of 7.85% (*SD*=7.04%) and a mean latency of 1377.75 (*SD*=743.39), which are largely consistent with those for Experiment 1, in spite of the timing changes. As observed in Experiment 1, the phasic Magnitude and Latency were significantly positively correlated (r=.49, $t(13886)$=66.48, $p<.001$).

Because this experiment included Non-Switch cues, it was possible to directly compare the pupillary response on Switch and Non-Switch trials by examining the cued trials. There was a significant effect of Cue on tonic pupil size, which could influence magnitude of subsequent phasic responses (β =.11, *SE*=.020, $t(13870)$=5.60, $p<.001$). So, in order to avoid this potential confound, pupil analyses were carried out on Cued and Non-Cued trials separately.

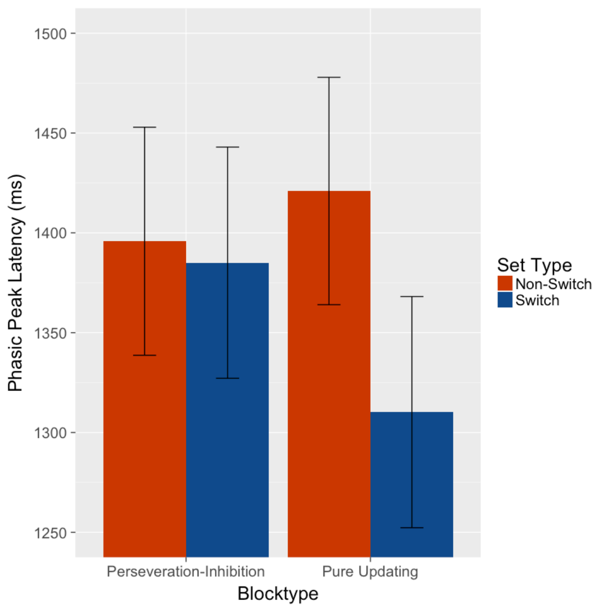

Figure 22. Phasic Latency as a function of Set Type and Block Type on Cued

The Cued trial models indicated that there were no significant effects of task on phasic pupil magnitude (*t*s<1.6, *n.s.*). In the latency model, there was a main effect of Switch, with the peak phasic response occurring 130ms earlier on Switch compared to Non-Switch trials (β =-130.67, *SE*=58.64, *t*(2832.1)=-2.23, *p*-.026). These main effects appear to be driven by an interaction between Switch and Block Type (β =238.61, SE=81.84, *t*(2831.40)=2.92, *p*=.0036), showing that phasic Latency did not differ on Switch and Non-Switch trials on Perseveration-Inhibition blocks; however on Pure Updating blocks, Switch trials had earlier peaks than did Non-Switch trials (Figure 22). In the latency model, the 3-way interaction between Switch, Congruence, and Block Type also reached significance (β =-284.83, *SE*=117.47, *t*(2831)=-2.43, *p*=.016). Whereas Pure Updating blocks showed the same pattern of earlier peak latency on Switch Trials across both Congruent and Incongruent trials, Perseveration-Inhibition blocks showed a similar pattern on Incongruent trials, but the opposite pattern on Congruent trials (Figure 23).

Analysis of Non-cued trials revealed one marginally significant interaction between Set Type and Block Type (β =.0060, *SE*=.0035, *t*(11310)=1.70, *p*=.089) in the magnitude model, which indicates that on Pure Updating blocks, phasic pupil responses tended to be smaller after a recent switch, whereas on Perseveration-Inhibition blocks, phasic responses were larger after a recent switch. No other effects approached significance in the Non-Cued trials (*ts*<1.6, *n.s.*).

Overall, these findings suggest that task condition-based variability in the peak latency of the pupil response is related to the Switch factor, either as a main effect or as an interaction with distractor congruence or block context. The lack of statistically significant findings on Uncued trials is consistent with the findings of Experiment 1, because there were no effects of Congruence or Block Type independent when a Switch factor could not be examined directly.

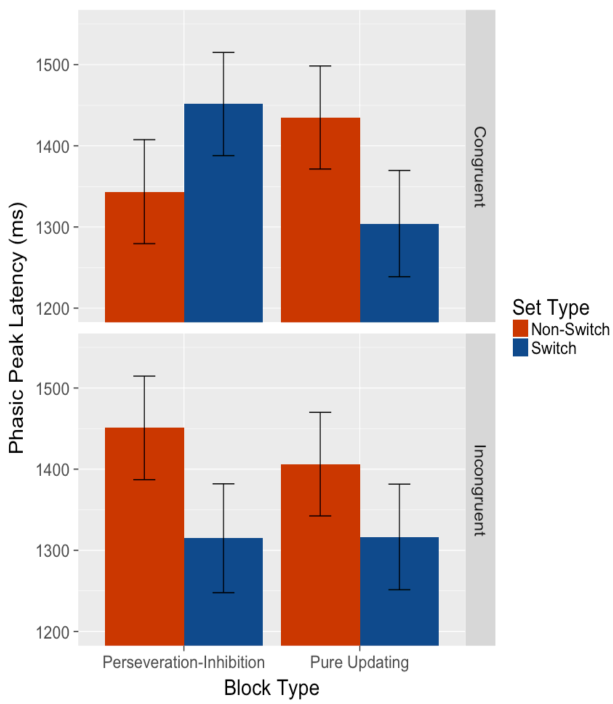

Figure 23. Phasic Latency as a function of Set Type, Congruence, and Block Type on Cued trials.

Within-Subjects Pupil Effects on Task Performance (N=28)

Here, too, models were run separately for Cued and Uncued trials, and for the phasic magnitude and latency predictor variables. This experiment did allow us to directly examine the relationship between pupil measures and attentional flexibility, by examining performance differences on Cued trials from Switch versus Non-Switch sets.

The correlation (VIF) between tonic pupil size and phasic magnitude and latency were .46 (1.29) and .22 (1.05) respectively, ensuring that model predictor variables are not too highly collinear.

RT

Cued Trials. On cued trials, large phasic Magnitude predicted slower RTs overall (β =.76, *SE*=.020, t(2486)=3.73, *p*<.001); however there was no main effect of Latency (*t*(2486)=1.50, *p*=.13). In this model, it was possible to directly assess the relationship between pupil measures and Switch performance. There was a significant interaction between phasic Latency and Switch (β =4.46x10^{-5}, *SE*=2.24x10^{-5}, *t*(2483)=1.99, *p*=.047), which demonstrated that trials with longer latencies had larger switch costs. There was additionally a marginal interaction between Switch, Block Type, and phasic Magnitude (β =-.77, *SE*=.43, *t*(2483)=-1.78, *p*=.075), with large phasic pupil dilations predicting larger switch costs on Pure Updating blocks, but not on Perseveration-Inhibition blocks. Pre-trial Tonic pupil size also interacted with Switch and Block Type (Magnitude model: β =-.080, *SE*=.028, *t*(2482)=-2.83, *p*=.004; Latency model: β =-.049, *SE*=.025, *t*(2482)=-1.92, *p*=.055). As shown in Figure 24, increasing tonic pupil size predicted larger

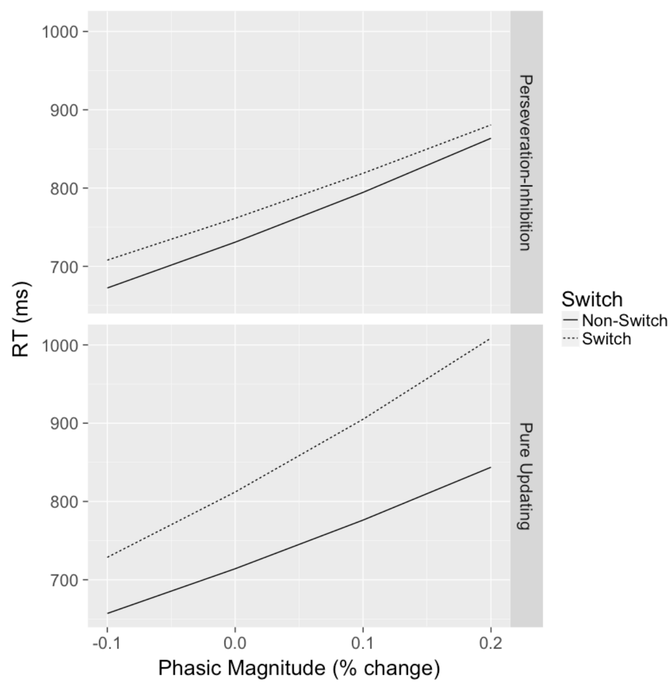

Figure 24. RT as a function of Switch Condition, Block Type, and phasic Magnitude on Cued trials. trials.

switch costs on Pure Updating blocks, but smaller Switch Costs, driven by increased Non-Switch RTs, on Perseveration-Inhibition blocks. Interestingly, phasic Magnitude^2 was also conditionally related to distractibility, as indexed by a 3-way interaction between Switch, Congruence, and Magnitude^2 (β =-7.30, *SE*=3.20, *t*(3483)=-2.28, *p*=.023), as well as Congruence, Blocktype, and Magnitude^2 (β =-6.21, *SE*=3.03, *t*(2484)=-2.05, *p*=.040). The first interaction indicates that on Switch trials, large and small phasic pupil magnitudes predict slower responding on Congruent trials and faster responding on Incongruent trials. Second, large and small phasic magnitudes predict increasingly negative incongruence costs, especially on Perseveration-Inhibition blocks.

Uncued Trials. Paralleling the findings of Experiment 1, both models had significant positive main effects of both phasic (Magnitude: β =.60, *SE*=.10, *t*(11340)=5.92, *p*<.001; Latency: β =3.13x10^{-5}, *SE*=7.51x10^{-6}, *t*(11340)=4.17, *p*<.001) and tonic (Magnitude model: β =.027, *SE*=.0067, *t*(11340)=4.04, *p*<.001; Latency model: β =.019, *SE*=.0062, *t*(11340)=3.11, *p*=.002) pupil measures. Additionally, there was a significant main effect of phasic Magnitude^2 (β =-1.92, *SE*=.95, *t*(11340)=-2.03, *p*=042), which was marginally significant for Latency^2 (β =-1.75x10^{-8}, *SE*=9.49x10^{-9}, *t*(11340)=-1.84, *p*=.066). In the latency model the main effect of Tonic Pupil^2 additionally reached marginal significance (β =.010, *SE*=.0056, *t*(11340)=1.80, *p*=.073). These findings are largely consistent with those of Experiment 1, with both tonic and phasic pupil measures having a general effect on RTs. We were also interested in the relationship between pupil measures and distractibility, evidenced by an interaction with the Congruence factor. Phasic Magnitude^2 interacted marginally significantly with Congruence (β =.23, *SE*=1.35, *t*(11340)=1.72, *p*=.085), indicating that phasic responses that were farther from the mean led to larger incongruence costs, and thus greater distractibility. Additionally, in both models there was a significant 4-way interaction between the 3 task factors and Tonic Pupil Size^2 (Magnitude model: β =-.046, *SE*=.016, *t*(11340)=-2.80, *p*=.005; Latency model: β =-.042, *SE*=.016, *t*(1134)=-2.56, *p*=.011). As shown in Figure 25, the effect of tonic pupil^2 had very different effects across Block Types and Switch Sets, with pupil sizes further from the mean leading to increased incongruence costs on Non-Switch sets of Perseveration-Inhibition blocks, but reducing incongruence costs, and even leading to better performance on Incongruent than Congruent trials on Switch sets of Perseveration-Inhibition blocks and Non-Switch sets of Pure Updating Blocks. Interestingly the quadratic phasic pupil measures also interacted significantly with Switch Set (Magnitude^2: β =3.13, *SE*=1.40, *t*(11340)=2.28, *p*=.023; Latency^2: β =2.73x10^{-8}, *SE*=1.37x10^{-8}, *t*(11340)=2.00, *p*=.045). This interaction suggests that even though participants were not actually switching on the uncued trials, phasic responses and latencies that were far from the mean (I.e. large or small) predicted slower performance on Switch

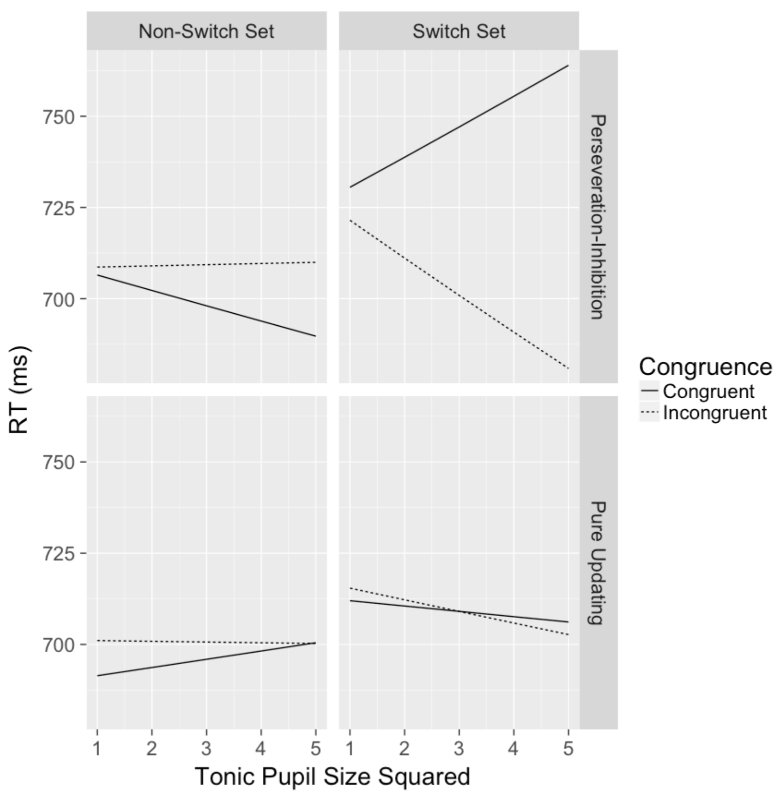

Figure 25. RT as a function of Set Type, Congruence, Block Type, and Tonic Pupil^2 on Uncued trials.

sets, when participants have recently switched, but not on Non-Switch Sets.

Overall, this experiment allowed us to directly test our question about the effects of pupil measures on the ability to flexibly switch the focus of attention. Our results suggest that longer phasic latencies predict slower switching. Additionally, the effects of tonic pupil size on switching varied across block contexts, with larger tonic pupil size predicting slower switching on Pure Updating blocks, while not affecting switch RTs on Perseveration-Inhibition blocks. This finding suggests that high baseline LC-NE activity may interfere with switching when it is necessary to inhibit a previously-relevant stimulus. In Experiment 1, we did not observe effects of pupil measures on Congruence; however with this updated design, some effects did emerge. On Switch trials, having large or small magnitude pupil dilations facilitated performance on Incongruent, relative to Congruent trials. On Uncued trials, on the other hand, there was marginal evidence that large and small phasic dilations were predictive of larger incongruence costs. Tonic pupil size also appears to have non-linear, context-dependent effects on distractibility across conditions.

Error Rate

In Experiment 1, tonic pupil size had context-dependent effects of error rate-linked measures of distractibility. Specifically, larger tonic pupil size was predictive of smaller incongruence costs on Perseveration-Inhibition blocks, but increased incongruence costs on Pure Updating blocks.

Cued Trials. Here, there was a marginally significant 3-way interaction between Set Type, Congruence, and Phasic Magnitude^2 (β =.11.95, *SE*=7.07, $t(172.41)=1.69$, $p=.093$). Phasic pupil responses that were farther from the mean predicted increased error rate Switch costs on Incongruent trials, but the effect was driven by a reduction in Non-Switch trial errors, rather than an increase in Switch trial errors. There was also a marginally significant 4-way interaction between all task factors and phasic Magnitude (β =3.18, *SE*=1.66, *t*(170.74)=1.92, *p*=.056). This effect suggests that larger phasic pupil responses predict increased error rate switch costs on Incongruent trials of Perseveration-Inhibition blocks and Congruent trials of Pure Updating blocks. On the other hand, on Congruent trials in Perseveration-Inhibition blocks and Incongruent trials of Pure Updating blocks, larger phasic pupil responses predict smaller error rate switch costs. No other effects involving phasic magnitude approached significance (*t*s<1.4, *n.s.*). In the latency model, there was a marginally significant interaction between Block Type and Latency^2 (β =-1.57x10^{-7}, *SE*=8.80x10^{-8}, *t*(175.2)=-1.75, *p*=.083), which suggests that latency had no effect on error rates in Perseveration-Inhibition blocks, but on Pure Updating Blocks, trials with early and late latencies had larger error rates. Additionally, there was a marginally significant 4-way interaction between Set Type, Block Type, and Tonic Pupil^2 (magnitude model: β =.13, *SE*=.082, *t*(173.8)=1.61, *p*=.11 latency model: β =.14, *SE*=.077, *t*(170.4)=1.78, *p*=.078). This trend-level effect suggests that increasing distance from the mean tonic pupil size predicts increased error rate switch costs on Perseveration-Inhibition blocks, but reduced switch costs on Pure Updating blocks. Overall, the relationship between tonic and phasic pupil measures and our index of flexibility in the error rate analyses appears to be dependent on both the block context as well as the congruence of the distractor letter.

Uncued Trials. No error rate effects reached significance in the models with uncued trials (*t*s<1.6, *n.s.*).

Overall, the pupil effects on error rate were largely different from those in Experiment 1. Although both experiments demonstrated highly context-dependent effects of pupil measures on distractibility, the specific pupil measures and direction of the effects are not necessarily consistent. For example, the finding that tonic pupil size exerted a variable effect on distractibility is consistent with Experiment 1; however the direction of the effect on Switch trials is different, and in this experiment the effect was present only on Cued trials, whereas in Experiment 1 it was present on both cued and uncued trials. This and other discrepancies may have arisen as a result of changes in the study design, which here included the addition of Non-Switch cues, and sets. Additionally, it is possible that some of the effects from Experiment 1 require greater statistical power to detect. Thus, it will be important to clarify these effects with a second large sample.

Global Switch Effects. In Experiment 1, both tonic and phasic pupil measures interacted with global RT switch costs; however here, there was only one marginally significant interaction between Switch Condition and phasic $Magnitude^2$ (β =-2.34, *SE*=1.41, $t(11830)=-1.66$, $p=.097$), illustrating that phasic pupil dilations that were more distant from the mean had more negative global switch effects, which was driven by more errors on Non-Switch blocks. The direction of this effect is the same as that observed in Experiment 1. All other interactions between pupil measures and Switch Condition did not approach significance (*t*s<1, *n.s.*). In the error rate analysis, there was a significant effect interaction between Switch Condition and Tonic Pupil Size, which was only marginally significant in the Latency model (magnitude model: β =.20, *SE*=.089, $t(162.6)=2.22$, $p=.028$; latency model: β =.16, *SE*=.091, $t(164.1)=1.77$, $p=.078$). This effect indicates that whereas tonic pupil size had no effect on error rates in Non-Switch blocks, increasing tonic pupil size predicted more errors on Switch blocks.

Overall, while the finding that large and small phasic responses predict smaller global switch effects was replicated from Experiment 1, all other effects here are different than those observed previously. As with the other results, these discrepancies could be related to reduced power in this Experiment, or to changes in the task design, which introduced Non-Switch sets into Switch Blocks, and thus reduced the frequency of switching.

Eye Tracking Analyses

Here, we were interested in whether the key eye tracking findings from Experiment 1 (detailed below) would replicate in an independent. Additionally, with the updated experimental design, it was possible to disentangle the presence of a cue from the observed Switch effects, to determine whether switching per se leads to increased probability of target fixation.

Task Effects on Fixations (N=19)

Probability of fixating on target and distractors. In this sample, participants first fixated on the target on 76.5% of trials (*SD*=11.3%), on the letter distractor on 12.4% of trials (*SD*=8.1%), and on the irrelevant symbol on 5.8% of trials (*SD*=4.8%), and these probabilities were highly consistent with those from Experiment 1.

In the target probability model, there was a marginally significant main effect of Cue, which indicated that participants were 5.8% more likely to fixate on the target first on Cued trials (β =.058, *SE*=.030, $t(270)=1.94$, $p=.053$). No other effects in this model reached significance, including effects that would correspond to the main effects of Switch and Block Type observed in Experiment 1 (*t*s<1.4, *n.s.*).

Results from the model predicting probability of first fixating on the distractor letter also indicated a main effect of Cue, indicating that on Uncued trials, participants were 6.2% more likely to fixate on the distractor (β =-.048, *SE*=.021, *t*(270)=-2.38, *p*=.018). There was additionally a 2-way interaction between Cue and Set Type (β =.069, *SE*=.029, *t*(270)=2.38, *p*=.018), which indicates that although cued trials were on average associated with less distraction by the irrelevant letter, Switch trials did not show this Cued trial advantage, and exhibited the largest probability of fixating on the distractor (Figure 26). No other effects in this model reached significance (*t*s<1.2). Taken together, these results suggest that the profile of reduced susceptibility to fixating on the target and increased fixation on the target on Switch trials from Experiment 1 was most likely driven by the presence of a cue, rather than by Switching per se. This explanation more closely agrees with other work suggesting that individuals are more distractible when switching (e.g. Dreisbach & Wenke, 2011). Unlike in Experiment 1, we did not observe any effect of Block Type on the probability of distractor fixation.

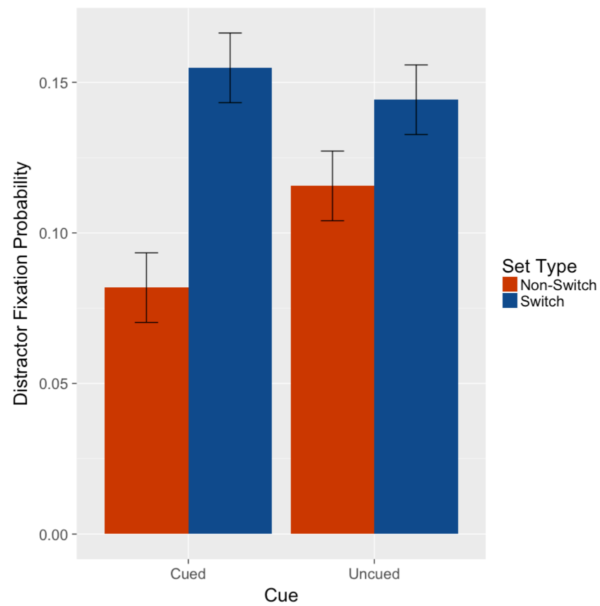

Figure 26. Distractor fixation probability as a function of Cue and Set Type on Uncued trials. trials.

We also examined the effects of task on the probability of first fixating the irrelevant symbol; however, there were no significant effects in this model, which also contrasts with the findings of Experiment 1, in which Switching, Congruence, and Block Type were all relevant to the likelihood of irrelevant symbol fixation.

Time to fixate on target. In Experiment 1, participants were slower to fixate on the target in Perseveration-Inhibition blocks. Here, however, no effects of task on the time to fixating on the target reached statistical significance (ts<1.3, *n.s.*).

Pupil Effects on Fixations (N=18)

To determine how pupil measures influenced the probability of fixating on target and distractor stimuli across task conditions, pupil measures were entered into the above models. As was done in the pupil analyses, Cued and Uncued trials were examined separately, in order to avoid having cue presence, a potential pupillary confound, influence results.

Probability of fixating on target and distractors. In the target fixation models for Cued trials, there was a significant 3-way interaction between Set Type, Block Type, and Latency^2 (β =-8.66x10^{-7}, SE=3.69x10^{-7}, $t(88.5)=2.35$, p=.021), in the context of a significant 4-way interaction that also included Congruence (β =1.21x10^{-6}, SE=4.85x10^{-7}, $t(89.6)=2.49$, p=.015). As shown in Figure 27, this finding suggests that on Perseveration-Inhibition blocks, having an early or late latency predicted a reduced probability of fixating on the target on Congruent Switch trials, but an increased probability of fixating on the target on Incongruent Switch trials. Latency^2 had less of an effect on fixation probability on Pure Updating blocks, however early and late latencies did predict increased probability of target fixation on Congruent Switch trials. There was additionally a marginally significant interaction between Congruence and phasic

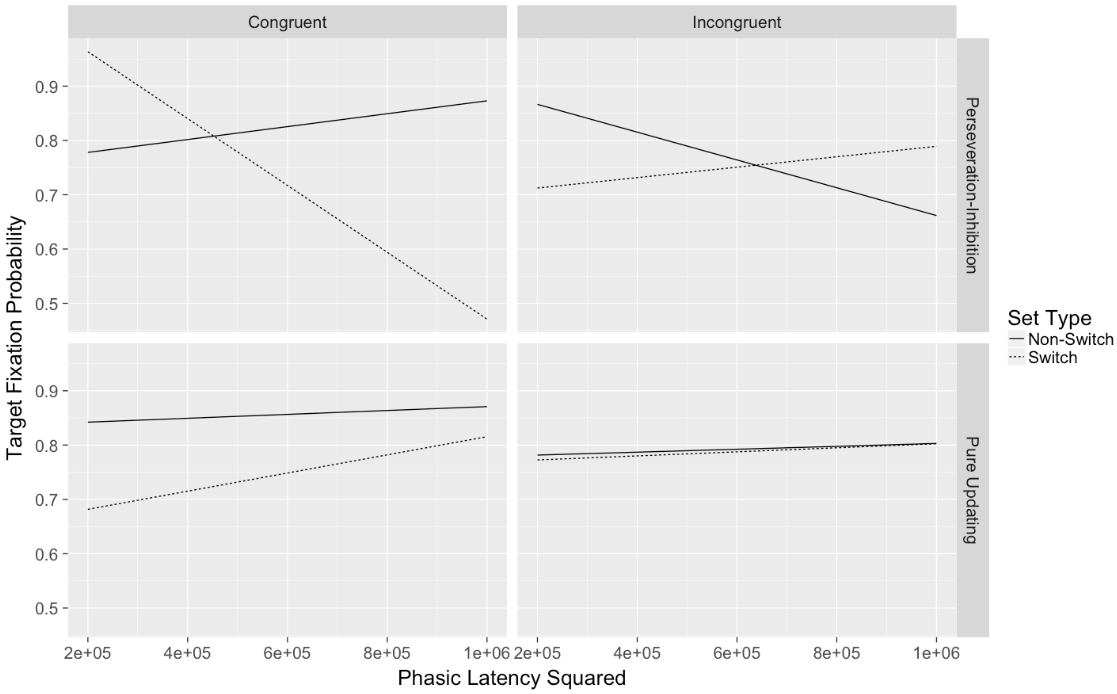

Figure 27. Target fixation probability on Cued trials as a function of Set Type, Congruence, and Block Type.

Magnitude (β =3.98, *SE*=2.28, *t*(85.5)=1.75, *p*=.084). Here, larger phasic pupil responses predicted reduced target fixation probability on Congruent trials, but had little effect on Incongruent trials.

Models predicting target fixation probability on Uncued trials indicated a marginally significant main effect of phasic Latency (β =-.165x10^{-4}, *SE*=9.52x10^{-5}, *t*(101.2)=-1.73, *p*=.087), as well as a significant interaction between Set Type and phasic Latency (β =2.16x10^{-4}, *SE*=1.07x10^{-4}, *t*(88.8)=2.01, *p*=.047). These effects suggest that longer latencies predicted reduced probability of target fixation overall, and particularly on Non-Switch Sets (I.e. trials when one has not recently switched sets). No effects of phasic magnitude or tonic pupil size approached significance (*t*s<1.6, *n.s.*).

Overall, these target fixation probability effects do not closely correspond to those from Experiment 1. Whereas those analyses suggested that Latency^2 and Magnitude^2 had general effects on target fixation on Switch and Non-Switch trials respectively, the pupil effects here are highly context-dependent.

Next, we examined pupil effects on probability of fixating the distractor letter. In Experiment 1, there were no pupil-related effects on distractor fixation probability. On Cued trials, there was a significant 3-way interactions between Set Type, Block Type, and phasic Latency^2 (β =6.37x10^{-7}, *SE*=2.40x10^{-7}, $t(87.3)=2.66$, $p=.009$) and a marginally significant interaction between Congruence, Block Type, and phasic Latency^2(β =6.37x10^{-7}, *SE*=4.07x10^{-7}, $t(88.1)=1.80$, $p=.076$). These interactions are perhaps better interpreted in light of a significant 4-way interaction between Set Type, Congruence, Block Type, and Latency^2 (β =-9.98x10^{-7}, *SE*=3.16x10^{-7}, $t(88.5)=-3.16$, $p=.002$). This interaction (Figure 28) suggests that on Perseveration-Inhibition blocks, increasing

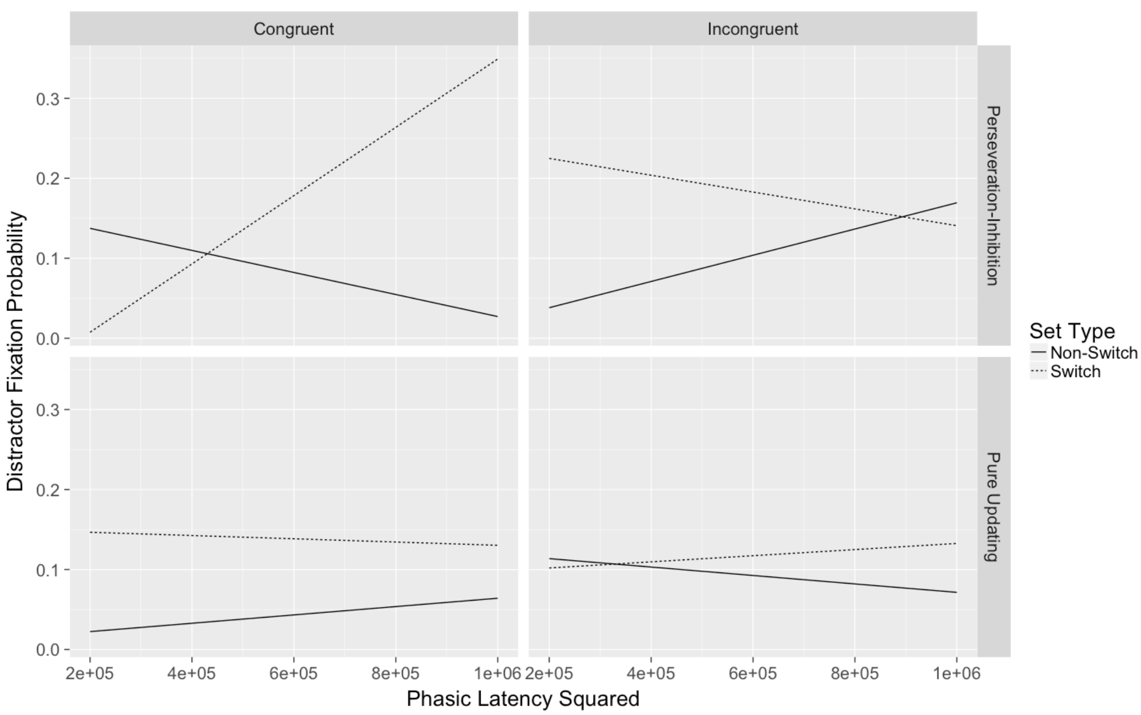

Figure 28. Distractor fixation probability on Cued trials as a function of Set Type, Congruence, Block Type, and phasic Latency^2.

distance from mean phasic latency (e.g. early or late peaks) predicted increased Switch Costs (I.e. greater likelihood of fixating the distractor on Switch trials) on Congruent trials, but reduced switch costs on Incongruent trials. On the other hand, on Pure Updating blocks, distance from mean phasic latency had little effect on distractor fixation probability on Switch trials, but a reduced probability of distractor fixation on Incongruent Non-Switch trials.

On Uncued trials, there was a 4-way interaction between Set Type, Congruence, Block Type, and Tonic Pupil^2, although it reached only marginal significance in the magnitude model (magnitude model: β =-.31, *SE*=.18, *t*(93.3)=-1.69, *p*=.095; latency model: β =-.36, *SE*=.17, *t*(90.5)=-2.06, *p*=.042). This interaction (Figure 29) indicated that on Pure Updating blocks, increasing distance from mean tonic pupil size predicted reduced or had little effect on distractor fixation probability. On Perseveration-Inhibition

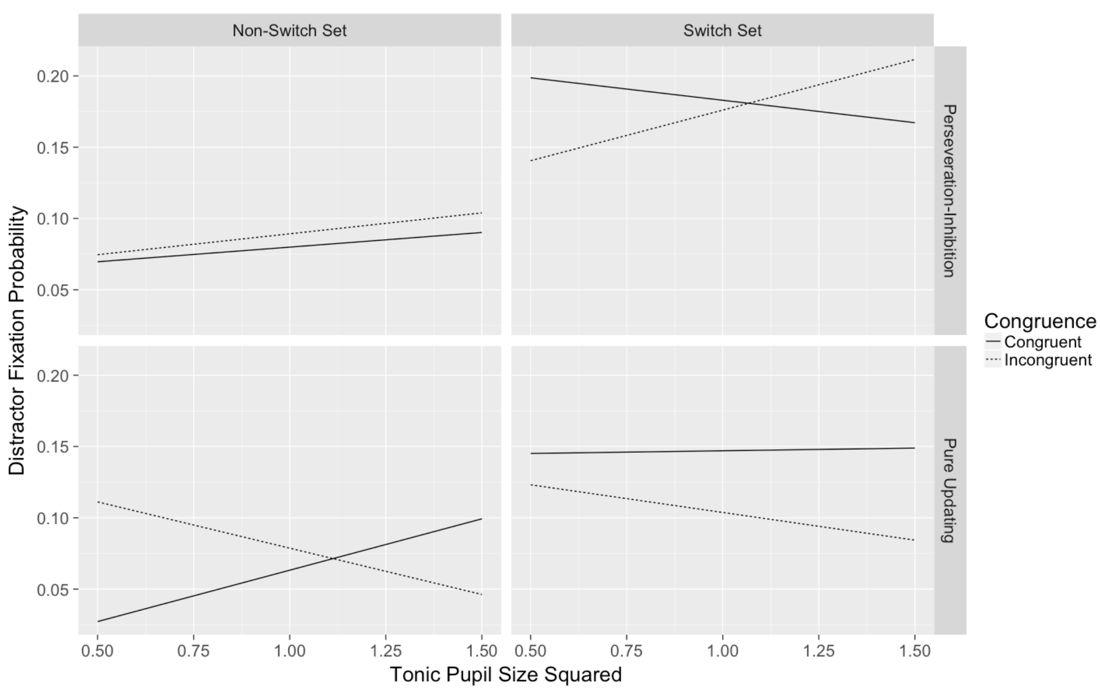

Figure 29. Distractor fixation probability on Uncued trials as a function of Set Type, Congruence, Block Type, and Tonic Pupil^2.

blocks, on the other hand, increasing distance from tonic pupil mean predicted increased probability of fixating on the distractor in most conditions, except for on Incongruent trials following a recent switch, which showed the opposite pattern.

Last, models were run to examine the effects of pupil measures on the probability of fixating the always-irrelevant symbol. In Experiment 1, however, we observed that phasic Latency was the only pupil index that was relevant to irrelevant symbol fixation probability. We had initially predicted that large tonic pupil size would predict greater general distractibility, and would thus predict greater probability of fixating on the symbol. Here, on Cued trials, larger tonic pupil was indeed marginally predictive of greater probability of fixating the distractor symbol (Magnitude model: β =.11, SE=.054, $t(93.1)$=1.96, p=.053; Latency model: β =.10, SE=.055, $t(93.7)$=1.84, p=.069). Phasic pupil measures also influenced probability of fixating the distractor symbol on Cued trials. There were interactions between Congruence and both phasic Magnitude (β =-1.79, SE=1.03, $t(87.7)$=-1.73, p=.087) and Latency (β =-1.31x10^{-4}, SE=7.40x10^{-5}, $t(89)$=-1.77, p=.081). Similarly, there were marginally significant 3-way interactions between Congruence, Block Type, and both phasic Magnitude (β =3.33, SE=1.72, $t(89.6)$=1.93, p=.056) and Latency (β =1.80x10^{-4}, SE=1.08x10^{-4}, $t(90.3)$=1.66, p=.10). These interactions ware largely driven by the relationship between phasic measures and distractor fixation probability on Incongruent trials, which was positive in Perseveration-Inhibition blocks, but negative on Pure Updating blocks.

On models predicting probability of fixating on the irrelevant symbol on Uncued trials, the only pupil-related effects to approach significance was a marginally significant interaction between Set Type and phasic Latency (β =-8.83x10^{-5}, SE=4.96x10^{-5}, $t(89.4)$=-

1.78, p=.079), in the context of a marginal 3-way interaction that also included Block Type (β =1.35x10^{-4}, SE=7.26x10^{-5}, t(89.4)89.5=1.86, p=.066). This interaction indicated that on Perseveration-Inhibition blocks, longer latencies predicted greater general distractibility on trials following a recent switch, and had little effect on trials on Non-Switch sets. On the other hand, on Pure Updating Blocks, longer latencies predicted a greater general distractibility on Non-Switch sets, and had little effect on Switch Sets. Thus, although phasic Latency appears to be relevant to irrelevant distractor fixation probability across both models; however differences in the study designs prevents direct mapping between findings of the two studies.

Time to fixate on Target. Here, we examined how pupil measures influenced the time it took for participants to fixate on the target. On Switch trials, there was a marginally significant main effect of Tonic Pupil^2 (Magnitude model: β =14.51, SE=7.94, t(1452.8)=1.83, p=.068; Latency Model: β =15.38, SE=7.89, t(1454)=1.95, p=.051), which suggests that on Switch trials, having large or small pre-trial pupil size predicted slower fixations to target. Tonic Pupil^2 also interacted significantly with Set Type (Magnitude Model: β =-25.41, SE=11.34, t(1453.8)=-2.24, p=.025); Latency model: β =-23.68, SE=11.11, t(1454)=-2.13, p=.033). This effect indicates that on whereas on Switch trials there was no clear relationship between Tonic Pupil^2 and fixation time, larger distance from mean tonic pupil size predicted slower fixation time on Non-Switch trials. Although most effects on Cued trials involved tonic pupil measures, there was also a significant interaction between Set Type and phasic Latency (β =.042, SE=.014, t(1455)=2.87, p=.004), in the context of a 3-way interaction that also included Congruence (β =-.037, SE=.021, t(1455)=-1.72, p=.085). These effects suggest that longer latencies predict slower target fixation times on Switch Trials and reduced fixation time on Non-Switch trials, and that this effect may be driven by Congruent trials. These effects are broadly consistent with those of Experiment 1, in which longer latencies predicted slower target fixation on Switch trials, and increasing distance from mean Tonic pupil size predicted slower target fixation on Non-Switch trials. It is important to note, however, that direct comparison is not possible because of differences in the study design.

Finally, we examined the effect of pupil measures on target fixation time on Uncued trials. Here, there was a significant main effect of phasic Magnitude (β =153.12, *SE*=63,94, *t*(6440)=2.45, *p*=.014), which suggested that large phasic pupil dilations predicted slower target fixation time. There was additionally a marginally significant main effect of phasic Latency^2 (β =-9.93x10^{-6}, *SE*=5.95x10^{-6}, *t*(6454)=-1.67, *p*=.095), suggesting that trials with early and late latencies tended to have shorter target fixation times. This effect is in contrast to a finding in Experiment 1 showing that on Non-Switch trials, larger Latency^2 predicted longer fixation times. Additionally, there was a significant interaction between Congruence and Phasic Latency^2 (β =2.04x10^{-5}, *SE*=8.70x10^{-6}, *t*(6450)=2.35, *p*=.019), which suggests that increasing distance from mean latency (e.g. early or late latencies) predicted faster target fixation on Congruent trials, but slower fixation on Incongruent trials. Tonic pupil measures also predicted target fixation time: There was also a significant 3-way interaction between Set Type, Congruence, and Tonic Pupil (magnitude model: β =18.22, *SE*=8.44, *t*(6448)=2.16, *p*=.031; latency Model: β =20.45, *SE*=7.83, *t*(6450)=2.61 *p*=.009). This interaction suggests that on Non-Switch sets, tonic pupil size had little effect on target fixation time, whereas on Switch Sets, larger tonic pupil size predicted faster fixations on Congruent trials, but slower fixations on Incongruent trials. There was additionally a marginally significant 4-way interaction between Set Type, Congruence, Block Type, and Tonic Pupil^2 (Magnitude model: β =-16.64, *SE*=10.01, *t*(6448)=-1.66, *p*=.097; Latency model: β =-17.54, *SE*=9.93, *t*(6450)=-1.76, *p*=.077). As depicted in Figure 30, this interaction suggests that on both Non-Switch sets on Perseveration-Inhibition blocks and Switch sets on Pure Updating blocks, there is a similar pattern, with increasing distance from the mean tonic pupil size predicting slower target fixations, especially on Incongruent trials. On the other hand, the relationship between tonic pupil size is much weaker on Switch Sets of Perseveration-Inhibition blocks and Non-Switch Sets of Pure Updating Blocks.

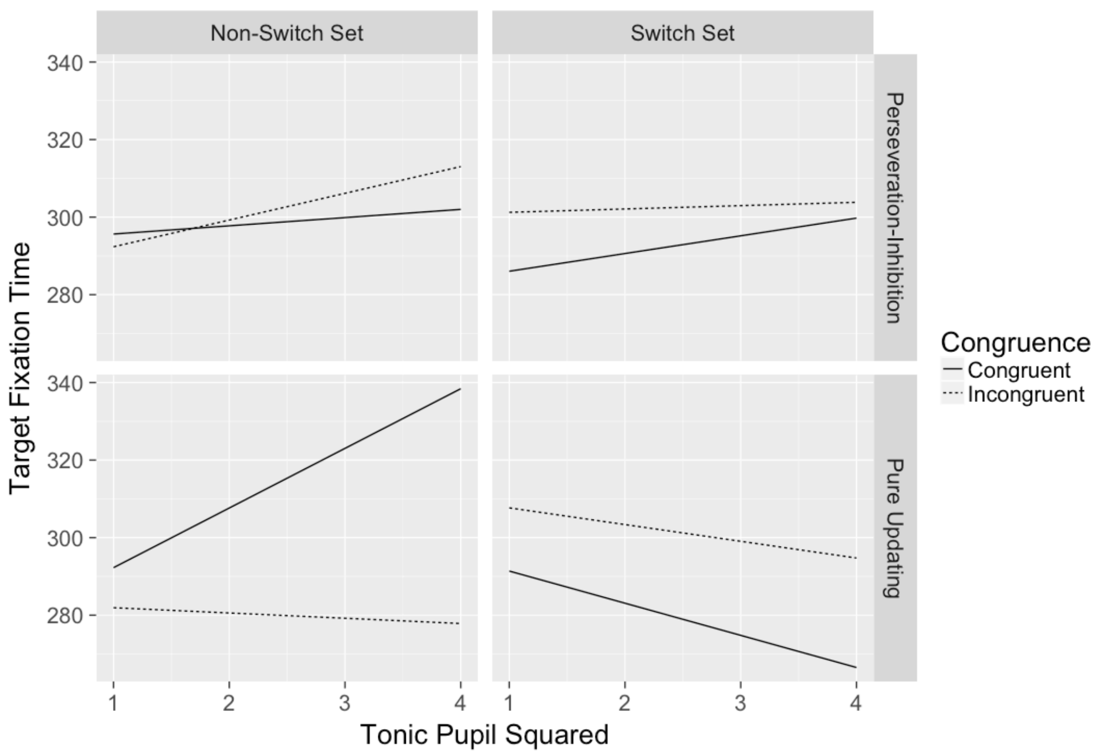

Figure 30. Target fixation time on Uncued trials as a function of Set Type, Congruence, Block Type, and Tonic Pupil^2.

Overall the fixation findings from this Experiment are much more condition-dependent than those in Experiment 1, as evidenced by a larger number of high-level interaction effects. The smaller number of condition-dependent effects in Experiment 1 may be attributable to the lack a separate Cue factor. Because of this lack of consistency, it will be important to replicate the eye tracking effects observed here in an independent sample using a task that also includes a Cue factor.

Overall, this experiment allowed us to directly assess the effect of switching, disentangled from the presence of a cue, and its relationship with pupil measures. Aside from the novel analyses testing the effect of Switch, the other effects show both convergence and divergence from Experiment 1. While the behavioral RT effects are largely consistent, there are notable differences in the error rate behavioral analyses. Although there was some overlap between the pupillary and eye tracking results, there were also several critical differences.

