Top-down modulation of task features in rapid instructed task learning:

An ERP study

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Declaration

I declare that this thesis is my own account of my research and contains as its main content work which has not previously been submitted for a degree at any tertiary educational institution.

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Abstract

Rapid instructed task learning (RITL) is the ability to quickly restructure behaviour into new configurations based on explicit instruction (Cole, Laurent, & Stocco, 2012). The majority of RITL research has been dominated by neuroimaging studies, which suggest unique involvements of the lateral prefrontal cortex and the posterior parietal cortex, although the exact mechanisms of RITL execution remain poorly understood. The electrophysiological responses of 22 adults undergoing a computerised RITL sequential dependency task were obtained, with the expectation that task relevance processes would be observable at posterior N1, anterior P2a/N2, and central P3b. Early top-down amplitudinal modulation was found in N1 for all item types, and this was related to non-target N2 amplitudes, with both time windows showing preliminary support for compositionality of individual task components. Evidence for compositionality in attentional template matching processes was also found in the P2a/N2 complex. Central P3b did not appear to be involved in task relevance processes per se, perhaps being more involved in attentional resource allocation. These findings answer important questions as how to task-relevant feature identification and task component sequencing occur in RITL.

Keywords: rapid instructed task learning, early top-down processing, event-related potentials, task execution

Top-down modulation of task features in rapid instructed task learning: An ERP study

The ability to execute novel instructions on the first attempt is not only a remarkable demonstration of cognitive control and flexibility (Braver & Barch, 2006), it is also an ability on which humans rely every day. Humans use this ability when they follow a new recipe to bake a cake or use an instruction manual to learn how to play a new game. In these tasks, even if some of the individual task rules or components may be familiar, their combination and sequencing into a larger task set is completely novel. Rapid instructed task learning (RITL; pronounced “rittle”), also known as instruction-based learning, is the ability to quickly restructure behaviour into new configurations based on explicit instruction (Cole, Laurent, & Stocco, 2012). This ability is an exemplar of our rapid cognitive processing and environmental adaptability (Cole et al., 2012). RITL allows humans to encode and successfully execute countless numbers of novel task sets composed of combinations and permutations of tens of thousands of previously learned task components, often on the first trial (Cole et al., 2012). Furthermore, RITL is considered to be an example of goal-directed behaviour due to the lack of habit formation or automaticity and the involvement of voluntary and effortful behavioural restructuring to achieve an outcome (Wolfensteller & Ruge, 2012). Despite humans' frequent reliance on RITL, its ubiquity in everyday life, and the remarkable degree of cognitive control and flexibility required, it is only recently receiving research attention. This study seeks to investigate the temporal course of RITL execution using event-related potentials (ERP) methodology, with a specific focus on task-relevant feature processing and task component sequencing. Although ERP methodology is a rather established approach to understanding the temporal course of cognitive processes (Handy, 2004), the use of this method is rather new to the study of RITL, so this study will be drawing extensively from fMRI studies on RITL and ERP studies on related cognitive processes to inform an integrative neurocognitive theory of RITL execution.

Although RITL is a rather new concept, the need to study explicit instruction execution has been noted (and relatively neglected) for some time (Monsell, 1996). Early studies supported the distinction between RITL and other cognitive functions and learning modalities. For example, people with lesions in the lateral prefrontal cortex (LPFC) can understand and repeat novel instructions, but exhibit goal neglect (i.e., the failure to execute task components despite understanding the instructions; Duncan et al., 2008) when attempting to execute these instructions (Luria, 1973; Luria, Pribram, & Homskaya, 1964). Goal neglect is also exhibited by neurologically intact people who understand and remember individual task components and can successfully execute these components when combined into a simple, novel task set, but exhibit higher probabilities of failure for novel task sets formed by a greater number of task components, regardless of individual task component complexity or the degree of cognitive load (Duncan, Schramm, Thompson, & Dumontheil, 2012). Furthermore, studies on the flanker compatibility effect found that administration of instructions for a completely irrelevant task had an autonomous priming effect on first-trial execution of the current task (Cohen-Kdoshay & Meiran, 2007, 2009). The evidence from these studies support a functional independence between RITL and linguistic or semantic memory processes. RITL is characterised by a remarkably high success rate for first-trial execution following explicit, novel instructions (approximately 90%; Cole, Bagic, Kass, & Schneider, 2010) making it distinct from reinforcement learning modalities (such as trial-and-error learning and shaping), which do not involve explicit instructions and require far more trials for successful execution (Cole et al., 2012; Petrides, 1997) and are faster and less effortful once success is achieved (Chein & Schneider, 2012; Huang, Hazy, Herd, & O'Reilly, 2013). The novelty of instructional sets makes RITL conceptually distinct from a similar form of cognitive flexibility known as task-switching (i.e., the ability to switch attention between different practiced tasks; Monsell, 2003), which specifically involves long-term memory retrieval of practiced task sets