One potential limitation of both Experiments 1 and 2 is that in order to accurately capture trial-by-trial indices of both tonic and phasic pupil, we needed to introduce a long inter-stimulus interval (ISI), which allows sufficient time for the pupil to return to baseline following a phasic response. This relatively long (3.5ms) interval between trials may have inadvertently altered the nature of the task, by increasing the need for participants to remain vigilant and maintain an attentional set during the long pauses. The following experiment aims to address this issue by determining the consistency of the behavioral results on a task with a shorter ISI.

CHAPTER IV

EXPERIMENT 3

One goal of Experiments 1 and 2 was to assess the respective contributions of tonic pupil size and task-related phasic pupil dilation to performance to a single trial. Because of the delayed nature of the phasic pupil response, a long ITI (3500ms) was necessary to allow adequate time for the pupil to return to baseline to obtain an accurate measure of tonic pupil size on the following trial. As a result, the attention shifting task had a slower pace than other tasks that have been used to assess attentional flexibility. For example, Dreisbach and Goschke (2004) had a 1500 ms interval between the end of a trial and the stimuli for the following trial. Consequentially, it is possible that slowing the task altered the balance of cognitive processes at work, by introducing the need to remain vigilant across pauses between task stimuli. In this final experiment, the ITI was reduced to determine whether subjects perform the task similarly at a faster pace.

Method

Participants

To reach a target of 32 subjects, 39 students at the University of Oregon took part in this study for partial course credit. Eligibility criteria were the same as for the previous experiments. Data from 2 subjects were excluded prior to analyses because of a lack of time to finish the task. The remaining 37 participants had a mean age of 19.27 (*SD*=1.47) and included 28 females (75.7%) and 9 males (24.3%)

Procedure

The procedure was identical to that for Experiment 2, except that participants performed the task without eyetracking, and in a separate room from the experimenter. Additionally, because of the shortened ITI, the experiment was shorter, lasting only approximately 1 hour.

Materials and Apparatus

Attention Shifting Task. The task used in this experiment was similar to that used in Experiment 2, except that it was modified to have an ITI of 1500ms, instead of 3500ms. The interval between the color word cues and the first trial of each set remained the same at 4000ms. As in Experiment 2, cues could signal either the need to switch target colors or to continue attending the same target color. Stimulus arrays remained on the screen until participant response, as in Experiment 1.

Apparatus. As in the previous experiments, the task was run with Psychtoolbox in MATLAB. The task was presented using an iMac computer with a 27’’ monitor and a resolution of 2560x1440 pixels.

Data Processing and Analysis

Data processing and analysis procedures were identical to those used for the behavioral data in the previous two experiments. All participants had an error rate less than 25% (Mean error rate=5.42%, *SD*=3.90%).

Results and Discussion

RT

To assess the effects of the faster task on indices of flexibility and distractibility, the data were entered into identical LMMs to those used for Experiment 2. The null model indicated an ICC of .30. Also of note, the overall mean RT in this experiment was

745.29ms, which is similar to that for Experiment 2 (742.41ms).

In the prediction model, the behavioral indices of flexibility were similar in direction to those for Experiment 2: There were significant main effects of both Cue (β =.12, *SE*=.013, *t*(22120)=9.17, *p*<.001) and Set Type (β =.017, *SE*=.0081, *t*(22120)=2.05, *p*=.041), as well as an interaction between the factors (β =.11, *SE*=019, *t*(22120)=5.99, *p*<.001). As shown in Figure X, the cue costs were larger for Switch Sets (151.21ms) compared to Non-Switch Sets (101.12ms). Additionally, the 2-way interaction between Set Type and Block Type was marginally significant (β =.020, *SE*=.012, *t*(22120)=1.73, *p*=.084); however this is better understood in the context of the significant 3-way interaction between Cue, Set Type, and Block Type (β =-.090, *SE*=.026, *t*(22120)=-3.42, *p*<.001). The 3-way interaction was consistent with Experiment 2, demonstrating larger switch costs (e.g. cue costs on Switch Sets) on Pure Updating blocks than on Perseveration-Inhibition blocks (Figure 31). Overall, the direction of the flexibility-related effects are very similar to those for the two prior experiments. It is worth noting, however, that the cue costs for both Switch and Non-Switch sets was

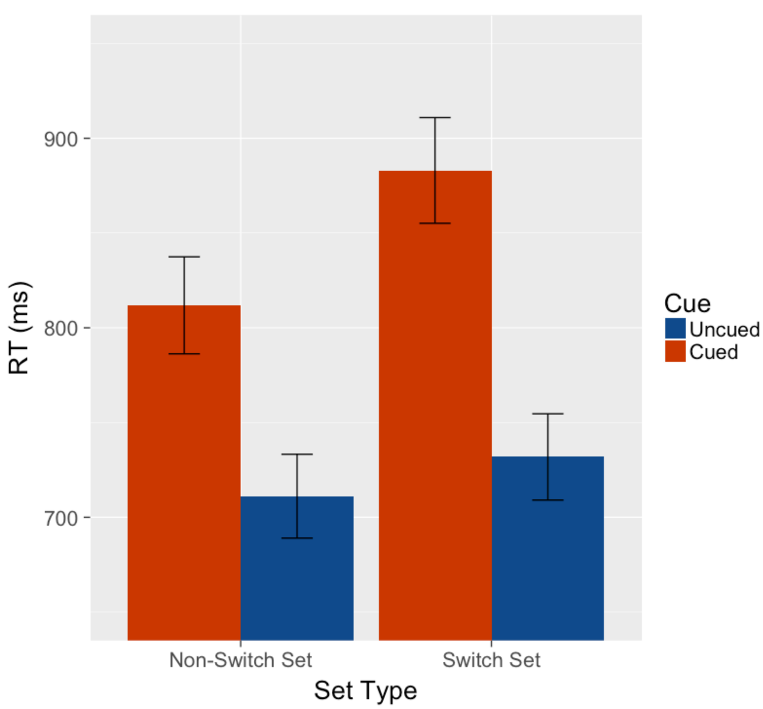

Figure 31. RT as a function of Cue and Set Type in Experiment 3.

much larger than those in Experiment 2. One possible explanation for the larger cue costs observed here is that in this experiment, the time between the cue and the first trial of a set (4000ms) was much larger than the 1500ms ISI. The decision to keep the cue-trial interval at 4000ms was made to keep a consistent time for switching across experiments, however in the faster context of Experiment 3 it may have affected participants' responding rhythm to a greater degree. No other main or interactive effects reached significance (*t*s<1.3, *n.s.*), including the main effects of Congruence and Block Type; thus, there was no evidence that participants were slowed by Incongruent trials or Perseveration-Inhibition blocks, unlike in the previous experiments.

Next, we examined the correlations between switch and congruence costs across overall, and for each Block Type (Table 5). In contrast to Experiments 1 and 2, there was no relationship between switch costs on Pure Updating and Perseveration-Inhibition blocks. Consistent with the prior experiments, there was no relationship between switch costs and incongruence costs, and also between incongruence costs for different Block Types. Also consistent with prior experiments, the reliability of both switch and incongruence cost measures was quite low, and so these findings should be interpreted with caution.

Table 5. *Correlations between switch and incongruence costs across Block Types*

	1.	2.	3.	4.	5.	Reliability	95% CI
1. Switch Cost	-					.26	-.07-.54
2. Switch Cost - Pure Upd	.79 ***	-				.18	-.15-.48
3. Switch Cost - PersInhib	.77 ***	.22	-			.27	-.06-.55
4. Incongruence Cost	-.03	-.08	.03	-		.03	-.30-.35
5. Incongruence Cost - PureUpd	.09	.11	.03	.79 ***	-	.13	-.21-.43
6. Incongruence Cost - PersInhib	-.13	-.23	.02	.72 ***	.16	-.09	-.40-.24

Note: *** *p*<.001, ** *p*<.01, * *p*<.05, . *p*<.10

Error Rate

The ICC of the null model for error rate was .31. In the full model, there was a significant interaction between Set Type, Congruence, and Block Type (β =.044, *SE*=.022, *t*(540)=2.02, *p*=.044), suggesting that Incongruent trials were particularly costly for error rates on Switch Sets of Perseveration-Inhibition blocks. All other effects did not reach significance (*t*s<1.6, *n.s.*).

Global Switch Effects

Models comparing performance on Switch versus Non-Switch block contexts indicated significant global switch costs in RT (β =.024, *SE*=.0074, *t*(19180)=3.28, *p*=001), with participants responding 17.29ms more slowly on uncued trials on Switch blocks. Similarly, the error rate analysis similarly showed that participants made 1.9% more errors on Switch blocks than on Non-Switch blocks (β =.019, *SE*=.0061, *t*(34)=3.09, *p*=.004). The finding of global RT switch costs in this experiment, in which the frequency of switch trials was also 50% that of Experiment 1, suggests that the lack of RT switch costs in Experiment 2 may be related to the fixed nature of the task timing, rather than to switch frequency.

Overall, the findings of Experiment 3, which used a faster ITI, suggest that many of the flexibility (e.g. switch)-related effects, as well as some of the distractibility (e.g. congruence)-related effects are consistent with those for the slower tasks used in Experiments 1 and 2.

CHAPTER V

EXPERIMENT 4

This final study replicates Studies 1-2, with the aim of determining the consistency of their findings. The large sample size enables analyses of both within-subjects pupil effects and between-subjects pupil and EBR effects with the updated experimental task that allows for direct comparison of pupillary correlates of flexibility by comparing Cued Switch and Non-Switch trials. Second, this study will test whether our indices of DA- and NE-linked individual differences in flexibility and distractibility are related to ecologically-valid and real-world behaviors.

Method

Participants

With the aim of reaching a complete sample of 100 subjects,117 students at the University of Oregon participated in this study. Recruitment was done through a combination of an online participant database and poster advertisements. To attract students who are interested in improving their academic performance, posters and online information asked the question “Do you want to be a better student?”. All participants were between the ages of 18-30, had normal or corrected-to-normal color vision, no history of significant psychological or neurological disorders, and were not taking medications that affect cognitive functioning. Participants were paid $10 per hour for in-lab sessions, $1 per questionnaire and a $1 bonus for completing all questionnaires, so participants could earn $60 for completing all parts of the study. Two participants withdrew partway through the first session, and so were not included in data analyses.

The remaining 115 participants completed at least the first session, and had a mean age of 20.02 (SD=2.10) and included 93 females (80.9%), 21 males (18.2%), and 1 who selected "Other/Prefer not to say" (<1%). Of these participants, 94 completed all components of the study (see Figure 32 for a full attrition breakdown). All study procedures were approved by the Committee for the Protection of Human Subjects at the University of Oregon.

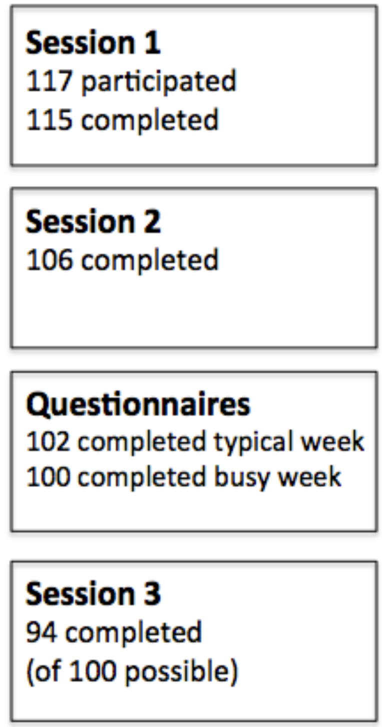

Figure 32. Attrition in Experiment 4.

Procedure

This study involved participants completing two longer in-lab sessions, followed by daily questionnaires for two weeks, and a brief final in-lab session. The measures collected in each component of the study are depicted in Figure 33.

Session 1. Upon arriving in the lab for the first session, participants provided their informed consent and completed a brief questionnaire about demographics, caffeine use, and the previous night's sleep. Next, the experimenter instructed participants on the attention shifting task and participants completed 3 brief practice blocks (approximately 30 trials in total). The eye tracker was then calibrated. Immediately following the first calibration, participants completed the first of two EBR baseline periods, and then began the task. Calibration was repeated after every 2 task blocks, and participants were given the opportunity to take breaks at each calibration point. At the end of the task, participants completed a final EBR baseline period. The session lasted approximately 2 hours.

Session 2. The second session began with a brief questionnaire to assess caffeine use and sleep. The eye tracker was then calibrated and participants completed an EBR baseline period. At this point, the experimenter directed the participant to a new room to complete the 90-minute internet search task. Finally, participants returned to the eye tracker to complete another EBR baseline period, after which they were dismissed. This session also lasted 2 hours.

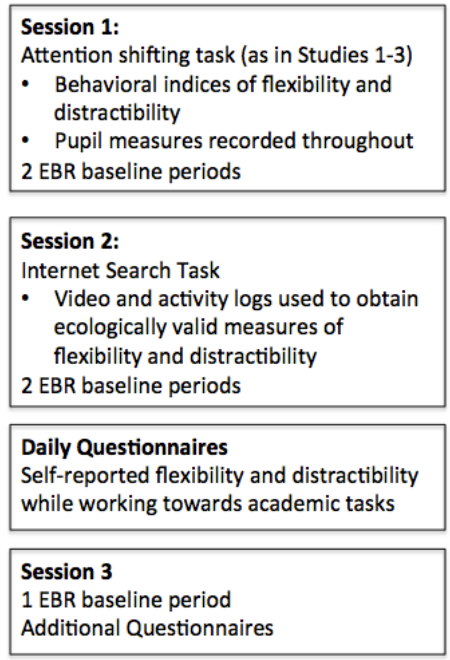

Figure 33. Measures collected at each session of Experiment 4.

Daily Questionnaires. Between the second and third sessions, participants completed brief (1-2 mins each) daily questionnaires for two weeks. The questionnaire weeks were selected by each participant to occur during one "typical" and one "busy" academic week. Questionnaires were sent to participants by email at 5pm each day, beginning on Monday and continuing through Sunday.

Session 3. The third session also began with a questionnaire, in this case to measure various individual differences (see below), in addition to caffeine use and sleep. Participants then completed a final calibration and EBR baseline period, and were then given the opportunity to ask questions about the study, and dismissed. This session lasted approximately 20 minutes.

Materials and Apparatus

Attention shifting task. The attention shifting task served to measure individual differences in the stability and flexibility of cognitive control, in order to determine the extent to which this lab-based measure predicts more ecologically valid and real-world behaviors. The task is similar to that used by Dreisbach and Goschke (2004), and requires participants to attend letters presented in a target color while ignoring stimuli presented in other colors. The target color switches periodically, and participants must update their attentional set to attend the new color. The ease with which participants were able to shift their attention served as a measure of flexibility, while the extent to which participants' performance was affected by distractors indexed the stability of cognitive control. To successfully perform the task, participants must attend letters in a periodically-changing target color and ignore distractor letters.

Task trials were organized into Blocks, and Sets, with each block containing either 6 or 12 sets. Sets began with a color cue for 2000ms to indicate which color to attend on the upcoming set (e.g. BLUE). A fixation cross was then displayed for 4000ms prior to the first trial. Task trials included a 100ms pre-stimulus period, during which the fixation cross disappeared, followed by the stimulus array, which consisted of a target letter, a distractor letter, and an always-irrelevant distractor symbol. Characters in the array were displayed in 3 of 12 possible locations spaced evenly around the center of the display, and the letter positions were never repeated on multiple trials in a row. On each trial, letter stimuli were randomly selected from 5 vowels (D, F, H, L, V) and 5 consonants (A, E, I, O, U), and non-letter characters were selected from 5 symbols (&, %, ?, #, @). Target and distractor letter colors remained consistent across each set, and were selected from 6 possible colors, while the color of non-letter characters was selected from a different color list and remained consistent across an entire block of trials. The trial ended when participants made their response to indicate whether the target letter is a consonant or a vowel, at which point the array was replaced by a fixation cross for an inter-stimulus interval (ISI) of 3500ms. The number of trials per set was a randomly selected number between 4-6.

On half of sets, the color cue indicated that the target color had changed from the previous set (Switch sets), and on the other half the color cue indicated a repeat of the same target color (Non-Switch sets). The first trial in each set (Cued trial) was contrasted against all other trials (Uncued trials), and flexibility was indexed by examining the interaction between Set Type and Cue. Here, only Cued Trials from Switch sets require flexible updating of the attentional set, and so performance (RTs, error rates) on these trials relative to Cued trials on Non-Switch Sets can serve as a measure of flexibility.

In order to assess distractibility, the congruence between target and distractor letter was manipulated. On Congruent trials, both target and distractor required the same participant response (e.g. two vowels), whereas on Incongruent trials, target and distractor letters corresponded to opposite participant responses (I.e. one vowel, one consonant). Distractibility is indexed as the difference in task performance between Congruent and Incongruent trials - if participants are not effectively filtering out distractors, this would be reflected in poorer performance on Incongruent trials and possibly facilitation on Congruent trials.

Participants completed the task in 3 separate block contexts. On Non-Switch blocks, the target and distractor colors remained the same throughout the block (I.e. all cues were Non-Switch cues). Non-Switch blocks were included to assess global switch costs, which were operationalized as the difference in performance between Uncued trials on Switch Blocks and Non-Switch Blocks. There were two types of Switch blocks. On Perseveration-Inhibition blocks, switch cues directed participants to attend the color that had been the distractor letter in the prior block. Thus, on these blocks, participants alternated between attending and ignoring one of two colors, and switching would require inhibition of the previously-relevant color and overcoming the inhibition of the previously-irrelevant color. On Pure-Updating blocks, by contrast, at each switch point, both the target and distractor color were different colors from those in the previous set, and so performance on these blocks indexed a pure measure of updating the attentional set, independent of perseveration or overcoming inhibition.

Participants were informed prior to the start of a block whether it would be a Switch or a Non-Switch block. Non-Switch blocks contained 6 sets and were the first and last blocks of the experiment. Switch blocks contained 12 sets, and participants completed 6 of each type in an alternating order. Over the course of the experiment, participants completed 14 blocks and approximately 780 trials.

EBR baseline. EBR baseline periods required participants to look at a fixation cross in the center of the screen for 5 minutes. Participants were instructed to relax and do their best to continue to look straight ahead. After 38 sessions had been run, it came to our attention that 2 participants had actively tried not to blink during this period, and following that point, participants were explicitly told that they could blink naturally during this period.

Internet search task. The internet search task was designed to closely mimic goal pursuit in real-world academic situations while also allowing for direct observation of participants' behavior through video recordings and tracking of computer use. This task took place in a room with a desktop computer and a set of headphones, and participants had their belongings in the room with them during the 90-minute task period. Participants were instructed to create a "Study Guide" that could be used to teach study skills to an incoming freshman at the University of Oregon. Additionally, participants were told that they could use their own experiences to inform the guide, but were also encouraged to use the internet "to find out what the experts are saying about how to do well in college". Study guides were typed directly into a template in Microsoft Word, which contained several sub-headings for different academic skills to help participants structure their guides (e.g., Test-Taking and Remembering, Research Skills, Self-Care). Participants were told that they could use these sub-headings or create their own. To increase the self-relevance of the task, participants were told that they could receive an electronic copy of their Study Guide after the session if they would like. After the experimenter read the instructions, participants were left to their own devices to complete the task for 90 minutes. Participants were informed that because we are interested in how people use their time, they would be video recorded and their computer use would be tracked while they completed the task.

Videos and computer activity logs from the session were coded by 6 research assistants to obtain measures of participants' distractibility and flexibility during the task. Research assistants watched the videos at 5 times the speed, and assigned a number from 1 (completely on task) to 5 (completely off-task) for each 2-minute video segment to indicate the participant's distractibility. Because the research assistants could not see what was on the participant's screen, these ratings were made based on whether or not the participant was looking at the computer screen. After watching the entire video, coders also provided an additional global rating of their overall impression from 1 (extremely focused; essentially on-task the entire time) to 5 (not focused; seems distracted for most of the time). To check reliability, data from the first 10 subjects were coded by 2 raters each, and the one-way random effects intra-class correlation (ICC) was calculated using the ICC command in the psych package for R (Revelle, 2016). The ICC was .63 for the global judgments, .65 for the individual ratings for each 2-minute block, and .87 for the mean ratings across all 2-minute blocks. Because the mean ratings had sufficiently high reliability, this measure was chosen for all analyses involving video data. The remaining videos were each coded by one research assistant.

Activity logs were formatted as spreadsheets, with each row representing an event and columns specifying the program being used, the duration of the event, and URL, in the case of online events. Raters first assigned a code to each event to denote the type of activity: 1-Working on activity log; 2-Task-relevant website; 3-Neutral Website (e.g. Google.com, which could be used to search for task-relevant or task-irrelevant information); 4-Task-irrelevant website; 5-Other task-irrelevant activity (I.e. non-internet programs); 6-Idle). For each type of event, raters tabulated the number of events, the total time on that activity type, and the mean time of each activity by averaging the total time by the total number of events of each type. For the task-relevant and task-irrelevant website events, the number of independent events was also tabulated by counting the number of different URLs visited to differentiate participants who visited a lot of different websites from those who visited few websites but returned to each several times. As a global index of how much participants switched between different events, coders also recorded the total number of events in each activity log. Reliability analyses examined consistency across raters for the first 10 subjects, using the counts for number of events and number of independent events, where relevant for each of the first 4 event types. The ICC was .90, indicating sufficient reliability, and so the remaining activity logs were each coded by one research assistant.

Coding assignments were made to ensure that a given participant's activity log and video were coded by different research assistants, and that the coding research assistant had not had prior contact with the participant while in the role of experimenter.

Questionnaire measures. At each lab session, participants completed a questionnaire about their caffeine intake and hours of sleep for that day, and how these compare to their usual daily amounts of caffeine and sleep. At the first session, participants also provided demographic information (age, gender, ethnicity). At the third session, participants answered additional questionnaires, including the Behavioral Activation and Inhibition Scales (BIS/BAS; Carver & White, 1994), Sensitivity to Punishment and Sensitivity to Reward Questionnaire (SPSRQ; Torrubia, Avila, Molto & Caseras, 2001), and the Barratt Impulsivity Scale (Patton, Stanford & Barratt, 1995).

In between Sessions 2 and 3, participants were emailed a questionnaire to be completed each evening about their work towards their academic goals for that day. Questionnaires were sent during a "busy" and a "typical" academic week, as selected by each participant based on their schedule, beginning on Monday and ending on Sunday. The Monday questionnaire first asked participants to list the top 3 academic tasks they hoped to complete that week, and to rate the importance of each. On the first day and on all subsequent days, participants responded about the amount of progress they made towards the tasks, how much effort they had put towards the tasks, and answered 7 questions to assess their daily experience of flexibility (e.g., "I switched tasks often today") and distractibility (e.g., "I felt distracted today"). On the final day, they additionally indicated how complete each task was, on a scale from 0-100% (see B for full questionnaire). Of particular interest for our planned analyses are estimates of each subject's daily experience of distractibility and flexibility.

Apparatus and Software. The attention shifting task was run in MATLAB using Psychtoolbox (Brainard, 1997; Pelli, 1997; Kleiner, Brainard & Pelli, 2007). The stimulus presentation computer was a Mac Mini with an 18" monitor with a resolution of 1024x768 pixels. Participant responses were made on a standard QWERTY keyboard.

Eye tracking was done with an Eyelink CL infrared eye tracker running Eyelink 1000 software (Version 4.56) with a sampling rate of 1000Hz. Participants completed the task with their heads stabilized in a chin rest located 50cm from the eye tracker.

Participants completed the internet search task was completed on an iMac computer with a 27" monitor. Video recordings were made using the iMac's built-in computer, and activity logs were produced using ActivTrak software (free version).

Data Processing and Analysis

Attention Shifting Task

Our general approach to analyzing data from Session 1 was to use linear mixed models (LMMs) to predict trial-based (for RT analyses) or condition-based (for error rate analyses) performance from task factors (Cue, Set Type, Congruence, Block Type), with subjects as a random factor. LMMs were be computed in R (R Core Team) using the lme4 and package (Bates, Maechler, Bolker & Walker, 2015).

As will be detailed in each section below, our approach to limiting the influence of outliers in the data varied depending on whether the outlier occurs at the single-trial level. Single-trial outliers that are greater than 3 standard deviations from the individual mean were removed from analyses. Outliers that occur at the participant or condition level (e.g. individual differences measures; means for a particular condition) were winsorized to 3 standard deviations from the group mean, in order to keep as many participants as possible in the analyses.

Behavioral data. All participants performed the task with greater than 25% accuracy, so all were included in behavioral analyses (*Mean* error rate=3.57%; *SD*=2.45). Cleaning of reaction time (RT) data involved removing all RTs less than 100ms and greater than 2000ms, transformation using the natural log to correct for non-normality (lnRT). Additionally, all RTs that deviated from a participant's overall mean lnRT by more than 3 standard deviations were be removed from RT analyses. Error trials were also be excluded from RT analyses. Error rate analyses predict participants' mean error rate for each condition. Cases in which the mean error rate was more than 3 standard deviations from the overall group mean were winsorized.

EBR data. Eye data were processed using the iTrackR package in R (Hubbard, 2015). Blinks were extracted from the eye tracker output by counting the number of intervals with missing pupil data during the EBR baseline periods with a duration between 50-500ms. EBR (in blinks per minute) was then calculated by dividing the number of blinks in each baseline period by 5, the number of minutes in the baseline period. Analyses of the effect of EBR on task performance used centered values for both

EBR and EBR2 as predictors, because of evidence for non-linear relationships between DA levels and task performance. To avoid undue influence of outliers, EBR values for participants with an EBR or EBR2 that diverged from the group mean by more than 3 standard deviations were winsorized. Participants who mentioned during debriefing that they had tried not to blink during the EBR baseline periods were excluded from EBR analyses.

Pupillometry data. Cleaning of data for pupil analyses first involved correction for blinks and other data loss using linear interpolation. The epoch of interest was defined as the period between -300ms prior to stimulus onset and 2500ms after stimulus onset. Trials that were missing more than 30% of data from this epoch (18.36% of trials) and 12 participants who were missing greater than 30% of data from this epoch on average will be removed from pupil analyses. Tonic pupil size was defined as the average pupil size in the 200ms prior to fixation offset (e.g. -300 to -100 prior to stimulus array onset). For within-subjects analyses, measures of tonic pupil size were normalized using Z-scores within each subject, to control for baseline differences in pupil size. For between-subject analyses, each subject's mean tonic pupil size was normalized using Z-scores across all subjects. Two separate indices of the phasic pupil response were examined. Phasic pupil magnitude was defined as the peak percent change in pupil size from the tonic pupil baseline over the 2500ms following stimulus onset, whereas phasic pupil latency was the time from stimulus onset to this peak pupil size. Statistical models also included quadratic terms for tonic and both phasic pupil measures, in order to test for the presence of non-linear effects. Trials with tonic or phasic pupil measures (including quadratic terms) that were greater than 3 standard deviations from the subject mean, or from the overall group mean were excluded from within-subjects analyses. In individual differences analyses, pupil values that deviated from the group mean by more than 3 standard deviations were winsorized.

Prior to testing hypotheses about the relationship between pupil measures and task performance, additional analyses assessed the effect of the task on pupil measures, to establish the pupillary responses across task conditions. Subsequent analyses examined the effects of pupil measures on indices of task performance (RT, error rate) across task conditions. Within-subjects pupil analyses entered either single-trial (for RT analyses) or aggregated-by-condition (for error rate analyses) pupil measures as predictors of task performance. Between-subjects analyses included each participant's mean pupil measures across the task, as well as their standard deviations, to serve as a measure of variability in pupil measures. All pupil predictors were centered prior to computation of quadratic terms and entry into statistical models (tonic via Z-scoring). Additionally, because the two measures of phasic pupil response are closely linked, phasic latency and phasic magnitude were examined in separate models. Separate models were also used to assess pupil effects on Cued and Uncued trials, because the presence of a cue could create a pupillary confound, by systematically altering tonic pupil size.

Eye Tracking data. Eye tracking data analyses assessed how the task factors, as well as pupil and EBR measures predict participants' tendency to first fixate on target letters, distractor letters and always-irrelevant symbols, as well as the amount of time it takes to fixate on the target. To classify participants' fixations, 12 elliptical (x radius=45, y radius=90) regions of interest (ROIs) were established, centered on each of the potential target locations. Data were then corrected for drift in a block-wise manner, using itrackR's drift_correct function and a minimum drift threshold of 15. Fixations were classified as "hits" if they fell within an ROI that contained the target or either distractor. 27 participants were excluded from fixation analyses if they fixated on the target in fewer than 75% of trials overall, in order to ensure that included participants were reliably making overt eye movements, and were not using a covert attention strategy. For fixation probability analyses, each participant's probability that their first "hit" fixation was to the target, the distractor letter, or the distractor symbol across each experimental condition was calculated. Probability values that were outside of 3 standard deviations from the group mean were winsorized. Probability analyses used separate LMMs to predict first fixation probabilities for the target and each distractor based on task condition, EBR, and pupil measures.

Separate analyses also examined how these predictors influence the time it takes for participants to first fixate on the target. These analyses examined only those trials in which participants did fixate on the target, and only fixations occurring while the stimuli were present on the screen were included. Any trials with fixation times outside of 3 standard deviations from each participant's overall mean were excluded from analyses.

Reliability of EBR Data

The reliability of EBR measures were examined, both within and across sessions. For within-session analyses, separate correlations were calculated for EBR at the beginning and end of sessions 1 and 2. For cross-session reliability analyses, the intra-class correlation coefficient (ICC) was computed for the first EBR measurement from each of the 3 sessions using a linear mixed model with subjects as a random factor. A second model also included gender, which has been shown to influence EBR in our own and others' work (e.g. Müller et al., 2007). In order to test whether the time of day significantly influenced EBR measurements, a third LMM also included the time of day as a fixed factor. Because of technical difficulties with the eye tracker, data from one subject is missing for both the Session 2 and the cross-session reliability tests.

Linking Attentional Flexibility and Distractibility to Ecologically-Valid and Real-World Goals Pursuit Behaviors

Our strategy for linking performance on the attention shifting task to participants' pursuit of real-world academic goals was to assume that the relation between the two (i.e., attention shifting performance and academic goals) would be at least partially mediated by observable behaviors during the ecologically valid task in the lab. In particular, we expected that any link between flexibility and distractibility on the attention shifting task and participants' nightly questionnaires would be mediated by participants' flexibility and distractibility during the internet search task. We first tested the strength of the links between our measures of flexibility and distractibility across the three main study components (attention shifting task, internet search task, nightly questionnaires), and also planned to test whether the relationship between flexibility and distractibility on the attention shifting task and the questionnaires is mediated by behaviors observed during the internet search task.

We then planned to examine whether individual differences in striatal DA tone or LC-NE system activity contributed to this relationship, by determining whether the variability in attention shifting task performance that is attributable to EBR and pupil measures predicts behavior on the internet search task and real-world academic goal pursuit. Below, the measures that were used to operationalize flexibility and distractibility across each of the three components of the experiment are detailed.

Attention Shifting Task. To index individual differences in flexibility and distractibility on the attention shifting task, participants' switch costs (Switch - Non-Switch RTs and error rates, from Cued trials only) and incongruence costs (Incongruent - Congruent RTs and error rates, for Uncued trials only) were computed for each level of the other Condition variables (i.e., Congruence and Block Type for switch costs; Set Type and Block Type for incongruence costs), as well as across all conditions.

Internet Search Task. Indices of flexibility on the internet search task included the total number of events in each subject's activity log, as well as the inverse of the mean time of on-task periods of typing the activity log and on task-relevant websites. The total number of events served as a global measure of participants' flexibility, and the mean time per event for typing the activity log and visiting task-relevant websites served as more specific indices of how often participants switched gears while completing the assigned task (where shorter times indicate greater flexibility). Indices of distractibility were the averaged distractibility score assigned across all 2-minute intervals of the video recordings, as well as the total amount of time doing task-irrelevant activities on the computer. Because we used multiple indices of flexibility and distractibility, we first examined whether indices are correlated with each other; however, no measures were correlated at greater than r=.6, so we examined each index separately.

Questionnaire Measures. The questionnaire that participants filled out each evening included 5 questions about distractibility and 2 questions related to task switching and flexibility. Reliability analyses determined that one item in the distractibility subscale ("I was distracted by school-related things today") was poorly correlated with the other measures, so it was removed from the scale. The resulting Distractibility scale had a Cronbach's alpha of .86, and the Flexibility scale had a Cronbach's alpha .71. The reliability for each subscale was adequate, items were combined to create composite measures of Flexibility and Distractibility. Participants' scores across for each day within a week of questionnaires were combined to obtain an overall index of flexibility and distractibility. Participants completed an average of 6.63 (*SD*=.86) during the typical week and 6.60 (*SD*=.93) questionnaires during the busy week. Participants (2 for each typical and busy weeks) who completed less than 4 questionnaires for a particular week were excluded from analyses. Because it is possible that individual differences in flexibility and distractibility will be more pronounced during busy versus typical weeks, separate correlations and mediation models were run for participants' busy and typical weeks.

EBR- and Pupil-Linked flexibility. In order to obtain a measure of EBR- and pupil-linked individual differences in cognitive control, we planned to run separate models predicting indices of flexibility and distractibility from Session 1 (I.e. switch costs, incongruence costs) from each EBR and pupil measure (EBR, EBR^2, phasic Latency, $Latency^2$, Latency SD, Magnitude, $Magnitude^2$, Magnitude SD, as well as Tonic pupil size and $Tonic^2$, and Tonic SD). The predicted values from these models were then to be used as measures of EBR- and pupil-related variability in flexibility and distractibility. Only those models in which EBR or pupil measures predicted significant variability in switch or incongruence costs would be examined in subsequent correlational and mediation analyses with measures from the internet search task and follow-up questionnaires.

To reduce the potential impact of outliers while also retaining as many participants in the analyses as possible, values of predictor or outcome variables in any of these cross-session analyses that are more than 3 standard deviations outside the group mean were winsorized to 3 standard deviations from the mean.

Results and Discussion

Session 1 Results

Behavioral Analyses (N=115)

Behavioral analyses established the effects of task factors (Cue, Set Type, Congruence, and Block Type) on RT and error rate. In addition to main effects of each factor, we also expected to see an interaction between Cue and Set Type, with larger Set Type effects on Cued trials, which would demonstrate the presence of a switch cost. We also expected that switch costs would be larger on Pure Updating blocks than on Perseveration-Inhibition blocks. We additionally tested for the presence of global switch costs, by comparing performance on Uncued trials in Non-Switch versus Switch blocks. Based on previous work with this task, we expected to observe global switch costs in both error rate and task performance.

RT. The null model that included RT and subjects as a random factor had an ICC of .30, indicating sufficient between-subject variability in RT to warrant the use of mixed models. Findings in the full model were largely as expected. There were main effects of Cue (β =.047, *SE*=.0068. $t(69840)=6.81$, $p<.001$) and Switch Set (β=.028, *SE*=4.31, *t*(69840)=6.57, *p*<.001), as well as a significant interaction between Cue and Switch Set (β =.11, *SE*=9.72, *t*(69840)=1.32, *p*<.001). This interaction indicated the presence of robust switch costs, with a much larger cue cost on Switch sets (91.98ms) compared to Non-Switch sets (33.81ms). There were additionally main effects of Congruence (β =.015, *SE*=.0043, *t*(69840)=3.45, *p*<.001) and Block Type (β =.016, *SE*=.0043, *t*(69840)=3.67, *p*<.001), which demonstrated that participants responded 11.22ms more slowly on Incongruent trials and 11.93ms more slowly on Perseveration-Inhibition blocks. The interaction between Switch Set and Block Type also reached significance (β =.015, *SE*=.0061, *t*(69840)=2.37, *p*=.018), suggesting that Switch Sets were slightly more costly on Perseveration-Inhibition blocks compared to Pure Updating blocks. Finally, the interaction between Cue, Switch Set, and Block Type was significant β =-.079, *SE*=.014, *t*(6984)=-5.78, *p*<.001). As hypothesized, this interaction (Figure 34) demonstrated that switch costs were significantly larger on Pure Updating blocks than on Perseveration-Inhibition blocks (107.55ms versus 59.83ms).

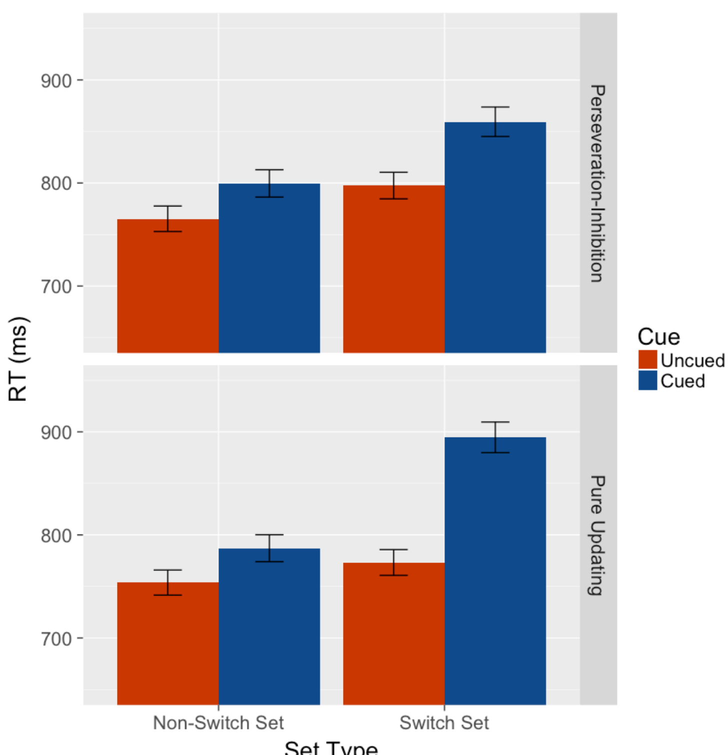

Figure 34. RT as a function of Cue, Set Type, and Block Type in Experiment 4.

To assess the relationships between our indices of flexibility and distractibility, correlations between switch and incongruence costs, both overall and for each block type were computed (Table 6). There was a marginally significant positive correlation between switch costs on Perseveration-Inhibition and Pure Updating blocks, which is in the same direction as previous studies. Interestingly, there was also a positive correlation between incongruence costs on the two block types, an effect that was not observed in the prior experiments. In general, switch costs were not correlated with the incongruence costs, with the exception of a negative correlation between the costs on Perseveration-Inhibition blocks. Similar to the previous experiments, low reliability of the switch and incongruence cost estimates was also an issue here.

Table 6.
Correlations between switch and incongruence costs across Block Types

	1.	2.	3.	4.	5.	Reliability	95% CI
1. Switch Cost	-					.35	.18-.50
2. Switch Cost - Pure Upd	.80 ***	-				.23	.05-.40
3. Switch Cost - PersInhib	.72 ***	.19 .	-			.16	-.02-.33
4. Incongruence Cost	-.12	.00	-.19 .	-		.10	-.08-.28
5. Incongruence Cost - PureUpd	-.09	.02	-.16	.76 ***	-	.04	-.14-.22
6. Incongruence Cost - PersInhib	-.15	-.03	-.20 *	.83 ***	.29 **	.12	-.07-.29

Note: *** p<.001, ** p<.01, * p<.05, . p<.10

Error rate. The null model for error rate had an ICC of .17. In the full model, and in contrast with previous experiments with this task, there was no main effect of Congruence (t(1710)=1.30, *n.s.*). However, there was a significant interaction between Switch Set and Congruence (β =.16 *SE*=.007, t(1710)=2.22, p=.026), in the context of a 3-way interaction between Set Type, Congruence, and Block Type (β =.035, *SE*=.010, t(1710)=3.49, p<.001). This latter interaction indicates that in Switch Sets specifically, error rate incongruence costs were larger on Perseveration-Inhibition blocks than on Pure Updating blocks (Figure 35). In other words, participants made more errors when required to ignore a color they had been previously attending when they had recently switched.

Global switch costs. The RT model assessing the effect of Switch Condition indicated the presence of robust (68.50ms) global switch costs (β =.048, *SE*=.004, *t*(60290)=11.93, *p*<.001). As expected, there were also significant global switch costs in error rate, with participants making 1.5% more errors on Switch blocks (β =.015, *SE*=.0030, *t*(114)=5.04, *p*<.001).

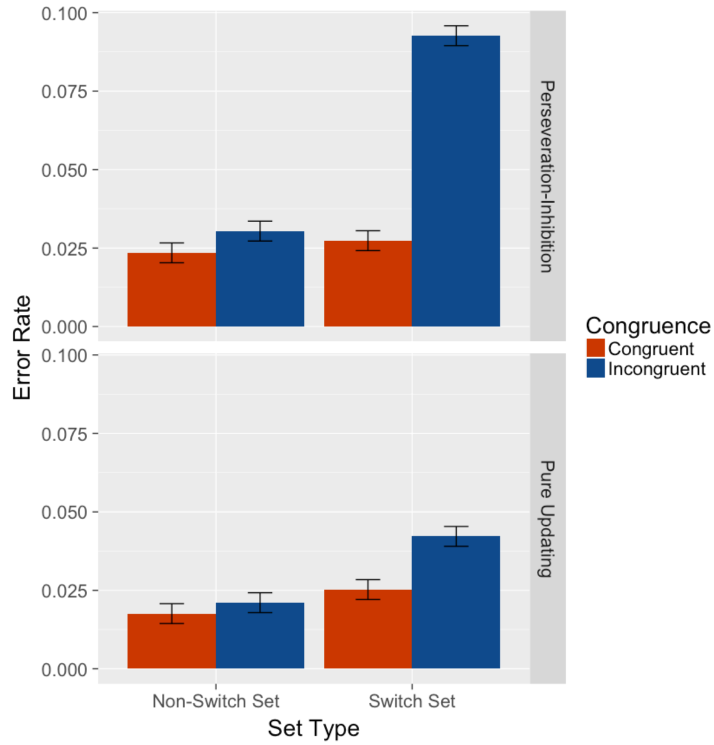

Figure 35. Error rate as a function of Set Type, Congruence, and Block Type in Experiment 4.

EBR Analyses (N=112)

In these analyses, EBR and EBR^2 were entered as predictors of RT and error rate, on the attention shifting task, with the goal of investigating the relationship between striatal DA and attentional flexibility. Because previous work, including our own, has demonstrated gender differences in EBR and EBR-cognitive control relationships, we also assessed how gender interacts with EBR-linked effects. We expected that higher EBR would predict larger switch costs, especially in male participants.

RT. In the RT model, there was a marginally significant main effect of EBR^2 (β $=2.28 \times 10^{-4}$, *SE*=1.92×10^{-4}, *t*(116)=1.76, *p*=.081), indicating a U-shaped relationship between RT and EBR. The hypothesized interaction between Cue, Set Type and EBR did not reach significance (β =-.0013, *SE*=.9.02x10^{-4}, *t*(68040)=11.47, *p*=.140). Interestingly, there was a significant interaction between Cue, Set Type and EBR^2 (β =1.83x10^{-4}, *SE*=7.79x10^{-5}, *t*(68040)=2.35, *p*=.019). This interaction showed that increasing distance from the mean predicted larger cue costs on Switch sets; in other words, there was a U-shaped relationship between EBR and switch costs.

Gender effects on RT (N=111). In our prior studies, males tended to show stronger effects of EBR on cognitive control than did females. When gender was added to the above model, however, there was no relationship between EBR, gender, and the flexibility-related factors Cue and Set Type (*t*s<.7, *n.s.*). There was, however, a marginally significant interaction between Block Type, EBR, and gender (β =-.0013, *SE*=6.67x10^{-4}, *t*(67450)=-1.95, *p*=.051). This effect showed that in males, higher EBR predicted slower RTs on all block types and more strongly for Pure Updating Blocks. In females, higher EBR had no effect on RTs on Pure Updating blocks, and a reduction in RT on Perseveration-Inhibition blocks.

Error Rate. Next, we examined the effect of EBR and EBR^2 on error rates across task conditions. Here, there were no significant EBR-linked effects (*t*s<1.3, *n.s.*).

Gender effects on error rate (N=111). Including gender in the above model did not yield any significant gender-linked EBR effects (*t*s<<1.1, *n.s.*).

Global switch effects. In the global switch model predicting RT, there was a significant interaction between EBR and Switch Condition (β =-.0027, *SE*=.0012, *t*(58780)=-2.20, *p*=.028), as well as a marginally significant interaction between EBR^2 and Switch Condition (β =-4.59x10^{-9}, *SE*=2.38x10^{-4}, *t*(58780)=-1.93, *p*=.054). These effects suggested that having a higher EBR, as well as having an EBR that was more distant from the mean, was predictive of smaller global switch costs, although the effect was driven by greater increases in Non-Switch block RTs, rather than a reduction in Switch Block RTs. In the error rate model, EBR measures did not relate to error rate switch costs (*t*s<.5, *n.s.*).

Gender effects on global switch effects (N=111). When gender was added to the RT and error rate global switch models, it did not interact with either EBR-linked global switch effect (*t*s<.8, *n.s.*).

Reliability of Pupil Measures (N=102)

Split-half reliability of mean-level and *SD* pupil measures are shown in Table 7. Reliability was similar to that for Experiments 1 and 2, suggesting that pupil measures were not reliable by-condition, and that tonic pupil measures were not reliable by-subject. One potential exception to this latter finding is that reliability was slightly higher for Uncued trials, suggesting that the presence of cues may be contributing to the poor reliability of tonic indices. However, given that reliability was still low compared to

Table 7
Reliability of Pupil Measures

	By Condition		By Subject	
	r	**95% CI**	***r***	**95% CI**
Magnitude	.60	.56-.63	.98	.97-.98
Latency	.53	.49-.56	.96	.94-.97
Tonic	.23	.18-.28	.57	.42-.69
Switch Cues			.50	.34-.63
Non-Switch Cues			.43	.25-.57
Uncued Trials			.66	.53-.75
Magnitude *SD*			.97	.96-.98
Latency *SD*			.97	.96-.98
Tonic *SD*			.36	.18-.52
Switch Cues			.10	-.09-.29
Non-Switch Cues			.09	-.10-.28
Uncued Trials			.38	.20-.54

Note: *** *p*<.001, ** *p*<.01, * *p*<.05, . *p*<.10

phasic measures, and also in the two Cued conditions, cue presence cannot completely account for the low reliability in the tonic pupil measures.

Task Effects on Pupil Measures (N=102)

To determine how pupil responses varied across task conditions, models predicted phasic Magnitude and Latency, from the factors Set Type, Congruence, and Block Type. Cued and Uncued trials were examined separately, because in our previous work as well as in this sample, there was a robust effect of Cue on tonic pupil size (β =.12, *SE*=.010, $t(53810)=11.99$, $t<.001$), which introduces a systematic source of variability into analyses of phasic pupil response. Thus, the effect of shifting one's attentional set on pupil measures can be assessed by examining the Set Type factor on Cued trials.

On Cued trials, there were no main effects of Set Type on measures of phasic pupil. There was, however, a marginally significant interaction between Set Type and Congruence in both Magnitude (β =-.0062, *SE*=.0037, $t(10100)=-1.70$, $p=.089$) and Latency models (β =70.95, *SE*=39.68, $t(10287)=1.79$, $p=.074$). This interaction suggests that on Perseveration-Inhibition blocks, phasic pupil responses were larger and later on Switch trials compared to Non-Switch trials, whereas on Pure Updating blocks, phasic pupil responses were larger and later on Non-Switch trials. There was additionally a significant 3-way interaction between Set Type, Congruence, and Block Type on phasic Magnitude (β =.012, *SE*=.0052, $t(10100)=2.24$, $p=.025$). This interaction (Figure 36) suggests that the interaction between Set Type and Block Type on phasic Magnitude was driven by Incongruent trials. Whereas phasic response did not vary across Set and Block Type on Congruent trials, on Incongruent trials, phasic responses were larger for Switch versus Non-Switch trials on Perseveration-Inhibition blocks, whereas the opposite effect was observed on Pure Updating blocks. All other effects did not reach significance (*t*s<1.6, *n.s.*).

On Uncued trials, there was a marginally significant main effect of Congruence on phasic Magnitude (β =.0023, *SE*=.0012, *t*(43560)=1.91, *p*=.056), indicating that at a trend level, phasic responses were larger on Incongruent trials. Also in the Magnitude model, there was a marginally significant interaction between Set Type and Congruence (β =-.0029, *SE*=.0017, *t*(43560)=, *p*=.088). This trend suggests that on Congruent trials, phasic pupil response was similar in magnitude for both Set Types, whereas on Incongruent trials, participants had smaller phasic responses on trials in which they had recently switched, compared to Non-Switch sets. All other predictors of phasic Magnitude and latency did not reach significance (*t*s<1.6, *n.s.*).

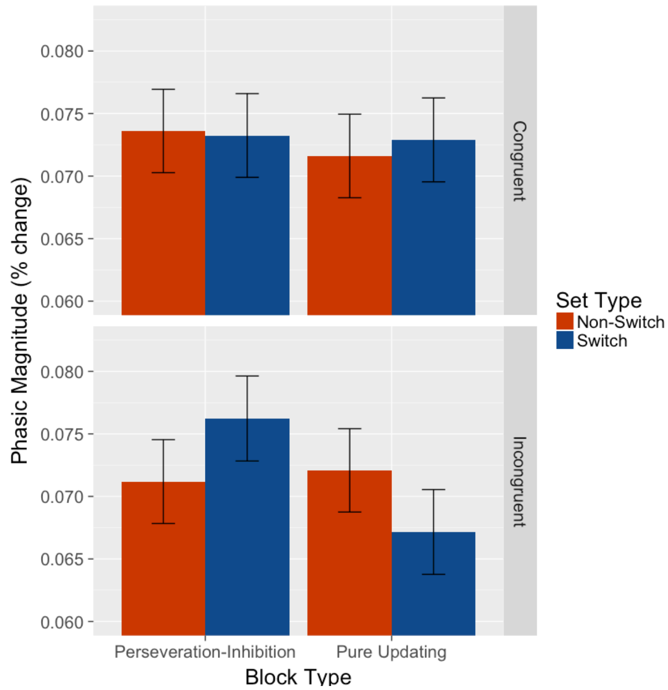

Figure 36. Phasic Magnitude as a function of Set Type, Congruence, and Block Type.

As will be discussed in more detail subsequently, these findings are largely not in agreement with our previous work using an almost identical task.

Within-Subjects Pupil Effects on Task Performance (N=102).

RT

Cued trials. As we have observed in similar studies, pupil measures had both global, main effects on RTs, as well as interactive effects with task factors. First, there were main effects of Phasic Pupil Magnitude (β =.66, *SE*=.13, $t(10070)=5.18$, $p<.001$), Latency (β =1.14x10^{-4}, *SE*=1.11x10^{-5}, $t(10070)=10.32$, $p<.001$), Latency^2 (β =1.23x10^{-7}, *SE*=1.33x10^{-8}, $t(10070)=9.20$, $p<.001$), as well as Tonic Pupil size (magnitude model: β =.032, *SE*=.0085, $t(10070)=3.75$, $p<.001$; latency model: β =.018, *SE*=.0075, $t(10060)=2.34$, $p=.019$), and a marginal effect of Tonic Pupil^2, which was less reliable in the latency model (magnitude model: β =.011, *SE*=.0067, $t(10060)=1.67$, $p=.095$ latency model: β =.0095, *SE*=.0062, $t(10060)=1.54$, $p=.12$). These main effects suggest trials with large tonic pupil sizes as well as those with larger and later phasic dilations tended to be slower. The quadratic effect of latency suggested that trials with earlier peak latencies may have also been slower compared to those with more intermediate latencies. With respect to flexibility, there was a significant interaction between Set Type and Phasic Latency^2 (β =3.88x10^{-8},

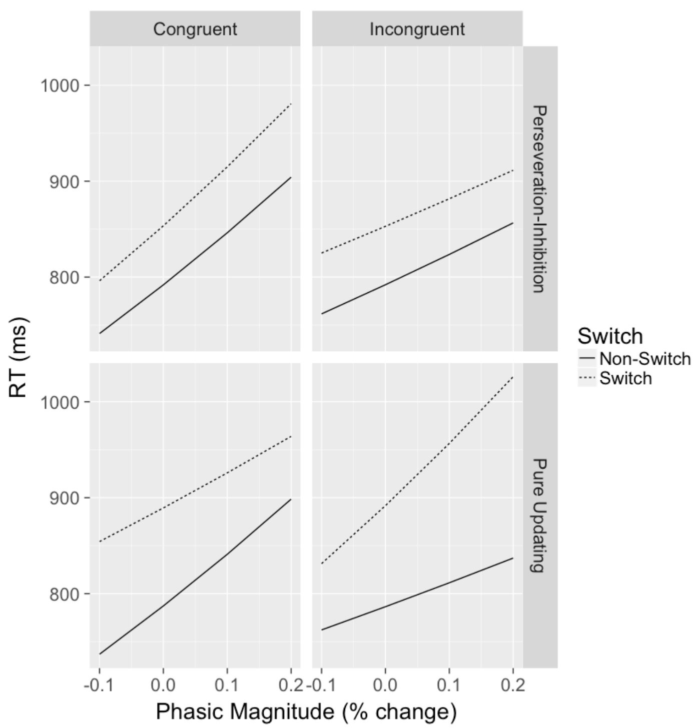

Figure 37. RT as a function of Set Type, Congruence, and Block Type on Cued Trials.

SE=1.88x10^{-8}, $t(10060)=2.06$, $p=.039$), which indicated that trials with early or late latencies tended to have larger switch RTs compared to those with intermediate peak latencies. Phasic Magnitude also interacted with task factors, as evidenced by a marginally significant interaction with Congruence (β =-.35, *SE*=.18, $t(10060)=-1.93$, $p=.053$), a significant 3-way interaction with Congruence and Set Type (β =.65, *SE*=.26, $t(10060)=2.52$, $p=.012$), and also a 4-way interaction that included Block Type (β =-.74, *SE*=.37, $t(10060)=-2.00$, $p=.045$). As shown in Figure 37, these effects suggest that whereas phasic Magnitude had little effect on flexibility on Perseveration-Inhibition blocks, on Pure Updating blocks, larger phasic dilations produced smaller switch costs on Congruent trials, but larger switch costs on Incongruent trials.

Uncued trials. On Uncued trials, there were also several main effects of pupil measures on RT. Specifically, there were main effects of phasic Magnitude (β =.22, *SE*=.068, $t(43540)=3.30$, $p<.001$), Magnitude^2 (β =1.44, *SE*=.53, $t(43540)=2.73$, $p=.006$), Latency (β =2.33x10^{-5}, *SE*=4.58x10^{-6}, $t(43530)=5.10$, $p<.001$), Latency^2 (β =4.14x10^{-8}, *SE*=6.32x10^{-9}, $t(43530)=6.55$, $p<.001$), and Tonic Pupil^2 (magnitude model: β =.0078, *SE*=.0033, $t(43540) =2.35$, $p=.019$; latency model: β =.0095, *SE*=.0033, $t(43530)=2.89$, $p=.004$). There was also a significant main effect of Tonic Pupil Size in the magnitude model (β =.014, *SE*=.0043, $t(43540)=3.18$, $p=.001$); however, it did not approach significance in the latency model ($t(43530)=.66$, *n.s.*). Thus, similar to the main effects for Cued trials, larger phasic dilations and both earlier and longer latencies were predictive of slower RTs. There were some points of divergence, however, as here there were additional quadratic main effects of phasic Magnitude and Tonic Pupil. Further, the relationship between Tonic Pupil size and RTs was less consistent on Uncued trials.

Beyond the main effects, there was a marginally significant interaction between Set Type and phasic Latency (β =1.20x10^{-5}, *SE*=6.48x10^{-6}, *t*(43530)=1.85, *p*=.064). Here, larger longer latencies were predictive of longer trials on trials when participants had recently switched. Also, there was a marginally significant 3-way interaction between Congruence, Block Type, and phasic Magnitude^2 (β =1.71, *SE*=1.02, *t*(43540)=1.68, *p*=.093), in the context of a marginal 4-way interaction that also included Set Type (β =-2.79, *SE*=1.45, *t*(43540)=-1.93, *p*=.054). As shown in Figure 38, having a large or small phasic dilation was predictive of larger incongruence Costs on Non-Switch Sets, but smaller incongruence costs on Switch Sets, specifically in Perseveration-Inhibition blocks. On Pure Updating blocks, the effects were smaller, and in the opposite direction, with large and small dilations predicting smaller incongruence costs on Non-Switch sets compared to Switch sets. Finally, in the magnitude model, there was a marginally significant 3-way interaction between Set Type, Block Type, and Tonic Pupil^2; however it was further from significance in the latency model (magnitude model: β =.012, *SE*=.0068, *t*(43540)=1.78, *p*=.076; latency model: β =.010, *SE*=.0066,

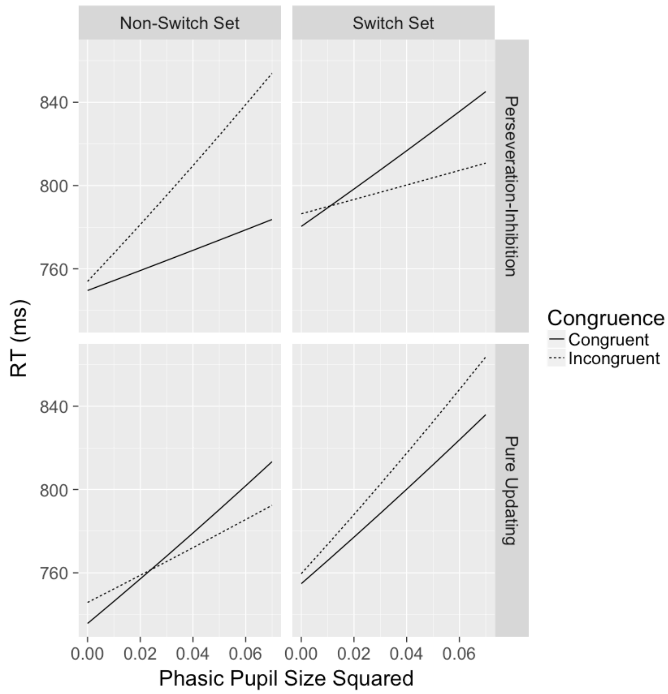

Figure 38. Error rate as a function of Set Type, Congruence, Block Type, and phasic Magnitude^2 on Uncued trials.

t(43530)=1.57, *p*=.11). This trend-level effect suggests that trials with large and small tonic pupil size predict smaller incongruence costs on Perseveration-Inhibition blocks.

Error Rate

Cued trials. On Cued trials, there were no effects of any pupil measures on error rates (*t*s<1.2, *n.s.*), and instead were several high-level interaction effects. First, there was a marginally significant 3-way interaction between Set Type, Congruence, and Phasic Magnitude (β =.72, *SE*=.27, *t*(709.1)=1.96, *p*=.051), in the context of a significant 4-way interaction that included Block Type (β =-1.11, *SE*=.53, *t*(699.8)=-2.08, *p*=.038). As shown in Figure 39, these interactions suggest that having larger phasic responses predicts higher error rates on Switch trials on Congruent trials in Perseveration-Inhibition Blocks and on Incongruent trials in Pure Updating blocks, while having less of an effect on Switch error rates in other conditions.

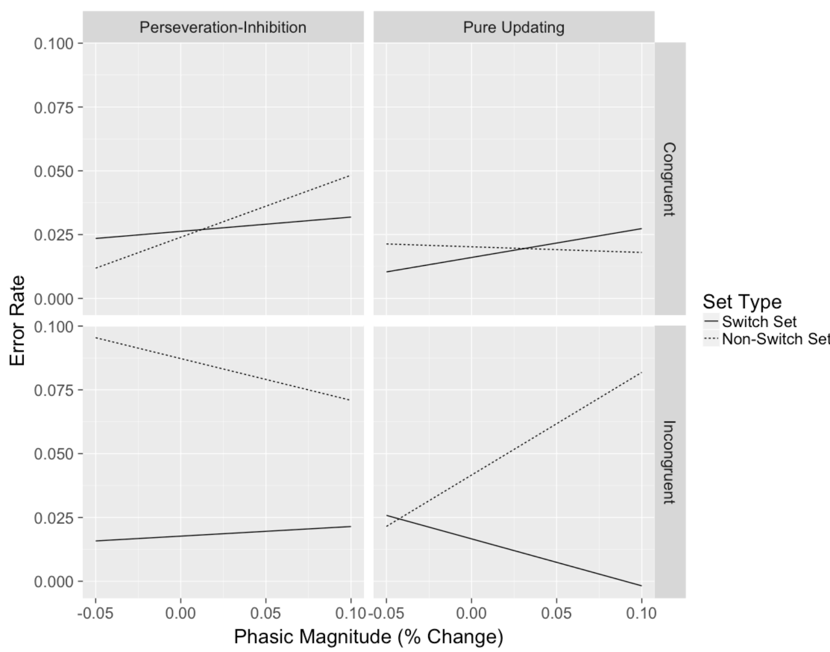

Figure 39. Error rate as a function of Set Type, Congruence, Block Type, and Phasic Magnitude on Cued trials.

There were also marginal effects of Phasic Magnitude^2, including a 3-way interaction involving Congruence and Block Type (β =-3.88, *SE*=2.22, *t*(707.2)=-1.75, *p*=.081) nested within a 4-way interaction that included Set Type (β =5.59, *SE*=3.09, *t*(710.8)=1.81, *p*=.071). These quadratic effects of phasic Magnitude are contrast to the linear effects, with increasing distance from mean phasic magnitude predicting increasing error rates on Non-Switch trials on Congruent trials in Perseveration-Inhibition blocks and Incongruent trials in Pure Updating blocks. On the other hand, large and small phasic dilations also predicted increased Switch error rates on Incongruent trials of Perseveration-Inhibition blocks. Additionally, there was a 4-way interaction between Phasic Latency^2 and all three task factors (β =1.63x10^{-7}, *SE*=6.00x10^{-8}, *t*(704.2)=2.71, *p*=.007). Here (Figure 40), Latency^2 did not influence switch costs on Pure Updating Blocks; however on Perseveration-Inhibition, having an early or late latency predicted larger error rate switch costs on Incongruent trials, but smaller and even reversed switch costs on Congruent trials. There were additionally two marginal effects related to tonic pupil size in the magnitude model (Set Type x Tonic Pupil^2: β =.030, *SE*=.018, *t*(731.4)=1.68, *p*=.094; Set Type x Congruence x Block Type x Tonic Pupil: β =-.084,

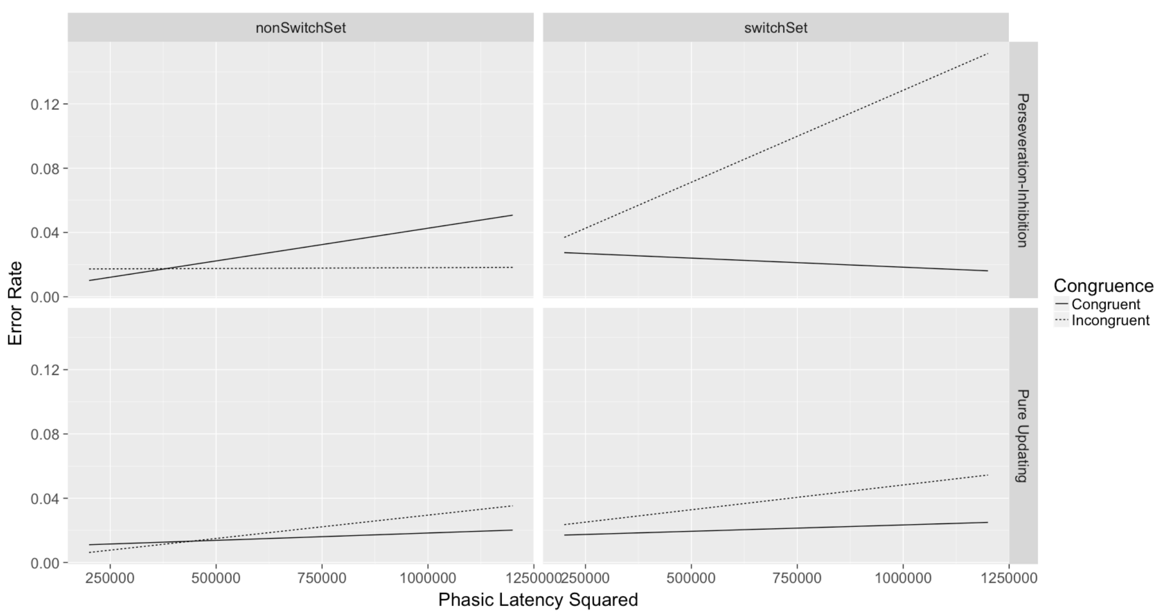

Figure 40. Error rate as a function of Set Type, Congruence, Block Type, and phasic Latency^2 on Cued trials.

SE=.046, *t*(723.7)=-1.85, *p*=.065); however, they did not approach significance in the latency model (*t*s<1.4, *n.s.*), so will not be discussed further here.

Uncued trials. On Uncued trials, pupil measures had no significant main or interactive effects on error rate (*t*s<1.5, *n.s.*).

Global Switch Effects

In the global switch models with RT, the only pupil index to interact with Switch Condition was phasic Latency^2 (β =3.07x10^{-8}, *SE*=8.05x10^{-5}, *t*(45710)=3.81, *p*<.001). This interaction suggests that trials with latencies more distant from the mean (i.e., early or late) have larger RTs on Switch blocks, and thus a larger global switch cost. All other pupil-linked global switch effects in the RT model did not approach significance (*t*s<1.2, *n.s.*).

In the error rate analyses, there was an interaction between Switch Condition and Tonic Pupil size, although it was only marginally significant in the latency model (magnitude model: β =.20, *SE*=.089, *t*(162.6)=2.22, *p*=.028; latency model: β =.16, *SE*=.091, *t*(164.1)=1.77, *p*=.078). This effect indicated that increasing tonic pupil size predicted higher error rates on Switch blocks, but had no effect on Non-Switch blocks, and thus predicted larger global switch costs in error rate. There was additionally a marginally significant interaction between Switch Condition and Tonic Pupil^2 in the magnitude model (β =.13, *SE*=.074, *t*(164.7)=1.70, *p*=.091); however, it was further from significance in the latency model (*t*<1.5, *p*=*n.s.*), so will not be discussed further here.

Between-Subjects Pupil Effects on Task Performance (N=102)

To assess the effects of individual differences in LC-NE system activity and participants' flexibility and distractibility, the mean and standard deviation of each pupil index was computed across all trials for each participant. These indices were then entered into a model predicting performance across different task conditions.

RT

Individual differences in mean pupil measures. The models examining mean-level pupil measures, there was a main effect of Tonic Pupil^2 (magnitude model: β =-.033, *SE*=.015, *t*(103)=-2.14, *p*=.035; latency model: β =-.034, *SE*=.015, *t*(104)=-2.26, *p*=.026). Contrary to what might be expected, this effect suggests that participants who had, on average, large or small tonic pupil size tended to have faster RTs. Relevant to individual differences in attentional flexibility across contexts, there was a significant interaction between Set Type, Cue, and phasic Latency (β =1.3x10^{-4}, *SE*=5.84x10^{-5}, *t*(55340)=2.19, *p*=.029), nested within a 3-way interaction that also included Block Type (β =-2.00x10^{-4}, *SE*=8.22x10^{-5}, *t*(55340)=-2.44, *p*=.015). As shown in Figure X, these effects suggest participants who had longer peak latencies had larger switch costs on Pure Updating blocks, but no difference on Switch costs on Perseveration-Inhibition blocks. Interestingly, longer latencies do appear to predict slower RTs on trials in which participants have recently switched on Perseveration-Inhibition blocks, but no effect on Pure Updating blocks. Relatedly, there was a significant interaction between Set Type, Block Type, and phasic Latency (β =8.62x10^{-5}, *SE*=3.62x10^{-4}, *t*(55340)=2.38, *p*=.017), which suggests that participants with longer latencies had a larger reaction time cost on Switch sets, but not necessarily on switch trials, on Perseveration-Inhibition blocks. Phasic Magnitude^2 also interacted significantly with Set Type, Cue, and Block Type (β =.33, *SE*=.15, *t*(55340)=2.19, *p*=.029). This interaction indicates on Cued trials, participants with either large or small peak phasic responses tended to have smaller switch costs on Pure Updating blocks, but slightly larger switch costs on Perseveration-Inhibition blocks.

Individual differences in pupil variability. Next, each participant's standard deviation for each pupil index was entered as a predictor of RTs, in order to determine how pupil variability affects task performance. There was a significant main effect of variability in phasic Latency ($\beta = 4.87 \times 10^{4}$, $SE = 1.41 \times 10^{-4}$, $t(107) = 3.45$, $p < .001$), which suggests that participants who had greater variability in their peak phasic latency also tended to have slower RTs. No other effects related to pupil variability reached significance (*t*s<1.8, *n.s.*).

Error Rate

Individual differences in mean pupil measures. In the mean-level individual difference models for error rate, no pupil-linked effects reached significance (*t*s<1.4, *n.s.*).

Individual differences in pupil variability. In the model that included measures of pupil variability, the only effect that approached significance was a marginally significant interaction between Set Type, Cue, and Tonic Pupil SD in the latency model; however it was farther from significance in the magnitude model (latency model: $\beta = -7.47 \times 10^{-5}$, $SE = 4.14 \times 10^{-5}$, $t(1485) = -1.80$, $p = .072$; magnitude model: $\beta = -1.22 \times 10^{-4}$, $SE = 7.73 \times 10^{-5}$, $t(1485) = -1.58$, $p = .11$). Although this effect should be interpreted with caution, its direction suggests that participants with greater variability in tonic pupil size had slower RTs on Uncued trials in Switch Sets.

Global Switch Effects

Individual differences in mean pupil measures and RT global switch effects. Individual differences in pupil measures did have several significant effects on global switch costs. In particular, there were significant interactions between Switch Condition and phasic Magnitude^2 (β =-12.63, *SE*=4.35, *t*(48420)=-2.90, *p*=.004), phasic Latency (β =5.03x10^{-5}, *SE*=2.37x10^{-5}, *t*(48420)=2.12, *p*=.034), Tonic Pupil Size (magnitude model: β =-.014, *SE*=.0047, *t*(48420)=-3.01, *p*=.0026; latency model: β =-.015, *SE*=.0047, *t*(48420)=-3.20, *p*=.0014), and Tonic Pupil Size^2 (magnitude model: β =-.0084, *SE*=.0039, *t*(48420)=-2.14, *p*=.032; latency model: β =-.0094, *SE*=.0039, *t*(48420)=-2.40, *p*=.016). With respect to phasic pupil measures, these effects suggest that participants with large and small phasic pupil dilations tend to have smaller global switch costs, whereas those with longer latencies have larger global switch costs. Tonic pupil size had both linear and quadratic effects, indicating that having both larger mean tonic size, as well as large and small mean tonic pupil size was predictive of smaller global switch effects in RT.

Individual differences in pupil variability and RT global switch effects. Switch Condition interacted significantly with variability in both phasic Latency (β =1.17x10^{-4}, *SE*=3.78x10^{-5}, *t*(48430)=3.09, *p*=.002) and Tonic Pupil Size (magnitude model: β =-6.82x10^{-5}, *SE*=2.37x10^{-7}, *t*(48420)=2.88, *p*=.014; latency model: β =-6.82x10^{-5}, *SE*=2.37x10^{-5}, *t*(48420)=-2.88, *p*=.004). These effects indicate that participants who had greater variability in phasic Latency tended to have larger global switch costs, whereas those with greater variability in tonic pupil size had smaller global switch costs.

Individual differences in pupil measures and error rate global switch effects. Neither mean-level or variability in pupil measures were predictive of global switch effects in error rate (*t*s<1.4, *n.s.*).

Eye Tracking Analysis

Analyses of eye tracking data aimed to gain insight into the patterns of eye movements that underlie the both the behavioral and the EBR- and pupil-linked effects on task performance. Specifically, these analyses examine the factors that influence the probability that participants' first fixations will be towards the target, distractor letter, and irrelevant distractor symbol, as well as the time it takes for participants to fixate on the target.

Task Effects on Fixations (N=87)

Probability of fixating on target and distractors.

In this sample, which consisted only those subjects who fixated on the target on 75% of trials, participants' first fixation were to the target on 77.7% of trials (*SD*=12.8%), to the letter distractor on 10.8% of trials (*SD*=8.4%), and to the irrelevant symbol on 5.1% of trials (*SD*=5.2%). These probabilities are consistent with previous work using this task.

First, we examined how the task factors Cue, Set Type, Congruence, and Block Type affect the probability that participants' first fixations will be towards the target. In this model, there were significant main effects of Cue (β =.043, *SE*=.013, $t(1290)=3.23$, p=.001) and Set Type (β =-.038, *SE*=.013, $t(1290)=-2.90$, p=.003), indicating that participants were 4.3% more likely to first fixate on the target on Cued trials, and 3.8% less likely to first fixate the target on Switch Sets. The effect of Cue in particular is consistent with earlier findings, suggesting that participants are more likely to first fixate the target when they have recently been informed of the target color. The only other effect that approached significance in this model was a marginally significant interaction between Set Type and Block Type (β =-.036, *SE*=.019, $t(1290)=-1.80$, $p=.072$). This trend suggests that on Switch Sets, in which participants had recently shifted their attention, participants were more likely to first fixate on the target in Pure Updating blocks than in Perseveration-Inhibition blocks. On Non-Switch sets, on the other hand, there was no difference in target fixation probability between the two block types. All other effects did not reach significance (*t*s<1.4, *n.s.*).

In the model predicting the probability of distractor fixation were complementary to those in the target fixation model. There was a significant main effect of Set Type (β =.030, *SE*=.0094, $t(1290)=3.18$, $p=.0015$), and a trend-level main effect of Cue (β =-1.57, *SE*=.0094, $t(1290)=-1.66$, $p=.097$). Here, participants were 3% more likely to fixate on the distractor on Perseveration-Inhibition blocks, and, although it did not reach significance, 1.57% less likely to fixate on the distractor on Cued trials. Also paralleling the target fixation results, there was a significant interaction between Set Type and Block Type (β =.004, *SE*=.013, $t(1290)=3.01$, $p=.003$). Although Switch sets increased the likelihood of fixating on the distractor in general, this effect was stronger on Perseveration-Inhibition blocks. Interestingly, there was no interaction between Cue and Set Type, which has been observed in other work with this same task. There was, however, a trend-level 3-way interaction between Cue, Set Type, and Block Type (β =.030, *SE*=.019, $t(1290)=1.61$, $p=.11$), which suggests that, at least at the trend level, there were switch costs, with Cued trials in Switch sets having a greater probability of distractor fixation than those in Non-Switch sets, and this effect was largest in

Perseveration-Inhibition blocks. All other effects did not approach significance (*t*s<1.3).

In the model predicting fixation probability for the always-irrelevant distractor symbol, the only effect that reached significance was a main effect of Cue (β =-.019, *SE*=.0063, *t*(1290)=-3.02, *p*=.003), which indicates that participants were 1.9% less likely to fixate on the always-irrelevant symbol on Cued trials.

Time to fixate on target. In the model predicting the time it takes for participants to fixate on the target, there was a marginally significant main effect of Cue (β =-6.80, *SD*=3.82, *t*(48966)=-1.83, *p*=.068). Thus, cues made participants not only more likely to fixate on the target first, but also faster at fixating on the target.

EBR Effects on Fixations (N=87)

Probability of fixating on target and distractors. Across all three fixation probability models, the only EBR-linked effect to approach significance was a trend-level interaction between Cue, Set Type, and EBR in the distractor letter model (β =-.0022, *SE*=.0013, *t*(1260)=-1.68, *p*=.092). This interaction suggests that higher EBR predicts reduced distractor fixation probability on Switch trials specifically.

Time to fixate on target. EBR indices were linked with the amount of time for participants to first fixate on the target. Relevant to our hypotheses about EBR and flexibility, there was a significant interaction 3-way interaction between Cue, Set Type, and EBR (β =-1.51, *SE*=.53, *t*(48900)=-2.85, *p*=.004). This interaction indicated that on Cued trials, increasing EBR predicted faster target fixation on Switch trials, but slower target fixation on Non-Switch trials (Figure X). There were additionally interactions between Block Type and both EBR (β =.56, *SE*=.24, *t*(48900)=2.37, *p*=.018) and EBR^2 (β =-.046, *SE*=.020, *t*(48900)=-2.29, *p*=.022). These effects suggest that whereas increasing values for EBR predict target fixations on Perseveration-Inhibition blocks and faster target fixation on Pure Updating Blocks, larger values for EBR^2 predict slower responding on Pure Updating blocks and have little effect on Perseveration-Inhibition blocks. Finally, there was a marginally significant 4-way interaction between Set Type, Congruence, Block Type, and EBR^2 (β =-.074, *SE*=.041, *t*(48900)=-1.82, *p*=.069). This interaction indicates that higher values of EBR^2 were generally predictive of slower target fixation on Pure Updating blocks, whereas on Perseveration-Inhibition blocks, this positive relationship was present only on Congruent trials in Switch Sets.

Pupil Effects on Fixations (N=83)

The following analyses examined how variability in pupil indices predicts eye fixation patterns across task conditions.

Probability of fixating on target and distractors. First, we examined pupil effects on target fixation probability on Cued trials. Results suggest that phasic Magnitude was particularly relevant for the probability that participants will fixate on the target first. First, there was significant interaction between Block Type and phasic Magnitude (β =-1.54, *SE*=.71, *t*(520.1)=-2.17, *p*=.031), as well as a marginally significant interaction between Set Type and phasic Magnitude (β =-1.37, *SE*=.70, *t*(522.7)=-1.95, *p*=.051). These interactions occurred in the context of a significant 3-way interaction between Set Type, Block Type, and phasic Magnitude (β =2.80, *SE*=1.02, *t*(523.5)=2.75, *p*=.006). There was additionally a significant interaction between Congruence, Block Type, and phasic Magnitude (β =2.16, *SE*=1.02, *t*(518.6)=2.10, *p*=.036), as well as a 4-way interaction that also included Set Type (β =-2.94, *SE*=1.47, *t*(517.6)=-2.00, *p*=.046). As shown in Figure 4, these effects indicate that larger phasic pupil dilations tended to predict reduced likelihood of first fixating on the target on Switch trials, and had a smaller or reversed effect on target fixations for Non-Switch trials. In other words, larger phasic responses predicted larger switch costs in target fixation probability. The one exception to this pattern was for Congruent trials on Perseveration-Inhibition blocks - here, larger phasic pupil responses were associated with a decrease in the probability of first fixating on the target on Non-Switch trials, and thus smaller Switch Costs. The quadratic Magnitude effect was also predictive of target fixation probability, as evidenced by a 2-way interaction involving Set Type and Magnitude^2 (β =12.11, *SE*=5.74, *t*(537.2)=2.11, *p*=.035), a 3-way interaction that also included Block Type (β =-16.44, *SE*=7.84, *t*(534.4)=-2.10, *p*=.037), as well as the 4-way interaction that additionally included Congruence (β =23.95, *SE*=11.43, *t*(527)=2.10, *p*=.037). These effects indicate that on Congruent trials on Pure Updating blocks and Incongruent trials in Perseveration-Inhibition blocks, increasing distance from the mean phasic pupil size predicted smaller switch costs in target fixation probability fixation. In the other conditions, larger values for phasic Magnitude^2 predicted either no change in switch costs, or increased switch costs, in the case of Congruent trials on Perseveration-Inhibition blocks. No effects involving phasic Latency approached significance (*t*s<1.5). With respect to Tonic Pupil measures, there was a marginally significant main effect of Tonic Pupil (magnitude model: β =-.059, *SE*=.034, *t*(544.7)=-1.73, *p*=.085; latency model: β =-.059, *SE*=.034, *t*(534.6)=-1.73, *p*=.085). In the latency model, there was additionally a significant interaction between Congruence and Tonic Pupil, although it was only marginally significant in the magnitude model (latency model: β =.10, *SE*=.050, *t*(526.7)=2.01, *p*=.045; magnitude model: β =.084, *SE*=.051, *t*(525.9)=1.64, *p*=.10). This trend-level effect suggests that increasing tonic pupil size was predictive of reduced target fixation probability on Congruent trials, but increased target fixation probability on Incongruent trials. In other words, larger tonic pupil size predicted a smaller incongruence cost in target fixation probability on Cued trials.

Separate models examined the probability first fixating the target on Uncued trials. In these models, there were no significant effects of either phasic Latency or Magnitude (*t*s<1.2, *n.s.*). There were, however, some effects of tonic pupil measures. First, there was a marginally significant interaction between Tonic Pupil Size and Set Type (magnitude model: β =-.10, *SE*=.058, *t*(542.1)=-2.97, *p*=.080; latency model: β =-.096, *SE*=.057, *t*(539.2)=-1.68, *p*=.094), suggesting that larger tonic pupil sizes were associated with decreasing target fixation probability, particularly on Switch Sets. Additionally, there was a significant 3-way interaction between Set Type, Congruence, and Tonic Pupil^2 (magnitude model: β =-.22, *SE*=.078, *t*(541.2)=-2.77, *p*=.006; latency model: β =-.23, *SE*=.78, *t*(540.7)=-2.97, *p*=.003). This interaction suggests that on Non-Switch sets, distance from mean pupil size predicted reduced target fixation probability, for Congruent trials in particular, whereas its relationship to target fixation probability did not differ between Congruent and Incongruent trials on Switch Sets (Figure X).

Next, we examined the probability of first fixating on the distractor letter on Cued trials. Here, too, phasic Magnitude indices were most predictive of participants' fixation patterns. There was a significant interaction between Block Type and phasic Magnitude (β =1.13, *SE*=.53, *t*(530.2)=2.15, *p*=.032). Here, increasing magnitude of phasic pupil responses predicted greater likelihood of fixating the distractor on Perseveration-Inhibition blocks, but not on Pure Updating blocks. There were additionally several marginally significant effects that involved phasic Magnitude^2, including a main effect (β =6.44, SE=3.39, $t(574.9)=1.90$, p=.058), an interaction with Congruence (β =-7.76, SE=4.69, $t(536.3)=-1.66$, p=.098), and an interaction with Block Type (β =-8.21, SE=4.24, $t(546.1)=-1.94$, p=.054). These effects indicate that at the trend level, large and small magnitude phasic pupil responses predicted a greater likelihood of fixating on the distractor in general; however this effect was reversed on Incongruent trials and on Perseveration-Inhibition blocks. No effects linked to phasic Latency or Tonic Pupil approached significance (ts<1.4).

In the models examining distractor fixation probability on Uncued trials, similar to what was observed in the models for target fixations, tonic pupil measures were the only significant pupillary predictors. Specifically, there was a significant 3-way interaction between Set Type, Congruence, and Tonic Pupil^2 (magnitude model: β =.14, SE=.058, $t(545.9)=2.36$, p=.019; latency model: β =.14, SE=.057, $t(546.4)=2.74$, p=.014), in the context of a trend-level 4-way interaction that also included Block Type (magnitude model: β =-.13, SE=.078, $t(642.8)=-1.67$, p=.096; latency model: β =-.13, SE=.077, $t(542.4)=-1.73$, p=.084). No effects involving phasic magnitude or latency approached significance (ts<1.2, *n.s.*).

Models examining the probability of attending the irrelevant symbol distractor implicated both Tonic Pupil measures and phasic Latency. First, there was an interaction between tonic pupil size and Congruence, although it reached only marginal significance in the Latency model (magnitude model: β =-.055, SE=.025, $t(538.4)=-2.19$, p=.029; latency model: β =-.048, SE=.024, $t(539.1)=-1.95$, p=.051). This interaction indicates larger tonic pupil size was associated with an increased probability of fixating on the distractor on Congruent trials, but a reduced probability on Incongruent trials. Phasic Latency^2 also interacted with Congruence (β =9.18x10^{-8}, *SE*=3.34x10^{-8}, t(535.2)=2.33, p=.020), within the context of a 3-way interaction that also included Set Type (β =-1.43x10^{-7}, *SE*=5.52x10^{-8}, t(529.8)=-2.59, p=.010). Here, phasic latencies that were early or late predicted a larger increase in distractibility on Incongruent Non-Switch trials and Congruent Switch trials (Figure 41).

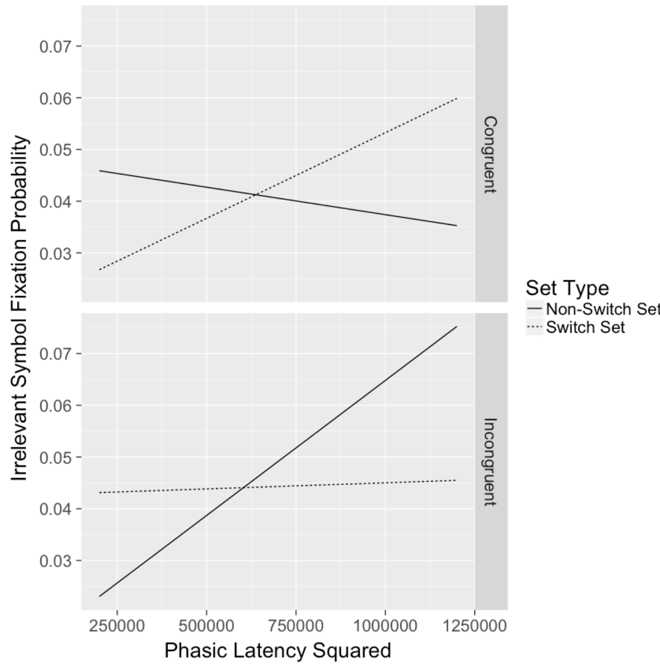

Figure 41. Irrelevant symbol fixation probability as a function of Set Type and phasic Latency^2 on Cued trials.

Finally, we examined irrelevant symbol fixation probability on Uncued trials. The only effect that reached significance was an interaction between Block Type and phasic Magnitude^2 (β =-4.42, *SE*=2.12, t(539.1)=-2.08, p=.038). This effect occurred alongside marginally significant interactions between Block Type, Set Type, and phasic Magnitude^2 (β =6.07, *SE*=3.23, t(541.3)=1.88, p=.061), as well as Congruence, Block Type, and Magnitude^2 (β =5.47, *SE*=2.96, t(540.5)=1.85, p=.065). These effects suggest that trials with large and small phasic pupil responses tend to increase the probability of fixating on the irrelevant distractor, and this tendency is stronger on Perseveration-Inhibition blocks, especially on Incongruent trials, and those trials in which participants have recently switched. On Pure

Updating Blocks, phasic Magnitude^2 was slightly less predictive of incresed distractor fixation probability, although there was a greater tendency on sets in which participants had not recently switched. There were additional trend-level effects, including a main effect of phasic Latency^2 (β =4.35x0^{-8}, *SE*=2.39x10^{-8}, *t*(611.1)=1.82, *p*=.069), suggesting that early and late phasic latencies predicted greater distractibility by the irrelevant symbol. Finally, there was a marginally significant interaction between Set Type, Congruence, and Tonic Pupil Size (magnitude model: β =-.071, *SE*=.039, *t*(544.5)=-1.83, *p*=.068; latency model: β =-.069, *SE*=.039, *t*(544.2)=-1.78, *p*=.076). This finding suggests that increasing tonic pupil size predicted greater distractibility on Congruent trials and less distractibility on Incongruent trials, and that these effects were strongest for trials in which participants had not recently switched.

Time to fixate on target. We were also interested in how pupil measures were related to the time it takes for participants to first fixate on the target. First, there were main effects of both phasic Latency (β =.014, *SE*=.0049, *t*(7498)=2.84, *p*=.005) and Latency^2 (β =1.98x10^{-5}, *SE*=5.98x10^{-6}, *t*(7505)=3.31, *p*<.001), indicating that on Cued trials, those with early or late peak latencies tended to fixate on the target more slowly. There was also a significant interaction between Set Type and phasic Magnitude (β =168.10, *SE*=83.33, *t*(7499)=2.02, *p*=.044), within the context of a trend-level 3-way interaction that also included Block Type (β =-218.16, *SE*=119.29, *t*(7498)=-1.83, *p*=.068). These effects indicate that large and small phasic pupil responses were predictive of slower target fixations on Switch trials compared to Non-Switch trials, and this effect was larger in Perseveration-Inhibition blocks. No tonic pupil effects approached significance (*t*s<1.4, *n.s.*).