(Cole et al., 2012). Although functional magnetic resonance imaging (fMRI) studies support a neurological continuity between the two, with novel and more abstract or complex tasks being represented by more anterior LPFC areas before practice causes a shift of activity to more posterior LPFC areas (Cole, Bagic, et al., 2010; Ruge & Wolfensteller, 2010). Thus, RITL is conceptually, behaviourally, and neurologically distinct from previously researched learning modalities, specifically due to the involvement of rapid task set formation processes within the first few trials following explicit and novel instructions.

Not a lot is known about these task set formation processes specifically, which appear to be crucially important in RITL, although they have been linked to LPFC and areas of the parietal cortex. Hartstra, Kühn, Verguts, and Brass (2011) pooled first-trial fMRI recordings of participants undergoing stimulus-response or novel object-colour tasks, finding that the LPFC was the only area activated during first-trial execution for both tasks and less so as tasks became practiced. Reverberi, Görgen, and Hayes (2012) used multivariate pattern recognition, an fMRI technique for identifying and decoding distributed, fine-grained activity patterns (Norman, Polyn, Detre, & Haxby, 2006), and localised simple stimulus-response rule representation in both the right inferior LPFC and the superior parietal cortex, with the left lateral parietal cortex coding cue identity. Additionally, Stocco, Lebiere, O'Reilly, and Anderson (2012) compared first-trial executions of novel and practised arithmetic operation sets and localised rule integration in the anterior LPFC and task maintenance in the posterior parietal cortex with fMRI. Woolgar, Hampshire, Thompson, and Duncan (2011) manipulated rule type and perceptual difficulty in a simple stimulus-response task and using multivariate pattern recognition reported increased activation in the LPFC and posterior parietal cortex with increased task demands. Cole, Bagic, et al. (2010) found an anterior-to-middle LPFC transition as novel tasks became more practised by examining the transition from novel

to practiced task execution using fMRI. Similarly, Ruge and Wolfensteller (2010), when using a more abstract and complex task than that of Cole, Bagic, et al.'s (2010), documented a middle-to-posterior LPFC transition using fMRI as novel tasks became more practised. Hence, the localisation of processes specific to RITL has been established enough to examine the mechanistic properties of these areas, formulate a comprehensive theory of the neurocognitive mechanisms behind RITL, and use this theory to investigate the temporal course of RITL execution.

Observations from previous research literature have noted that RITL occurs quickly (which is inferred from its extremely high success rate for first-trial execution; Cohen-Kdoshay & Meiran, 2007, 2009; Cole, Bagic, et al., 2010) and is highly versatile in terms of instructional content (Cole, Bagic, et al., 2010; Ruge & Wolfensteller, 2010). With these characteristics in mind, there are at least two requirements for a neural mechanistic framework of RITL to be feasible: (1) access to thousands of task rule and task component representations, and (2) the ability to rapidly assemble or update the working task rules or components (Cole et al., 2012). Several features of the human LPFC and its connections to other regions make this possible. Firstly, the human LPFC exhibits vast interconnectedness within itself as well as with other cortical regions, including the premotor, parietal, and secondary visual cortex, allowing itself access to a variety of sensorimotor representations, the connections of which converge into specific areas of the LPFC (Cole et al., 2012; Cole, Pathak, & Schneider, 2010; Miller & Cohen, 2001). The global connectivity allows access to a wide variety of task components, whereas the convergence of these connections and extensive interconnectivity within the LPFC provides the possibility of combining task components together into a single task set and configuring or adapting them relative to other task rule representations if necessary (Cole et al., 2012; Cole, Pathak, et al., 2010; Miller & Cohen, 2001). Secondly, the LPFC carries extensive connectivity with the mid-brain, particularly the

basal ganglia (Stocco, Lebiere, O'Reilly, & Anderson, 2010). It is theorised that the LPFC's ability to rapidly update its own activated neural representations is due to the basal ganglia's dopamine gating mechanism which allows the current task to be interrupted by reward prediction signals relevant to a new task (Stocco et al., 2010). Hence, preliminary observations demonstrate that the LPFC is minimally anatomically capable of RITL execution, although there are other important properties of the LPFC and the parietal cortex that are involved in RITL execution.