The models for Uncued trials indicated that here, both tonic and phasic pupil indices were relevant to participants' fixation times. First, there were significant main effects of phasic Latency^2 (β =1.20x10^{-5}, *SE*=2.83x10^{-6}, *t*(31780)=4.24, *p*<.001), Tonic Pupil Size (magnitude model: β =-5.97, *SE*=1.94, *t*(31748)=-3.08, *p*=.002; latency model: β =-8.92, *SE*=1.78, *t*(31770)=-5.00, *p*<.001), and Tonic Pupil^2 (magnitude model: β =4.69, *SE*=1.59, *t*(31734)=2.95, *p*=.003; latency model: β =4.60, *SE*=1.57, *t*(31760)=2.92, *p*=.003). On one hand, these findings suggest a linear effect with larger tonic pupil sizes predicting faster target fixation, while at the same time suggesting that large and small tonic pupil sizes, as well as early and late latencies, predict slower target fixation. Tonic Pupil Size also interacted significantly with Set Type (magnitude model: β =6.50, *SE*=2.73, *t*(31734)=2.38, *p*=.017; latency model: β =8.19, *SE*=2.53, *t*(31760)=3.24, *p*=.001), suggesting that although larger pupils led to faster target fixation in general, this effect was strongest for trials in Non-Switch

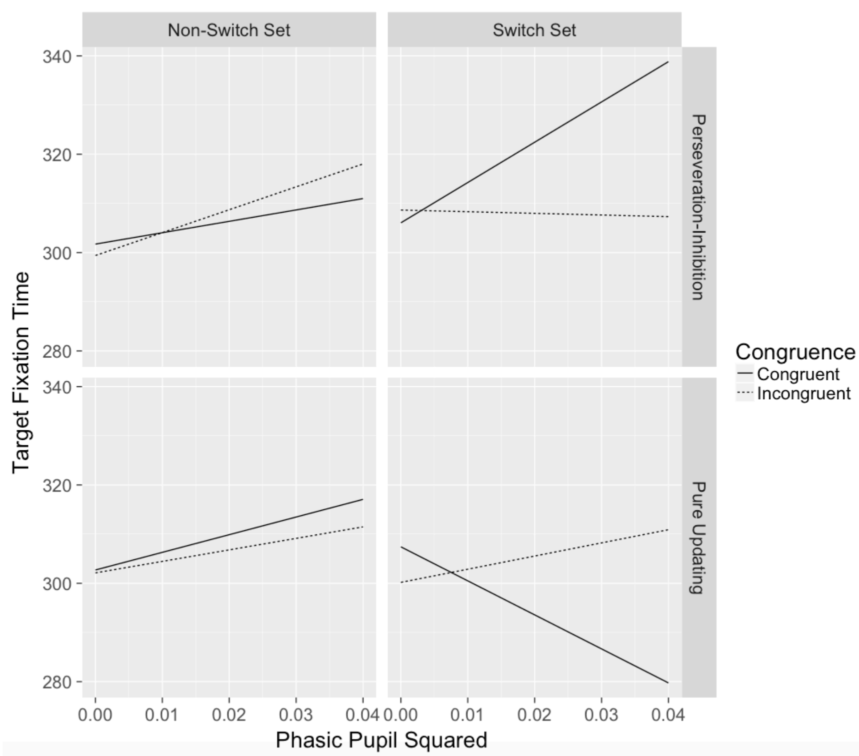

Figure 42. Target fixation time as a function of Set Type, Congruence, Block Type, and phasic Magnitude^2 on Uncued

sets, in which participants have not recently had to update their attentional set. There was additionally an interaction between Set Type and Phasic Magnitude^2 (β =-1050.98, *SE*=436.16, *t*(31734)=-2.41, *p*=.016), as well as a 3-way interaction that also included Block Type (β =1638.93, *SE*=633.29, *t*(31734)=2.59, *p*=.010), and a trend-level interaction that also included Congruence (β =1084.95, *SE*=612.33, *t*(31734)=1.77, *p*=.076). These effects emerged in the context of a the 4-way interaction between all three task factors and phasic Magnitude^2 (β =-2171.92, *SE*=886.18, *t*(31734)=-2.45, *p*=.014). Taken together, these effects suggest that on sets in which participants had recently switched, large and small phasic responses were predictive of slower target fixation on Congruent trials in Perseveration-Inhibition blocks, but faster Congruent target fixation in Pure Updating blocks (Figure 42). Finally, there were also quadratic effects of phasic Latency, as evidenced by a marginally-significant interaction between Block Type and phasic Latency^2 (β =-7.57x10^{-6}, *SE*=3.97x10^{-6}, *t*(31760)=-1.91, *p*=.056), in the context of a significant 3-way interaction that included Set Type (β =1.25x10^{-5}, *SE*=5.72x10^{-6}, *t*(31760)=2.19, *p*=.029). These effects suggest that while early and late latencies predicted slower target fixation overall, these effects were strongest on Switch sets in Perseveration-Inhibition blocks and Non-Switch sets in Pure Updating blocks.

EBR-Pupillometry Interaction (N=100).

In order to explore how EBR and pupil measures interact to predict performance, we entered both into the same models to predict RT across task conditions. As with the pupillometry analyses, separate models were run for phasic Latency and Magnitude predictors, and also for Cued and Uncued trials. Additional models were run with Gender included as a factor, given its moderating effect on EBR. The output from these models can be found in Appendix C.

EBR Reliability Analyses

Within-session reliability (N=114 for Session 1 and N=105 for Session 2). To determine the reliability of EBR measurements within a session, the 5-minute EBR baseline measurements taken at the beginning and end of Sessions were correlated, separately for Sessions 1 and 2. At Session 1, there was mean-level change in EBR, with participants having significantly higher EBR at the beginning of the session versus at the end of the session (Mean Time 1=19.60, *SD*=12.51, Mean Time 2=22.25, *SD*=14.33; *t*(113)=-2.92, *p*=.004). However, the correlation between participants' EBR at the beginning versus the end of the session was still very large (*r*=.75, *t*(112)=11.96,

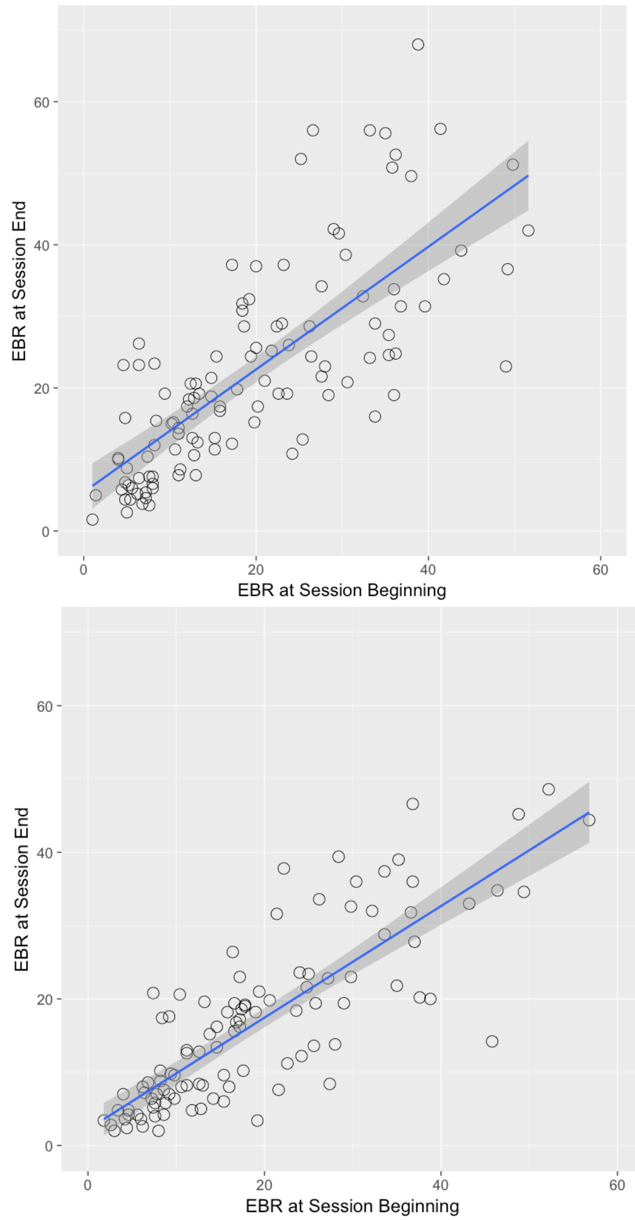

Figure 43. Correlation between EBR at beginning and end of Session 1 (a; *r*=.75, *p*<.001) and 2 (b; *r*=.82, *p*<.001).

p<.001; Figure 43a). Interestingly, at the second session, mean eye blink rate significantly decreased from the beginning to the end of the session (Mean Time 1=18.96, *SD*=12.60, Mean Time 2=16.65, *SD*=11.72; $t(104)=3.21$, $p=.002$; Figure 43b) . Here, too, the correlation between each subject's EBR at each point within the session was very high ($r=.82$, $t(103)=14.45$, $p<.001$). Thus, there is evidence that in spite of mean-level changes in EBR over each session, participants' relative EBR remained consistent within each session.

Cross-session reliability (N=92). To assess the reliability of EBR across sessions, participants' first EBR measurements from each session were entered into a mixed model with subjects as a random factor, and the ICC was computed. In the null model, the ICC was .76, indicating that 76% of the cross-session variability in EBR measurements is attributable to the subject factor. Additional models examined the effects of gender and time of day on EBR; however neither was a significant predictor in this dataset (*t*s<1.3, *n.s.*). Going forward, then, we have evidence that EBR at one time point is predictive of EBR at other time points.

Linking Flexibility and Distractibility Across Sessions

Behavior (N=99/98/97). In order to determine the relationships between our indices of flexibility and distractibility across the two lab sessions and follow-up questionnaires, we tested a series of correlations (N=99). It is important to note that although we are performing many statistical tests, we chose not to correct for multiple comparisons, because this is the first time, to our knowledge, that a study as attempted to link performance on an attention task to ecologically valid and real-world behavior. An additional caution is that, as shown in Table 6 above, the reliability of switch and incongruence costs was quite low. Table 8 shows the correlations between the Session 1 indices (Switch and Incongruence costs across different conditions) and Session 2 indices (total number of events, mean time spent for each task-relevant event, Video-coded distractibility, and time spent on irrelevant websites). The only correlation that reached statistical significance was a positive correlation between switch costs on Perseveration-Inhibition blocks and mean time spent each visit to task-relevant website (Figure 44). With that said, these results should be interpreted with caution, and will require replication. This correlation is in the expected direction - participants who exhibited greater flexibility when switching on Perseveration-Inhibition blocks were more likely to visit on-task websites more briefly, and thus switched tasks more frequently. Other correlations were significant at the trend level. Mean time on task-relevant websites was also marginally related to switch costs in general, also in the predicted direction. Additionally, participants' total time spent on task-irrelevant websites was negatively correlated at the trend level with both Incongruence costs overall, as well as with Incongruence costs on Non-Switch sets. These correlations are not in the expected

Table 8
Correlation between Flexibility and Distractibility Measures at Sessions 1 and 2

	Swich Cost	Switch Cost Pure Upd	Switch Cost PersInhib	Switch Cost Cong	Switch Cost Incong	Incong. Cost	Incong. Cost Pure Upd	Incong. Cost Pers Inhib	Incong. Cost NS Set	Incong. Cost SW Set
Video Distractibility	.12	.10	.08	.15	.04	-.08	-.15	-.01	-.07	-.06
Total Off-Task Time	-.02	-.01	-.04	.08	-.15	-.17.	-.15	-.09	-.19.	-.05
Total Events	-.01	-.02	-.04	.09	.06	-.04	-.02	-.06	.04	-.08
Mean time On-Task Log	.01	.08	-.01	.03	-.03	.05	.05	.04	-.06	.13
Mean time On-Task Web	.17.	-.05	.35***	.15	.14	-.03	-.05	-.04	.08	-.13

Note: Pure Upd= Pure Updating Blocks; Pers. Inhib= Perseveration Inhibition Blocks; Cong = Congruent; Incong=Incongruent; NS Set = Non-Switch Set; SW Set=Switch Set
*** p<.001, ** p<.01, * p<.05, . p<.10

direction, as greater distractibility on the ecologically valid task was related to smaller incongruence costs, and thus less distractibility, in the attentional shifting task.

Next, we examined the relationships between performance on the attention shifting task and self-reported flexibility and distractibility on the follow-up questionnaires during participants' busy (N=98) and typical weeks (N=97; Table 9).

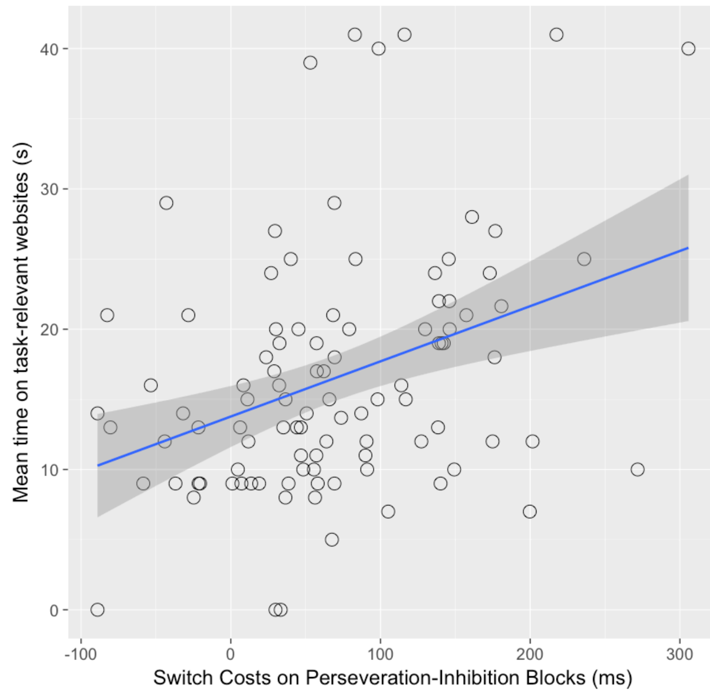

Figure 44. Correlation between switch costs on Perseveration-Inhibition blocks and mean time per visit to task-relevant websites (r=.35, p<.001). The shaded region represents the 95% confidence interval.

Here, there were some marginally significant relationships. First, there was a negative relationship between self-reported distractibility during the typical week and switch costs on Incongruent trials. Additionally, self-reported flexibility during the busy week was positively correlated at the trend level with switch costs on Pure Updating blocks and Incongruent trials. These effects are not in the hypothesized direction - we had initially expected that participants who exhibited greater flexibility in our task would also exhibit more flexible behavior in everyday life; however, it was the participants who had higher switch costs, or less flexibility on the task, who self-reported behaving in a more flexible

Table 9
Correlation between Flexibility and Distractibility Measures at Session 1 and on Questionnaires

	Swich Cost	Switch Cost Pure Upd	Switch Cost PersInhib	Switch Cost Cong	Switch Cost Incong	Incong. Cost	Incong. Cost Pure Upd	Incong. Cost Pers Inhib	Incong. Cost NS Set	Incong. Cost SW Set
Distractibility - Typical Week	-.11	-.04	-.13	.02	-.20 *	-.05	.04	-.07	-.14	.08
Flexibility - Typical Week	.05	.09	-.02	.08	-.02	.02	.06	-.01	-.05	.11
Distractibility - Busy Week	.09	.01	.10	.12	.05	-.05	.03	-.10	-.06	.02
Flexibility - Busy Week	.16	.17.	.04	.19.	.04	-.06	-.07	-.05	-.07	.01

Note: Pure Upd= Pure Updating Blocks; Pers. Inhib= Perseveration Inhibition Blocks; Cong = Congruent; Incong=Incongruent; NS Set = Non-Switch Set; SW Set=Switch Set
*** *p*<.001, ** *p*<.01, * *p*<.05, . *p*<.10

manner.

Finally, we examined the relationships between measures of flexibility and distractibility during the Session 2 internet search task and self-reported flexibility and distractibility on the follow-up questionnaires (Table 10). Contrary to our expectations, none of these tests reached significance.

Overall, with the exception of our finding that larger switch costs on Perseveration-Inhibition blocks in particular predicted longer times spent on each website during the internet search task, these findings are largely not as expected. Further, although our initial aim was to test mediation models, with behavior at Session 2 mediating the link

Table 10
Correlation between Flexibility and Distractibility Measures at Session 2 and on Questionnaires

	Distractibility - Typical Week	Flexibility - Typical Week	Distractibility - Busy Week	Flexibility - Busy Week
Video Distractibility	.02	.01	-.13	-.04
Total Off-Task Time	-.01	.09	.10	.07
Total Events	.04	.07	.04	.08
Mean time On-Task Log	-.06	.06	-.05	.06
Mean time On-Task Web	-.04	-.13	.03	-.13

Note: *** *p*<.001, ** *p*<.01, * *p*<.05, . *p*<.10

between Session 1 and follow-up questionnaires, there are no indices of flexibility or distractibility with consistent relationships across the different measurement points, and thus no clear mediation models to test. Instead, we will report here how EBR and pupil measures from Session 1 were related to our indices of flexibility and distractibility at Session 2 and on the follow-up questionnaires.

EBR (N=97/96/95). When relationships with EBR and indices of flexibility and distractibility were examined (Table 11), the only effect to reach significance was a positive correlation between EBR^2 and the total number of events on the internet search task. Here, participants who had high or low EBR tended to complete the internet search task by executing many separate events, rather than working more methodically.

Table 11
Correlation between EBR and Flexibility and Distractibility Measures at Session 2 and Questionnaires

	EBR	EBR^2
Video Distractibility	.09	.07
Total Off-Task Time	-.14	-.05
Total Events	-.08	-.21*
Mean time On-Task Log	.06	.16
Mean time On-Task Web	-.04	-.06
Distractibility - Typical Week	-.10	.08
Flexibility - Typical Week	-.14	.05
Distractibility - Busy Week	-.15	-.07
Flexibility - Busy Week	-.03	-.07

Note: *** $p<.001$, ** $p<.01$, * $p<.05$, . $p<.10$

Pupil Measures (N=88). Participants' mean-level pupil measures during the attentional shifting task were predictive of subsequent behavior in other parts of the study (Table 12). First, participants' mean phasic magnitude was negatively correlated with self-reported distractibility during their busy week, and at a trend level, during their typical week as well. This finding fits well with the adaptive gain theory of LC-NE function, which posits that larger phasic responses would facilitate exploitation of a

Table 12
Correlation between Pupil Measures and Flexibility and Distractibility Measures at Sessions 2 and on Questionnaires

	Magnitude	$Magnitude^2$	Latency	$Latency^2$	Tonic	$Tonic^2$	Magnitude SD	Latency SD	Tonic SD
Video Distractibility	.05	.06	-.08	<.01	.17	.03	.12	.17	.11
Total Off-Task Time	-.17	.07	-.20.	.12	-.01	-.04	-.11	.08	-.11
Total Events	.07	.03	-.03	.20.	-.07	-.05	.04	-.11	<.01
Mean time On-Task Log	.05	-.05	.08	-.18.	.06	.06	.06	.05	<.01
Mean time On-Task Web	-.14	-.08	.01	-.05	-.15	-.01	-.15	-.02	-.16
Distractibility - Typical Week	-.19.	.01	.04	.03	-.19.	-.09	-.19.	.16	-.027**
Flexibility - Typical Week	-.03	.01	-.02	.04	.01	.06	<.01	.07	-.05
Distractibility - Busy Week	-.22*	.04	-.13	.08	-.22*	-.24*	-.15	.29**	-.17
Flexibility - Busy Week	.17	.13	.07	.07	<.01	.09	.18	-.02	.13

Note: *** $p<.001$, ** $p<.01$, * $p<.05$, . $p<.10$

current task and less distractibility. Phasic Latency was positively correlated with time spent on task-irrelevant websites at the trend level, while phasic $Latency^2$ was marginally positively correlated with the total number of events during the internet search task. Interestingly, large tonic pupil size tended to related to self-reports of less distractibility, while on the other hand, the quadratic effect, Tonic $Pupil^2$, was positively correlated with distractibility during the busy week.

Pupil variability was also related to self-reported distractibility. Specifically, greater variability in Tonic Pupil Size (significantly) and Phasic Magnitude (at a trend level) were negatively correlated with distractibility during the typical week. Interestingly, variability in phasic Latency, on the other hand, was positively correlated with

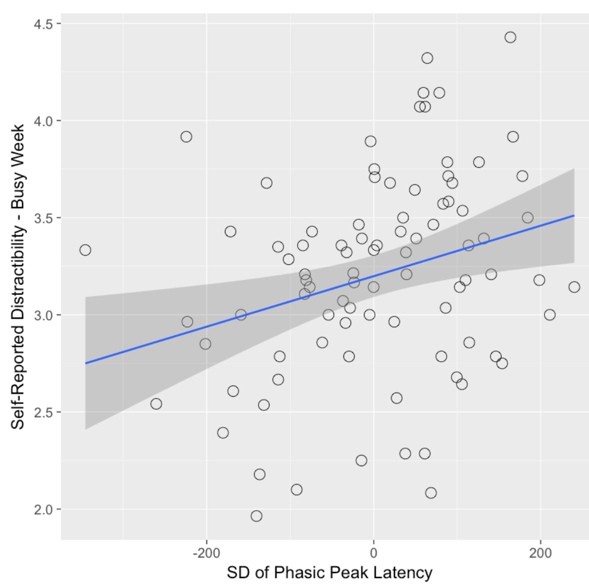

Figure 45. Correlation between variability of Phasic Pupil Latency and self-Reported distractibility during the busy week (r=.29, p<.01). The shaded region represents the 95% confidence interval.

distractibility during the busy week (Figure 45).

Reliability of Activity Logs (N=10)

To investigate the internal consistency of activity logs, 10 logs were randomly selected for a split-half reliability analysis. Odd- and even-numbered events from each activity log were separated, and the number of events, and mean time per event was calculated for each event type within each half. This interleaved, rather than random, selection of events for the split half was used to account for the possibility that subjects employed a different strategy over the course of the session (i.e. researching at the beginning, writing study guide at the end). The reliability for the number of events was generally high (Typing Study Guide: .88 ; Task-Relevant website: .99 ; Task-Irrelevant website: .82). Reliability was lower for mean time per event type (Typing Study Guide: .51 ; Task-Relevant website: .29 ; Task-Irrelevant website: .91, but note that this latter estimate may be inflated by a large number of 0s). These findings suggest that using the mean time per event as indices of flexibility may have increased unnecessary noise, given that there are other more reliable indices (number of events).

CHAPTER VI

DISCUSSION

In a series of experiments, we examined how EBR and pupil predictors, which index striatal DA tone and LC-NE activity respectively, relate to the ability to stably maintain the attentional set in the face of distraction, as well as the ability to flexibly update the attentional set, across different task contexts. We additionally tested whether individual differences in flexibility and distractibility indices from the attentional set-shifting task are predictive of flexibility and distractibility in an ecologically-valid lab task, self-reported real-world experience. Here, we will briefly summarize findings from each component of the study.

Behavioral Findings

All four experiments used variants of the attention-shifting task, which differed in the number of conditions as well as the timing. As shown in Table 13, the attention

Table 13
Behavioral results on the Attention Shifting Task across experiments

		Study 1 (N=110)			Study 2 (N=36)			Study 3 (N=37)			Study 4 (N=115)		
	Effect	β	p		β	p		β	p		β	p	
RT	Cue				0.025	0.014	*	0.012	<.001	***	0.047	<.001	***
	Set Type				0.029	<.001	***	0.017	0.037	*	0.028	<.001	***
	Switch	0.11	<.001	***									
	Cue x Set Type (Switch)				0.083	<.001	***	0.11	<.001	***	0.11	<.001	***
	Congruence	0.012	0.006	**	0.013	0.043	*	0.008	0.32		0.015	<.001	***
	Block Type	0.05	<.001	***	0.023	<.001	***	0.0085	0.29		0.016	<.001	***
	Switch x Congruence	-0.021	0.033	*									
	Cue x Set Type x Congruence				0.015	0.47		-0.029	0.27		-0.015	0.27	
	Switch x Blocktype	-0.032	0.001	**									
	Cue x Set Type x Block Type				-0.058	0.0043	**	-0.89	<.001	***	-0.079	<.001	***
	Set Type x Block Type				4.25e-4	0.96		0.022	0.06	.	0.015	0.018	*
Error Rate	Congruence	0.013	0.031	*	0.018	0.12		0.012	0.28		0.0064	0.19	
	Switch	0.0044	0.46										
	Cue x Set Type (Switch)				0.053	0.0012	**	0.0018	0.9		8.21e-4	0.91	
	Set Type x Congruence				0.003	0.86		0.012	0.44		0.016	0.026	*
	Congruence x Block Type	0.034	<.001	***	-0.004	0.81		0.012	0.44		0.0083	0.21	
	Switch x Block Type	-0.0069	0.42										
	Cue x Set Type x Block Type				-0.045	0.053	.	-0.015	0.48		-8.16e4-	0.93	
	Set Type x Congruence x Block Type				0.052	0.027	*	0.044	0.044	*	0.035	<.001	***
Global - RT	Switch Condition	0.057	<.001	***	0.0038	0.53		0.024	0.0014	**	0.048	<.001	***
Global - Error Rate	Switch Condition	0.017	<.001	***	0.019	0.004	**	0.018	0.0045	**	0.015	<.001	***

Note: *** p<.001, ** p<.01, * p<.05, . p<.10

shifting task had several consistent effects on behavior across the different versions. Most notably, data from all studies indicated robust RT switch costs, as well as a consistent finding that switch costs were larger in Perseveration-Inhibition blocks compared to Pure Updating blocks. Correlational analyses suggested that in 3 of 4 experiments, switch costs on the two block types were positively correlated with each other, albeit not always strongly (r=.58-.19). This finding suggests that there may be some overlapping variance contributing to switch costs on the two block types, as well as some divergent influences. Incongruence costs, our index of distractibility, were smaller in size and occurred in only 3 of 4 experiments; however we will note that there was a large degree of variability in incongruence costs, with some participants being more susceptible than others.

The error rate findings were less consistent across studies than the RT effects, suggesting that in this task, error rate may be more susceptible to subtle task or participant characteristics. We also note that we observed robust global switch costs in RT (3 of 4 studies) and error rate (all studies), indicating that participants were slower and more prone to errors on Non-Switch trials within a switching context.

Using eye tracking data, we additionally examined how participants' tendencies to fixate on target and distractor stimuli, as well as the time it takes to fixate on the target, varies across task conditions. As shown in Tables 14 and 15, in spite of the consistency in behavioral results, there was no clear pattern across studies to suggest a specific fixation pattern underlies the observed behavioral results.

Table 14
Fixation probability for target and distractors across experiments

	Effect	Study 1 (N=76) β	Study 1 (N=76) *p*		Study 2 (N=19) β	Study 2 (N=19) *p*		Study 4 (N=87) β	Study 4 (N=87) *p*	
Target Probability	Cue				.058	.053	.	.046	.001	**
	Set Type				-.0096	.75		-.038	.004	**
	Switch	.023	.10	.						
	Cue x Set Type				-.059	.17		-.0048	.80	
	Block Type	-.036	.010	**	-9.99E-04	.97		-.012	.37	
	Set Type x Block Type				-.047	.27		-.034	.072	.
Distractor Probability	Cue				-.049	.018	*	-.016	.097	.
	Set Type				.013	.52		.030	.002	**
	Switch	.0063	.55							
	Cue x Set Type				.069	.018	*	-.0077	.56	
	Block Type	.039	<.001	***	.021	.31		.0091	.34	
	Set Type x Block Type				.033	.26		.040	.003	**
	Switch x Block Type	-.029	.049	*						
	Cue x Set Type x Block Type				-.029	.48		.030	.11	
	Switch x Congruence x Block Type	.045	.033	*						
	Cue x Set Type x Congruence x Block Type				.021	.72		-.021	.43	
Irrelevant Symbol Probability	Cue				-.0056	.69		-.019	.003	**
	Switch	-.015	.025	*						
	Cue x Set Type				.0060	.76		.010	.26	
	Switch x Congruence	.017	.074	.						
	Cue x Set Type x Congruence				-.0098	.73		-.0058	.64	
	Switch x Congruence x Block Type	-.027	.041	*						
	Cue x Set Type x Congruence x Block Type				.0090	.82		.0096	.59	

Note: *** *p*<.001, ** *p*<.01, * *p*<.05, . *p*<.10

Table 15
Target fixation time across experiments

	Effect	Study 1 (N=76) β	Study 1 (N=76) *p*		Study 2 (N=19) β	Study 2 (N=19) *p*	Study 4 (N=87) β	Study 4 (N=87) *p*	
Target Fixation Time	Cue				-1.97	.76	-6.80	.068	.
	Block Type	10.31	<.001	***	2.58	.54	-.35	.88	

Note: *** *p*<.001, ** *p*<.01, * *p*<.05, . *p*<.10

EBR Findings

In Experiments 1 and 4, we examined how EBR, our index of striatal DA, affected flexibility and distractibility on the attention shifting task. Based on previous findings and our own pilot data, we had expected that higher striatal DA levels, as determined by higher EBR, would facilitate updating of the attentional set, while simultaneously enhancing the inhibition of irrelevant distractors. Thus, we expected that larger EBR would facilitate switching on Pure Updating blocks, in which the participant merely needs to switch their attentional set held in WM. On the other hand, we expected that larger EBR would predict slower switching on Perseveration-Inhibition blocks, in which

Table 16

EBR-linked effects on RT and Error Rate across experiments

		Study 1 (N=105/104)			Study 4 (N=112/111)		
	Effect	**β**	***p***		**β**	***p***	
RT	EBR^2	-7.74E-05	0.64		2.28E-04	0.081	.
	Switch x EBR	8.19E-04	0.067	.			
	Cue x Set Type x EBR				-0.0013	0.14	
	Switch x EBR^2	-4.15E-04	0.32				
	Cue x Set Type x EBR^2				1.83E-04	0.019	*
	Block Type x EBR	5.14E-04	0.07	.	-2.78E-04	0.49	
w/ Gender	Gender	0.11	0.078	.	-0.064	0.36	
	Switch x EBR x Gender	0.0028	2.15	*			
	Cue x Set Type x EBR x Gender				6.29E-04	0.67	
	Block Type x EBR x Gender	-0.0023	0.0057	**	-0.0013	0.051	.
	Block Type x EBR^2 x Gender	-4.05E-05	<.001	***	9.56E-06	0.87	
Error Rate w/ Gender	no significant effects						
Global - RT	Switch Condition x EBR	-2.76E-04	0.46		-0.0027	0.028	*
	Switch Condition x EBR^2	-4.49E-05	0.2		-4.59E-05	0.054	.
w/ Gender	Switch Condition x Gender	0.033	0.019	*	-0.047	0.21	
	Switch Condition x Gender x EBR	-0.0019	0.075	.	-0.0023	0.48	
	Switch Condition x Gender x EBR^2	-3.70E-04	<.001	***	-2.76E-05	0.65	
Global - Error Rate w/ Gender	Switch Condition x Gender x EBR^2	-1.55E-04	0.063	.	9.72E-04	0.68	

Note: *** $p<.001$, ** $p<.01$, * $p<.05$, . $p<.10$

participants must not only shift their attention, but also overcome the inhibition of a previously-irrelevant target to attend it. We additionally tested for non-linear effects by including a quadratic term, EBR^2 in the model, because of previous work suggesting a non-linear relationship between DA levels and cognitive function (e.g. Cools & D'Esposito, 2011).

As summarized in Table 16, while our findings do suggest that EBR is related to attentional flexibility, they do not support this specific hypothesis, and are largely inconsistent across the two experiments. In Experiment 1, we observed that higher EBR predicted slower switching in general, rather than in a context-specific manner, and further, that this effect was evident only in male participants. In Experiment 2, on the other hand, we observed that EBR^2, rather than EBR, modulated flexibility, indicating a U-shaped relationship between EBR and switch costs. Although there was no direct evidence that EBR modulated flexibility differently across block contexts, there was evidence that both linear (Experiment 1 only) and quadratic EBR measures had different effects depending on the block context, which differ in the salience of distractors, and thus it is possible that EBR is modulating the ability to suppress distraction.

Although our EBR-related hypotheses were not supported by the RT and error rate indices of performance, in Experiment 1, there was some preliminary evidence of EBR-linked variability in cognitive control being context-dependent in our analyses of participants' eye movements (Tables 17 and 18). In particular, we found that, typically, participants with high EBR were less likely to fixate on the distractor letter on Perseveration-Inhibition blocks on Non-Switch trials, but not on Switch trials, which indicates that on blocks in which distractors are typically more salient, higher EBR

Table 17
EBR-linked effects on target and distractor fixation probability across experiments

	Effect	Study 1 (N=72) β	Study 1 (N=72) p		Study 4 (N=87) β	Study 4 (N=87) p	
Target Fixation Time	Block Type x EBR	.91	.011	*	.56	.018	*
	Block Type x EBR^2	.0085	.79		-.046	.022	*
	Switch x EBR	.41	.45				
	Cue x Set Type x EBR				1.51	.0044	**
	Switch x EBR^2	-.087	.063	.			
	Cue x Set Type x EBR^2				.064	.15	
	Switch x Block Type x EBR^2	.12	.082	.			
	Cue x Set Type x Block Type x EBR^2				.017	.79	
	Set Type x Congruence x Block Type x EBR^2				-.074	.069	.
	Switch x Congruence x Block Type x EBR^2	-.20	.045	*			
	Cue x Set Type x Congruence x Block Type x EBR^2				-.019	.83	

Note: *** p<.001, ** p<.01, * p<.05, . p<.10

predicts better distractor inhibition after the switch has been made. The lack of an effect of EBR on distractor fixation on Switch trials is interesting, because it suggests that EBR-linked increases in switch costs are not caused by Perseveration on the previously-relevant target. However, this result was not replicated in Experiment 4. Interestingly, in both experiments, higher EBR predicted faster responding on Pure Updating blocks, and either a smaller reduction in fixation time (Experiment 1), or slower target fixation time (Experiment 4). Although this effect did not emerge for Switch trials specifically, it is in the direction we would expect if higher striatal DA is leading to stronger inhibition of irrelevant targets that may be more difficult to overcome, resulting in a weaker, or more negative relationship between EBR and target fixation time in Perseveration-Inhibition blocks.

Although there were some consistent findings in the EBR results, there were also many discrepancies between the results of the two experiments. One potential contributor to the divergent findings was the different duration of EBR baseline periods. In Experiment 1, blinks were recorded for 2 minutes, whereas in Experiment 4, blinks were

Table 18
EBR-linked effects on target fixation time across experiments

	Effect	Study 1 (N=72) β	Study 1 (N=72) *p*		Study 4 (N=87) β	Study 4 (N=87) *p*	
Target Fixation Time	Block Type x EBR	.91	.011	*	.56	.018	*
	Block Type x EBR^2	.0085	.79		-.046	.022	*
	Switch x EBR	.41	.45				
	Cue x Set Type x EBR				1.51	.0044	**
	Switch x EBR^2	-.087	.063	.			
	Cue x Set Type x EBR^2				.064	.15	
	Switch x Block Type x EBR^2	.12	.082	.			
	Cue x Set Type x Block Type x EBR^2				.017	.79	
	Set Type x Congruence x Block Type x EBR^2				-.074	.069	.
	Switch x Congruence x Block Type x EBR^2	-.20	.045	*			
	Cue x Set Type x Congruence x Block Type x EBR^2				-.019	.83	

Note: *** p<.001, ** p<.01, * p<.05, . p<.10

recorded for 5 minutes. However, a follow-up analysis of Experiment 4 data in which blinks were counted for only the first 2 minutes of the baseline period did not lead to results consistent with Experiment 1.

Additionally, task-related differences between experiments could explain the inconsistent results. Specifically, in Experiment 1, all Switch trials were Cued, whereas Experiment 2 also included Cued Non-Switch trials. Thus, in the Experiment 1 results, is not possible to tease apart the effects attributable to a switching process per se from those attributable to the presence of a cue.

An additional potential contributor to differences across experiments is that the proportion of males and females differed between Experiment 1 (40% male) and Experiment 4 (20% male). Given that we observed large gender differences in Experiment 1, and that males appear to drive many of the EBR-linked effects, it is possible that the gender balance could be contributing to the discrepant results. Although we did explicitly test for gender effects in Experiment 4, it is possible that our male sample was too small to adequately measure gender differences in that sample.

The finding of significant gender effects in our EBR analysis is consistent with other work (Müller et al., 2007; see Jongkees & Colzato, 2016 for review), and suggests that future work with EBR should explicitly test for gender effects. One potential explanation for these gender effects is that females may have different DA levels at different points in the menstrual cycle, and depending on oral contraceptive use (Jongkees & Colzato, 2016). The present study did not gather data to account for these variables, and so at present it is not possible to determine whether these factors are influencing our EBR results.

Pupillometry Findings

Prior to examining the effects of pupil measures on task performance, we first examined how the phasic pupillary response varied across task conditions (Table 19). Surprisingly, although we did observe pupillary differences across task conditions in Experiments 2 and 4, there was little consistency between the two experiments. There did appear to be a fairly consistent finding that on Pure Updating blocks, the latency of the phasic response is earlier on Switch trials compared to (Cued) non-Switch trials.

Table 19
Effects of task on phasic pupil measures across experiments

		Study 1 (N=94)		Study 2 (N=28)			Study 4 (N=102)		
	Effect	**β**	***p***	**β**	***p***		**β**	***p***	
Phasic Magnitude - 1st Trials of Set	Set Type x Congruence			.0086	.25		-.0062	.089	.
	Set Type x Block Type			.0066	.37		-.0016	.65	
	Set Type x Congruence x Block Type			-.013	.23		.012	.025	*
2nd-6th Trials of Set	Congruence	.0011	.33	.0025	.30		.0023	.056	.
	Set Type x Congruence			-.0027	.44		-.0029	.088	.
	Set Type x Block Type			.0060	.089	.	4.18E-04	.81	
Phasic Latency 1st Trials of Set	Set Type			-130.67	.026	*	-34.35	.22	
	Set Type x Block Type			238.61	.0036	**	70.95	.074	.
	Congruence x Block Type	4.93	.90	135.92	.093	.	59.37	.13	
	Set Type x Congruence x Block Type			-284.83	.015	*	-50.27	.38	

Note: *** $p<.001$, ** $p<.01$, * $p<.05$, . $p<.10$

Next, we turned to examining the relationship between tonic pupil measures and task performance on a trial-by-trial basis, in order to better understand how LC-NE system activity influences the flexibility and distractibility of cognitive control. Previous work on the relationship between the LC-NE system and cognitive control led us to

Table 20a
Within-Subjects pupil-linked effects on RT

	Effect	Study 1 (N=94) β	p		Study 2 (N=28) β	p		Study 4 (N=102) β	p	
RT- 1st Trials of Set (Study 1 Switch; Studies 2 & 4 Cued)	Magnitude	.34	.018	*	.076	<.001	***	.66	<.001	***
	Latency	9.3E-05	<.001	***	2.29E-05	.13		1.14E-04	<.001	***
	Latency^2	1.2E-07	<.001	***	-2.62E-09	.89		1.23E-07	<.001	***
	Tonic	.02 .012	.033 .18	*	.015 -.0037	.30 .78		.032 .018	<.001 .019	*** *
	Tonic^2	-.011 -.010	.18 .17		.0077 .010	.51 .39		.011 .0095	.095 .12	.
	Set Type x Latency				4.46E-05	.047	*	1.86E-05	.23	
	Set Type x Latency^2				2.30E-08	.43		3.88E-08	.039	*
	Congruence x Magnitude	.20	.33		.16	.58		-.35	.053	.
	Block Type x Magnitude	.36	.071	.	.23	.44		.0016	.99	
	Block Type x Latency	4.76E-7	.004	**	-2.72E-05	.41		-1.86E-06	.90	
	Set Type x Congruence x Magnitude				-.24	.58		.65	.012	*
	Set Type x Congruence x Magnitude^2				-7.30	.023	*	-2.68	.17	
	Set Type x Block Type x Magnitude				-.77	.075	.	.29	.25	
	Set Type x Block Type x Tonic				-.080 -.049	.005 .055	** .	.0088 -.0034	.61 .82	
	Congruence x Block Type x Magnitude^2	-.081	.98		6.21	.040	*	.077	.77	
	Set Type x Congruence x Block Type x Magnitude				.85	.16		-.74	.045	*
2nd-6th Trials of Set (Study 1 Non-Switch; Studies 2 & 4 Uncued)	Magnitude	.39	<.001	***	.54	<.001	***	.22	<.001	***
	Magnitude^2	.42	.52		-1.43	.039	*	1.44	.006	**
	Latency	2.72E-05	<.001	***	2.29E-05	.13		2.33E-05	<.001	***
	Latency^2	2.72E-08	<.001	***	-2.62E-09	.89		4.14E-08	<.001	***
	Tonic	.028 .015	<.001 <.001	*** ***	.023 -.0037	<.001 .78	** *	.014 .0026	.001 .51	**
	Tonic^2	-8.67E-07 .0013	.80 .70		.0032 .010	.51 .38		.0078 .0095	.019 .0038	* **
	Set Type x Magnitude^2				.0058	.97		.024	.97	
	Set Type x Latency				4.46E-05	.047	*	1.20E-05	.064	.
	Congruence x Magnitude^2	-.039	.69		.16	.27		-.57	.43	
	Block Type x Latency	3.04E-05	<.001	***	2.16E-05	.32		5.99E-06	.35	
	Block Type x Tonic^2	.0073 .0087	.15 .083	 .	.0018 -.015	.84 .33		-.0052 -.0043	.27 .36	
	Set Type x Block Type x Tonic				-6.35E-5 -.049	.96 .055	 .	.011 .0072	.21 .35	
	Set Type x Block Type x Tonic^2				-.635E-04 -.018	.96 .41		.012 .010	.076 .12	.
	Congruence x Block Type x Magnitude^2	-.014	-.10		-2.09	.16		1.71	.093	.
	Set Type x Congruence x Block Type x Magnitude^2				.73	.73		-2.79	.054	.
	Set Type x Congruence x Block Type x Tonic^2				-.033 -.033	.026 .026	* *	.0038 .0042	.69 .65	

Note: *** *p*<.001, ** *p*<.01, * *p*<.05, . *p*<.10

predict that trials with intermediate or small tonic pupil size and large phasic pupil dilations would tend to be predict less distraction than those with large tonic pupil size and smaller phasic pupil dilations. Findings from the within-subjects pupillometry analyses are in Table 20. By far the most consistent pupillary effects across studies were the main effects, particularly for the RT results. Contrary to our expectations, our results suggest that, in many cases, large phasic pupil dilations do not always predict optimal on-task performance on this particular task. Instead, we repeatedly observed that large phasic

Table 20b

Within-Subjects pupil-linked effects on Error Rate and Global Switch Effects

		Study 1 (N=94)			Study 2 (N=28)			Study 4 (N=102)		
	Effect	**β**	***p***		**β**	***p***		**β**	***p***	
Error Rate -	Magnitude	.55	.010	*	-.38	.54		.11	.55	
1st Trials of Set	Latency	6.97E-05	<.001	***	2.53E-05	.51		2.33E-05	.25	
					-.075	.18		.030	.094	.
(Study 1 Switch;	Set Type x Tonic^2				-.088	.11		-.015	.48	
Studies 2 & 4 Cued)	Congruence x Magnitude	-.58	.038	*	.77	.37		-.30	.25	
	Congruence x Latency	-5.59E-05	.029	*	4.26E-05	.48		-8.10E-07	.98	
	Block Type x Latency^2	-9.23E-09	.76		-1.56E-07	.083	.	3.16E-08	.31	
	Set Type x Congruence x Magnitude				-1.74	.14		.72	.051	.
	Set Type x Congruence x Magnitude^2				11.95	.093	.	-1.48	.49	
	Congruence x Block Type x Magnitude^2	-2.38	.33		6.83	.36		-3.88	.081	.
	Congruence x Block Type x Tonic	-.087	.006	**	-.11	.21		.0063	.85	
		-.0063	.042	*	-.13	.12		.014	.67	
	Set Type x Congruence x Block Type x Magnitude				3.18	.056	.	-1.11	.038	*
	Set Type x Congruence x Block Type x Magnitude^2				-14.49	.14		5.59	.071	.
	Set Type x Congruence x Block Type x Latency^2				1.39E-07	.43		1.63E-07	.007	**
					.10	.43		-.084	.065	.
	Set Type x Congruence x Block Type x Tonic				.12	.35		-.053	.23	
					-.060	.58		-.036	.29	
	Set Type x Congruence x Block Type x Tonic^2				-.091	.37		-.045	.17	
2nd-6th Trials of Set	Congruence x Block Type x Magnitude	-.61	.061	.	-.16	.88		.054	.87	
(Study 1 Non-Switch;	Congruence x Block Type x Latency^2	6.89E-08	.066	.	-4.25E-08	.70		1.69E-08	.63	
	Congruence x Block Type x Tonic	-.081	.034	*	.0080	.93		.026	.48	
Studies 2 & 4 Uncued)		-.0073	.049	*	-.031	.74		.024	.51	
		-.074	.059	.	-.056	.47		-6.07E-04	.98	
	Congruence x Block Type x Tonic^2	-.080	.039	*	-.058	.44		-.0050	.86	
Global - RT	Switch Condition x Magnitude	.27	.003	**	-.0024	.99		.018	.83	
	Switch Condition x Magnitude^2	-1.81	.059	.	-2.34	.097	.	.073	.39	
	Switch Condition x Latency	2.73E-05	<.001	***	8.81E-07	.93		4.71E06	.45	
	Switch Condition x Latency^2	1.31E-08	.12		8.99E-10	.94		3.07E-08	<.001	***
	Switch Condition x Tonic	.026	<.001	***	5.20E-05	.95				
		.020	<.001	***	.0029	.69		.0031	.57	
Global - Error Rate	Switch Condition x Latency	2.36E-05	.067	.	-1.39E-05	.76		6.24E-06	.71	
	Switch Condition x Latency^2	4.99E-08	.005	***	-5.84E-09	.91		2.39E-08	.20	
	Switch Condition x Tonic	-.035	.53		-.036	.81		.20	.028	*
		-.023	.68		-.027	.86		.16	.078	.
	Switch Condition x Tonic^2	.033	.50		-.14	.27		.12	.091	.
		.031	.51		-.12	.86		.098	.19	

Note: *** $p<.001$, ** $p<.01$, * $p<.05$, . $p<.10$

responses predicted slower responding. This finding may suggest that the largest phasic responses on our task may be reflective of re-orienting to the task, following periods of relative inattention (e.g. Murphy, Robertson, Balsters & O'Connell, 2011), and so they do not always correspond to the fastest or least distracted trials. Supporting this idea is that there were often also quadratic effects of phasic pupil indices, suggesting that in some cases, the largest and smallest phasic responses have more similar RTs compared to intermediate-magnitude phasic responses, which may be reflective of optimal on-task responding. Another interesting finding from the pupil analyses is that the latency of the phasic response, in addition to the magnitude, often had both linear and quadratic effects on

Table 21a

Pupil-linked effects on target and distractor letter fixation probability

	Effect	Study 1 (N=68) β	Study 1 (N=68) *p*		Study 2 (N=18) β	Study 2 (N=18) *p*		Study 4 (N=83) β	Study 4 (N=83) *p*	
Target Probability 1st Trials of Set	Latency^2	-1.19E-07	.053	.	3.58E-08	.86		-6.09E-8	.29	
	Tonic	.023 .022	.61 .62		-.059 -.050	.62 .66		-.059 .10	.084 .045	. *
	Set Type x Magnitude				.62	.77		-1.37	.051	.
	Set Type x Magnitude^2				-9.71	.60		12.11	.035	*
	Congruence x Magnitude	.99	.22		3.98	.084	.	-.14	.85	
	Block Type x Magnitude	-.98	.20		1.93	.51		-1.54	.031	*
	Set Type x Block Type x Magnitude				-.95	.80		2.80	.006	**
	Set Type x Block Type x Magnitude^2				9.32	.73		-16.44	.037	*
	Set Type x Block Type x Latency^2				-8.66E-07	.021	*	6.16E-05	.53	
	Congruence x Block Type x Magnitude	-.040	.97		-3.88	.31		2.16	.036	*
	Set Type x Congruence x Block Type x Magnitude				.10	.99		-2.94	.046	*
	Set Type x Congruence x Block Type x Magnitude^2				5.89	.88		23.95	.037	*
	Set Type x Congruence x Block Type x Latency^2				1.21E-06	.014	*	-5.44E-08	.74	
2nd-6th Trial of Set	Magnitude^2	-7.68	.064	.	16.94	.24		-3.82	.29	
	Latency	-1.86E-06	.97		-1.65E-04	.087	.	-3.10E-05	.44	
	Set Type x Latency				2.16E-04	.047	*	-4.25E-05	.41	
	Set Type x Tonic				.14 .18	.29 .12		-.10 -.096	.080 .094	. .
	Set Type x Congruence x Tonic^2				-.037 .019	.80 .91		-.22 -.23	.006 .003	** **
Distractor Probability 1st Trial of Set	Magnitude^2	.45	.91		-15.80	.10		6.44	.058	.
	Block Type x Magnitude	.028	.97		-.37	.85		1.13	.032	*
	Congruence x Magnitude^2	2.79	.62		12.97	.32		-7.76	.098	.
	Block Type x Phasic^2	-2.05	.72		13.20	.37		-8.21	.054	.
	Set Type x Block Type x Latency^2				6.37E-07	.009	**	3.71E-08	.67	
	Congruence x Block Type x Latency^2	3.13E-08	.78		4.07E-07	.076	.	-5.41E-08	.52	
	Congruence x Block Type x Tonic	-.026 .012	.69 .86		-.10 -.27	.50 .058	 .	-.039 -.0066	.54 .91	
	Set Type x Congruence x Block Type x Latency^2				-9.98E-07	.002	**	1.21E-06	.92	
2nd-6th Trials of Set	Set Type x Congruence x Tonic^2				.099 .10	.35 .37		.14 .14	.018 .014	* *
	Set Type x Congruence x Block Type x Tonic^2				-.31 -.36	.095 .042	. *	-.13 -.13	.09 .084	. .

Note: *** p<.001, ** p<.01, * p<.05, . p<.10

cognitive control. More consistent with our predictions, larger tonic pupil size also predicted slower RTs. Given that large tonic pupil size is thought to reflect the LC-NE system's tonic exploratory mode, the large pupils coupled with slower responding observed here may reflect task disengagement.

Aside from these main effects, trial-by-trial pupil measures also had interactive effects on indices of both flexibility and distractibility; however because of a lack of consistency across studies, it is not clear how reliable these findings will prove, especially given the high degree of similarity in the task across experiments. There was additionally no clear pattern of fixation probability or fixation time across the different experiments (Tables 21 and 22).

Thus, although this study aimed to determine specifically how trial-by-trial pupil indices predict flexibility and distractibility of cognitive control across experimental

Table 21b

Pupil-linked effects on irrelevant symbol fixation probability

		Study 1 (N=68)			Study 2 (N=18)			Study 4 (N=83)		
	Effect	**β**	***p***		**β**	***p***		**β**	***p***	
Irrelevant Symbol Probability 1st Trial of Set	Tonic	.0039 .0077	.84 .69		.11 .10	.053 .069	. .	.0047 .0014	.78 .93	
	Congruence x Magnitude	-.16	.66		-1.79	.087	.	-.60	.10	
	Congruence x Latency	2.99E-05	.30		-1.31E-04	.081	.	9.18E-08	.020	*
	Congruence x Tonic	.019 .032	.45 .19		-.10 -.11	.17 .16		-.055 -.048	.029 .051	* .
	Set Type x Tonic				-.11 -.13	.17 .084	 .	.013 .011	.61 .67	
	Block Type x Tonic	-.022 -.032	.46 .26		-.12 -.12	.094 .11	.	.043 .038	.17 .20	
	Set Type x Congruence x Latency^2				-1.05E-07	.50		-1.43E-07	.010	**
	Congruence x Block Type x Magnitude	.058	.90		3.33	.057	.	.18	.72	
	Congruence x Block Type x Latency	-4.91E-05	.22		1.80E-04	.10	.	-5.40E-6	.91	
2nd-6th Trials of Set	Latency	-3.32E-05	.098	.	7.02E-05	.10		7.23E-06	.71	
	Latency^2	5.37E-10	.98		6.17E-08	.24		4.25E-08	.070	.
	Set Type x Latency				-8.83E-05	.079	.	1.03E-05	.68	
	Congruence x Latency	6.42E-05	.008	**	1.85E-05	.74		1.83E-05	.74	
	Block Type x Magnitude	.079	.78		-.33	.76		-4.42	.038	*
	Block Type x Latency	7.54E-05	.002	**	-4.66E-5	.42		9.52E-06	.69	
	Block Type x Latency^2	5.84E-08	.043	*	3.23E-08	.65		-1.83E-08	.53	
	Set Type x Congruence x Tonic				.050 .038	.49 .60		-.071 -.069	.068 .076	. .
	Set Type x Block Type x Magnitude^2				12.48	.30		6.07	.061	.
	Set Type x Block Type x Latency				1.35E-05	.066	.	-1.39E-05	.68	
	Congruence x Block Type x Magnitude^2	-2.31	.47		-15.61	.27		5.47	.065	.
	Congruence x Block Type x Latency	-8.18E-05	.014	*	3.90E-06	.96		-1.33E-05	.69	
	Congruence x Block Type x Latency^2	-6.70E-08	.093	.	-9.41E-08	.37		3.72E-08	.36	

Note: *** p<.001, ** p<.01, * p<.05, . p<.10

conditions, the results make it difficult to reach definitive conclusions, aside from those relating to the main pupil effects. Some inconsistency was to be expected, particularly between Experiment 1 and the other experiments, because the addition of a Non-Switch cue factor in Experiment 2 creates a distinction between Switch and Non-Switch Cued trials, as well as Uncued trials within Switch and Non-Switch Sets, thereby introducing greater complexity and making cross-study comparisons difficult. Additionally, Experiment 2 had a smaller sample size, and so although the task was very similar in Experiments 2 and 4, it is possible that Experiment 2 did not have sufficient power to detect the same effects as Experiment 4. One additional contributor to this discrepancy is that Experiment 2 had a constant stimulus presentation time of 1000ms, whereas in the other experiments, stimuli remained on the screen until participant response. It is possible that this divergence in stimulus presentation timing introduced systematic variability into participants' performance of the task, or by directly altering their pupillary response.

One potential contributor to the inconsistent trial-by-trial pupil findings is that the by-condition reliability of pupil measures was low. Although this low reliability does not rule out a consistent relationship between pupil measures and task performance, it does suggest that the pattern of participants' pupil responses across different task conditions was not consistent. It may be the case that because it is noisy, pupil data may provide more consistent results when aggregated by subject.

Table 22
Pupil-Linked effects on target fixation time

	Effect	Study 1 (N=68) β	*p*		Study 2 (N=18) β	*p*		Study 4 (N=83) β	*p*	
Target Probability 1st Trials of Set	Magnitude	169.22	.034	*	115.06	.38		35.11	.55	
	Magnitude²	1816.19	017	*	1200.26	.42		-292.81	.62	
	Latency	.014	.029	*	-.0064	.51		.014	.004	**
	Latency²	1.37E-05	.097	.	1.11E-05	.38		1.98E-05	<.001	***
	Tonic	-.31	.90		-8.76	.32		-3.83	.31	
		1.54	.75		18.02	.032	*	-4.18	.24	
	Tonic²	5.45	.006	**	14.51	.068	.	4.06	.20	
		4.13	.34		15.38	.051	.	2.31	.46	
	Set Type x Magnitude				297.28	.15		168.10	.044	*
	Set Type x Latency				.042	.004	**	.0024	.73	
	Set Type x Tonic²				-25.41	.025	*	-4.63	.29	
					-23.68	.033	*	-2.87	.50	
	Block Type x Magnitude²	-217.55	.68		-761.99	.74		-1.49	.73	
	Set Type x Congruence x Latency				-.037	.085	.	.0081	.42	
	Set Type x Block Type x Magnitude				-14.00	.96		-218.16	.068	.
	Set Type x Block Type x Tonic²				24.98	.11		786.48	.51	
					26.13	.090	.	5.72	.36	
2nd-6th Trial of Set	Magnitude	20.07	.63		152.63	.018	*	37.39	.25	
	Latency	.0027	.33		.0028	.57		.0024	.23	
	Latency²	9.96E-06	.007	**	-.993E-06	.095	.	1.20E-05	<.001	***
	Tonic	-.31	.90		2.83	.49		-5.97	.002	**
		-1.84	.41		.55	.89		-8.92	<.001	***
	Tonic²	5.45	.006	**	4.35	.20		4.69	.003	**
		5.22	.007	**	4.91	.15		4.60	.003	**
	Set Type x Magnitude²				-33.63	.72		-1050.98	.016	*
	Set Type x Tonic				-5.55	.35		6.50	.017	*
					-5.44	.33		8.19	.001	**
	Congruence x Latency²	-9.10E-07	.86		2.04E-05	.019	*	-1.42E-04	.96	
	Block Type x Latency²	5.97E-07	.91		9.16E-05	.28		-7.57E-06	.056	.
	Block Type x Tonic²	-4.80	.10		3.14	.51		-.095	.68	
		-5.02	.083	.	2.32	.62		-.61	.79	
	Set Type x Congruent x Magnitude²				9.83	.94		1084.95	.076	
	Set Type x Congruent x Tonic				18.22	.031	*	-3.01	.43	
					20.45	.009	**	-5.07	.15	
	Set Type x Block Type x Magnitude²				-208.25	.89		1638.93	.010	**
	Set Type x Block Type x Latency²				-8.77E-06	.48		1.25E-05	.029	*
	Set Type x Congruence x Block Type x Magnitude²				-429.84	.83		-2171.91	.014	*
	Set Type x Congruence x Block Type x Tonic²				-16.64	.097	.	-2.74	.55	
					17.54	.77	.	-3.81	.40	

Note: *** $p<.001$, ** $p<.01$, * $p<.05$, . $p<.10$

Experiments 1 and 4 did also investigate how individual differences in pupil indices predicts performance. Here, our initial expectations were similar to those for the within-subjects analyses, with larger phasic pupil responses predicting less distractibility, but larger tonic pupil size predicting greater distractibility. However, results here were often opposite to our expectations. For example, Experiment 1 participants with large and small tonic pupil size, which we would expect to be associated with high distractibility, were actually faster to respond on Incongruent trials. Similarly, in Experiment 2, there was a main effect, in which participants with large or small tonic pupil size, which are believed to reflect drowsy and restless LC-NE modes respectively, tended to have faster RTs. These findings may suggest that mean-level pupil measures over a session may relate to performance differently than trial-by-trial indices. Interestingly, larger variability tended to be predictive of worse performance on conditions requiring greater cognitive control, including on Switch blocks (vs. Non-Switch blocks), Switch trials, and Incongruent trials. As is evident in Table 23, however, there was also not a great deal of consistency between the two experiments, and so these findings should be interpreted with caution. Individual differences in pupil indices were often relevant to global switch costs; however these effects were not always in the same direction.

The reliability of phasic pupil measures was markedly higher when aggregated by subject, compared to aggregation by condition (within each subject), suggesting that subjects show a high degree of consistency in both mean-level and variability of pupil measures. The reliability of tonic pupil measures was still quite low, however, and this poor reliability was not fully explained by baseline differences in cued versus uncued trials. Given that other studies (e.g. Unsworth & Robison, *2017a*), have found tonic pupil indices to be reliable, it will be important to determine why our measure of tonic pupil size was not reliable. In the meantime, it is important to interpret our tonic pupil findings with caution.

Thus, based on results from the attention shifting task, these experiments reinforce previous findings that striatal DA tone and LC-NE activity are predictive of performance on a cognitive control task, and may suggest that their specific relationships with behavior are complex, often non-linear, and highly task-dependent (e.g. Dreisbach et al., 2005; Cools & D’Esposito, 2011; Müller et al., 2004). On the other hand, the because of a high degree of variability in the results across experiments, it is difficult precisely characterize these relationships.

Table 23a

Effects of individual differences in pupil indices on task performance on RTs

		Study 1 (N=94)			Study 4 (N=102)		
	Effect	**β**	***p***		**β**	***p***	
RT	Latency	1.75E-04	0.093	.	1.62E-07	.68	
Mean-level Indices	Tonic²	.0022 3.38E-04	.92 .99		-.033 -.034	.035 .026	* *
	Switch x Latency	4.84E-05	.22				
	Cue x Set Type x Latency				1.28E-04	.029	*
	Congruence x Magnitude	-.31	.076	.	.18	.26	
	Congruence x Tonic²	-.0095 -.0084	.060 .095	. .	.0024 .0026	.57 .54	
	Block Type x Magnitude²	-.17	.013	*	-2.21	.63	
	Block Type x Latency	1.15E-04	<.001	***	-2.87E-05	.27	
	Switch x Congruence x Magnitude	1.03	.010	*			
	Cue x Set Type x Congruence x Magnitude				.91	.076	.
	Switch x Block Type x Magnitude²	-.13	.42				
	Cue x Set Type x Block Type x Magnitude²				.33	.029	*
	Switch x Block Type x Latency	3.97E-05	.48				
	Cue x Set Type x Block Type x Latency				-2.00E-04	.015	*
	Set Type x Block Type x Latency				8.62E-05	.017	*
Variability indices	Latency SD	8.12E-04	<.001	***	8.87E-04	<.001	***
	Tonic SD	2.41E-04	.24		-1.36E-04	.43	
	Switch x Contgruence x Magnitude SD	1.22	.04	*			
	Cue x Set Type x Congruence x Magnitude SD				-.13	.91	
	Cue x Congruence x Tonic SD				-1.31E-04 -9.91E-05	.23 .099	 .
	Switch x Congruence x Block Type x Latency SD	1.99E-05	.87				
	Cue x Set Type x Congruence x Block Type x Latency SD				3.16E-04	.089	.
	Switch x Congruence x Block Type x Tonic SD	-1.94E-04 -2.03E-04	.22 .094	 .			
	Cue x Set Type x Congruence x Block Type x Tonic SD				2.23E-05 -7.29E-05	.32 .54	

Note: *** p<.001, ** p<.01, * p<.05, . p<.10

Table 23b

Effects of individual differences in pupil indices on task performance on error rate and global switch effects

	Effect	Study 1 (N=94) β	*p*		Study 4 (N=102) β	*p*	
Error Rate	Switch x Latency	7.34E-05	.017	*			
Mean-level indices	Cue x Set Type x Latency				-1.14E-05	.78	
	Congruence x Tonic	-.013	.071	.	-8.09E-04	.89	
		-.012	.082	.	-9.73E-04	.87	
	Switch x Congruence x Latency	-1.29E-04	.003	**			
	Cue x Set Type x Congruence x Latency				3.04E-05	.61	
Variability indices	Switch x Tonic SD	-9.68E-06	.87				
		9.91E-06	.83				
	Cue x Set Type x Tonic SD				-1.22E-04	.11	
					-7.47E-05	.072	.
Global - RT	Switch Condition x Magnitude	.42	.010	*	-.16	.28	
Mean-level indices	Switch Condition x Magnitude^2	3.15	.64		-.13	.004	**
	Switch Condition x Latency	6.23E-05	.0078	**	5.03E-05	0.034	*
	Switch Condition x Tonic	.0089	.095	.	-.014	.003	**
		.010	.057	.	-.015	.001	**
	Switch Condition x Tonic^2	.0068	.16		-.0084	.032	*
		.0058	.22		-.0094	.016	*
Variability indices	Switch Condition x Latency SD	-3.09E-05	.40		1.17E-04	.002	**
	Switch Condition x Tonic SD	1.11E-04	.014	*	-1.12E-04	.014	*
		1.14E-04	.001	**	-6.82E-05	.004	**
Global - Error Rate Variability indices	Switch Condition x Latency SD	6.23E-05	.013	*	3.38E-05	.19	

Note: *** $p<.001$, ** $p<.01$, * $p<.05$, . $p<.10$

These individual difference findings are also relevant to a recent model proposing that in variability, rather than mean-level LC-NE function account for individual differences in attention control (Unsworth & Robison, 2017a; 2017b). Specifically, this model suggests that individuals with poor attentional control are less able to regulate their arousal to facilitate optimal performance, and instead are under-aroused on some trials and over-aroused on others, resulting in performance decrements. Here, we did observe across both experiments that participants with more variable phasic latency did show overall poorer performance. Additionally, increased variability in phasic pupil measures generally predicted increased poorer performance on Switch blocks, which are more attentionally demanding than Non-Switch blocks. Both of these findings suggest that in our sample, more variable pupil measures predicted poorer performance, which would support Unsworth and Robison's model.

In spite of some findings that map onto prior work on DA and NE, it is also important to draw attention to the inconsistencies across the experiments performed here. There are several potential explanations for the high degree of inconsistency observed here. First, it is possible that pupil and EBR-linked relationships with cognitive control are subtle, and highly susceptible to task factors, such as the proportion of Switch to Non-Switch trials, which differed between Experiment 1 and the others, or to changes in task timing Additionally, because of the large number of statistical tests performed here, it is possible that some of the significant findings here are spurious, especially given that many did not replicate within the current project. An additional contributor to the inconsistencies could be the low reliability of pupil data at the condition level, as well as tonic pupil data at the subject level. In future work, it will be important to determine the cause of poor reliability of tonic pupil data, and perhaps employ analysis strategies that rely on pupil data that is aggregated by subject.

Finally, it is possible that our strategies for data analysis exacerbated the noise in this data. Although linear mixed models have many strengths, including the ability to control for between-subject variance, they are also more susceptible to outliers than are more traditional analysis techniques. While we attempted to remove influential outliers, the skewed nature of the quadratic variables in particular may have increased the susceptibility of these data to random noise. Relatedly, our choice of testing for non-linear effects using quadratic predictors may not have been the best fit for detecting non-linear patterns in the data, because the quadratic formula makes the largest values more extreme, rather than equidistant from a midpoint. Future work with these data will explore alternative strategies for testing theoretically-based predictions about non-linear effects.

Cross-Session Analyses

The final aim of this project was to assess whether it is possible to link neurotransmitter-mediated individual differences in cognitive control to individuals' flexibility and distractibility in an ecologically valid lab-based task, as well as their real-world goal pursuit behavior. Although we had initially aimed to test mediation models to determine whether observable behaviors in the lab mediate the relationship between the attention shifting task performance and self-reported real-world behaviors, there were no indices that could form a relationship across all three components of the study, so we were not able to test those hypotheses in this dataset.

A promising cross-session finding is that, although the effects of EBR on cognitive control seemed to vary, participants' EBR showed a high degree of reliability, both within and across sessions. This finding is in agreement with other work demonstrating reliability repeated measures reliability of EBR (see Jongkees & Colzato for review), and and suggests that EBR may be a promising low-cost measure for examining DA-linked in-lab effects to behaviors at other time points and in the real world.

An important contribution of this project was the use of a novel, ecologically-valid task to measure participants' distractibility and flexibility in the lab. The Internet

Search Task, in which participants completed a standardized, but open-ended assignment, complements other work examining media multitasking the lab, which has used more restrictive but well-controlled tasks (Ie, Haller, Langer & Courvoisier, 2012), or the unstandardized, but highly valid task of completing one's own homework (Calderwood, Ackerman & Conklin, 2014). Here, participants all had the same goal of creating a guide that could assist an incoming college freshman. This particular task was chosen for its relevance to participants' real-world academic goals, because learning about how to be an effective college student could also help participants achieve their own goals. Because the task is standardized, we will also be able to examine the thoroughness, quality, and originality of participants' Study Guides as an outcome measure. An additional advantage of our approach is that we were able to record participants' specific patterns of computer use, to determine, for example, whether participants tended to complete many brief events (high switching) or fewer longer events (low switching). It is also important to note that, contrary to expectations, we did not observe a link between flexibility and distractibility during the internet search task and real-world behavior. As is discussed in more detail below, there are several possible explanations for why our study may have failed to uncover a link if one exists. However, it is also important to acknowledge that the Internet Search Task may provide useful information that is not captured by self-report, especially in light of the finding that people often estimate their own media multitasking inaccurately (Moreno et al., 2012). Future analyses, including those that will examine self-reported goal pursuit effectiveness will be important to establish the validity of the behavioral measures acquired during the Internet Search Task.

Although we were not able to test our planned mediation hypotheses, we did observe some correlations between performance on the attention shifting task and behavior in other components of the study. Most notably, participants' switch costs on Perseveration-Inhibition blocks were significantly correlated with the average time they spent on each website. Participants with large switch costs tended to spend more time on task-relevant websites, suggesting that they may have been using a more stable, and less flexible strategy for completing the internet search task. On the other hand, it is important to note that other observed correlations were in the opposite direction to our predictions, for example at the trend level, participants who had larger incongruence costs on the attention shifting task, for whom we would expect to observe greater distractibility, spent less time on off-task websites during the internet search task. It is also important to note that because of the novelty of this approach, we chose not to correct for multiple comparisons, which increases the likelihood of false positive results. Nonetheless, it is encouraging to observe some links between performance on a neutral lab-based task and performance on a more ecologically-valid task, as well as real-world behavior.

It is also interesting that pupil measures from Session 1 predicted self-reported distractibility. Specifically, participants with large mean phasic magnitude, as well as larger tonic pupil size tended to report less distractibility during the busy week, whereas variability in phasic peak latency predicted greater self-reported distractibility. From our findings, it is not possible to determine whether these effects are caused by NE-mediated changes in distractibility, or rather if these effects reflect a more general cognitive or motivational characteristic.

Future work with these and other data will be important to address some limitations and pursue additional directions, to test links between attention task performance and ecologically valid and real-world behaviors. First, our behavioral indices of flexibility and distractibility on the attention shifting task (flexibility and distractibility), as well as some of our indices from the Internet Search Task (mean time per event type) had poor reliability. Thus, it will be important to determine whether our findings replicate with alternative, more reliable measures of behavior.

Future work would also benefit from a latent variable approach, in which the indices of cognitive control (flexibility and distractibility in this case) are combined to create a single composite measure, which is then used to test relationships between lab-based and real-world cognitive control. Such an approach would reduce the number of comparisons and thereby decrease the likelihood of spurious results.

In addition to potential statistical issues, there are also potential conceptual explanations for our finding of few significant relationships between performance on the attention shifting task and the Internet Search Task and follow-up questionnaires. First, it is possible that our measures lacked breadth and/or specificity. On the one hand, our attention shifting task may have been too narrow to capture variance in cognitive control relevant to real-world behavior. Previous research showing that in-lab cognitive performance has been predictive of real-world behavior (e.g. Unsworth, Brewer & Spillers, 2012) has used composite measures of cognitive abilities, by combining multiple tasks into a latent variable. On the other hand, it is also possible that some of our measures lacked specificity. In particular, our self-report questionnaires asked participants broad questions about how distractible they were, and how much they switched tasks each day. Other work (e.g. Unsworth et al., 2012) has instead included questions about specific types of attention failures, rather than distractibility more broadly. These targeted questions may be more relevant to the attentional processes of interest, and may have the added benefit of being easier to accurately self-report.

Finally, motivational considerations may also account for the relatively weak link between attention task performance and our other indices of flexibility and distractibility. Recent work has emphasized that cognitive control is a value-based choice (Shenhav et al., 2017), such that our willingness to exert cognitive effort towards a task determines the effectiveness of cognitive control while performing the task (Westbrook & Braver, 2016). Essentially, an individual's cognitive control does not depend solely on their abilities, but also on their current motivational state. If participants' motivational state differed across our different indices of flexibility and distractibility, it is likely that we would not observe a strong relationship between them. In order to bring participants' motivational state during lab tasks more closely into alignment with their real-world motivation to pursue goals, it may be helpful to frame the attention tasks to be more relevant to those goals. Additionally, it will be important that future research measure participants' motivation across different experimental components, in order to account for any variability in motivation.

Overall, addressing these issues may increase the likelihood of finding meaningful differences relationships between cognitive control in the lab and in real-world measures, and additionally increase confidence in any relationships that are observed.

In conclusion, the experiments reported here aimed to determine how DA and NE contribute to maintenance and updating of an attentional set across different contexts using EBR and pupillometry indices respectively. Additionally, we aimed to begin an investigation of how individual differences in cognitive control performance are related to behavior in an ecologically valid task and in the real world. In general, the results support the notion that EBR is related to the flexibility of cognitive control; however the precise nature of the relationship (linear versus non-linear) was not consistent in our experiments. Further, although the main effects of pupil measures were consistent across experiments, the specific effects on task performance across conditions varied a great deal from experiment to experiment. Future work with this and other data sets will be important for establishing whether these discrepancies are caused by to subtle differences in the task or participant populations, shortcomings of our statistical analysis strategy, or inherent noisiness of pupillometry and EBR data. Our cross-session of Experiment 4 did indicate some relationships between participants' distractibility and flexibility across the different study components; however more work is needed before it can be determined whether these relationships are the result of variability in the flexibility and distractibility of cognitive control.

APPENDIX A

EXPERIMENT 1 EBR X PUPIL RESULTS

Model 1: Predicting RT Across Conditions from EBR and Pupil Measures (N=91)

Cued Trials

	Magnitude Model			Latency Model		
	B	*std. Error*	*p*	*B*	*std. Error*	*p*
Fixed Parts						
(Intercept)	6.780	0.04	<.001	6.719	0.03	<.001
Congruentincongruent	-0.054	0.02	.022	-0.041	0.02	.086
BlocktypePersInhib	0.004	0.02	.854	-0.006	0.02	.809
phasicCtr	0.548	0.21	.010			
phasicSq	-0.934	2.12	.660			
tonicZ	0.028	0.01	.052	0.019	0.01	.128
tonicSq	-0.023	0.01	.042	-0.023	0.01	.034
ebrCtr	-0.001	0.00	.706	-0.000	0.00	.835
ebrSq	-0.000	0.00	.064	-0.000	0.00	.097
Congruentincongruent:BlocktypePersInhib	0.068	0.03	.040	0.038	0.03	.264
Congruentincongruent:phasicCtr	-0.087	0.30	.771			
BlocktypePersInhib:phasicCtr	0.278	0.30	.350			
Congruentincongruent:ebrCtr	0.001	0.00	.454	0.000	0.00	.983
BlocktypePersInhib:ebrCtr	0.002	0.00	.117	0.001	0.00	.322
phasicCtr:ebrCtr	-0.001	0.01	.929			
Congruentincongruent:ebrSq	0.000	0.00	.002	0.000	0.00	.024
BlocktypePersInhib:ebrSq	0.000	0.00	.476	0.000	0.00	.415
phasicCtr:ebrSq	-0.001	0.00	.222			
Congruentincongruent:phasicSq	3.313	3.01	.272			
BlocktypePersInhib:phasicSq	3.223	3.11	.302			
phasicSq:ebrCtr	0.200	0.12	.092			

phasicSq:ebrSq	0.017	0.01	.141			
Congruentincongruent:tonicZ	-0.003	0.02	.876	-0.000	0.02	.987
BlocktypePersInhib:tonicZ	0.019	0.02	.369	0.006	0.02	.725
tonicZ:ebrCtr	-0.001	0.00	.187	-0.001	0.00	.283
tonicZ:ebrSq	-0.000	0.00	.379	-0.000	0.00	.310
Congruentincongruent:tonicSq	0.026	0.02	.103	0.017	0.02	.272
BlocktypePersInhib:tonicSq	0.003	0.02	.851	0.018	0.02	.253
tonicSq:ebrCtr	0.000	0.00	.767	0.000	0.00	.629
tonicSq:ebrSq	0.000	0.00	.103	0.000	0.00	.090
Congruentincongruent:BlocktypePersInhib:phasicCtr	0.200	0.42	.638			
Congruentincongruent:BlocktypePersInhib:ebrCtr	-0.001	0.00	.486	-0.001	0.00	.704
Congruentincongruent:phasicCtr:ebrCtr	0.023	0.02	.187			
BlocktypePersInhib:phasicCtr:ebrCtr	0.004	0.02	.809			
Congruentincongruent:BlocktypePersInhib:ebrSq	-0.000	0.00	.134	-0.000	0.00	.459
Congruentincongruent:phasicCtr:ebrSq	0.003	0.00	.119			
BlocktypePersInhib:phasicCtr:ebrSq	0.001	0.00	.728			
Congruentincongruent:BlocktypePersInhib:phasicSq	-6.195	4.32	.153			
Congruentincongruent:phasicSq:ebrCtr	-0.078	0.19	.681			
BlocktypePersInhib:phasicSq:ebrCtr	-0.153	0.17	.369			
Congruentincongruent:phasicSq:ebrSq	-0.029	0.02	.083			
BlocktypePersInhib:phasicSq:ebrSq	-0.020	0.02	.221			
Congruentincongruent:BlocktypePersInhib:tonicZ	-0.013	0.03	.652	-0.017	0.03	.520
Congruentincongruent:tonicZ:ebrCtr	0.002	0.00	.139	0.000	0.00	.643
BlocktypePersInhib:tonicZ:ebrCtr	-0.000	0.00	.890	-0.000	0.00	.766
Congruentincongruent:tonicZ:ebrSq	0.000	0.00	.176	0.000	0.00	.321
BlocktypePersInhib:tonicZ:ebrSq	-0.000	0.00	.957	0.000	0.00	.658
Congruentincongruent:BlocktypePersInhib:tonicSq	-0.019	0.02	.427	-0.018	0.02	.437
Congruentincongruent:tonicSq:ebrCtr	-0.001	0.00	.451	-0.001	0.00	.462

BlocktypePersInhib:tonicSq:ebrCtr	-0.001	0.00	.451	-0.001	0.00	.379
Congruentincongruent:tonicSq:ebrSq	-0.000	0.00	.061	-0.000	0.00	.137
BlocktypePersInhib:tonicSq:ebrSq	0.000	0.00	.960	-0.000	0.00	.532
Congruentincongruent:BlocktypePersInhib:phasicCtr:ebrCtr	-0.027	0.02	.257			
Congruentincongruent:BlocktypePersInhib:phasicCtr:ebrSq	-0.003	0.00	.223			
Congruentincongruent:BlocktypePersInhib:phasicSq:ebrCtr	0.009	0.25	.971			
Congruentincongruent:BlocktypePersInhib:phasicSq:ebrSq	0.037	0.02	.114			
Congruentincongruent:BlocktypePersInhib:tonicZ:ebrCtr	-0.002	0.00	.279	-0.000	0.00	.818
Congruentincongruent:BlocktypePersInhib:tonicZ:ebrSq	-0.000	0.00	.717	-0.000	0.00	.972
Congruentincongruent:BlocktypePersInhib:tonicSq:ebrCtr	0.002	0.00	.217	0.001	0.00	.355
Congruentincongruent:BlocktypePersInhib:tonicSq:ebrSq	0.000	0.00	.919	0.000	0.00	.961
latencyCtr				0.000	0.00	<.001
latencySq				0.000	0.00	<.001
Congruentincongruent:latencyCtr				-0.000	0.00	.579
BlocktypePersInhib:latencyCtr				0.000	0.00	.052
latencyCtr:ebrCtr				0.000	0.00	.012
latencyCtr:ebrSq				-0.000	0.00	.132
Congruentincongruent:latencySq				0.000	0.00	.744
BlocktypePersInhib:latencySq				0.000	0.00	.412
latencySq:ebrCtr				0.000	0.00	.168
latencySq:ebrSq				0.000	0.00	.979
Congruentincongruent:BlocktypePersInhib:latencyCtr				-0.000	0.00	.707
Congruentincongruent:latencyCtr:ebrCtr				-0.000	0.00	.856
BlocktypePersInhib:latencyCtr:ebrCtr				-0.000	0.00	.051
Congruentincongruent:latencyCtr:ebrSq				0.000	0.00	.219

BlocktypePersInhib:latencyCtr:ebrSq				-0.000	0.00	.735
Congruentincongruent:BlocktypePersInhib:latencySq				-0.000	0.00	.955
Congruentincongruent:latencySq:ebrCtr				0.000	0.00	.888
BlocktypePersInhib:latencySq:ebrCtr				-0.000	0.00	.349
Congruentincongruent:latencySq:ebrSq				-0.000	0.00	.404
BlocktypePersInhib:latencySq:ebrSq				-0.000	0.00	.446
Congruentincongruent:BlocktypePersInhib:latencyCtr:ebrCtr				0.000	0.00	.529
Congruentincongruent:BlocktypePersInhib:latencyCtr:ebrSq				-0.000	0.00	.500
Congruentincongruent:BlocktypePersInhib:latencySq:ebrCtr				0.000	0.00	.387
Congruentincongruent:BlocktypePersInhib:latencySq:ebrSq				0.000	0.00	.703
Random Parts						
σ^2		0.061			0.057	
$\tau_{00, ID}$		0.043			0.035	
N_{ID}		94			94	
ICC_{ID}		0.413			0.380	
Observations		4596			4596	
R^2 / Ω_0^2		.417 / .416			.457 / .456	

Uncued Trials

	Magnitude Model			Latency Model		
	B	*std. Error*	*p*	*B*	*std. Error*	*p*
Fixed Parts						
(Intercept)	6.780	0.04	<.001	6.719	0.03	<.001
Congruentincongruent	-0.054	0.02	.022	-0.041	0.02	.086
BlocktypePersInhib	0.004	0.02	.854	-0.006	0.02	.809
phasicCtr	0.548	0.21	.010			
phasicSq	-0.934	2.12	.660			
tonicZ	0.028	0.01	.052	0.019	0.01	.128
tonicSq	-0.023	0.01	.042	-0.023	0.01	.034
ebrCtr	-0.001	0.00	.706	-0.000	0.00	.835
ebrSq	-0.000	0.00	.064	-0.000	0.00	.097
Congruentincongruent:BlocktypePersInhib	0.068	0.03	.040	0.038	0.03	.264
Congruentincongruent:phasicCtr	-0.087	0.30	.771			
BlocktypePersInhib:phasicCtr	0.278	0.30	.350			
Congruentincongruent:ebrCtr	0.001	0.00	.454	0.000	0.00	.983
BlocktypePersInhib:ebrCtr	0.002	0.00	.117	0.001	0.00	.322
phasicCtr:ebrCtr	-0.001	0.01	.929			
Congruentincongruent:ebrSq	0.000	0.00	.002	0.000	0.00	.024
BlocktypePersInhib:ebrSq	0.000	0.00	.476	0.000	0.00	.415
phasicCtr:ebrSq	-0.001	0.00	.222			
Congruentincongruent:phasicSq	3.313	3.01	.272			
BlocktypePersInhib:phasicSq	3.223	3.11	.302			
phasicSq:ebrCtr	0.200	0.12	.092			
phasicSq:ebrSq	0.017	0.01	.141			
Congruentincongruent:tonicZ	-0.003	0.02	.876	-0.000	0.02	.987
BlocktypePersInhib:tonicZ	0.019	0.02	.369	0.006	0.02	.725

tonicZ:ebrCtr	-0.001	0.00	.187	-0.001	0.00	.283
tonicZ:ebrSq	-0.000	0.00	.379	-0.000	0.00	.310
Congruentincongruent:tonicSq	0.026	0.02	.103	0.017	0.02	.272
BlocktypePersInhib:tonicSq	0.003	0.02	.851	0.018	0.02	.253
tonicSq:ebrCtr	0.000	0.00	.767	0.000	0.00	.629
tonicSq:ebrSq	0.000	0.00	.103	0.000	0.00	.090
Congruentincongruent:BlocktypePersInhib:phasicCtr	0.200	0.42	.638			
Congruentincongruent:BlocktypePersInhib:ebrCtr	-0.001	0.00	.486	-0.001	0.00	.704
Congruentincongruent:phasicCtr:ebrCtr	0.023	0.02	.187			
BlocktypePersInhib:phasicCtr:ebrCtr	0.004	0.02	.809			
Congruentincongruent:BlocktypePersInhib:ebrSq	-0.000	0.00	.134	-0.000	0.00	.459
Congruentincongruent:phasicCtr:ebrSq	0.003	0.00	.119			
BlocktypePersInhib:phasicCtr:ebrSq	0.001	0.00	.728			
Congruentincongruent:BlocktypePersInhib:phasicSq	-6.195	4.32	.153			
Congruentincongruent:phasicSq:ebrCtr	-0.078	0.19	.681			
BlocktypePersInhib:phasicSq:ebrCtr	-0.153	0.17	.369			
Congruentincongruent:phasicSq:ebrSq	-0.029	0.02	.083			
BlocktypePersInhib:phasicSq:ebrSq	-0.020	0.02	.221			
Congruentincongruent:BlocktypePersInhib:tonicZ	-0.013	0.03	.652	-0.017	0.03	.520
Congruentincongruent:tonicZ:ebrCtr	0.002	0.00	.139	0.000	0.00	.643
BlocktypePersInhib:tonicZ:ebrCtr	-0.000	0.00	.890	-0.000	0.00	.766
Congruentincongruent:tonicZ:ebrSq	0.000	0.00	.176	0.000	0.00	.321
BlocktypePersInhib:tonicZ:ebrSq	-0.000	0.00	.957	0.000	0.00	.658
Congruentincongruent:BlocktypePersInhib:tonicSq	-0.019	0.02	.427	-0.018	0.02	.437
Congruentincongruent:tonicSq:ebrCtr	-0.001	0.00	.451	-0.001	0.00	.462
BlocktypePersInhib:tonicSq:ebrCtr	-0.001	0.00	.451	-0.001	0.00	.379

Congruentincongruent:tonicSq:ebrSq	-0.000	0.00	.061	-0.000	0.00	.137
BlocktypePersInhib:tonicSq:ebrSq	0.000	0.00	.960	-0.000	0.00	.532
Congruentincongruent:BlocktypePersInhib:phasicCtr:ebrCtr	-0.027	0.02	.257			
Congruentincongruent:BlocktypePersInhib:phasicCtr:ebrSq	-0.003	0.00	.223			
Congruentincongruent:BlocktypePersInhib:phasicSq:ebrCtr	0.009	0.25	.971			
Congruentincongruent:BlocktypePersInhib:phasicSq:ebrSq	0.037	0.02	.114			
Congruentincongruent:BlocktypePersInhib:tonicZ:ebrCtr	-0.002	0.00	.279	-0.000	0.00	.818
Congruentincongruent:BlocktypePersInhib:tonicZ:ebrSq	-0.000	0.00	.717	-0.000	0.00	.972
Congruentincongruent:BlocktypePersInhib:tonicSq:ebrCtr	0.002	0.00	.217	0.001	0.00	.355
Congruentincongruent:BlocktypePersInhib:tonicSq:ebrSq	0.000	0.00	.919	0.000	0.00	.961
latencyCtr				0.000	0.00	<.001
latencySq				0.000	0.00	<.001
Congruentincongruent:latencyCtr				-0.000	0.00	.579
BlocktypePersInhib:latencyCtr				0.000	0.00	.052
latencyCtr:ebrCtr				0.000	0.00	.012
latencyCtr:ebrSq				-0.000	0.00	.132
Congruentincongruent:latencySq				0.000	0.00	.744
BlocktypePersInhib:latencySq				0.000	0.00	.412
latencySq:ebrCtr				0.000	0.00	.168
latencySq:ebrSq				0.000	0.00	.979
Congruentincongruent:BlocktypePersInhib:latencyCtr				-0.000	0.00	.707
Congruentincongruent:latencyCtr:ebrCtr				-0.000	0.00	.856
BlocktypePersInhib:latencyCtr:ebrCtr				-0.000	0.00	.051
Congruentincongruent:latencyCtr:ebrSq				0.000	0.00	.219
BlocktypePersInhib:latencyCtr:ebrSq				-0.000	0.00	.735

Congruentincongruent:BlocktypePersInhib:latencySq				-0.000	0.00	.955
Congruentincongruent:latencySq:ebrCtr				0.000	0.00	.888
BlocktypePersInhib:latencySq:ebrCtr				-0.000	0.00	.349
Congruentincongruent:latencySq:ebrSq				-0.000	0.00	.404
BlocktypePersInhib:latencySq:ebrSq				-0.000	0.00	.446
Congruentincongruent:BlocktypePersInhib:latencyCtr:ebrCtr				0.000	0.00	.529
Congruentincongruent:BlocktypePersInhib:latencyCtr:ebrSq				-0.000	0.00	.500
Congruentincongruent:BlocktypePersInhib:latencySq:ebrCtr				0.000	0.00	.387
Congruentincongruent:BlocktypePersInhib:latencySq:ebrSq				0.000	0.00	.703
Random Parts						
σ^2	0.061			0.057		
$\tau_{00, ID}$	0.043			0.035		
N_{ID}	94			94		
ICC_{ID}	0.413			0.380		
Observations	4596			4596		
R^2 / Ω_0^2	.417 / .416			.457 / .456		

Model 2: Predicting RT Across Conditions from EBR, Pupil Measures, and Gender (N=91)

Cued Trials

	Magnitude Model			Latency Model		
	B	*std. Error*	*p*	*B*	*std. Error*	*p*
Fixed Parts						
(Intercept)	6.748	0.04	<.001	6.694	0.04	<.001
Congruentincongruent	-0.041	0.03	.134	-0.023	0.03	.398
BlocktypePersInhib	0.014	0.03	.607	0.005	0.03	.857
phasicCtr	0.870	0.24	<.001			
phasicSq	-1.828	2.50	.464			
tonicZ	0.048	0.02	.005	0.038	0.02	.012
tonicSq	-0.018	0.01	.189	-0.016	0.01	.217
ebrCtr	-0.004	0.00	.178	-0.003	0.00	.186
ebrSq	-0.000	0.00	.951	0.000	0.00	.915
genderMale	0.110	0.08	.173	0.101	0.07	.168