Recent evidence has been accumulating supporting a hierarchical, compositional coding theory of RITL. The LPFC itself is organised across an anterior-to-posterior hierarchy of abstraction or complexity (Badre & D'Esposito, 2007; Cole, Bagic, et al., 2010; Petrides, 2005; Ruge & Wolfensteller, 2010), with novel instructions being initially represented in more anterior regions of the LPFC the more abstract or complex a task set is, before activation shifts to more posterior LPFC regions (e.g., the premotor cortex) with practice, presumably causing task representations to become more concrete and obtaining their own prepared motor response (Cole, Bagic, et al., 2010; Ruge & Wolfensteller, 2010). Anterior regions initially drive the premotor areas via bottom-up assembly of individual task components, which guide task execution (Chein & Schneider, 2012; Cole, Bagic, et al., 2010). Cole, Bagic, et al. (2010) using magneto-encephalography found that this flow of neural activation reverses with practice, at which point the premotor areas would then drive anterior LPFC activation, presumably because task-switching involves a motor program being retrieved for task execution (Mayr & Reinhold, 2000). Other studies using multivariate pattern recognition methodology have found additive effects of rule representation in novel task set formation within the LPFC—that is, novel task sets were initially represented within the LPFC as the sum of the neural representations of their individual task components (Cole, Etzel, Zacks, Schneider, & Braver, 2011; Reverberi et al., 2012). Cole et al. (2012) argue that this compositional scheme is coarse-coded (i.e., the neural

representation for a novel task resembles a Venn diagram of overlapping task-relevant and task-related features) and that their neural signals are activated in synchrony. They further argue that this hierarchically organised, synchronous coarse-coding within the LPFC allows individual task components to be abstractly organised, modified, transferred, and recycled (Cole et al., 2012). Chein and Schneider (2012) support this theory, suggesting that this facilitates the practice-related transfer of individual task components to other task sets, an observation which has been demonstrated in research (Cole et al., 2011; Zanto & Gazzaley, 2013). However, this theory requires the assignment of PFC neurons one or more specific representations, thus being in direct conflict with adaptive coding theory, which argues for total flexibility of the neural representations of PFC neurons (Woolgar et al., 2011). Rigotti, Rubin, Wang, and Fusi (2010) partially reconcile these two theories by arguing for the presence of PFC neurons with mixed selectivity (i.e., neurons responding to a range of loosely related task components as well as contextual information) in their mathematical model of task rule representation. Thus far, the compositional coding theory of RITL is gaining the most preliminary support from research evidence, so it will be tentatively assumed that RITL encoding involves bottom-up assembly of individual task components into a novel task set (Cole, Bagic, et al., 2010), where the LPFC's extensive intra- and inter-regional connectivity as well as its hierarchical and composition coding scheme provide this region with the ability to cope with an almost infinite variety of complex tasks. This explains the versatility of RITL, but does not explain its goal-directed nature or its recruitment of cognitive control capabilities, which require top-down processing.

In contrast with the lack of research in RITL task set formation processes, top-down processing during task execution (particularly visual task execution) has a wealth of research to draw from to inform a neurocognitive theory of RITL execution. Like most top-down processes, the top-down processes inherent in RITL appear to be subserved by

the frontoparietal network (FPN), which includes the LPFC and posterior parietal cortex (Dumontheil, Thompson, and Duncan, 2010; Duncan, 2010; Stocco et al., 2012). The FPN is an extensive neural network recruited for a variety of executive functions requiring information integration and top-down control (Gazzaley, Cooney, McEvoy, Knight, & D'Esposito, 2005; Kastner & Ungelieder, 2000; Miller & Cohen, 2001; Zanto & Gazzaley, 2013). Within the FPN, the PFC typically provides the initial signals that drive activity in the parietal regions, before activity flows to other areas of the brain (Hillyard & Anllo-Vento, 1998; Shomstein, Kravitz, & Behrmann, 2012; Stokes, 2011). This observation is supported by ERP and repetitive trans-cranial magnetic stimulation (rTMS) studies tracing upstream neural signals to the PFC in a variety of executive functions (Shomstein et al., 2012; Yago, Duarte, Wong, Barceló, and Knight, 2004; Zanto, Rubens, Thangavel, & Gazzaley, 2011). Thus far, the vast majority of the aforementioned RITL studies used the visual modality in their task paradigms, so the executive functions of greatest interest here would be visual selective attention and working memory for visual tasks.