Congruentincongruent:BlocktypePersInhib	0.024	0.04	.526	-0.023	0.04	.561
Congruentincongruent:phasicCtr	-0.184	0.34	.592			
BlocktypePersInhib:phasicCtr	0.143	0.34	.678			
Congruentincongruent:ebrCtr	0.002	0.00	.296	-0.000	0.00	.910
BlocktypePersInhib:ebrCtr	0.001	0.00	.492	0.000	0.00	.780
phasicCtr:ebrCtr	-0.007	0.02	.709			
Congruentincongruent:genderMale	-0.039	0.05	.477	-0.059	0.05	.269
BlocktypePersInhib:genderMale	-0.019	0.05	.723	-0.040	0.05	.457
phasicCtr:genderMale	-1.196	0.51	.019			
ebrCtr:genderMale	0.005	0.00	.288	0.005	0.00	.195
Congruentincongruent:ebrSq	0.000	0.00	.080	0.000	0.00	.178
BlocktypePersInhib:ebrSq	0.000	0.00	.732	0.000	0.00	.763
phasicCtr:ebrSq	-0.002	0.00	.101			
ebrSq:genderMale	-0.001	0.00	.061	-0.001	0.00	.055
Congruentincongruent:phasicSq	3.552	3.63	.329			
BlocktypePersInhib:phasicSq	0.686	3.73	.854			
phasicSq:ebrCtr	0.139	0.16	.395			
phasicSq:genderMale	2.550	5.03	.612			
phasicSq:ebrSq	0.020	0.01	.143			
Congruentincongruent:tonicZ	-0.011	0.02	.640	-0.023	0.02	.285

BlocktypePersInhib:tonicZ	0.002	0.02	.922	-0.015	0.02	.476
tonicZ:ebrCtr	-0.002	0.00	.219	-0.001	0.00	.319
tonicZ:genderMale	-0.073	0.03	.034	-0.059	0.03	.041
tonicZ:ebrSq	-0.000	0.00	.246	-0.000	0.00	.131
Congruentincongruent:tonicSq	0.014	0.02	.475	0.008	0.02	.680
BlocktypePersInhib:tonicSq	-0.018	0.02	.388	-0.003	0.02	.858
tonicSq:ebrCtr	0.000	0.00	.631	0.001	0.00	.580
tonicSq:genderMale	-0.007	0.03	.771	-0.018	0.02	.448
tonicSq:ebrSq	0.000	0.00	.262	0.000	0.00	.182
Congruentincongruent:BlocktypePersInhib:phasicCtr	0.497	0.49	.314			

Congruentincongruent:BlocktypePersInhib:ebrCtr	-0.001	0.00	.809	0.001	0.00	.661
Congruentincongruent:phasicCtr:ebrCtr	0.020	0.03	.457			
BlocktypePersInhib:phasicCtr:ebrCtr	0.009	0.02	.711			
Congruentincongruent:BlocktypePersInhib:genderMale	0.149	0.08	.051	0.215	0.08	.005
Congruentincongruent:phasicCtr:genderMale	0.563	0.72	.434			
BlocktypePersInhib:phasicCtr:genderMale	0.379	0.71	.591			
Congruentincongruent:ebrCtr:genderMale	-0.003	0.00	.314	-0.002	0.00	.491
BlocktypePersInhib:ebrCtr:genderMale	0.004	0.00	.228	0.002	0.00	.606
phasicCtr:ebrCtr:genderMale	0.008	0.03	.769			
Congruentincongruent:BlocktypePersInhib:ebrSq	0.000	0.00	.951	0.000	0.00	.557
Congruentincongruent:phasicCtr:ebrSq	0.003	0.00	.143			
BlocktypePersInhib:phasicCtr:ebrSq	0.001	0.00	.528			
Congruentincongruent:ebrSq:genderMale	0.000	0.00	.647	0.000	0.00	.686
BlocktypePersInhib:ebrSq:genderMale	0.000	0.00	.383	0.000	0.00	.358
phasicCtr:ebrSq:genderMale	0.004	0.00	.166			

Congruentincongruent:BlocktypePersInhib:phasicSq	-5.142	5.29	.331
Congruentincongruent:phasicSq:ebrCtr	-0.055	0.26	.830
BlocktypePersInhib:phasicSq:ebrCtr	-0.030	0.23	.896
Congruentincongruent:phasicSq:genderMale	-0.644	6.91	.926
BlocktypePersInhib:phasicSq:genderMale	9.106	7.16	.203

phasicSq:ebrCtr:genderMale	0.271	0.27	.323			
Congruentincongruent:phasicSq:ebrSq	-0.028	0.02	.163			
BlocktypePersInhib:phasicSq:ebrSq	-0.009	0.02	.663			
phasicSq:ebrSq:genderMale	-0.012	0.03	.695			
Congruentincongruent:BlocktypePersInhib:tonicZ	-0.008	0.03	.820	0.005	0.03	.874
Congruentincongruent:tonicZ:ebrCtr	0.002	0.00	.379	0.001	0.00	.635
BlocktypePersInhib:tonicZ:ebrCtr	0.001	0.00	.445	0.001	0.00	.454
Congruentincongruent:tonicZ:genderMale	0.029	0.05	.546	0.083	0.04	.046
BlocktypePersInhib:tonicZ:genderMale	0.034	0.05	.497	0.053	0.04	.216
tonicZ:ebrCtr:genderMale	0.000	0.00	.893	0.000	0.00	.951
Congruentincongruent:tonicZ:ebrSq	0.000	0.00	.196	0.000	0.00	.146
BlocktypePersInhib:tonicZ:ebrSq	0.000	0.00	.938	0.000	0.00	.468
tonicZ:ebrSq:genderMale	0.000	0.00	.166	0.000	0.00	.190
Congruentincongruent:BlocktypePersInhib:tonicSq	0.019	0.03	.515	0.024	0.03	.379
Congruentincongruent:tonicSq:ebrCtr	-0.001	0.00	.440	-0.001	0.00	.341
BlocktypePersInhib:tonicSq:ebrCtr	-0.000	0.00	.933	-0.000	0.00	.989
Congruentincongruent:tonicSq:genderMale	0.036	0.04	.325	0.024	0.03	.477
BlocktypePersInhib:tonicSq:genderMale	0.055	0.04	.155	0.058	0.04	.109
tonicSq:ebrCtr:genderMale	-0.001	0.00	.542	-0.001	0.00	.323

Congruentincongruent:tonicSq:ebrSq	-0.000	0.00	.226	-0.000	0.00	.307
BlocktypePersInhib:tonicSq:ebrSq	0.000	0.00	.697	-0.000	0.00	.623
tonicSq:ebrSq:genderMale	-0.000	0.00	.969	-0.000	0.00	.771
Congruentincongruent:BlocktypePersInhib:phasicCtr:ebrCtr	-0.041	0.04	.248			
Congruentincongruent:BlocktypePersInhib:phasicCtr:genderMale	-1.040	1.00	.300			
Congruentincongruent:BlocktypePersInhib:ebrCtr:genderMale	-0.005	0.00	.251	-0.003	0.00	.565
Congruentincongruent:phasicCtr:ebrCtr:genderMale	-0.023	0.05	.648			
BlocktypePersInhib:phasicCtr:ebrCtr:genderMale	-0.046	0.04	.265			
Congruentincongruent:BlocktypePersInhib:phasicCtr:ebrSq	-0.003	0.00	.263			
Congruentincongruent:BlocktypePersInhib:ebrSq:genderMale	-0.001	0.00	.006	-0.001	0.00	.012
Congruentincongruent:phasicCtr:ebrSq:genderMale	-0.003	0.00	.460			
BlocktypePersInhib:phasicCtr:ebrSq:genderMale	-0.004	0.00	.276			
Congruentincongruent:BlocktypePersInhib:phasicSq:ebrCtr	-0.066	0.35	.848			
Congruentincongruent:BlocktypePersInhib:phasicSq:genderMale	-2.084	9.70	.830			
Congruentincongruent:phasicSq:ebrCtr:genderMale	-0.093	0.45	.836			
BlocktypePersInhib:phasicSq:ebrCtr:genderMale	-0.639	0.44	.148			

Congruentincongruent:BlocktypePersInhib:phasicSq:ebrSq	0.027	0.03	.356			
Congruentincongruent:phasicSq:ebrSq:genderMale	0.007	0.04	.866			
BlocktypePersInhib:phasicSq:ebrSq:genderMale	-0.063	0.04	.131			
Congruentincongruent:BlocktypePersInhib:tonicZ:ebrCtr	-0.004	0.00	.113	-0.003	0.00	.241
Congruentincongruent:BlocktypePersInhib:tonicZ:genderMale	0.003	0.07	.971	-0.078	0.06	.199
Congruentincongruent:tonicZ:ebrCtr:genderMale	-0.000	0.00	.896	0.001	0.00	.786
BlocktypePersInhib:tonicZ:ebrCtr:genderMale	-0.006	0.00	.076	-0.006	0.00	.065
Congruentincongruent:BlocktypePersInhib:tonicZ:ebrSq	-0.000	0.00	.980	-0.000	0.00	.905
Congruentincongruent:tonicZ:ebrSq:genderMale	-0.000	0.00	.548	-0.000	0.00	.213
BlocktypePersInhib:tonicZ:ebrSq:genderMale	-0.000	0.00	.194	-0.000	0.00	.125
Congruentincongruent:BlocktypePersInhib:tonicSq:ebrCtr	0.001	0.00	.781	0.000	0.00	.887
Congruentincongruent:BlocktypePersInhib:tonicSq:genderMale	-0.135	0.05	.012	-0.133	0.05	.009
Congruentincongruent:tonicSq:ebrCtr:genderMale	0.003	0.00	.223	0.003	0.00	.151
BlocktypePersInhib:tonicSq:ebrCtr:genderMale	0.001	0.00	.715	0.002	0.00	.373
Congruentincongruent:BlocktypePersInhib:tonicSq:ebrSq	-0.000	0.00	.805	-0.000	0.00	.695
Congruentincongruent:tonicSq:ebrSq:genderM	0.000	0.00	.870	0.000	0.00	.599

ale						
BlocktypePersInhib:tonicSq:ebrSq:genderMale	-0.000	0.00	.701	0.000	0.00	.759
Congruentincongruent:BlocktypePersInhib:phasicCtr:ebrCtr:genderMale	0.069	0.07	.316			
Congruentincongruent:BlocktypePersInhib:phasicCtr:ebrSq:genderMale	0.005	0.01	.420			

Congruentincongruent:BlocktypePersInhib:phasicSq:ebrCtr:genderMale	0.241	0.64	.708			
Congruentincongruent:BlocktypePersInhib:phasicSq:ebrSq:genderMale	0.019	0.06	.742			
Congruentincongruent:BlocktypePersInhib:tonicZ:ebrCtr:genderMale	0.009	0.00	.057	0.007	0.00	.091
Congruentincongruent:BlocktypePersInhib:tonicZ:ebrSq:genderMale	0.000	0.00	.526	0.000	0.00	.187
Congruentincongruent:BlocktypePersInhib:tonicSq:ebrCtr:genderMale	-0.002	0.00	.591	-0.004	0.00	.287
Congruentincongruent:BlocktypePersInhib:tonicSq:ebrSq:genderMale	0.000	0.00	.354	0.000	0.00	.600
latencyCtr				0.000	0.00	<.001
latencySq				0.000	0.00	<.001
Congruentincongruent:latencyCtr				-0.000	0.00	.037
BlocktypePersInhib:latencyCtr				0.000	0.00	.783
latencyCtr:ebrCtr				0.000	0.00	.965
latencyCtr:genderMale				-0.000	0.00	.014
latencyCtr:ebrSq				-0.000	0.00	.230
Congruentincongruent:latencySq				-0.000	0.00	.959
BlocktypePersInhib:latencySq				0.000	0.00	.873
latencySq:ebrCtr				-0.000	0.00	.625
latencySq:genderMale				0.000	0.00	.149
latencySq:ebrSq				0.000	0.00	.258

Congruentincongruent:BlocktypePersInhib:latencyCtr	0.000	0.00	.067
Congruentincongruent:latencyCtr:ebrCtr	0.000	0.00	.117
BlocktypePersInhib:latencyCtr:ebrCtr	-0.000	0.00	.984
Congruentincongruent:latencyCtr:genderMale	0.000	0.00	.003
BlocktypePersInhib:latencyCtr:genderMale	0.000	0.00	.010
latencyCtr:ebrCtr:genderMale	0.000	0.00	.015
Congruentincongruent:latencyCtr:ebrSq	0.000	0.00	.387

BlocktypePersInhib:latencyCtr:ebrSq	0.000	0.00	.934
latencyCtr:ebrSq:genderMale	0.000	0.00	.063
Congruentincongruent:BlocktypePersInhib:latencySq	0.000	0.00	.398
Congruentincongruent:latencySq:ebrCtr	0.000	0.00	.079
BlocktypePersInhib:latencySq:ebrCtr	0.000	0.00	.772
Congruentincongruent:latencySq:genderMale	0.000	0.00	.672
BlocktypePersInhib:latencySq:genderMale	0.000	0.00	.269
latencySq:ebrCtr:genderMale	0.000	0.00	.013
Congruentincongruent:latencySq:ebrSq	-0.000	0.00	.138
BlocktypePersInhib:latencySq:ebrSq	-0.000	0.00	.846
latencySq:ebrSq:genderMale	-0.000	0.00	.605
Congruentincongruent:BlocktypePersInhib:latencyCtr:ebrCtr	-0.000	0.00	.250
Congruentincongruent:BlocktypePersInhib:latencyCtr:genderMale	-0.000	0.00	<.001
Congruentincongruent:latencyCtr:ebrCtr:genderMale	-0.000	0.00	.091
BlocktypePersInhib:latencyCtr:ebrCtr:genderMale	-0.000	0.00	.033
Congruentincongruent:BlocktypePersInhib:latencyCtr:ebrSq	-0.000	0.00	.322
Congruentincongruent:latencyCtr:ebrSq:genderMale	-0.000	0.00	.156
BlocktypePersInhib:latencyCtr:ebrSq:gender	-0.000	0.00	.027

Male						
Congruentincongruent:BlocktypePersInhib:latencySq:ebrCtr				-0.000	0.00	.329
Congruentincongruent:BlocktypePersInhib:latencySq:genderMale				-0.000	0.00	.199
Congruentincongruent:latencySq:ebrCtr:genderMale				-0.000	0.00	.313
BlocktypePersInhib:latencySq:ebrCtr:genderMale				-0.000	0.00	.055
Congruentincongruent:BlocktypePersInhib:latencySq:ebrSq				0.000	0.00	.525
Congruentincongruent:latencySq:ebrSq:genderMale				0.000	0.00	.476
BlocktypePersInhib:latencySq:ebrSq:genderMale				-0.000	0.00	.082
Congruentincongruent:BlocktypePersInhib:latencyCtr:ebrCtr:genderMale				0.000	0.00	.293
Congruentincongruent:BlocktypePersInhib:latencyCtr:ebrSq:genderMale				0.000	0.00	.094
Congruentincongruent:BlocktypePersInhib:latencySq:ebrCtr:genderMale				-0.000	0.00	.708
Congruentincongruent:BlocktypePersInhib:latencySq:ebrSq:genderMale				-0.000	0.00	.450
Random Parts						
σ^2	0.060			0.056		
$\tau_{00, ID}$	0.041			0.032		
N_{ID}	93			93		
ICC_{ID}	0.401			0.363		
Observations	4568			4568		

R^2 / Ω_0^2	.426 / .425	.470 / .470

Unued Trials

	Magnitude Model	Latency Model

	B	*std. Error*	*p*	*B*	*std. Error*	*p*
Fixed Parts						
(Intercept)	6.593	0.04	<.001	6.580	0.03	<.001
Congruentincongruent	0.015	0.01	.206	0.015	0.01	.248
BlocktypePersInhib	0.047	0.01	<.001	0.043	0.01	.001
phasicCtr	0.437	0.13	<.001			
phasicSq	1.257	1.16	.279			
tonicZ	0.036	0.01	<.001	0.019	0.01	.005
tonicSq	-0.000	0.01	.947	0.005	0.01	.391
ebrCtr	-0.003	0.00	.162	-0.004	0.00	.075
ebrSq	0.000	0.00	.169	0.000	0.00	.168
genderMale	0.123	0.07	.077	0.114	0.07	.096
Congruentincongruent:BlocktypePersInhib	-0.011	0.02	.533	-0.005	0.02	.794
Congruentincongruent:phasicCtr	0.241	0.18	.169			

BlocktypePersInhib:phasicCtr	0.460	0.18	.009			
Congruentincongruent:ebrCtr	0.000	0.00	.620	0.001	0.00	.141
BlocktypePersInhib:ebrCtr	0.001	0.00	.126	0.001	0.00	.165
phasicCtr:ebrCtr	0.021	0.01	.016			
Congruentincongruent:genderMale	-0.004	0.02	.873	-0.015	0.03	.569
BlocktypePersInhib:genderMale	0.041	0.02	.087	0.018	0.03	.507
phasicCtr:genderMale	-0.031	0.25	.899			
ebrCtr:genderMale	0.003	0.00	.408	0.004	0.00	.339
Congruentincongruent:ebrSq	-0.000	0.00	.132	-0.000	0.00	.169
BlocktypePersInhib:ebrSq	-0.000	0.00	.177	-0.000	0.00	.153

phasicCtr:ebrSq	0.001	0.00	.439			
ebrSq:genderMale	-0.001	0.00	.008	-0.001	0.00	.009
Congruentincongruent:phasicSq	-1.498	1.64	.362			
BlocktypePersInhib:phasicSq	-2.125	1.65	.197			
phasicSq:ebrCtr	-0.083	0.07	.238			
phasicSq:genderMale	0.605	2.31	.793			
phasicSq:ebrSq	-0.010	0.01	.106			
Congruentincongruent:tonicZ	0.004	0.01	.724	0.006	0.01	.553
BlocktypePersInhib:tonicZ	0.016	0.01	.148	0.010	0.01	.286
tonicZ:ebrCtr	0.001	0.00	.219	-0.000	0.00	.464
tonicZ:genderMale	-0.032	0.01	.031	-0.025	0.01	.058
tonicZ:ebrSq	0.000	0.00	.745	0.000	0.00	.490
Congruentincongruent:tonicSq	0.003	0.01	.734	0.002	0.01	.768

BlocktypePersInhib:tonicSq	0.006	0.01	.461	0.005	0.01	.572
tonicSq:ebrCtr	0.001	0.00	.155	0.000	0.00	.339
tonicSq:genderMale	-0.008	0.01	.495	-0.013	0.01	.270
tonicSq:ebrSq	-0.000	0.00	.387	-0.000	0.00	.150
Congruentincongruent:BlocktypePersInhib:phasicCtr	-0.589	0.25	.018			
Congruentincongruent:BlocktypePersInhib:ebrCtr	-0.000	0.00	.828	-0.001	0.00	.423
Congruentincongruent:phasicCtr:ebrCtr	-0.014	0.01	.242			
BlocktypePersInhib:phasicCtr:ebrCtr	-0.038	0.01	.001			
Congruentincongruent:BlocktypePersInhib:genderMale	-0.003	0.03	.940	0.004	0.04	.908
Congruentincongruent:phasicCtr:genderMale	-0.577	0.34	.090			
BlocktypePersInhib:phasicCtr:genderMale	-0.942	0.34	.006			

Congruentincongruent:ebrCtr:genderMale	-0.000	0.00	.772	-0.001	0.00	.361
BlocktypePersInhib:ebrCtr:genderMale	-0.001	0.00	.377	-0.001	0.00	.388
phasicCtr:ebrCtr:genderMale	-0.023	0.02	.137			
Congruentincongruent:BlocktypePersInhib:ebrSq	0.000	0.00	.514	0.000	0.00	.351
Congruentincongruent:phasicCtr:ebrSq	-0.001	0.00	.459			
BlocktypePersInhib:phasicCtr:ebrSq	-0.002	0.00	.019			
Congruentincongruent:ebrSq:genderMale	0.000	0.00	.159	0.000	0.00	.098
BlocktypePersInhib:ebrSq:genderMale	-0.000	0.00	.269	0.000	0.00	.883
phasicCtr:ebrSq:genderMale	-0.002	0.00	.129			
Congruentincongruent:BlocktypePersInhib:phasicSq	1.948	2.36	.409			
Congruentincongruent:phasicSq:ebrCtr	0.117	0.10	.225			

BlocktypePersInhib:phasicSq:ebrCtr	0.101	0.10	.315			
Congruentincongruent:phasicSq:genderMale	-0.720	3.20	.822			
BlocktypePersInhib:phasicSq:genderMale	3.867	3.29	.240			
phasicSq:ebrCtr:genderMale	0.174	0.16	.290			
Congruentincongruent:phasicSq:ebrSq	0.010	0.01	.247			
BlocktypePersInhib:phasicSq:ebrSq	0.011	0.01	.186			
phasicSq:ebrSq:genderMale	0.010	0.01	.463			
Congruentincongruent:BlocktypePersInhib:tonicZ	-0.014	0.02	.349	-0.003	0.01	.809
Congruentincongruent:tonicZ:ebrCtr	-0.001	0.00	.364	0.000	0.00	.969
BlocktypePersInhib:tonicZ:ebrCtr	-0.001	0.00	.137	0.000	0.00	.526
Congruentincongruent:tonicZ:genderMale	-0.005	0.02	.816	0.003	0.02	.872
BlocktypePersInhib:tonicZ:genderMale	-0.007	0.02	.746	0.012	0.02	.529

tonicZ:ebrCtr:genderMale	-0.001	0.00	.215	-0.000	0.00	.904
Congruentincongruent:tonicZ:ebrSq	-0.000	0.00	.895	-0.000	0.00	.422
BlocktypePersInhib:tonicZ:ebrSq	-0.000	0.00	.119	-0.000	0.00	.201
tonicZ:ebrSq:genderMale	0.000	0.00	.789	0.000	0.00	.529
Congruentincongruent:BlocktypePersInhib:tonicSq	-0.011	0.01	.386	-0.011	0.01	.361
Congruentincongruent:tonicSq:ebrCtr	0.000	0.00	.755	0.000	0.00	.426
BlocktypePersInhib:tonicSq:ebrCtr	-0.000	0.00	.651	-0.000	0.00	.682
Congruentincongruent:tonicSq:genderMale	0.012	0.02	.475	0.009	0.02	.591
BlocktypePersInhib:tonicSq:genderMale	-0.004	0.02	.826	-0.000	0.02	.977
tonicSq:ebrCtr:genderMale	-0.001	0.00	.231	-0.001	0.00	.338
Congruentincongruent:tonicSq:ebrSq	0.000	0.00	.835	0.000	0.00	.494
BlocktypePersInhib:tonicSq:ebrSq	0.000	0.00	.502	0.000	0.00	.318
tonicSq:ebrSq:genderMale	0.000	0.00	.142	0.000	0.00	.080

Congruentincongruent:BlocktypePersInhib:phasicCtr:ebrCtr	0.029	0.02	.086			
Congruentincongruent:BlocktypePersInhib:phasicCtr:genderMale	1.772	0.49	<.001			
Congruentincongruent:BlocktypePersInhib:ebrCtr:genderMale	-0.000	0.00	.796	0.000	0.00	.890
Congruentincongruent:phasicCtr:ebrCtr:genderMale	0.026	0.02	.223			
BlocktypePersInhib:phasicCtr:ebrCtr:genderMale	0.022	0.02	.318			
Congruentincongruent:BlocktypePersInhib:phasicCtr:ebrSq	0.002	0.00	.087			
Congruentincongruent:BlocktypePersInhib:ebrSq:genderMale	-0.000	0.00	.546	-0.000	0.00	.391
Congruentincongruent:phasicCtr:ebrSq:genderMale	0.002	0.00	.218			
BlocktypePersInhib:phasicCtr:ebrSq:genderMale	0.005	0.00	.010			
Congruentincongruent:BlocktypePersInhib:phasicSq:ebrCtr	-0.202	0.15	.174			
Congruentincongruent:BlocktypePersInhib:phasicSq:genderMale	-5.593	4.73	.237			
Congruentincongruent:phasicSq:ebrCtr:genderMale	-0.279	0.22	.199			
BlocktypePersInhib:phasicSq:ebrCtr:genderMale	0.039	0.22	.857			
Congruentincongruent:BlocktypePersInhib:phasicSq:ebrSq	-0.012	0.01	.336			

Congruentincongruent:phasicSq:ebrSq:genderMale	-0.004	0.02	.841			
BlocktypePersInhib:phasicSq:ebrSq:genderMale	-0.013	0.02	.511			
Congruentincongruent:BlocktypePersInhib:tonicZ:ebrCtr	0.001	0.00	.258	0.000	0.00	.877
Congruentincongruent:BlocktypePersInhib:tonicZ:genderMale	0.037	0.03	.238	0.004	0.03	.879
Congruentincongruent:tonicZ:ebrCtr:genderMale	0.001	0.00	.251	0.001	0.00	.533
BlocktypePersInhib:tonicZ:ebrCtr:genderMale	0.002	0.00	.184	0.000	0.00	.788

Congruentincongruent:BlocktypePersInhib:tonicZ:ebrSq	0.000	0.00	.283	0.000	0.00	.344
Congruentincongruent:tonicZ:ebrSq:genderMale	0.000	0.00	.890	0.000	0.00	.902
BlocktypePersInhib:tonicZ:ebrSq:genderMale	0.000	0.00	.245	0.000	0.00	.672
Congruentincongruent:BlocktypePersInhib:tonicSq:ebrCtr	-0.000	0.00	.917	-0.000	0.00	.727
Congruentincongruent:BlocktypePersInhib:tonicSq:genderMale	0.019	0.03	.459	0.023	0.03	.351
Congruentincongruent:tonicSq:ebrCtr:genderMale	0.001	0.00	.469	0.000	0.00	.737
BlocktypePersInhib:tonicSq:ebrCtr:genderMale	-0.000	0.00	.732	-0.001	0.00	.635
Congruentincongruent:BlocktypePersInhib:tonicSq:ebrSq	0.000	0.00	.778	-0.000	0.00	.897
Congruentincongruent:tonicSq:ebrSq:genderMale	-0.000	0.00	.273	-0.000	0.00	.209
BlocktypePersInhib:tonicSq:ebrSq:genderMale	-0.000	0.00	.434	-0.000	0.00	.369

Congruentincongruent:BlocktypePersInhib:phasicCtr:ebrCtr:genderMale	-0.006	0.03	.854			
Congruentincongruent:BlocktypePersInhib:phasicCtr:ebrSq:genderMale	-0.006	0.00	.027			
Congruentincongruent:BlocktypePersInhib:phasicSq:ebrCtr:genderMale	0.028	0.30	.924			
Congruentincongruent:BlocktypePersInhib:phasicSq:ebrSq:genderMale	0.023	0.03	.398			
Congruentincongruent:BlocktypePersInhib:tonicZ:ebrCtr:genderMale	-0.000	0.00	.846	-0.000	0.00	.979
Congruentincongruent:BlocktypePersInhib:tonicZ:ebrSq:genderMale	-0.000	0.00	.337	-0.000	0.00	.527

Congruentincongruent:BlocktypePersInhib:tonicSq:ebrCtr:genderMale	0.001	0.00	.586	0.001	0.00	.400
Congruentincongruent:BlocktypePersInhib:tonicSq:ebrSq:genderMale	-0.000	0.00	.788	-0.000	0.00	.882
latencyCtr				0.000	0.00	.099
latencySq				0.000	0.00	.084
Congruentincongruent:latencyCtr				0.000	0.00	.017
BlocktypePersInhib:latencyCtr				0.000	0.00	<.001
latencyCtr:ebrCtr				-0.000	0.00	.512
latencyCtr:genderMale				0.000	0.00	.013
latencyCtr:ebrSq				0.000	0.00	.003
Congruentincongruent:latencySq				-0.000	0.00	.488
BlocktypePersInhib:latencySq				-0.000	0.00	.831
latencySq:ebrCtr				0.000	0.00	.030
latencySq:genderMale				0.000	0.00	.227
latencySq:ebrSq				-0.000	0.00	.779

Congruentincongruent:BlocktypePersInhib:latencyCtr	-0.000	0.00	.021
Congruentincongruent:latencyCtr:ebrCtr	-0.000	0.00	.379
BlocktypePersInhib:latencyCtr:ebrCtr	0.000	0.00	.753
Congruentincongruent:latencyCtr:genderMale	-0.000	0.00	.103
BlocktypePersInhib:latencyCtr:genderMale	-0.000	0.00	.419
latencyCtr:ebrCtr:genderMale	0.000	0.00	.279
Congruentincongruent:latencyCtr:ebrSq	-0.000	0.00	.104
BlocktypePersInhib:latencyCtr:ebrSq	-0.000	0.00	.006
latencyCtr:ebrSq:genderMale	-0.000	0.00	.006
Congruentincongruent:BlocktypePersInhib:latencySq	0.000	0.00	.654
Congruentincongruent:latencySq:ebrCtr	-0.000	0.00	.121

BlocktypePersInhib:latencySq:ebrCtr	-0.000	0.00	.941
Congruentincongruent:latencySq:genderMale	0.000	0.00	.387
BlocktypePersInhib:latencySq:genderMale	0.000	0.00	.021
latencySq:ebrCtr:genderMale	0.000	0.00	.628
Congruentincongruent:latencySq:ebrSq	0.000	0.00	.651
BlocktypePersInhib:latencySq:ebrSq	0.000	0.00	.213
latencySq:ebrSq:genderMale	0.000	0.00	.774
Congruentincongruent:BlocktypePersInhib:latencyCtr:ebrCtr	-0.000	0.00	.786
Congruentincongruent:BlocktypePersInhib:latencyCtr:genderMale	0.000	0.00	.157
Congruentincongruent:latencyCtr:ebrCtr:genderMale	0.000	0.00	.056
BlocktypePersInhib:latencyCtr:ebrCtr:genderMale	0.000	0.00	.876
Congruentincongruent:BlocktypePersInhib:latencyCtr:ebrSq	0.000	0.00	.090
Congruentincongruent:latencyCtr:ebrSq:genderMale	0.000	0.00	.077
BlocktypePersInhib:latencyCtr:ebrSq:genderMale	0.000	0.00	.316
Congruentincongruent:BlocktypePersInhib:latencySq:ebrCtr	0.00	0.00	.621

				0		
Congruentincongruent:BlocktypePersInhib:latencySq:genderMale				-0.000	0.00	.064
Congruentincongruent:latencySq:ebrCtr:genderMale				0.000	0.00	.401
BlocktypePersInhib:latencySq:ebrCtr:genderMale				0.000	0.00	.635
Congruentincongruent:BlocktypePersInhib:latencySq:ebrSq				-0.000	0.00	.266
Congruentincongruent:latencySq:ebrSq:genderMale				-0.000	0.00	.692
BlocktypePersInhib:latencySq:ebrSq:genderMale				-0.000	0.00	.012
Congruentincongruent:BlocktypePersInhib:latencyCtr:ebrCtr:genderMale				-0.000	0.00	.262
Congruentincongruent:BlocktypePersInhib:latencyCtr:ebrSq:genderMale				-0.000	0.00	.058
Congruentincongruent:BlocktypePersInhib:latencySq:ebrCtr:genderMale				-0.000	0.00	.185
Congruentincongruent:BlocktypePersInhib:latencySq:ebrSq:genderMale				0.000	0.00	.311
Random Parts						
σ^2		0.058			0.057	
$\tau_{00, ID}$		0.037			0.035	
N_{ID}		93			93	

ICC_{ID}	0.388	0.379
Observations	19672	19672
R^2 / Ω_0^2	.391 / .391	.396 / .396

APPENDIX B

GOAL PROGRESS QUESTIONNAIRE

Subjects will receive this questionnaire 7 days in a week, with different questions being asked on different days:
Day 1 – Section 1 & Section 2
Days 2-6 – Section 2
Day 7 - Section 2 & 3

Section 1:

1. Please list the top 3 academic tasks that you plan to complete this week.
2. Rate the importance of each task on a scale from 1 (Not at all important) to 5 (Extremely Important)

Section 2:
You planned to complete the following academic tasks this week:
[list subject's tasks]

Please answer the following questions below about your work towards these tasks today:

1. Did you do what you planned to do on these tasks today?
   1 (did not do anything I had planned) 2 3 4 5 (I did everything that I had planned)
2. How much effort did you put towards accomplishing these tasks today?
   1 (no effort) 2 3 4 5 (extreme effort)

Please answer the following questions below about your work towards these tasks today:

Strongly Agree / Agree / Neither Agree nor Disagree / Disagree / Strongly Disagree

1. I felt distracted today.
2. I felt more distracted than usual today.
3. I felt less distracted than usual today.
4. I felt distracted by school-related things today.
5. I felt distracted by non-school-related things today.
6. I switched tasks often today.
7. I multitasked often today.

Additional Comments:

Section 3:
For each of the 3 tasks listed this week, answer the following question:
On a scale of 0-100%, how complete is this task?

APPENDIX C

EXPERIMENT 4 EBR X PUPIL RESULTS

Model 1: Predicting RT Across Conditions from EBR and Pupil Measures (N=100)

Cued Trials

	Magnitude Model			Latency Model		
	B	*std. Error*	*p*	*B*	*std. Error*	*p*
Fixed Parts						
(Intercept)	6.647	0.03	<.001	6.597	0.03	<.001
switchSetswitchSet	0.106	0.02	<.001	0.085	0.02	<.001
Congruentincongruent	-0.016	0.02	.464	-0.011	0.02	.612
BlocktypePersInhib	0.004	0.02	.863	-0.009	0.02	.698
phasicCtr	0.654	0.19	<.001			
phasicSq	-0.838	1.87	.654			
tonicZ	0.048	0.01	<.001	0.035	0.01	.003
tonicSq	-0.005	0.01	.640	-0.003	0.01	.765
ebrCtr	-0.000	0.00	.699	-0.000	0.00	.747
ebrSq	0.000	0.00	.866	-0.000	0.00	.771
switchSetswitchSet:Congruentincongruent	-0.000	0.03	.998	-0.002	0.03	.957

switchSetswitchSet:BlocktypePersInhib	-0.045	0.03	.154	-0.028	0.03	.386
Congruentincongruent:BlocktypePersInhib	0.002	0.03	.942	0.021	0.03	.516
switchSetswitchSet:phasicCtr	-0.360	0.27	.186			
Congruentincongruent:phasicCtr	-0.132	0.28	.633			

BlocktypePersInhib:phasicCtr	0.351	0.27	.195			
switchSetswitchSet:ebrCtr	-0.001	0.00	.113	-0.001	0.00	.029
Congruentincongruent:ebrCtr	-0.000	0.00	.412	-0.000	0.00	.580
BlocktypePersInhib:ebrCtr	-0.001	0.00	.023	-0.001	0.00	.026
phasicCtr:ebrCtr	0.005	0.01	.304			
switchSetswitchSet:ebrSq	0.000	0.00	.070	0.000	0.00	.175
Congruentincongruent:ebrSq	0.000	0.00	.508	0.000	0.00	.224
BlocktypePersInhib:ebrSq	0.000	0.00	.487	0.000	0.00	.202
phasicCtr:ebrSq	0.000	0.00	.628			
switchSetswitchSet:phasicSq	0.193	2.65	.942			
Congruentincongruent:phasicSq	0.561	2.69	.835			
BlocktypePersInhib:phasicSq	-2.439	2.64	.355			
phasicSq:ebrCtr	-0.041	0.05	.441			
phasicSq:ebrSq	0.001	0.00	.574			
switchSetswitchSet:tonicZ	-0.020	0.02	.279	-0.004	0.02	.808
Congruentincongruent:tonicZ	-0.014	0.02	.479	-0.014	0.02	.403
BlocktypePersInhib:tonicZ	-0.027	0.02	.150	-0.017	0.02	.306
tonicZ:ebrCtr	0.001	0.00	.091	0.000	0.00	.111

tonicZ:ebrSq	-0.000	0.00	.196	-0.000	0.00	.090
switchSetswitchSet:tonicSq	0.003	0.02	.861	-0.003	0.01	.842
Congruentincongruent:tonicSq	0.005	0.02	.766	0.003	0.01	.848
BlocktypePersInhib:tonicSq	0.014	0.02	.373	0.010	0.01	.479
tonicSq:ebrCtr	-0.000	0.00	.910	0.000	0.00	.748
tonicSq:ebrSq	0.000	0.00	.053	0.000	0.00	.111
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib	0.016	0.05	.734	-0.015	0.05	.750
switchSetswitchSet:Congruentincongruent:phasicCtr	0.556	0.40	.164			
switchSetswitchSet:BlocktypePersInhib:phasicCtr	-0.245	0.39	.529			
Congruentincongruent:BlocktypePersInhib:phasicCtr	-0.332	0.40	.404			
switchSetswitchSet:Congruentincongruent:ebrCtr	0.001	0.00	.194	0.001	0.00	.165
switchSetswitchSet:BlocktypePersInhib:ebrCtr	0.002	0.00	.035	0.002	0.00	.022
Congruentincongruent:BlocktypePersInhib:ebrCtr	0.001	0.00	.251	0.001	0.00	.449

switchSetswitchSet:phasicCtr:ebrCtr	-0.012	0.01	.085			
Congruentincongruent:phasicCtr:ebrCtr	0.006	0.01	.407			
BlocktypePersInhib:phasicCtr:ebrCtr	-0.004	0.01	.549			
switchSetswitchSet:Congruentincongruent:ebrSq	-0.000	0.00	.877	-0.000	0.00	.535
switchSetswitchSet:BlocktypePersInhib:ebrSq	-0.000	0.00	.900	-0.000	0.00	.590
Congruentincongruent:BlocktypePersInhib:ebrSq	0.000	0.00	.458	-0.000	0.00	.555
switchSetswitchSet:phasicCtr:ebrSq	0.000	0.00	.709			
Congruentincongruent:phasicCtr:ebrSq	-0.000	0.00	.171			
BlocktypePersInhib:phasicCtr:ebrSq	-0.000	0.00	.051			

switchSetswitchSet:Congruentincongruent:phasicSq	3.039	3.97	.444			
switchSetswitchSet:BlocktypePersInhib:phasicSq	3.749	3.77	.320			
Congruentincongruent:BlocktypePersInhib:phasicSq	1.761	3.79	.643			
switchSetswitchSet:phasicSq:ebrCtr	0.025	0.08	.747			
Congruentincongruent:phasicSq:ebrCtr	0.049	0.08	.533			
BlocktypePersInhib:phasicSq:ebrCtr	0.042	0.07	.569			
switchSetswitchSet:phasicSq:ebrSq	0.001	0.00	.660			
Congruentincongruent:phasicSq:ebrSq	0.001	0.00	.664			
BlocktypePersInhib:phasicSq:ebrSq	0.003	0.00	.277			
switchSetswitchSet:Congruentincongruent:tonicZ	0.020	0.03	.468	0.017	0.02	.489
switchSetswitchSet:BlocktypePersInhib:tonicZ	0.011	0.03	.690	-0.010	0.02	.690
Congruentincongruent:BlocktypePersInhib:tonicZ	0.033	0.03	.231	0.027	0.02	.246
switchSetswitchSet:tonicZ:ebrCtr	-0.000	0.00	.461	-0.000	0.00	.440
Congruentincongruent:tonicZ:ebrCtr	-0.000	0.00	.683	-0.000	0.00	.384
BlocktypePersInhib:tonicZ:ebrCtr	-0.000	0.00	.625	0.000	0.00	.978
switchSetswitchSet:tonicZ:ebrSq	0.000	0.00	.236	0.000	0.00	.412
Congruentincongruent:tonicZ:ebrSq	-0.000	0.00	.884	0.000	0.00	.912