Desimone and Duncan's (1995) biased competition model is perhaps the most empirically supported model of visual selective attention. It proposes that the finite availability of cognitive resources means that only a small portion of sensory experiences are processed at any one time, hence stimuli compete for selection and neural processing (Desimone & Duncan, 1995). They then suggest that this competition is resolved via simultaneous top-down and bottom-up visual processes (Desimone & Duncan, 1995). There are several features of the biased competition model which are relevant to the study of RITL, particularly for visual task execution. Firstly, it argues that the PFC is responsible for creating signals to organise the attentional template that drives visual task execution by providing enhanced processing to the space- and feature-specific visual cortical areas according to task-relevance, thereby lowering their

activation thresholds and enhancing their responses to task-relevant stimuli that appear within their receptive fields (Desimone & Duncan, 1995). This occurs at the cost of diminishing the processing resources available to neural representations of visual areas representing task-irrelevant spaces or features (Desimone & Duncan, 1995). This observation is supported by fMRI studies showing enhanced preparatory neural activation in corresponding visual processing areas during visual selective attention to colour (in V4; Reynolds & Desimone, 2003), shape (in the lateral occipital complex; Murray & Wojciulik, 2004), and motion (in the inferior temporal regions; Pasternak & Greenlee, 2005; Wright, 2005). Secondly, it argues that this attentional template is coarse-coded using neural representations of task-relevant features within the visual areas, and that its successful application to visual task execution depends upon its activation (Desimone & Duncan, 1995). A review by Kastner and Ungelieder (2000) argued for the mechanism of low-level, sensory coarse-coding by presenting studies using single-cell recordings of secondary visual cortical neurons that measured their spatial and featural receptive fields as well as fMRI studies on humans. The biased competition model then concludes that the automaticity of visual search depends on the degree of dissimilarity between task-relevant and task-irrelevant features of the available visual stimuli; stimuli are processed automatically when the attentional template of the target is dissimilar to distractors, otherwise processing occurs more slowly and in series (Desimone & Duncan, 1995). Thus, this model demonstrates some convergence with observations from RITL studies, adding research observations regarding the occipital activation of task-relevant features during visual tasks by the PFC, the diminished attentional resources available to task-irrelevant features during visual search, and the problems associated with similarity between task-relevant and irrelevant features. Despite the lack of research dedicated to the mechanisms of RITL execution specifically, taken together, these observations suggest that the LPFC activates the neural representations of each individual task-relevant and task-related

component (e.g., colours in V4, motor responses in the premotor cortex, shapes in the lateral occipital cortex), binds them together into a single task set via higher-level, synchronous coarse-coding, and maintains this task set from the LPFC to guide task execution. It is not currently known exactly how compositional coding in RITL is modulated to cope with stimuli of differing levels of task-relevance, nor is it known how the sequencing of individual task components within novel task sets is achieved. Investigating these gaps in research is not easily achieved with fMRI (which has been the dominant tool used in RITL research thus far) because of the need for temporal information to investigate these questions. However these gaps are fertile ground for investigation using ERP methodology, which will be described (and argued for) below.

ERP methodology involves taking scalp measurements of the voltage changes in the electrical fields generated by the brain's neural populations in response to an event using an electroencephalogram (EEG; Matsumoto, 2009). These measurements are repeated and summed to create ERP data (Handy, 2004), which can be used to investigate when and how cognitive processes occur. For instance, the ERPs between two different visual stimuli could be compared to determine the earliest point at which the brain is able to discriminate between the two. Usually ERP studies have one or more ERP components (i.e., 'bumps' in an ERP line graph which occur within a specific time window at a particular scalp region) that are of interest, each representing a particular stage of a cognitive process (Handy, 2004). These components are usually named after their polarity (i.e., positive or negative voltage) and their latency (i.e., time post-stimulus onset; Matsumoto, 2009). For example, the N100 (or N1) component is a negative peak in voltage occurring approximately 100 ms post-stimulus onset, whereas the P300 (or P3) component is a positive peak in voltage occurring approximately 300 ms post-stimulus onset. A major strength of ERPs is their high temporal resolution compared to fMRI (Nunez & Srinivasan, 2005). Examining the minute changes in the

amplitudes of ERP components between stimuli of differing levels of task relevance could afford the opportunity to investigate the temporal course of task relevance processing. Furthermore, explicating a novel sequencing rule, then examining the difference in amplitudes elicited by single task-relevant component when it is presented prematurely versus when it is appropriately cued for would be an ideal way to examine how sequencing of task components occurs in RITL. Thus, after explaining the visual selective attention and working memory processes inherent in RITL execution of a visual task, it is necessary to choose the appropriate ERP components that would best reflect these processes.