BlocktypePersInhib:tonicZ:ebrSq	0.000	0.00	.290	0.000	0.00	.400

switchSetsswitchSet:Congruentincongruent:tonicSq	0.009	0.02	.692	0.015	0.02	.476
switchSetsswitchSet:BlocktypePersInhib:tonicSq	-0.023	0.02	.307	-0.014	0.02	.502
Congruentincongruent:BlocktypePersInhib:tonicSq	-0.011	0.02	.625	-0.007	0.02	.720
switchSetsswitchSet:tonicSq:ebrCtr	-0.000	0.00	.676	-0.000	0.00	.405
Congruentincongruent:tonicSq:ebrCtr	0.000	0.00	.546	0.000	0.00	.596
BlocktypePersInhib:tonicSq:ebrCtr	0.000	0.00	.448	0.000	0.00	.755
switchSetsswitchSet:tonicSq:ebrSq	-0.000	0.00	.043	-0.000	0.00	.171
Congruentincongruent:tonicSq:ebrSq	-0.000	0.00	.372	-0.000	0.00	.598
BlocktypePersInhib:tonicSq:ebrSq	-0.000	0.00	.054	-0.000	0.00	.142
switchSetsswitchSet:Congruentincongruent:BlocktypePersInhib:phasicCtr	-0.231	0.57	.685			
switchSetsswitchSet:Congruentincongruent:BlocktypePersInhib:ebrCtr	-0.000	0.00	.709	-0.001	0.00	.411
switchSetsswitchSet:Congruentincongruent:phasicCtr:ebrCtr	-0.002	0.01	.855			
switchSetsswitchSet:BlocktypePersInhib:phasicCtr:ebrCtr	0.000	0.01	.963			
Congruentincongruent:BlocktypePersInhib:phasicCtr:ebrCtr	-0.017	0.01	.109			
switchSetsswitchSet:Congruentincongruent:BlocktypePersInhib:ebrSq	-0.000	0.00	.225	0.000	0.00	.824
switchSetsswitchSet:Congruentincongruent:phasi	0.000	0.00	.788			

cCtr:ebrSq						
switchSetswitchSet:BlocktypePersInhib:phasicCtr:ebrSq	0.001	0.00	.069			
Congruentincongruent:BlocktypePersInhib:phasicCtr:ebrSq	0.001	0.00	.129			
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:phasicSq	- 3.495	5.49	.525			
switchSetswitchSet:Congruentincongruent:phasicSq:ebrCtr	0.003	0.11	.978			
switchSetswitchSet:BlocktypePersInhib:phasicSq:ebrCtr	0.005	0.11	.963			
Congruentincongruent:BlocktypePersInhib:phasicSq:ebrCtr	- 0.070	0.11	.517			
switchSetswitchSet:Congruentincongruent:phasicSq:ebrSq	- 0.004	0.00	.299			
switchSetswitchSet:BlocktypePersInhib:phasicSq:ebrSq	- 0.007	0.00	.078			
Congruentincongruent:BlocktypePersInhib:phasicSq:ebrSq	- 0.003	0.00	.400			
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:tonicZ	- 0.025	0.04	.526	-0.009	0.03	.785
switchSetswitchSet:Congruentincongruent:tonicZ:ebrCtr	- 0.000	0.00	.830	0.000	0.00	.779
switchSetswitchSet:BlocktypePersInhib:tonicZ:ebrCtr	- 0.001	0.00	.429	-0.001	0.00	.355
Congruentincongruent:BlocktypePersInhib:tonicZ:ebrCtr	0.001	0.00	.428	0.001	0.00	.282
switchSetswitchSet:Congruentincongruent:tonicZ:ebrSq	- 0.000	0.00	.784	-0.000	0.00	.511
switchSetswitchSet:BlocktypePersInhib:tonicZ:e	-	0.00	.744	0.000	0.00	.850

brSq	0.000					
Congruentincongruent:BlocktypePersInhib:tonicZ:ebrSq	-0.000	0.00	.566	-0.000	0.00	.760
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:tonicSq	-0.006	0.03	.848	-0.018	0.03	.547
switchSetswitchSet:Congruentincongruent:tonicSq:ebrCtr	0.000	0.00	.804	0.000	0.00	.635
switchSetswitchSet:BlocktypePersInhib:tonicSq:ebrCtr	-0.000	0.00	.980	0.000	0.00	.811
Congruentincongruent:BlocktypePersInhib:tonicSq:ebrCtr	-0.000	0.00	.523	-0.000	0.00	.589
switchSetswitchSet:Congruentincongruent:tonicSq:ebrSq	0.000	0.00	.690	0.000	0.00	.891
switchSetswitchSet:BlocktypePersInhib:tonicSq:ebrSq	0.000	0.00	.059	0.000	0.00	.221
Congruentincongruent:BlocktypePersInhib:tonicSq:ebrSq	-0.000	0.00	.856	-0.000	0.00	.654
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:phasicCtr:ebrCtr	0.029	0.01	.047			
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:phasicCtr:ebrSq	-0.001	0.00	.188			
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:phasicSq:ebrCtr	-0.033	0.15	.827			
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:phasicSq:ebrSq	0.007	0.01	.213			
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:tonicZ:ebrCtr	0.001	0.00	.429	0.000	0.00	.630
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:tonicZ:ebrSq	-0.000	0.00	.837	-0.000	0.00	.964
switchSetswitchSet:Congruentincongruent:Block	-	0.00	.340	-0.001	0.00	.308

typePersInhib:tonicSq:ebrCtr	0.001					
switchSetswitchSet:Congruentincongruent:Block typePersInhib:tonicSq:ebrSq	0.000	0.00	.625	0.000	0.00	.484
latencyCtr				0.000	0.00	<.001
latencySq				0.000	0.00	<.001
switchSetswitchSet:latencyCtr				0.000	0.00	.531
Congruentincongruent:latencyCtr				-0.000	0.00	.560
BlocktypePersInhib:latencyCtr				0.000	0.00	.405
latencyCtr:ebrCtr				0.000	0.00	.272
latencyCtr:ebrSq				0.000	0.00	.666
switchSetswitchSet:latencySq				0.000	0.00	.119
Congruentincongruent:latencySq				-0.000	0.00	.945
BlocktypePersInhib:latencySq				-0.000	0.00	.781

latencySq:ebrCtr	-0.000	0.00	.860
latencySq:ebrSq	0.000	0.00	.263
switchSetswitchSet:Congruentincongruent:latencyCtr	0.000	0.00	.196
switchSetswitchSet:BlocktypePersInhib:latencyCtr	-0.000	0.00	.432
Congruentincongruent:BlocktypePersInhib:latencyCtr	-0.000	0.00	.718
switchSetswitchSet:latencyCtr:ebrCtr	-0.000	0.00	.802
Congruentincongruent:latencyCtr:ebrCtr	0.000	0.00	.946
BlocktypePersInhib:latencyCtr:ebrCtr	0.000	0.00	.218
switchSetswitchSet:latencyCtr:ebrSq	-0.000	0.00	.887
Congruentincongruent:latencyCtr:ebrSq	-0.000	0.00	.812
BlocktypePersInhib:latencyCtr:ebrSq	-0.000	0.00	.359
switchSetswitchSet:Congruentincongruent:latencySq	-0.000	0.00	.862
switchSetswitchSet:BlocktypePersInhib:latencySq	-0.000	0.00	.991
Congruentincongruent:BlocktypePersInhib:latencySq	-0.000	0.00	.759

switchSetswitchSet:latencySq:ebrCtr	0.000	0.00	.167
Congruentincongruent:latencySq:ebrCtr	-0.000	0.00	.612
BlocktypePersInhib:latencySq:ebrCtr	0.000	0.00	.453
switchSetswitchSet:latencySq:ebrSq	-0.000	0.00	.786
Congruentincongruent:latencySq:ebrSq	-0.000	0.00	.829
BlocktypePersInhib:latencySq:ebrSq	0.000	0.00	.476
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:latencyCtr	0.000	0.00	.979
switchSetswitchSet:Congruentincongruent:latencyCtr:ebrCtr	0.000	0.00	.422
switchSetswitchSet:BlocktypePersInhib:latencyCtr:ebrCtr	-0.000	0.00	.078
Congruentincongruent:BlocktypePersInhib:latencyCtr:ebrCtr	-0.000	0.00	.366
switchSetswitchSet:Congruentincongruent:latencyCtr:ebrSq	-0.000	0.00	.374
switchSetswitchSet:BlocktypePersInhib:latencyCtr:ebrSq	0.000	0.00	.286
Congruentincongruent:BlocktypePersInhib:latencyCtr:ebrSq	0.000	0.00	.318
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:latencySq	0.000	0.00	.345
switchSetswitchSet:Congruentincongruent:latencySq:ebrCtr	0.000	0.00	.906
switchSetswitchSet:BlocktypePersInhib:latencySq:ebrCtr	-0.000	0.00	.400
Congruentincongruent:BlocktypePersInhib:laten	0.000	0.00	.732

cySq:ebrCtr					
switchSetswitchSet:Congruentincongruent:latencySq:ebrSq		0.000	0.00	.882	
switchSetswitchSet:BlocktypePersInhib:latencySq:ebrSq		-0.000	0.00	.443	
Congruentincongruent:BlocktypePersInhib:latencySq:ebrSq		0.000	0.00	.801	
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:latencyCtr:ebrCtr		0.000	0.00	.116	
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:latencyCtr:ebrSq		-0.000	0.00	.524	
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:latencySq:ebrCtr		0.000	0.00	.897	
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:latencySq:ebrSq		-0.000	0.00	.580	
Random Parts					
σ^2	0.058		0.053		
$\tau_{00, ID}$	0.034		0.028		
N_{ID}	100		100		
ICC_{ID}	0.369		0.344		
Observations	9702		9702		
R^2 / Ω_0^2	.401 / .401		.453 / .453		

Uncued Trials

	Magnitude Model			Latency Model		
	B	*std. Error*	*p*	*B*	*std. Error*	*p*
Fixed Parts						
(Intercept)	6.647	0.03	<.001	6.597	0.03	<.001
switchSetswitchSet	0.106	0.02	<.001	0.085	0.02	<.001
Congruentincongruent	-0.016	0.02	.464	-0.011	0.02	.612
BlocktypePersInhib	0.004	0.02	.863	-0.009	0.02	.698
phasicCtr	0.654	0.19	<.001			
phasicSq	-0.838	1.87	.654			
tonicZ	0.048	0.01	<.001	0.035	0.01	.003
tonicSq	-0.005	0.01	.640	-0.003	0.01	.765
ebrCtr	-0.000	0.00	.699	-0.000	0.00	.747
ebrSq	0.000	0.00	.866	-0.000	0.00	.771
switchSetswitchSet:Congruentincongruent	-0.000	0.03	.998	-0.002	0.03	.957
switchSetswitchSet:BlocktypePersInhib	-0.045	0.03	.154	-0.028	0.03	.386

Congruentincongruent:BlocktypePersInhib	0.002	0.03	.942	0.021	0.03	.516
switchSetsswitchSet:phasicCtr	-0.360	0.27	.186			
Congruentincongruent:phasicCtr	-0.132	0.28	.633			
BlocktypePersInhib:phasicCtr	0.351	0.27	.195			
switchSetsswitchSet:ebrCtr	-0.001	0.00	.113	-0.001	0.00	.029
Congruentincongruent:ebrCtr	-0.000	0.00	.412	-0.000	0.00	.580
BlocktypePersInhib:ebrCtr	-0.001	0.00	.023	-0.001	0.00	.026
phasicCtr:ebrCtr	0.005	0.01	.304			
switchSetsswitchSet:ebrSq	0.000	0.00	.070	0.000	0.00	.175
Congruentincongruent:ebrSq	0.000	0.00	.508	0.000	0.00	.224
BlocktypePersInhib:ebrSq	0.000	0.00	.487	0.000	0.00	.202
phasicCtr:ebrSq	0.000	0.00	.628			
switchSetsswitchSet:phasicSq	0.193	2.65	.942			
Congruentincongruent:phasicSq	0.561	2.69	.835			
BlocktypePersInhib:phasicSq	-2.439	2.64	.355			
phasicSq:ebrCtr	-0.041	0.05	.441			
phasicSq:ebrSq	0.001	0.00	.574			
switchSetsswitchSet:tonicZ	-0.020	0.02	.279	-0.004	0.02	.808
Congruentincongruent:tonicZ	-0.014	0.02	.479	-0.014	0.02	.403

BlocktypePersInhib:tonicZ	-0.027	0.02	.150	-0.017	0.02	.306
tonicZ:ebrCtr	0.001	0.00	.091	0.000	0.00	.111
tonicZ:ebrSq	-0.000	0.00	.196	-0.000	0.00	.090
switchSetswitchSet:tonicSq	0.003	0.02	.861	-0.003	0.01	.842
Congruentincongruent:tonicSq	0.005	0.02	.766	0.003	0.01	.848
BlocktypePersInhib:tonicSq	0.014	0.02	.373	0.010	0.01	.479
tonicSq:ebrCtr	-0.000	0.00	.910	0.000	0.00	.748
tonicSq:ebrSq	0.000	0.00	.053	0.000	0.00	.111
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib	0.016	0.05	.734	-0.015	0.05	.750
switchSetswitchSet:Congruentincongruent:phasicCtr	0.556	0.40	.164			
switchSetswitchSet:BlocktypePersInhib:phasicCtr	-0.245	0.39	.529			
Congruentincongruent:BlocktypePersInhib:phasicCtr	-0.332	0.40	.404			
switchSetswitchSet:Congruentincongruent:ebrCtr	0.001	0.00	.194	0.001	0.00	.165
switchSetswitchSet:BlocktypePersInhib:ebrCtr	0.002	0.00	.035	0.002	0.00	.022
Congruentincongruent:BlocktypePersInhib:ebrCtr	0.001	0.00	.251	0.001	0.00	.449
switchSetswitchSet:phasicCtr:ebrCtr	-0.012	0.01	.085			
Congruentincongruent:phasicCtr:ebrCtr	0.006	0.01	.407			
BlocktypePersInhib:phasicCtr:ebrCtr	-0.004	0.01	.549			
switchSetswitchSet:Congruentincongruent:ebrSq	-0.000	0.00	.877	-0.000	0.00	.535

switchSetswitchSet:BlocktypePersInhib:ebrSq	-0.000	0.00	.900	-0.000	0.00	.590
Congruentincongruent:BlocktypePersInhib:ebrSq	0.000	0.00	.458	-0.000	0.00	.555
switchSetswitchSet:phasicCtr:ebrSq	0.000	0.00	.709			
Congruentincongruent:phasicCtr:ebrSq	-0.000	0.00	.171			
BlocktypePersInhib:phasicCtr:ebrSq	-0.000	0.00	.051			
switchSetswitchSet:Congruentincongruent:phasicSq	3.039	3.97	.444			
switchSetswitchSet:BlocktypePersInhib:phasicSq	3.749	3.77	.320			
Congruentincongruent:BlocktypePersInhib:phasicSq	1.761	3.79	.643			
switchSetswitchSet:phasicSq:ebrCtr	0.025	0.08	.747			
Congruentincongruent:phasicSq:ebrCtr	0.049	0.08	.533			
BlocktypePersInhib:phasicSq:ebrCtr	0.042	0.07	.569			
switchSetswitchSet:phasicSq:ebrSq	0.001	0.00	.660			
Congruentincongruent:phasicSq:ebrSq	0.001	0.00	.664			
BlocktypePersInhib:phasicSq:ebrSq	0.003	0.00	.277			
switchSetswitchSet:Congruentincongruent:tonicZ	0.020	0.03	.468	0.017	0.02	.489
switchSetswitchSet:BlocktypePersInhib:tonicZ	0.011	0.03	.690	-0.010	0.02	.690
Congruentincongruent:BlocktypePersInhib:tonicZ	0.033	0.03	.231	0.027	0.02	.246
switchSetswitchSet:tonicZ:ebrCtr	-0.000	0.00	.461	-0.000	0.00	.440
Congruentincongruent:tonicZ:ebrCtr	-0.000	0.00	.683	-0.000	0.00	.384

BlocktypePersInhib:tonicZ:ebrCtr	-0.000	0.00	.625	0.000	0.00	.978
switchSetswitchSet:tonicZ:ebrSq	0.000	0.00	.236	0.000	0.00	.412
Congruentincongruent:tonicZ:ebrSq	-0.000	0.00	.884	0.000	0.00	.912
BlocktypePersInhib:tonicZ:ebrSq	0.000	0.00	.290	0.000	0.00	.400
switchSetswitchSet:Congruentincongruent:tonicSq	0.009	0.02	.692	0.015	0.02	.476
switchSetswitchSet:BlocktypePersInhib:tonicSq	-0.023	0.02	.307	-0.014	0.02	.502
Congruentincongruent:BlocktypePersInhib:tonicSq	-0.011	0.02	.625	-0.007	0.02	.720
switchSetswitchSet:tonicSq:ebrCtr	-0.000	0.00	.676	-0.000	0.00	.405
Congruentincongruent:tonicSq:ebrCtr	0.000	0.00	.546	0.000	0.00	.596
BlocktypePersInhib:tonicSq:ebrCtr	0.000	0.00	.448	0.000	0.00	.755
switchSetswitchSet:tonicSq:ebrSq	-0.000	0.00	.043	-0.000	0.00	.171
Congruentincongruent:tonicSq:ebrSq	-0.000	0.00	.372	-0.000	0.00	.598
BlocktypePersInhib:tonicSq:ebrSq	-0.000	0.00	.054	-0.000	0.00	.142

switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:phasicCtr	-0.231	0.57	.685			
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:ebrCtr	-0.000	0.00	.709	-0.001	0.00	.411
switchSetswitchSet:Congruentincongruent:phasicCtr:ebrCtr	-0.002	0.01	.855			
switchSetswitchSet:BlocktypePersInhib:phasicCtr:ebrCtr	0.000	0.01	.963			
Congruentincongruent:BlocktypePersInhib:phasicCtr:ebrCtr	-0.017	0.01	.109			
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:ebrSq	-0.000	0.00	.225	0.000	0.00	.824
switchSetswitchSet:Congruentincongruent:phasicCtr:ebrSq	0.000	0.00	.788			
switchSetswitchSet:BlocktypePersInhib:phasicCtr:ebrSq	0.001	0.00	.069			
Congruentincongruent:BlocktypePersInhib:phasicCtr:ebrSq	0.001	0.00	.129			
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:phasicSq	-3.495	5.49	.525			
switchSetswitchSet:Congruentincongruent:phasicSq:ebrCtr	0.003	0.11	.978			
switchSetswitchSet:BlocktypePersInhib:phasicSq:ebrCtr	0.005	0.11	.963			
Congruentincongruent:BlocktypePersInhib:phasicSq:ebrCtr	-0.070	0.11	.517			
switchSetswitchSet:Congruentincongruent:phasicSq:ebrSq	-0.004	0.00	.299			
switchSetswitchSet:BlocktypePersInhib:phasicSq:ebrSq	-0.007	0.00	.078			

Congruentincongruent:BlocktypePersInhib:phasicSq:ebrSq	-0.003	0.00	.400			
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:tonicZ	-0.025	0.04	.526	-0.009	0.03	.785
switchSetswitchSet:Congruentincongruent:tonicZ:ebrCtr	-0.000	0.00	.830	0.000	0.00	.779
switchSetswitchSet:BlocktypePersInhib:tonicZ:ebrCtr	-0.001	0.00	.429	-0.001	0.00	.355
Congruentincongruent:BlocktypePersInhib:tonicZ:ebrCtr	0.001	0.00	.428	0.001	0.00	.282
switchSetswitchSet:Congruentincongruent:tonicZ:ebrSq	-0.000	0.00	.784	-0.000	0.00	.511
switchSetswitchSet:BlocktypePersInhib:tonicZ:ebrSq	-0.000	0.00	.744	0.000	0.00	.850
Congruentincongruent:BlocktypePersInhib:tonicZ:ebrSq	-0.000	0.00	.566	-0.000	0.00	.760
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:tonicSq	-0.006	0.03	.848	-0.018	0.03	.547
switchSetswitchSet:Congruentincongruent:tonicSq:ebrCtr	0.000	0.00	.804	0.000	0.00	.635
switchSetswitchSet:BlocktypePersInhib:tonicSq:ebrCtr	-0.000	0.00	.980	0.000	0.00	.811
Congruentincongruent:BlocktypePersInhib:tonicSq:ebrCtr	-0.000	0.00	.523	-0.000	0.00	.589
switchSetswitchSet:Congruentincongruent:tonicSq:ebrSq	0.000	0.00	.690	0.000	0.00	.891
switchSetswitchSet:BlocktypePersInhib:tonicSq:ebrSq	0.000	0.00	.059	0.000	0.00	.221
Congruentincongruent:BlocktypePersInhib:tonicSq:ebrSq	-0.000	0.00	.856	-0.000	0.00	.654

switchSetsswitchSet:Congruentincongruent:BlocktypePersInhib:phasicCtr:ebrCtr	0.029	0.01	.047			
switchSetsswitchSet:Congruentincongruent:BlocktypePersInhib:phasicCtr:ebrSq	-0.001	0.00	.188			
switchSetsswitchSet:Congruentincongruent:BlocktypePersInhib:phasicSq:ebrCtr	-0.033	0.15	.827			
switchSetsswitchSet:Congruentincongruent:BlocktypePersInhib:phasicSq:ebrSq	0.007	0.01	.213			
switchSetsswitchSet:Congruentincongruent:BlocktypePersInhib:tonicZ:ebrCtr	0.001	0.00	.429	0.000	0.00	.630
switchSetsswitchSet:Congruentincongruent:BlocktypePersInhib:tonicZ:ebrSq	-0.000	0.00	.837	-0.000	0.00	.964
switchSetsswitchSet:Congruentincongruent:BlocktypePersInhib:tonicSq:ebrCtr	-0.001	0.00	.340	-0.001	0.00	.308
switchSetsswitchSet:Congruentincongruent:BlocktypePersInhib:tonicSq:ebrSq	0.000	0.00	.625	0.000	0.00	.484
latencyCtr				0.000	0.00	<.001
latencySq				0.000	0.00	<.001
switchSetsswitchSet:latencyCtr				0.000	0.00	.531
Congruentincongruent:latencyCtr				-0.000	0.00	.560
BlocktypePersInhib:latencyCtr				0.000	0.00	.405
latencyCtr:ebrCtr				0.000	0.00	.272
latencyCtr:ebrSq				0.000	0.00	.666
switchSetsswitchSet:latencySq				0.000	0.00	.119

Congruentincongruent:latencySq	-0.000	0.00	.945
BlocktypePersInhib:latencySq	-0.000	0.00	.781
latencySq:ebrCtr	-0.000	0.00	.860
latencySq:ebrSq	0.000	0.00	.263
switchSetswitchSet:Congruentincongruent:latencyCtr	0.000	0.00	.196
switchSetswitchSet:BlocktypePersInhib:latencyCtr	-0.000	0.00	.432
Congruentincongruent:BlocktypePersInhib:latencyCtr	-0.000	0.00	.718
switchSetswitchSet:latencyCtr:ebrCtr	-0.000	0.00	.802
Congruentincongruent:latencyCtr:ebrCtr	0.000	0.00	.946
BlocktypePersInhib:latencyCtr:ebrCtr	0.000	0.00	.218
switchSetswitchSet:latencyCtr:ebrSq	-0.000	0.00	.887
Congruentincongruent:latencyCtr:ebrSq	-0.000	0.00	.812
BlocktypePersInhib:latencyCtr:ebrSq	-0.000	0.00	.359
switchSetswitchSet:Congruentincongruent:latencySq	-0.000	0.00	.862
switchSetswitchSet:BlocktypePersInhib:latencySq	-0.000	0.00	.991

Congruentincongruent:BlocktypePersInhib:latencySq	-0.000	0.00	.759
switchSetswitchSet:latencySq:ebrCtr	0.000	0.00	.167
Congruentincongruent:latencySq:ebrCtr	-0.000	0.00	.612
BlocktypePersInhib:latencySq:ebrCtr	0.000	0.00	.453

switchSetswitchSet:latencySq:ebrSq	-0.000	0.00	.786
Congruentincongruent:latencySq:ebrSq	-0.000	0.00	.829
BlocktypePersInhib:latencySq:ebrSq	0.000	0.00	.476
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:latencyCtr	0.000	0.00	.979
switchSetswitchSet:Congruentincongruent:latencyCtr:ebrCtr	0.000	0.00	.422
switchSetswitchSet:BlocktypePersInhib:latencyCtr:ebrCtr	-0.000	0.00	.078
Congruentincongruent:BlocktypePersInhib:latencyCtr:ebrCtr	-0.000	0.00	.366
switchSetswitchSet:Congruentincongruent:latencyCtr:ebrSq	-0.000	0.00	.374
switchSetswitchSet:BlocktypePersInhib:latencyCtr:ebrSq	0.000	0.00	.286
Congruentincongruent:BlocktypePersInhib:latencyCtr:ebrSq	0.000	0.00	.318
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:latencySq	0.000	0.00	.345
switchSetswitchSet:Congruentincongruent:latencySq:ebrCtr	0.000	0.00	.906
switchSetswitchSet:BlocktypePersInhib:latencySq:ebrCtr	-0.000	0.00	.400
Congruentincongruent:BlocktypePersInhib:latencySq:ebrCtr	0.000	0.00	.732
switchSetswitchSet:Congruentincongruent:latencySq:ebrSq	0.000	0.00	.882
switchSetswitchSet:BlocktypePersInhib:latencySq:ebrSq	-0.000	0.00	.443

Congruentincongruent:BlocktypePersInhib:latencySq:ebrSq		0.000	0.00	.801
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:latencyCtr:ebrCtr		0.000	0.00	.116
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:latencyCtr:ebrSq		-0.000	0.00	.524
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:latencySq:ebrCtr		0.000	0.00	.897
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:latencySq:ebrSq		-0.000	0.00	.580
Random Parts				
σ^2	0.058	0.053		
$\tau_{00, ID}$	0.034	0.028		
N_{ID}	100	100		
ICC_{ID}	0.369	0.344		
Observations	9702	9702		
R^2 / Ω_0^2	.401 / .401	.453 / .453		

Model 2: Predicting RT Across Conditions from EBR, Pupil Measures, and Gender (N=99)

Cued Trials

	Magnitude Model			Latency Model		
	B	*std. Error*	*p*	*B*	*std. Error*	*p*
Fixed Parts						
(Intercept)	6.664	0.04	<.001	6.610	0.03	<.001
switchSetswitchSet	0.111	0.03	<.001	0.096	0.03	<.001
Congruentincongruent	-0.015	0.02	.535	-0.023	0.03	.368
BlocktypePersInhib	0.001	0.03	.968	-0.007	0.03	.791
phasicCtr	0.654	0.22	.003			
phasicSq	-1.027	2.04	.615			
tonicZ	0.047	0.02	.002	0.029	0.01	.031
tonicSq	-0.006	0.01	.649	-0.006	0.01	.584
ebrCtr	0.000	0.00	.842	0.000	0.00	.762
ebrSq	0.000	0.00	.901	-0.000	0.00	.752
genderMale	-0.113	0.09	.193	-0.087	0.08	.282
switchSetswitchSet:Congruentincongruent	-0.026	0.04	.486	-0.014	0.04	.707
switchSetswitchSet:BlocktypePersInhib	-0.054	0.04	.132	-0.042	0.04	.256
Congruentincongruent:BlocktypePersInhib	-0.001	0.04	.971	0.022	0.04	.546
switchSetswitchSet:phasicCtr	-0.475	0.31	.127			

Congruentincongruent:phasicCtr	-0.030	0.31	.922			
BlocktypePersInhib:phasicCtr	0.364	0.30	.231			
switchSetswitchSet:ebrCtr	-0.001	0.00	.044	-0.002	0.00	.006
Congruentincongruent:ebrCtr	-0.001	0.00	.232	-0.001	0.00	.141
BlocktypePersInhib:ebrCtr	-0.002	0.00	.020	-0.002	0.00	.021
phasicCtr:ebrCtr	0.005	0.01	.451			
switchSetswitchSet:genderMale	-0.051	0.06	.421	-0.056	0.06	.364
Congruentincongruent:genderMale	0.034	0.06	.577	0.079	0.06	.189
BlocktypePersInhib:genderMale	0.023	0.06	.696	-0.008	0.06	.893
phasicCtr:genderMale	0.115	0.53	.828			
ebrCtr:genderMale	-0.002	0.00	.267	-0.001	0.00	.405
switchSetswitchSet:ebrSq	0.000	0.00	.283	0.000	0.00	.639
Congruentincongruent:ebrSq	-0.000	0.00	.936	0.000	0.00	.281
BlocktypePersInhib:ebrSq	0.000	0.00	.439	0.000	0.00	.275

phasicCtr:ebrSq	0.000	0.00	.671			
ebrSq:genderMale	0.000	0.00	.517	0.000	0.00	.499
switchSetswitchSet:phasicSq	-0.086	2.97	.977			
Congruentincongruent:phasicSq	-0.323	2.96	.913			
BlocktypePersInhib:phasicSq	-0.460	2.96	.877			
phasicSq:ebrCtr	-0.079	0.06	.206			
phasicSq:genderMale	4.712	5.80	.417			

phasicSq:ebrSq	0.001	0.00	.688			
switchSetswitchSet:tonicZ	-0.021	0.02	.333	0.002	0.02	.896
Congruentincongruent:tonicZ	-0.010	0.02	.645	-0.009	0.02	.636
BlocktypePersInhib:tonicZ	-0.029	0.02	.179	-0.014	0.02	.442
tonicZ:ebrCtr	0.001	0.00	.191	0.000	0.00	.451
tonicZ:genderMale	0.009	0.03	.793	0.032	0.03	.325
tonicZ:ebrSq	-0.000	0.00	.287	-0.000	0.00	.252
switchSetswitchSet:tonicSq	0.004	0.02	.798	0.002	0.02	.896
Congruentincongruent:tonicSq	0.014	0.02	.411	0.013	0.02	.400
BlocktypePersInhib:tonicSq	0.012	0.02	.504	0.012	0.02	.466
tonicSq:ebrCtr	-0.000	0.00	.260	-0.000	0.00	.394
tonicSq:genderMale	0.020	0.03	.527	0.029	0.03	.315
tonicSq:ebrSq	0.000	0.00	.499	0.000	0.00	.450
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib	0.059	0.05	.256	0.032	0.05	.560
switchSetswitchSet:Congruentincongruent:phasicCtr	0.475	0.46	.302			
switchSetswitchSet:BlocktypePersInhib:phasicCtr	-0.276	0.44	.531			
Congruentincongruent:BlocktypePersInhib:phasicCtr	-0.544	0.45	.226			
switchSetswitchSet:Congruentincongruent:ebrCtr	0.001	0.00	.241	0.001	0.00	.189
switchSetswitchSet:BlocktypePersInhib:ebrCtr	0.002	0.00	.050	0.002	0.00	.016

Congruentincongruent:BlocktypePersInhib:ebrCtr	0.001	0.00	.209	0.001	0.00	.127
switchSetswitchSet:phasicCtr:ebrCtr	-0.012	0.01	.149			
Congruentincongruent:phasicCtr:ebrCtr	0.010	0.01	.274			
BlocktypePersInhib:phasicCtr:ebrCtr	-0.002	0.01	.807			
switchSetswitchSet:Congruentincongruent:gender Male	0.143	0.09	.112	0.068	0.09	.443
switchSetswitchSet:BlocktypePersInhib:genderMa le	0.037	0.09	.668	0.073	0.09	.392
Congruentincongruent:BlocktypePersInhib:gender Male	-0.054	0.09	.531	-0.044	0.09	.608
switchSetswitchSet:phasicCtr:genderMale	0.674	0.72	.348			
Congruentincongruent:phasicCtr:genderMale	-0.195	0.76	.797			
BlocktypePersInhib:phasicCtr:genderMale	0.071	0.77	.926			
switchSetswitchSet:ebrCtr:genderMale	0.002	0.00	.189	0.002	0.00	.244
Congruentincongruent:ebrCtr:genderMale	0.002	0.00	.135	0.002	0.00	.054
BlocktypePersInhib:ebrCtr:genderMale	0.001	0.00	.411	0.001	0.00	.568
phasicCtr:ebrCtr:genderMale	0.001	0.01	.933			
switchSetswitchSet:Congruentincongruent:ebrSq	0.000	0.00	.413	-0.000	0.00	.978
switchSetswitchSet:BlocktypePersInhib:ebrSq	0.000	0.00	.939	-0.000	0.00	.782
Congruentincongruent:BlocktypePersInhib:ebrSq	0.000	0.00	.265	-0.000	0.00	.721
switchSetswitchSet:phasicCtr:ebrSq	0.000	0.00	.405			
Congruentincongruent:phasicCtr:ebrSq	-0.001	0.00	.089			

BlocktypePersInhib:phasicCtr:ebrSq	-0.001	0.00	.095			
switchSetswitchSet:ebrSq:genderMale	0.000	0.00	.412	0.000	0.00	.391
Congruentincongruent:ebrSq:genderMale	0.000	0.00	.590	-0.000	0.00	.467
BlocktypePersInhib:ebrSq:genderMale	-0.000	0.00	.476	-0.000	0.00	.736
phasicCtr:ebrSq:genderMale	-0.000	0.00	.830			
switchSetswitchSet:Congruentincongruent:phasicSq	5.824	4.62	.207			
switchSetswitchSet:BlocktypePersInhib:phasicSq	3.496	4.27	.413			
Congruentincongruent:BlocktypePersInhib:phasicSq	1.632	4.30	.704			
switchSetswitchSet:phasicSq:ebrCtr	0.063	0.09	.474			
Congruentincongruent:phasicSq:ebrCtr	0.029	0.09	.749			
BlocktypePersInhib:phasicSq:ebrCtr	0.064	0.09	.465			
switchSetswitchSet:phasicSq:genderMale	0.662	7.71	.932			

Congruentincongruent:phasicSq:genderMale	5.485	8.32	.510			
BlocktypePersInhib:phasicSq:genderMale	-12.888	7.70	.094			
phasicSq:ebrCtr:genderMale	0.206	0.12	.096			
switchSetswitchSet:phasicSq:ebrSq	0.002	0.00	.551			
Congruentincongruent:phasicSq:ebrSq	0.003	0.00	.415			
BlocktypePersInhib:phasicSq:ebrSq	0.001	0.00	.670			
phasicSq:ebrSq:genderMale	-0.001	0.00	.801			
switchSetswitchSet:Congruentincongruent:tonicZ	0.027	0.03	.395	0.018	0.03	.510
switchSetswitchSet:BlocktypePersInhib:tonicZ	0.024	0.03	.440	-0.009	0.03	.731
Congruentincongruent:BlocktypePersInhib:tonicZ	0.036	0.03	.243	0.029	0.03	.274
switchSetswitchSet:tonicZ:ebrCtr	-0.000	0.00	.518	-0.000	0.00	.572
Congruentincongruent:tonicZ:ebrCtr	0.000	0.00	.719	0.000	0.00	.671
BlocktypePersInhib:tonicZ:ebrCtr	-0.000	0.00	.600	0.000	0.00	.800
switchSetswitchSet:tonicZ:genderMale	0.002	0.05	.970	-0.037	0.05	.411
Congruentincongruent:tonicZ:genderMale	0.018	0.05	.740	-0.022	0.05	.650
BlocktypePersInhib:tonicZ:genderMale	0.001	0.05	.978	-0.021	0.05	.642
tonicZ:ebrCtr:genderMale	-0.001	0.00	.404	0.000	0.00	.640
switchSetswitchSet:tonicZ:ebrSq	0.000	0.00	.229	0.000	0.00	.581
Congruentincongruent:tonicZ:ebrSq	-0.000	0.00	.888	-0.000	0.00	.990
BlocktypePersInhib:tonicZ:ebrSq	0.000	0.00	.365	0.000	0.00	.514

tonicZ:ebrSq:genderMale	-0.000	0.00	.594	-0.000	0.00	.416
switchSetswitchSet:Congruentincongruent:tonicSq	0.010	0.03	.704	0.010	0.02	.672
switchSetswitchSet:BlocktypePersInhib:tonicSq	-0.018	0.03	.483	-0.010	0.02	.683
Congruentincongruent:BlocktypePersInhib:tonicSq	-0.016	0.03	.517	-0.014	0.02	.546
switchSetswitchSet:tonicSq:ebrCtr	0.000	0.00	.674	0.000	0.00	.782
Congruentincongruent:tonicSq:ebrCtr	0.001	0.00	.097	0.001	0.00	.098
BlocktypePersInhib:tonicSq:ebrCtr	0.001	0.00	.148	0.000	0.00	.265
switchSetswitchSet:tonicSq:genderMale	-0.012	0.04	.765	-0.029	0.04	.461
Congruentincongruent:tonicSq:genderMale	-0.079	0.05	.088	-0.059	0.04	.163
BlocktypePersInhib:tonicSq:genderMale	0.008	0.04	.843	-0.015	0.04	.706
tonicSq:ebrCtr:genderMale	0.001	0.00	.040	0.001	0.00	.135
switchSetswitchSet:tonicSq:ebrSq	-0.000	0.00	.238	-0.000	0.00	.373
Congruentincongruent:tonicSq:ebrSq	-0.000	0.00	.438	-0.000	0.00	.390
BlocktypePersInhib:tonicSq:ebrSq	-0.000	0.00	.284	-0.000	0.00	.263
tonicSq:ebrSq:genderMale	0.000	0.00	.299	0.000	0.00	.871
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:phasicCtr	0.036	0.65	.956			
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:ebrCtr	-0.001	0.00	.603	-0.002	0.00	.290
switchSetswitchSet:Congruentincongruent:phasicCtr:ebrCtr	-0.008	0.01	.502			

switchSetswitchSet:BlocktypePersInhib:phasicCtr:ebrCtr	-0.009	0.01	.486			
Congruentincongruent:BlocktypePersInhib:phasicCtr:ebrCtr	-0.021	0.01	.101			
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:genderMale	-0.157	0.13	.210	-0.195	0.13	.120
switchSetswitchSet:Congruentincongruent:phasicCtr:genderMale	0.300	1.06	.776			
switchSetswitchSet:BlocktypePersInhib:phasicCtr:genderMale	-0.128	1.05	.903			
Congruentincongruent:BlocktypePersInhib:phasicCtr:genderMale	0.154	1.09	.888			
switchSetswitchSet:Congruentincongruent:ebrCtr:genderMale	-0.000	0.00	.886	-0.001	0.00	.783
switchSetswitchSet:BlocktypePersInhib:ebrCtr:genderMale	-0.001	0.00	.774	-0.001	0.00	.586
Congruentincongruent:BlocktypePersInhib:ebrCtr:genderMale	-0.002	0.00	.292	-0.003	0.00	.109
switchSetswitchSet:phasicCtr:ebrCtr:genderMale	0.001	0.02	.932			
Congruentincongruent:phasicCtr:ebrCtr:genderMale	0.002	0.02	.898			
BlocktypePersInhib:phasicCtr:ebrCtr:genderMale	-0.005	0.02	.761			
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:ebrSq	-0.000	0.00	.024	-0.000	0.00	.405
switchSetswitchSet:Congruentincongruent:phasicCtr:ebrSq	0.000	0.00	.573			
switchSetswitchSet:BlocktypePersInhib:phasicCtr:ebrSq	0.001	0.00	.124			
Congruentincongruent:BlocktypePersInhib:phasic	0.001	0.00	.028			

Ctr:ebrSq						
switchSetswitchSet:Congruentincongruent:ebrSq:genderMale	-0.000	0.00	.038	-0.000	0.00	.411
switchSetswitchSet:BlocktypePersInhib:ebrSq:genderMale	-0.000	0.00	.597	-0.000	0.00	.826
Congruentincongruent:BlocktypePersInhib:ebrSq:genderMale	-0.000	0.00	.802	0.000	0.00	.756
switchSetswitchSet:phasicCtr:ebrSq:genderMale	-0.001	0.00	.151			
Congruentincongruent:phasicCtr:ebrSq:genderMale	0.000	0.00	.428			

BlocktypePersInhib:phasicCtr:ebrSq:genderMale	-0.000	0.00	.982
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:phasicSq	-6.485	6.34	.306
switchSetswitchSet:Congruentincongruent:phasicSq:ebrCtr	-0.067	0.13	.611
switchSetswitchSet:BlocktypePersInhib:phasicSq:ebrCtr	-0.038	0.12	.757
Congruentincongruent:BlocktypePersInhib:phasicSq:ebrCtr	-0.068	0.13	.596
switchSetswitchSet:Congruentincongruent:phasicSq:genderMale	-20.517	11.66	.078
switchSetswitchSet:BlocktypePersInhib:phasicSq:genderMale	-1.905	10.51	.856
Congruentincongruent:BlocktypePersInhib:phasicSq:genderMale	2.046	10.81	.850
switchSetswitchSet:phasicSq:ebrCtr:genderMale	-0.299	0.19	.115
Congruentincongruent:phasicSq:ebrCtr:genderMale	0.096	0.20	.634
BlocktypePersInhib:phasicSq:ebrCtr:genderMale	-0.154	0.17	.376
switchSetswitchSet:Congruentincongruent:phasicSq:ebrSq	-0.007	0.01	.141
switchSetswitchSet:BlocktypePersInhib:phasicSq:ebrSq	-0.005	0.00	.243
Congruentincongruent:BlocktypePersInhib:phasicSq:ebrSq	-0.004	0.00	.394

switchSetswitchSet:phasicSq:ebrSq:genderMale	-0.004	0.01	.560			
Congruentincongruent:phasicSq:ebrSq:genderMale	-0.009	0.01	.176			
BlocktypePersInhib:phasicSq:ebrSq:genderMale	0.006	0.01	.338			
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:tonicZ	-0.052	0.04	.246	-0.026	0.04	.511
switchSetswitchSet:Congruentincongruent:tonicZ:ebrCtr	-0.001	0.00	.524	-0.000	0.00	.891
switchSetswitchSet:BlocktypePersInhib:tonicZ:ebrCtr	0.000	0.00	.985	0.000	0.00	.840
Congruentincongruent:BlocktypePersInhib:tonicZ:ebrCtr	0.000	0.00	.653	0.000	0.00	.617
switchSetswitchSet:Congruentincongruent:tonicZ:genderMale	-0.083	0.08	.276	-0.016	0.07	.812
switchSetswitchSet:BlocktypePersInhib:tonicZ:genderMale	-0.063	0.07	.375	0.034	0.07	.601
Congruentincongruent:BlocktypePersInhib:tonicZ:genderMale	-0.047	0.08	.533	0.018	0.07	.788
switchSetswitchSet:tonicZ:ebrCtr:genderMale	0.001	0.00	.379	0.000	0.00	.740
Congruentincongruent:tonicZ:ebrCtr:genderMale	0.001	0.00	.576	-0.001	0.00	.412

BlocktypePersInhib:tonicZ:ebrCtr:genderMale	0.001	0.00	.402	0.000	0.00	.884
switchSetswitchSet:Congruentincongruent:tonicZ:ebrSq	-0.000	0.00	.514	-0.000	0.00	.550
switchSetswitchSet:BlocktypePersInhib:tonicZ:ebrSq	-0.000	0.00	.352	-0.000	0.00	.931
Congruentincongruent:BlocktypePersInhib:tonicZ:ebrSq	-0.000	0.00	.665	-0.000	0.00	.623
switchSetswitchSet:tonicZ:ebrSq:genderMale	-0.000	0.00	.817	0.000	0.00	.631
Congruentincongruent:tonicZ:ebrSq:genderMale	-0.000	0.00	.707	0.000	0.00	.859
BlocktypePersInhib:tonicZ:ebrSq:genderMale	0.000	0.00	.901	0.000	0.00	.673
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:tonicSq	-0.028	0.04	.451	-0.039	0.03	.251
switchSetswitchSet:Congruentincongruent:tonicSq:ebrCtr	-0.000	0.00	.557	-0.000	0.00	.474

switchSetswitchSet:BlocktypePersInhib:tonicSq:ebrCtr	-0.000	0.00	.498	-0.000	0.00	.461
Congruentincongruent:BlocktypePersInhib:tonicSq:ebrCtr	-0.001	0.00	.274	-0.001	0.00	.315
switchSetswitchSet:Congruentincongruent:tonicSq:genderMale	0.028	0.06	.655	0.022	0.06	.701
switchSetswitchSet:BlocktypePersInhib:tonicSq:genderMale	0.016	0.06	.793	0.012	0.05	.834
Congruentincongruent:BlocktypePersInhib:tonicSq:genderMale	0.053	0.06	.380	0.041	0.05	.449
switchSetswitchSet:tonicSq:ebrCtr:genderMale	-0.001	0.00	.127	-0.001	0.00	.232
Congruentincongruent:tonicSq:ebrCtr:genderMale	-0.003	0.00	.006	-0.002	0.00	.034
BlocktypePersInhib:tonicSq:ebrCtr:genderMale	-0.001	0.00	.150	-0.001	0.00	.344
switchSetswitchSet:Congruentincongruent:tonicSq:ebrSq	0.000	0.00	.795	0.000	0.00	.657
switchSetswitchSet:BlocktypePersInhib:tonicSq:ebrSq	0.000	0.00	.435	0.000	0.00	.665
Congruentincongruent:BlocktypePersInhib:tonicSq:ebrSq	-0.000	0.00	.841	-0.000	0.00	.993
switchSetswitchSet:tonicSq:ebrSq:genderMale	-0.000	0.00	.504	0.000	0.00	.896
Congruentincongruent:tonicSq:ebrSq:genderMale	0.000	0.00	.493	0.000	0.00	.336
BlocktypePersInhib:tonicSq:ebrSq:genderMale	-0.000	0.00	.480	0.000	0.00	.712
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:phasicCtr:ebrCtr	0.042	0.02	.018			
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:phasicCtr:genderMale	-0.611	1.53	.689			
switchSetswitchSet:Congruentincongruent:Blockt	0.001	0.00	.767	0.002	0.00	.524

ypePersInhib:ebrCtr:genderMale						
switchSetswitchSet:Congruentincongruent:phasicCtr:ebrCtr:genderMale	0.011	0.02	.635			
switchSetswitchSet:BlocktypePersInhib:phasicCtr:ebrCtr:genderMale	0.052	0.03	.039			
Congruentincongruent:BlocktypePersInhib:phasicCtr:ebrCtr:genderMale	-0.006	0.02	.822			
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:phasicCtr:ebrSq	-0.001	0.00	.029			
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:ebrSq:genderMale	0.000	0.00	.021	0.000	0.00	.100
switchSetswitchSet:Congruentincongruent:phasicCtr:ebrSq:genderMale	-0.000	0.00	.653			
switchSetswitchSet:BlocktypePersInhib:phasicCtr:ebrSq:genderMale	0.001	0.00	.533			