As argued above, RITL for visual tasks recruits the FPN and the secondary visual areas that represent each task-relevant feature, with areas of the PFC (particularly the LPFC) driving the processes occurring in the other cortical regions. Quite a few ERP components are dependent on the LPFC in their activation, though it will be argued below that anterior P2a, central P3b, and posterior N1 are ideal ERP components of interest. Yago, Duarte, Wong, Barceló, and Knight (2004) compared LPFC lesion patients and neurologically intact controls who were both being recorded with EEGs while undergoing an attentional switching task involving parallel visual stimuli. They found early deficits in target processing exhibited by the lesioned group in the amplitudes of P1, selective negativity (SN), and anterior N2, as well as extended latencies in SN and diminished amplitudes in the anterior P2a and the parietal N2b for attended neutral stimuli (Yago et al., 2004). Although they expected changes in the P3b component, none were found, and they reasoned that perhaps there were other intact neurological sources generating it (Yago et al., 2004). In visual tasks, posterior P1 is generally considered to be related to spatial attention, whereas the SN component (which has its onset approximately 150 ms post-stimulus) is generally related to the maintenance of feature-based attention (see Hillyard & Anllo-Vento, 1998 for a review;

Michie et al., 1999; Yago et al., 2004). The anterior P2a/N2 complex tends to work to compare task-relevant features to stimulus ones (respectively), acting as an attentional template comparison process and exhibiting larger amplitudes for task-relevant stimuli requiring a motor response (Potts, 2004; Potts, Patel, & Azzam, 2003; Potts & Tucker, 2001). Where a match is found, the anterior P2a is evoked, whereas mismatches to the attentional template tend to evoke an anterior N2 instead within the same time window (Folstein & Van Petten, 2008; Potts, 2004). Anterior N2 and P3b are goal-related, with N2 being involved in response expectancy and selection (Azizian, Freitas, Parvaz, & Squires, 2006; Folstein & Van Petten, 2008; Gajewski, Stoerig, & Falkenstein, 2007) and error monitoring (Mathalon, Whitfield, & Ford, 2003) and P3b being involved in the parietal area processes of attentional orienting and (in particular) target identification (Polich, 2007). Gajewski et al. (2007) in a response-cueing task where cue validity was manipulated found that items eliciting response conflict and revision tended to evoke larger amplitudes in anterior N2. Zanto and Gazzaley (2009) obtained ERPs from participants undergoing a colour-or-motion recall task and found that the instructions that required remembering colour evoked a larger posterior N1 amplitude for the entire group than for remembering motion, which was attributed to early top-down influences on working memory due to the equivalence of stimuli in terms of features (but not in terms of task relevance). Posterior N1 has been posited to be related to early, goal-directed discrimination of stimulus features and object categorisation (Chen, Li, Qiu, & Luo, 2006; Potts et al., 2003; Vogel & Luck, 2000). Interestingly, Zanto and Gazzaley (2009) found that low-performing participants tended to maintain this large amplitude for instructions that required ignoring colour (and remembering motion), whereas high-performing participants tended to exhibit diminished posterior N1 amplitude and increased posterior P1 amplitude (Zanto & Gazzaley, 2009). This performance-related difference in ERP amplitude was attributed to the need for simultaneous enhancement of task-relevant features (i.e., motion) and the suppression of

task-irrelevant features (i.e., colour) for higher working memory performance, a phenomenon which was later termed 'neural contrast' (Zanto et al., 2011). Zanto et al. (2011) applied rTMS over to LPFC areas and took fMRI and EEG recordings of participants during the same task and found a decline in P1 amplitude that corresponded to a decline in V4 activity and working memory performance for colours. They interpreted this as evidence for early top-down modulation of P1 directly affecting feature-based visual selective attention (Zanto et al., 2011). This feature-based attentional change in P1 tends to contradict its aforementioned role in spatial attention, which is said to drive feature-based attention (Hillyard & Anllo-Vento, 1998). This effect can be partially explained by the findings of Zhang and Luck (2009) which found similar effects of a colour-or-brightness recall task on P1, but only when visual stimuli were presented in parallel; stimuli presented sequentially elicited no such differences in P1 amplitude, suggesting an interaction between stimulus competition and feature-based processing in the magnitude of P1 amplitude during visual task execution. Together, these findings illustrate the operation of early PFC-driven feature discrimination processes which occur in the occipital areas in N1 (and under certain circumstances, P1), later attentional template comparison and response selection processes occurring between 200-300 ms after stimulus onset in P2a or N2, and target identification processes which occur in parietal P3b approximately 300 ms after stimulus onset during the execution of visual tasks recruiting top-down processes.