Congruentincongruent:BlocktypePersInhib:phasicCtr:ebrSq:genderMale	-0.001	0.00	.273			
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:phasicSq:ebrCtr	0.057	0.18	.755			
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:phasicSq:genderMale	23.153	15.39	.132			
switchSetswitchSet:Congruentincongruent:phasicSq:ebrCtr:genderMale	0.092	0.27	.738			
switchSetswitchSet:BlocktypePersInhib:phasicSq:ebrCtr:genderMale	0.443	0.29	.128			
Congruentincongruent:BlocktypePersInhib:phasicSq:ebrCtr:genderMale	-0.013	0.26	.961			
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:phasicSq:ebrSq	0.011	0.01	.128			
switchSetswitchSet:Congruentincongruent:phasicSq:ebrSq:genderMale	0.021	0.01	.025			
switchSetswitchSet:BlocktypePersInhib:phasicSq:ebrSq:genderMale	0.013	0.01	.186			
Congruentincongruent:BlocktypePersInhib:phasicSq:ebrSq:genderMale	0.007	0.01	.426			
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:tonicZ:ebrCtr	0.000	0.00	.802	-0.000	0.00	.768
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:tonicZ:genderMale	0.176	0.11	.097	0.044	0.10	.648
switchSetswitchSet:Congruentincongruent:tonicZ:ebrCtr:genderMale	-0.001	0.00	.386	-0.000	0.00	.766

switchSetswitchSet:BlocktypePersInhib:tonicZ:ebrCtr:genderMale	-0.003	0.00	.051	-0.003	0.00	.040
Congruentincongruent:BlocktypePersInhib:tonicZ:ebrCtr:genderMale	-0.001	0.00	.606	0.000	0.00	.799
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:tonicZ:ebrSq	0.000	0.00	.633	0.000	0.00	.622
switchSetswitchSet:Congruentincongruent:tonicZ:ebrSq:genderMale	0.000	0.00	.176	0.000	0.00	.618
switchSetswitchSet:BlocktypePersInhib:tonicZ:ebrSq:genderMale	0.000	0.00	.253	-0.000	0.00	.829
Congruentincongruent:BlocktypePersInhib:tonicZ:ebrSq:genderMale	0.000	0.00	.506	0.000	0.00	.834
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:tonicSq:ebrCtr	-0.000	0.00	.897	0.000	0.00	.985
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:tonicSq:genderMale	0.008	0.09	.928	0.057	0.08	.464
switchSetswitchSet:Congruentincongruent:tonicSq:ebrCtr:genderMale	0.003	0.00	.023	0.003	0.00	.036
switchSetswitchSet:BlocktypePersInhib:tonicSq:ebrCtr:genderMale	0.002	0.00	.078	0.002	0.00	.101
Congruentincongruent:BlocktypePersInhib:tonicSq:ebrCtr:genderMale	0.002	0.00	.171	0.001	0.00	.392
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:tonicSq:ebrSq	0.000	0.00	.204	0.000	0.00	.224
switchSetswitchSet:Congruentincongruent:tonicSq:ebrSq:genderMale	-0.000	0.00	.816	-0.000	0.00	.535
switchSetswitchSet:BlocktypePersInhib:tonicSq:ebrSq:genderMale	0.000	0.00	.573	0.000	0.00	.866
Congruentincongruent:BlocktypePersInhib:tonicSq:ebrSq:genderMale	-0.000	0.00	.560	-0.000	0.00	.335

switchSetsswitchSet:Congruentincongruent:BlocktypePersInhib:phasicCtr:ebrCtr:genderMale	-0.058	0.04	.099			
switchSetsswitchSet:Congruentincongruent:BlocktypePersInhib:phasicCtr:ebrSq:genderMale	0.002	0.00	.172			
switchSetsswitchSet:Congruentincongruent:BlocktypePersInhib:phasicSq:ebrCtr:genderMale	-0.245	0.39	.535			
switchSetsswitchSet:Congruentincongruent:BlocktypePersInhib:phasicSq:ebrSq:genderMale	-0.038	0.01	.004			
switchSetsswitchSet:Congruentincongruent:BlocktypePersInhib:tonicZ:ebrCtr:genderMale	0.004	0.00	.063	0.004	0.00	.082
switchSetsswitchSet:Congruentincongruent:BlocktypePersInhib:tonicZ:ebrSq:genderMale	-0.000	0.00	.055	-0.000	0.00	.387
switchSetsswitchSet:Congruentincongruent:BlocktypePersInhib:tonicSq:ebrCtr:genderMale	-0.004	0.00	.028	-0.004	0.00	.041
switchSetsswitchSet:Congruentincongruent:BlocktypePersInhib:tonicSq:ebrSq:genderMale	-0.000	0.00	.776	-0.000	0.00	.635
latencyCtr				0.000	0.00	<.001
latencySq				0.000	0.00	<.001
switchSetsswitchSet:latencyCtr				0.000	0.00	.634
Congruentincongruent:latencyCtr				0.000	0.00	.886
BlocktypePersInhib:latencyCtr				0.000	0.00	.427
latencyCtr:ebrCtr				-0.000	0.00	.941
latencyCtr:genderMale				0.000	0.00	.432
latencyCtr:ebrSq				-0.000	0.00	.754
switchSetsswitchSet:latencySq				0.000	0.00	.327

Congruentincongruent:latencySq	0.000	0.00	.903
BlocktypePersInhib:latencySq	-0.000	0.00	.698
latencySq:ebrCtr	-0.000	0.00	.666
latencySq:genderMale	-0.000	0.00	.587
latencySq:ebrSq	0.000	0.00	.865
switchSetswitchSet:Congruentincongruent:latencyCtr	0.000	0.00	.467
switchSetswitchSet:BlocktypePersInhib:latencyCtr	-0.000	0.00	.200
Congruentincongruent:BlocktypePersInhib:latencyCtr	-0.000	0.00	.452
switchSetswitchSet:latencyCtr:ebrCtr	0.000	0.00	.946
Congruentincongruent:latencyCtr:ebrCtr	0.000	0.00	.160
BlocktypePersInhib:latencyCtr:ebrCtr	0.000	0.00	.057
switchSetswitchSet:latencyCtr:genderMale	-0.000	0.00	.806
Congruentincongruent:latencyCtr:genderMale	-0.000	0.00	.361
BlocktypePersInhib:latencyCtr:genderMale	-0.000	0.00	.642
latencyCtr:ebrCtr:genderMale	0.000	0.00	.036

switchSetsswitchSet:latencyCtr:ebrSq	0.000	0.00	.625
Congruentincongruent:latencyCtr:ebrSq	-0.000	0.00	.415
BlocktypePersInhib:latencyCtr:ebrSq	-0.000	0.00	.660
latencyCtr:ebrSq:genderMale	0.000	0.00	.467
switchSetsswitchSet:Congruentincongruent:latencySq	-0.000	0.00	.944
switchSetsswitchSet:BlocktypePersInhib:latencySq	0.000	0.00	.865
Congruentincongruent:BlocktypePersInhib:latencySq	-0.000	0.00	.873
switchSetsswitchSet:latencySq:ebrCtr	0.000	0.00	.126
Congruentincongruent:latencySq:ebrCtr	-0.000	0.00	.924
BlocktypePersInhib:latencySq:ebrCtr	0.000	0.00	.499
switchSetsswitchSet:latencySq:genderMale	0.000	0.00	.631
Congruentincongruent:latencySq:genderMale	-0.000	0.00	.676
BlocktypePersInhib:latencySq:genderMale	-0.000	0.00	.970
latencySq:ebrCtr:genderMale	0.000	0.00	.404
switchSetsswitchSet:latencySq:ebrSq	0.000	0.00	.759
Congruentincongruent:latencySq:ebrSq	-0.000	0.00	.796
BlocktypePersInhib:latencySq:ebrSq	0.000	0.00	.389
latencySq:ebrSq:genderMale	0.000	0.00	.161
switchSetsswitchSet:Congruentincongruent:BlocktypePersInhib:latencyCtr	0.000	0.00	.560

switchSetswitchSet:Congruentincongruent:latencyCtr:ebrCtr	0.000	0.00	.805
switchSetswitchSet:BlocktypePersInhib:latencyCtr:ebrCtr	-0.000	0.00	.068
Congruentincongruent:BlocktypePersInhib:latencyCtr:ebrCtr	-0.000	0.00	.056
switchSetswitchSet:Congruentincongruent:latencyCtr:genderMale	0.000	0.00	.344
switchSetswitchSet:BlocktypePersInhib:latencyCtr:genderMale	0.000	0.00	.103
Congruentincongruent:BlocktypePersInhib:latencyCtr:genderMale	0.000	0.00	.406
switchSetswitchSet:latencyCtr:ebrCtr:genderMale	-0.000	0.00	.666
Congruentincongruent:latencyCtr:ebrCtr:genderMale	-0.000	0.00	.064
BlocktypePersInhib:latencyCtr:ebrCtr:genderMale	-0.000	0.00	.083
switchSetswitchSet:Congruentincongruent:latencyCtr:ebrSq	-0.000	0.00	.769
switchSetswitchSet:BlocktypePersInhib:latencyCtr:ebrSq	0.000	0.00	.211
Congruentincongruent:BlocktypePersInhib:latencyCtr:ebrSq	0.000	0.00	.332
switchSetswitchSet:latencyCtr:ebrSq:genderMale	-0.000	0.00	.427
Congruentincongruent:latencyCtr:ebrSq:genderMale	0.000	0.00	.510
BlocktypePersInhib:latencyCtr:ebrSq:genderMale	-0.000	0.00	.617
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:latencySq	0.000	0.00	.724

switchSetswitchSet:Congruentincongruent:latencySq:ebrCtr	0.000	0.00	.951
switchSetswitchSet:BlocktypePersInhib:latencySq:ebrCtr	-0.000	0.00	.549
Congruentincongruent:BlocktypePersInhib:latencySq:ebrCtr	-0.000	0.00	.866
switchSetswitchSet:Congruentincongruent:latencySq:genderMale	-0.000	0.00	.891
switchSetswitchSet:BlocktypePersInhib:latencySq:genderMale	-0.000	0.00	.961
Congruentincongruent:BlocktypePersInhib:latencySq:genderMale	-0.000	0.00	.978
switchSetswitchSet:latencySq:ebrCtr:genderMale	-0.000	0.00	.405
Congruentincongruent:latencySq:ebrCtr:genderMale	-0.000	0.00	.475
BlocktypePersInhib:latencySq:ebrCtr:genderMale	-0.000	0.00	.609

switchSetswitchSet:Congruentincongruent:latencySq:ebrSq	-0.000	0.00	.824
switchSetswitchSet:BlocktypePersInhib:latencySq:ebrSq	-0.000	0.00	.539
Congruentincongruent:BlocktypePersInhib:latencySq:ebrSq	-0.000	0.00	.890
switchSetswitchSet:latencySq:ebrSq:genderMale	-0.000	0.00	.287
Congruentincongruent:latencySq:ebrSq:genderMale	-0.000	0.00	.836
BlocktypePersInhib:latencySq:ebrSq:genderMale	-0.000	0.00	.495
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:latencyCtr:ebrCtr	0.000	0.00	.070
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:latencyCtr:genderMale	-0.000	0.00	.134
switchSetswitchSet:Congruentincongruent:latencyCtr:ebrCtr:genderMale	0.000	0.00	.493
switchSetswitchSet:BlocktypePersInhib:latencyCtr:ebrCtr:genderMale	0.000	0.00	.306
Congruentincongruent:BlocktypePersInhib:latencyCtr:ebrCtr:genderMale	0.000	0.00	.101
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:latencyCtr:ebrSq	-0.000	0.00	.300
switchSetswitchSet:Congruentincongruent:latencyCtr:ebrSq:genderMale	-0.000	0.00	.397
switchSetswitchSet:BlocktypePersInhib:latencyCtr:ebrSq:genderMale	-0.000	0.00	.339

Congruentincongruent:BlocktypePersInhib:latencyCtr:ebrSq:genderMale	-0.000	0.00	.963
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:latencySq:ebrCtr	-0.000	0.00	.940
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:latencySq:genderMale	0.000	0.00	.560
switchSetswitchSet:Congruentincongruent:latencySq:ebrCtr:genderMale	0.000	0.00	.809
switchSetswitchSet:BlocktypePersInhib:latencySq:ebrCtr:genderMale	0.000	0.00	.942
Congruentincongruent:BlocktypePersInhib:latencySq:ebrCtr:genderMale	0.000	0.00	.384
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:latencySq:ebrSq	0.000	0.00	.766
switchSetswitchSet:Congruentincongruent:latencySq:ebrSq:genderMale	0.000	0.00	.475
switchSetswitchSet:BlocktypePersInhib:latencySq:ebrSq:genderMale	0.000	0.00	.800
Congruentincongruent:BlocktypePersInhib:latencySq:ebrSq:genderMale	0.000	0.00	.389
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:latencyCtr:ebrCtr:genderMale	-0.000	0.00	.283
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:latencyCtr:ebrSq:genderMale	0.000	0.00	.244
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:latencySq:ebrCtr:genderMale	0.000	0.00	.780
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:latencySq:ebrSq:genderMale	-0.000	0.00	.150
Random Parts			

σ^2	0.058	0.053
$\tau_{00, ID}$	0.034	0.028
N_{ID}	99	99
ICC_{ID}	0.373	0.348
Observations	9625	9625
R^2 / Ω_0^2	.412 / .412	.464 / .464

Uncued Trials

	Magnitude Model			Latency Model		
	B	*std. Error*	*p*	*B*	*std. Error*	*p*
Fixed Parts						
(Intercept)	6.664	0.04	<.001	6.610	0.03	<.001
switchSetswitchSet	0.111	0.03	<.001	0.096	0.03	<.001
Congruentincongruent	-0.015	0.02	.535	-0.023	0.03	.368
BlocktypePersInhib	0.001	0.03	.968	-0.007	0.03	.791
phasicCtr	0.654	0.22	.003			
phasicSq	-1.027	2.04	.615			
tonicZ	0.047	0.02	.002	0.029	0.01	.031
tonicSq	-0.006	0.01	.649	-0.006	0.01	.584
ebrCtr	0.000	0.00	.842	0.000	0.00	.762

ebrSq	0.000	0.00	.901	-0.000	0.00	.752
genderMale	-0.113	0.09	.193	-0.087	0.08	.282
switchSetswitchSet:Congruentincongruent	-0.026	0.04	.486	-0.014	0.04	.707
switchSetswitchSet:BlocktypePersInhib	-0.054	0.04	.132	-0.042	0.04	.256
Congruentincongruent:BlocktypePersInhib	-0.001	0.04	.971	0.022	0.04	.546
switchSetswitchSet:phasicCtr	-0.475	0.31	.127			
Congruentincongruent:phasicCtr	-0.030	0.31	.922			
BlocktypePersInhib:phasicCtr	0.364	0.30	.231			
switchSetswitchSet:ebrCtr	-0.001	0.00	.044	-0.002	0.00	.006
Congruentincongruent:ebrCtr	-0.001	0.00	.232	-0.001	0.00	.141
BlocktypePersInhib:ebrCtr	-0.002	0.00	.020	-0.002	0.00	.021
phasicCtr:ebrCtr	0.005	0.01	.451			
switchSetswitchSet:genderMale	-0.051	0.06	.421	-0.056	0.06	.364
Congruentincongruent:genderMale	0.034	0.06	.577	0.079	0.06	.189
BlocktypePersInhib:genderMale	0.023	0.06	.696	-0.008	0.06	.893
phasicCtr:genderMale	0.115	0.53	.828			
ebrCtr:genderMale	-0.002	0.00	.267	-0.001	0.00	.405
switchSetswitchSet:ebrSq	0.000	0.00	.283	0.000	0.00	.639
Congruentincongruent:ebrSq	-0.000	0.00	.936	0.000	0.00	.281
BlocktypePersInhib:ebrSq	0.000	0.00	.439	0.000	0.00	.275

phasicCtr:ebrSq	0.000	0.00	.671			
ebrSq:genderMale	0.000	0.00	.517	0.000	0.00	.499
switchSetswitchSet:phasicSq	-0.086	2.97	.977			
Congruentincongruent:phasicSq	-0.323	2.96	.913			
BlocktypePersInhib:phasicSq	-0.460	2.96	.877			
phasicSq:ebrCtr	-0.079	0.06	.206			
phasicSq:genderMale	4.712	5.80	.417			
phasicSq:ebrSq	0.001	0.00	.688			
switchSetswitchSet:tonicZ	-0.021	0.02	.333	0.002	0.02	.896
Congruentincongruent:tonicZ	-0.010	0.02	.645	-0.009	0.02	.636
BlocktypePersInhib:tonicZ	-0.029	0.02	.179	-0.014	0.02	.442
tonicZ:ebrCtr	0.001	0.00	.191	0.000	0.00	.451
tonicZ:genderMale	0.009	0.03	.793	0.032	0.03	.325
tonicZ:ebrSq	-0.000	0.00	.287	-0.000	0.00	.252
switchSetswitchSet:tonicSq	0.004	0.02	.798	0.002	0.02	.896
Congruentincongruent:tonicSq	0.014	0.02	.411	0.013	0.02	.400
BlocktypePersInhib:tonicSq	0.012	0.02	.504	0.012	0.02	.466
tonicSq:ebrCtr	-0.000	0.00	.260	-0.000	0.00	.394
tonicSq:genderMale	0.020	0.03	.527	0.029	0.03	.315
tonicSq:ebrSq	0.000	0.00	.499	0.000	0.00	.450

switchSetswitchSet:Congruentincongruent:BlocktypePersInhib	0.059	0.05	.256	0.032	0.05	.560
switchSetswitchSet:Congruentincongruent:phasicCtr	0.475	0.46	.302			
switchSetswitchSet:BlocktypePersInhib:phasicCtr	-0.276	0.44	.531			
Congruentincongruent:BlocktypePersInhib:phasicCtr	-0.544	0.45	.226			
switchSetswitchSet:Congruentincongruent:ebrCtr	0.001	0.00	.241	0.001	0.00	.189

switchSetswitchSet:BlocktypePersInhib:ebrCtr	0.002	0.00	.050	0.002	0.00	.016
Congruentincongruent:BlocktypePersInhib:ebrCtr	0.001	0.00	.209	0.001	0.00	.127
switchSetswitchSet:phasicCtr:ebrCtr	-0.012	0.01	.149			
Congruentincongruent:phasicCtr:ebrCtr	0.010	0.01	.274			
BlocktypePersInhib:phasicCtr:ebrCtr	-0.002	0.01	.807			
switchSetswitchSet:Congruentincongruent:genderMale	0.143	0.09	.112	0.068	0.09	.443
switchSetswitchSet:BlocktypePersInhib:genderMale	0.037	0.09	.668	0.073	0.09	.392
Congruentincongruent:BlocktypePersInhib:genderMale	-0.054	0.09	.531	-0.044	0.09	.608
switchSetswitchSet:phasicCtr:genderMale	0.674	0.72	.348			
Congruentincongruent:phasicCtr:genderMale	-0.195	0.76	.797			
BlocktypePersInhib:phasicCtr:genderMale	0.071	0.77	.926			
switchSetswitchSet:ebrCtr:genderMale	0.002	0.00	.189	0.002	0.00	.244
Congruentincongruent:ebrCtr:genderMale	0.002	0.00	.135	0.002	0.00	.054
BlocktypePersInhib:ebrCtr:genderMale	0.001	0.00	.411	0.001	0.00	.568
phasicCtr:ebrCtr:genderMale	0.001	0.01	.933			
switchSetswitchSet:Congruentincongruent:ebrSq	0.000	0.00	.413	-0.000	0.00	.978
switchSetswitchSet:BlocktypePersInhib:ebrSq	0.000	0.00	.939	-0.000	0.00	.782
Congruentincongruent:BlocktypePersInhib:ebrSq	0.000	0.00	.265	-0.000	0.00	.721

switchSetswitchSet:phasicCtr:ebrSq	0.000	0.00	.405			
Congruentincongruent:phasicCtr:ebrSq	-0.001	0.00	.089			
BlocktypePersInhib:phasicCtr:ebrSq	-0.001	0.00	.095			
switchSetswitchSet:ebrSq:genderMale	0.000	0.00	.412	0.000	0.00	.391
Congruentincongruent:ebrSq:genderMale	0.000	0.00	.590	-0.000	0.00	.467
BlocktypePersInhib:ebrSq:genderMale	-0.000	0.00	.476	-0.000	0.00	.736
phasicCtr:ebrSq:genderMale	-0.000	0.00	.830			
switchSetswitchSet:Congruentincongruent:phasicSq	5.824	4.62	.207			
switchSetswitchSet:BlocktypePersInhib:phasicSq	3.496	4.27	.413			
Congruentincongruent:BlocktypePersInhib:phasicSq	1.632	4.30	.704			
switchSetswitchSet:phasicSq:ebrCtr	0.063	0.09	.474			
Congruentincongruent:phasicSq:ebrCtr	0.029	0.09	.749			
BlocktypePersInhib:phasicSq:ebrCtr	0.064	0.09	.465			
switchSetswitchSet:phasicSq:genderMale	0.662	7.71	.932			
Congruentincongruent:phasicSq:genderMale	5.485	8.32	.510			
BlocktypePersInhib:phasicSq:genderMale	-12.888	7.70	.094			
phasicSq:ebrCtr:genderMale	0.206	0.12	.096			
switchSetswitchSet:phasicSq:ebrSq	0.002	0.00	.551			
Congruentincongruent:phasicSq:ebrSq	0.003	0.00	.415			

BlocktypePersInhib:phasicSq:ebrSq	0.001	0.00	.670			
phasicSq:ebrSq:genderMale	-0.001	0.00	.801			
switchSetswitchSet:Congruentincongruent:tonicZ	0.027	0.03	.395	0.018	0.03	.510
switchSetswitchSet:BlocktypePersInhib:tonicZ	0.024	0.03	.440	-0.009	0.03	.731
Congruentincongruent:BlocktypePersInhib:tonicZ	0.036	0.03	.243	0.029	0.03	.274
switchSetswitchSet:tonicZ:ebrCtr	-0.000	0.00	.518	-0.000	0.00	.572
Congruentincongruent:tonicZ:ebrCtr	0.000	0.00	.719	0.000	0.00	.671
BlocktypePersInhib:tonicZ:ebrCtr	-0.000	0.00	.600	0.000	0.00	.800
switchSetswitchSet:tonicZ:genderMale	0.002	0.05	.970	-0.037	0.05	.411
Congruentincongruent:tonicZ:genderMale	0.018	0.05	.740	-0.022	0.05	.650
BlocktypePersInhib:tonicZ:genderMale	0.001	0.05	.978	-0.021	0.05	.642
tonicZ:ebrCtr:genderMale	-0.001	0.00	.404	0.000	0.00	.640
switchSetswitchSet:tonicZ:ebrSq	0.000	0.00	.229	0.000	0.00	.581
Congruentincongruent:tonicZ:ebrSq	-0.000	0.00	.888	-0.000	0.00	.990
BlocktypePersInhib:tonicZ:ebrSq	0.000	0.00	.365	0.000	0.00	.514
tonicZ:ebrSq:genderMale	-0.000	0.00	.594	-0.000	0.00	.416
switchSetswitchSet:Congruentincongruent:tonicSq	0.010	0.03	.704	0.010	0.02	.672

switchSetswitchSet:BlocktypePersInhib:tonicSq	-0.018	0.03	.483	-0.010	0.02	.683
Congruentincongruent:BlocktypePersInhib:tonicSq	-0.016	0.03	.517	-0.014	0.02	.546
switchSetswitchSet:tonicSq:ebrCtr	0.000	0.00	.674	0.000	0.00	.782
Congruentincongruent:tonicSq:ebrCtr	0.001	0.00	.097	0.001	0.00	.098
BlocktypePersInhib:tonicSq:ebrCtr	0.001	0.00	.148	0.000	0.00	.265
switchSetswitchSet:tonicSq:genderMale	-0.012	0.04	.765	-0.029	0.04	.461
Congruentincongruent:tonicSq:genderMale	-0.079	0.05	.088	-0.059	0.04	.163

BlocktypePersInhib:tonicSq:genderMale	0.008	0.04	.843	-0.015	0.04	.706
tonicSq:ebrCtr:genderMale	0.001	0.00	.040	0.001	0.00	.135
switchSetswitchSet:tonicSq:ebrSq	-0.000	0.00	.238	-0.000	0.00	.373
Congruentincongruent:tonicSq:ebrSq	-0.000	0.00	.438	-0.000	0.00	.390
BlocktypePersInhib:tonicSq:ebrSq	-0.000	0.00	.284	-0.000	0.00	.263
tonicSq:ebrSq:genderMale	0.000	0.00	.299	0.000	0.00	.871
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:phasicCtr	0.036	0.65	.956			
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:ebrCtr	-0.001	0.00	.603	-0.002	0.00	.290
switchSetswitchSet:Congruentincongruent:phasicCtr:ebrCtr	-0.008	0.01	.502			
switchSetswitchSet:BlocktypePersInhib:phasicCtr:ebrCtr	-0.009	0.01	.486			
Congruentincongruent:BlocktypePersInhib:phasicCtr:ebrCtr	-0.021	0.01	.101			
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:genderMale	-0.157	0.13	.210	-0.195	0.13	.120
switchSetswitchSet:Congruentincongruent:phasicCtr:genderMale	0.300	1.06	.776			
switchSetswitchSet:BlocktypePersInhib:phasicCtr:genderMale	-0.128	1.05	.903			
Congruentincongruent:BlocktypePersInhib:phasicCtr:genderMale	0.154	1.09	.888			

switchSetswitchSet:Congruentincongruent:ebrCtr:genderMale	-0.000	0.00	.886	-0.001	0.00	.783
switchSetswitchSet:BlocktypePersInhib:ebrCtr:genderMale	-0.001	0.00	.774	-0.001	0.00	.586
Congruentincongruent:BlocktypePersInhib:ebrCtr:genderMale	-0.002	0.00	.292	-0.003	0.00	.109
switchSetswitchSet:phasicCtr:ebrCtr:genderMale	0.001	0.02	.932			
Congruentincongruent:phasicCtr:ebrCtr:genderMale	0.002	0.02	.898			
BlocktypePersInhib:phasicCtr:ebrCtr:genderMale	-0.005	0.02	.761			
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:ebrSq	-0.000	0.00	.024	-0.000	0.00	.405
switchSetswitchSet:Congruentincongruent:phasicCtr:ebrSq	0.000	0.00	.573			
switchSetswitchSet:BlocktypePersInhib:phasicCtr:ebrSq	0.001	0.00	.124			
Congruentincongruent:BlocktypePersInhib:phasicCtr:ebrSq	0.001	0.00	.028			
switchSetswitchSet:Congruentincongruent:ebrSq:genderMale	-0.000	0.00	.038	-0.000	0.00	.411
switchSetswitchSet:BlocktypePersInhib:ebrSq:genderMale	-0.000	0.00	.597	-0.000	0.00	.826
Congruentincongruent:BlocktypePersInhib:ebrSq:genderMale	-0.000	0.00	.802	0.000	0.00	.756
switchSetswitchSet:phasicCtr:ebrSq:genderMale	-0.001	0.00	.151			
Congruentincongruent:phasicCtr:ebrSq:genderMale	0.000	0.00	.428			

BlocktypePersInhib:phasicCtr:ebrSq:genderMale	-0.000	0.00	.982
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:phasicSq	-6.485	6.34	.306
switchSetswitchSet:Congruentincongruent:phasicSq:ebrCtr	-0.067	0.13	.611
switchSetswitchSet:BlocktypePersInhib:phasicSq:ebrCtr	-0.038	0.12	.757
Congruentincongruent:BlocktypePersInhib:phasicSq:ebrCtr	-0.068	0.13	.596
switchSetswitchSet:Congruentincongruent:phasicSq:genderMale	-20.517	11.66	.078
switchSetswitchSet:BlocktypePersInhib:phasicSq:genderMale	-1.905	10.51	.856
Congruentincongruent:BlocktypePersInhib:phasicSq:genderMale	2.046	10.81	.850

switchSetswitchSet:phasicSq:ebrCtr:genderMale	-0.299	0.19	.115			
Congruentincongruent:phasicSq:ebrCtr:genderMale	0.096	0.20	.634			
BlocktypePersInhib:phasicSq:ebrCtr:genderMale	-0.154	0.17	.376			
switchSetswitchSet:Congruentincongruent:phasicSq:ebrSq	-0.007	0.01	.141			
switchSetswitchSet:BlocktypePersInhib:phasicSq:ebrSq	-0.005	0.00	.243			
Congruentincongruent:BlocktypePersInhib:phasicSq:ebrSq	-0.004	0.00	.394			
switchSetswitchSet:phasicSq:ebrSq:genderMale	-0.004	0.01	.560			
Congruentincongruent:phasicSq:ebrSq:genderMale	-0.009	0.01	.176			
BlocktypePersInhib:phasicSq:ebrSq:genderMale	0.006	0.01	.338			
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:tonicZ	-0.052	0.04	.246	-0.026	0.04	.511
switchSetswitchSet:Congruentincongruent:tonicZ:ebrCtr	-0.001	0.00	.524	-0.000	0.00	.891
switchSetswitchSet:BlocktypePersInhib:tonicZ:ebrCtr	0.000	0.00	.985	0.000	0.00	.840
Congruentincongruent:BlocktypePersInhib:tonicZ:ebrCtr	0.000	0.00	.653	0.000	0.00	.617
switchSetswitchSet:Congruentincongruent:tonicZ:genderMale	-0.083	0.08	.276	-0.016	0.07	.812
switchSetswitchSet:BlocktypePersInhib:tonicZ:genderMale	-0.063	0.07	.375	0.034	0.07	.601

Congruentincongruent:BlocktypePersInhib:tonicZ:genderMale	-0.047	0.08	.533	0.018	0.07	.788
switchSetswitchSet:tonicZ:ebrCtr:genderMale	0.001	0.00	.379	0.000	0.00	.740
Congruentincongruent:tonicZ:ebrCtr:genderMale	0.001	0.00	.576	-0.001	0.00	.412
BlocktypePersInhib:tonicZ:ebrCtr:genderMale	0.001	0.00	.402	0.000	0.00	.884
switchSetswitchSet:Congruentincongruent:tonicZ:ebrSq	-0.000	0.00	.514	-0.000	0.00	.550
switchSetswitchSet:BlocktypePersInhib:tonicZ:ebrSq	-0.000	0.00	.352	-0.000	0.00	.931
Congruentincongruent:BlocktypePersInhib:tonicZ:ebrSq	-0.000	0.00	.665	-0.000	0.00	.623
switchSetswitchSet:tonicZ:ebrSq:genderMale	-0.000	0.00	.817	0.000	0.00	.631
Congruentincongruent:tonicZ:ebrSq:genderMale	-0.000	0.00	.707	0.000	0.00	.859
BlocktypePersInhib:tonicZ:ebrSq:genderMale	0.000	0.00	.901	0.000	0.00	.673
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:tonicSq	-0.028	0.04	.451	-0.039	0.03	.251
switchSetswitchSet:Congruentincongruent:tonicSq:ebrCtr	-0.000	0.00	.557	-0.000	0.00	.474
switchSetswitchSet:BlocktypePersInhib:tonicSq:ebrCtr	-0.000	0.00	.498	-0.000	0.00	.461
Congruentincongruent:BlocktypePersInhib:tonicSq:ebrCtr	-0.001	0.00	.274	-0.001	0.00	.315
switchSetswitchSet:Congruentincongruent:tonicSq:genderMale	0.028	0.06	.655	0.022	0.06	.701
switchSetswitchSet:BlocktypePersInhib:tonicSq:genderMale	0.016	0.06	.793	0.012	0.05	.834

Congruentincongruent:BlocktypePersInhib:tonicSq:genderMale	0.053	0.06	.380	0.041	0.05	.449
switchSetswitchSet:tonicSq:ebrCtr:genderMale	-0.001	0.00	.127	-0.001	0.00	.232
Congruentincongruent:tonicSq:ebrCtr:genderMale	-0.003	0.00	.006	-0.002	0.00	.034
BlocktypePersInhib:tonicSq:ebrCtr:genderMale	-0.001	0.00	.150	-0.001	0.00	.344
switchSetswitchSet:Congruentincongruent:tonicSq:ebrSq	0.000	0.00	.795	0.000	0.00	.657

switchSetswitchSet:BlocktypePersInhib:tonicSq:ebrSq	0.000	0.00	.435	0.000	0.00	.665
Congruentincongruent:BlocktypePersInhib:tonicSq:ebrSq	-0.000	0.00	.841	-0.000	0.00	.993
switchSetswitchSet:tonicSq:ebrSq:genderMale	-0.000	0.00	.504	0.000	0.00	.896
Congruentincongruent:tonicSq:ebrSq:genderMale	0.000	0.00	.493	0.000	0.00	.336
BlocktypePersInhib:tonicSq:ebrSq:genderMale	-0.000	0.00	.480	0.000	0.00	.712
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:phasicCtr:ebrCtr	0.042	0.02	.018			
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:phasicCtr:genderMale	-0.611	1.53	.689			
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:ebrCtr:genderMale	0.001	0.00	.767	0.002	0.00	.524
switchSetswitchSet:Congruentincongruent:phasicCtr:ebrCtr:genderMale	0.011	0.02	.635			
switchSetswitchSet:BlocktypePersInhib:phasicCtr:ebrCtr:genderMale	0.052	0.03	.039			
Congruentincongruent:BlocktypePersInhib:phasicCtr:ebrCtr:genderMale	-0.006	0.02	.822			
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:phasicCtr:ebrSq	-0.001	0.00	.029			
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:ebrSq:genderMale	0.000	0.00	.021	0.000	0.00	.100
switchSetswitchSet:Congruentincongruent:phasicCtr:ebrSq:genderMale	-0.000	0.00	.653			
switchSetswitchSet:BlocktypePersInhib:phasicCtr:ebrSq:genderMale	0.001	0.00	.533			
Congruentincongruent:BlocktypePersInhib:phas	-0.001	0.00	.273			

icCtr:ebrSq:genderMale			
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:phasicSq:ebrCtr	0.057	0.18	.755
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:phasicSq:genderMale	23.153	15.39	.132
switchSetswitchSet:Congruentincongruent:phasicSq:ebrCtr:genderMale	0.092	0.27	.738
switchSetswitchSet:BlocktypePersInhib:phasicSq:ebrCtr:genderMale	0.443	0.29	.128
Congruentincongruent:BlocktypePersInhib:phasicSq:ebrCtr:genderMale	-0.013	0.26	.961
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:phasicSq:ebrSq	0.011	0.01	.128
switchSetswitchSet:Congruentincongruent:phasicSq:ebrSq:genderMale	0.021	0.01	.025
switchSetswitchSet:BlocktypePersInhib:phasicSq:ebrSq:genderMale	0.013	0.01	.186
Congruentincongruent:BlocktypePersInhib:phasicSq:ebrSq:genderMale	0.007	0.01	.426

switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:tonicZ:ebrCtr	0.000	0.00	.802	-0.000	0.00	.768
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:tonicZ:genderMale	0.176	0.11	.097	0.044	0.10	.648
switchSetswitchSet:Congruentincongruent:tonicZ:ebrCtr:genderMale	-0.001	0.00	.386	-0.000	0.00	.766
switchSetswitchSet:BlocktypePersInhib:tonicZ:ebrCtr:genderMale	-0.003	0.00	.051	-0.003	0.00	.040
Congruentincongruent:BlocktypePersInhib:tonicZ:ebrCtr:genderMale	-0.001	0.00	.606	0.000	0.00	.799
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:tonicZ:ebrSq	0.000	0.00	.633	0.000	0.00	.622
switchSetswitchSet:Congruentincongruent:tonicZ:ebrSq:genderMale	0.000	0.00	.176	0.000	0.00	.618
switchSetswitchSet:BlocktypePersInhib:tonicZ:ebrSq:genderMale	0.000	0.00	.253	-0.000	0.00	.829
Congruentincongruent:BlocktypePersInhib:tonicZ:ebrSq:genderMale	0.000	0.00	.506	0.000	0.00	.834

switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:tonicSq:ebrCtr	-0.000	0.00	.897	0.000	0.00	.985
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:tonicSq:genderMale	0.008	0.09	.928	0.057	0.08	.464
switchSetswitchSet:Congruentincongruent:tonicSq:ebrCtr:genderMale	0.003	0.00	.023	0.003	0.00	.036
switchSetswitchSet:BlocktypePersInhib:tonicSq:ebrCtr:genderMale	0.002	0.00	.078	0.002	0.00	.101
Congruentincongruent:BlocktypePersInhib:tonicSq:ebrCtr:genderMale	0.002	0.00	.171	0.001	0.00	.392
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:tonicSq:ebrSq	0.000	0.00	.204	0.000	0.00	.224
switchSetswitchSet:Congruentincongruent:tonicSq:ebrSq:genderMale	-0.000	0.00	.816	-0.000	0.00	.535
switchSetswitchSet:BlocktypePersInhib:tonicSq:ebrSq:genderMale	0.000	0.00	.573	0.000	0.00	.866
Congruentincongruent:BlocktypePersInhib:tonicSq:ebrSq:genderMale	-0.000	0.00	.560	-0.000	0.00	.335
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:phasicCtr:ebrCtr:genderMale	-0.058	0.04	.099			
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:phasicCtr:ebrSq:genderMale	0.002	0.00	.172			
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:phasicSq:ebrCtr:genderMale	-0.245	0.39	.535			
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:phasicSq:ebrSq:genderMale	-0.038	0.01	.004			
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:tonicZ:ebrCtr:genderMale	0.004	0.00	.063	0.004	0.00	.082
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:tonicZ:ebrSq:genderMale	-0.000	0.00	.055	-0.000	0.00	.387

switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:tonicSq:ebrCtr:genderMale	-0.004	0.00	.028	-0.004	0.00	.041
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:tonicSq:ebrSq:genderMale	-0.000	0.00	.776	-0.000	0.00	.635
latencyCtr				0.000	0.00	<.001
latencySq				0.000	0.00	<.001
switchSetswitchSet:latencyCtr				0.000	0.00	.634
Congruentincongruent:latencyCtr				0.000	0.00	.886
BlocktypePersInhib:latencyCtr				0.000	0.00	.427
latencyCtr:ebrCtr				-0.000	0.00	.941
latencyCtr:genderMale				0.000	0.00	.432
latencyCtr:ebrSq				-0.000	0.00	.754
switchSetswitchSet:latencySq				0.000	0.00	.327
Congruentincongruent:latencySq				0.000	0.00	.903
BlocktypePersInhib:latencySq				-0.000	0.00	.698
latencySq:ebrCtr				-0.000	0.00	.666
latencySq:genderMale				-0.000	0.00	.587
latencySq:ebrSq				0.000	0.00	.865

switchSetswitchSet:Congruentincongruent:latencyCtr	0.000	0.00	.467
switchSetswitchSet:BlocktypePersInhib:latencyCtr	-0.000	0.00	.200
Congruentincongruent:BlocktypePersInhib:latencyCtr	-0.000	0.00	.452
switchSetswitchSet:latencyCtr:ebrCtr	0.000	0.00	.946
Congruentincongruent:latencyCtr:ebrCtr	0.000	0.00	.160
BlocktypePersInhib:latencyCtr:ebrCtr	0.000	0.00	.057
switchSetswitchSet:latencyCtr:genderMale	-0.000	0.00	.806
Congruentincongruent:latencyCtr:genderMale	-0.000	0.00	.361
BlocktypePersInhib:latencyCtr:genderMale	-0.000	0.00	.642
latencyCtr:ebrCtr:genderMale	0.000	0.00	.036
switchSetswitchSet:latencyCtr:ebrSq	0.000	0.00	.625
Congruentincongruent:latencyCtr:ebrSq	-0.000	0.00	.415
BlocktypePersInhib:latencyCtr:ebrSq	-0.000	0.00	.660
latencyCtr:ebrSq:genderMale	0.000	0.00	.467
switchSetswitchSet:Congruentincongruent:latencySq	-0.000	0.00	.944
switchSetswitchSet:BlocktypePersInhib:latencySq	0.000	0.00	.865
Congruentincongruent:BlocktypePersInhib:latencySq	-0.000	0.00	.873
switchSetswitchSet:latencySq:ebrCtr	0.000	0.00	.126

Congruentincongruent:latencySq:ebrCtr	-0.000	0.00	.924
BlocktypePersInhib:latencySq:ebrCtr	0.000	0.00	.499
switchSetswitchSet:latencySq:genderMale	0.000	0.00	.631
Congruentincongruent:latencySq:genderMale	-0.000	0.00	.676
BlocktypePersInhib:latencySq:genderMale	-0.000	0.00	.970
latencySq:ebrCtr:genderMale	0.000	0.00	.404
switchSetswitchSet:latencySq:ebrSq	0.000	0.00	.759
Congruentincongruent:latencySq:ebrSq	-0.000	0.00	.796
BlocktypePersInhib:latencySq:ebrSq	0.000	0.00	.389
latencySq:ebrSq:genderMale	0.000	0.00	.161
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:latencyCtr	0.000	0.00	.560
switchSetswitchSet:Congruentincongruent:latencyCtr:ebrCtr	0.000	0.00	.805
switchSetswitchSet:BlocktypePersInhib:latencyCtr:ebrCtr	-0.000	0.00	.068
Congruentincongruent:BlocktypePersInhib:latencyCtr:ebrCtr	-0.000	0.00	.056
switchSetswitchSet:Congruentincongruent:latencyCtr:genderMale	0.000	0.00	.344
switchSetswitchSet:BlocktypePersInhib:latencyCtr:genderMale	0.000	0.00	.103
Congruentincongruent:BlocktypePersInhib:latencyCtr:genderMale	0.000	0.00	.406

switchSetswitchSet:latencyCtr:ebrCtr:genderMale	-0.000	0.00	.666
Congruentincongruent:latencyCtr:ebrCtr:genderMale	-0.000	0.00	.064
BlocktypePersInhib:latencyCtr:ebrCtr:genderMale	-0.000	0.00	.083
switchSetswitchSet:Congruentincongruent:latencyCtr:ebrSq	-0.000	0.00	.769
switchSetswitchSet:BlocktypePersInhib:latencyCtr:ebrSq	0.000	0.00	.211
Congruentincongruent:BlocktypePersInhib:latencyCtr:ebrSq	0.000	0.00	.332
switchSetswitchSet:latencyCtr:ebrSq:genderMale	-0.000	0.00	.427
Congruentincongruent:latencyCtr:ebrSq:genderMale	0.000	0.00	.510
BlocktypePersInhib:latencyCtr:ebrSq:genderMale	-0.000	0.00	.617
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:latencySq	0.000	0.00	.724
switchSetswitchSet:Congruentincongruent:latencySq:ebrCtr	0.000	0.00	.951
switchSetswitchSet:BlocktypePersInhib:latencySq:ebrCtr	-0.000	0.00	.549
Congruentincongruent:BlocktypePersInhib:latencySq:ebrCtr	-0.000	0.00	.866
switchSetswitchSet:Congruentincongruent:latencySq:genderMale	-0.000	0.00	.891
switchSetswitchSet:BlocktypePersInhib:latencySq:genderMale	-0.000	0.00	.961

Congruentincongruent:BlocktypePersInhib:latencySq:genderMale	-0.000	0.00	.978
switchSetswitchSet:latencySq:ebrCtr:genderMale	-0.000	0.00	.405

Congruentincongruent:latencySq:ebrCtr:gender Male	-0.000	0.00	.475
BlocktypePersInhib:latencySq:ebrCtr:genderMa le	-0.000	0.00	.609
switchSetswitchSet:Congruentincongruent:laten cySq:ebrSq	-0.000	0.00	.824
switchSetswitchSet:BlocktypePersInhib:latency Sq:ebrSq	-0.000	0.00	.539
Congruentincongruent:BlocktypePersInhib:late ncySq:ebrSq	-0.000	0.00	.890
switchSetswitchSet:latencySq:ebrSq:genderMal e	-0.000	0.00	.287
Congruentincongruent:latencySq:ebrSq:gender Male	-0.000	0.00	.836
BlocktypePersInhib:latencySq:ebrSq:genderMa le	-0.000	0.00	.495
switchSetswitchSet:Congruentincongruent:Bloc ktypePersInhib:latencyCtr:ebrCtr	0.000	0.00	.070
switchSetswitchSet:Congruentincongruent:Bloc ktypePersInhib:latencyCtr:genderMale	-0.000	0.00	.134
switchSetswitchSet:Congruentincongruent:laten cyCtr:ebrCtr:genderMale	0.000	0.00	.493
switchSetswitchSet:BlocktypePersInhib:latency Ctr:ebrCtr:genderMale	0.000	0.00	.306
Congruentincongruent:BlocktypePersInhib:late ncyCtr:ebrCtr:genderMale	0.000	0.00	.101
switchSetswitchSet:Congruentincongruent:Bloc ktypePersInhib:latencyCtr:ebrSq	-0.000	0.00	.300
switchSetswitchSet:Congruentincongruent:laten cyCtr:ebrSq:genderMale	-0.000	0.00	.397

switchSetswitchSet:BlocktypePersInhib:latencyCtr:ebrSq:genderMale	-0.000	0.00	.339
Congruentincongruent:BlocktypePersInhib:latencyCtr:ebrSq:genderMale	-0.000	0.00	.963
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:latencySq:ebrCtr	-0.000	0.00	.940
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:latencySq:genderMale	0.000	0.00	.560
switchSetswitchSet:Congruentincongruent:latencySq:ebrCtr:genderMale	0.000	0.00	.809
switchSetswitchSet:BlocktypePersInhib:latencySq:ebrCtr:genderMale	0.000	0.00	.942
Congruentincongruent:BlocktypePersInhib:latencySq:ebrCtr:genderMale	0.000	0.00	.384
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:latencySq:ebrSq	0.000	0.00	.766
switchSetswitchSet:Congruentincongruent:latencySq:ebrSq:genderMale	0.000	0.00	.475
switchSetswitchSet:BlocktypePersInhib:latencySq:ebrSq:genderMale	0.000	0.00	.800
Congruentincongruent:BlocktypePersInhib:latencySq:ebrSq:genderMale	0.000	0.00	.389
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:latencyCtr:ebrCtr:genderMale	-0.000	0.00	.283
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:latencyCtr:ebrSq:genderMale	0.000	0.00	.244
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:latencySq:ebrCtr:genderMale	0.000	0.00	.780
switchSetswitchSet:Congruentincongruent:BlocktypePersInhib:latencySq:ebrSq:genderMale	-0.000	0.00	.150

Random Parts		
σ^2	0.058	0.053
$\tau_{00, ID}$	0.034	0.028
N_{ID}	99	99
ICC_{ID}	0.373	0.348
Observations	9625	9625
R^2 / Ω_0^2	.412 / .412	.464 / .464

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