The current study sought to investigate the temporal course of RITL execution for visual tasks, paying special attention to task-relevant feature processing and task component sequencing. To investigate this, a computerised RITL sequential dependency task was administered to participants while their electrophysiological activity was being recorded with an EEG. This task involved administering a series of trial blocks (i.e., a series of test stimuli presented in a group) each preceded by a unique and novel task rule

in the form of "If A then B", where participants are expected to respond to "B" stimuli, but only if they appear immediately following an "A" stimulus. "A" and "B" represented task features (i.e., colours or shapes). The administration of each task rule effectively divided the stimuli of the subsequent trial block into four categories in terms of task relevance: targets, triggers, target distractors, and neutrals. For example, for the task rule "If triangle then square", participants would be required to respond specifically to any square stimulus (i.e., a target) that occurred immediately following a triangle stimulus (i.e., a trigger). Furthermore, participants would also be required to withhold any responses to any square stimulus that did not appear immediately following a triangle stimulus (i.e., a target distractor) or any other item, such as a circle (i.e., a neutral). Thus, targets fulfilled all criteria of the task rule, whereas triggers and target distractors fulfilled only a single task component each, and neutrals fulfilled no task criteria. The inclusion of items possessing zero, one, or all task rule criteria allowed the investigation of Cole et al.'s (2012) compositional theory and Desimone and Duncan's (1995) biased competition model in RITL execution whereas the use of task rules requiring the sequencing of task-relevant features allowed the examination of task component sequencing. Out of the aforementioned item types, however, targets are the only ones to receive facilitated processing by virtue of being cued for by a trigger, a phenomenon which, in itself, tends to produce larger ERP amplitudes (Carrasco, 2011). Hence, triggers which preceded a neutral (instead of a target) were added to all trial blocks. By comparing targets with these neutrals (known as facilitated neutrals), target-specific task relevance processes could be examined in targets after accounting for cue facilitation. As mentioned previously, anterior P2a/N2, central P3b, and posterior N1 are the ERP components of interest to this study. The inclusion of posterior N1 meant that the presence of early top-down modulation could be tested and the inclusion of the later components meant that target identification and attentional template matching processes could also be observed for each item type.

Using these design features, it is hypothesised that early top-down modulation will be observed between stimuli that differ in task-relevance which reflect enhanced processing of task-relevant features—that is, more task-relevant stimuli will elicit greater mean amplitudes than less task-relevant stimuli. To this end, three sets of planned comparisons of interest to this study: (1) neutrals versus targets, target distractors, and triggers, (2) target distractors versus targets and triggers, and (3) targets versus facilitated neutrals. These comparisons allowed the detection and examination of task relevance processes, task component sequencing, and the controlling of cue facilitation, respectively. These task-relevant modulations are expected to occur in posterior N1 (for early top-down modulation of task-relevant features) and central P3b (for late target identification). Due to the aforementioned involvement of anterior P2a/N2 in task relevance processing and attentional template conflict, it is hypothesised that targets and target distractors will elicit a P2a (with targets evoking larger amplitudes than target distractors), whereas all other item types will elicit an N2 (with less task-relevant items eliciting larger N2 amplitudes).

Method

Participants

Twenty-three participants (M_{Age} = 27.65 years, SD_{Age} = 9.25 years, 11 women) were recruited for this study. One participant who did not complete the experiment had their data removed from analysis. Participants were invited to participate if they were over 18 years old, had normal or corrected-to-normal vision, were free from any known motor or neurological disorders, were not taking psychoactive drugs or medications, and were not wearing a hearing aid. Abstinence from caffeine and nicotine three hours prior was also requested of participants due to their effects on ERP amplitudes (Pritchard, Sokhadze, & Houlihan, 2004; Ruijter, Lorist, Snel, & De Ruiter, 2000). All participants gave their informed and written consent prior to their inclusion in the study and were either given course credit or an entry into a raffle for a $50 gift card.

Design

A within-participants design was used to assess the effect of the degree of task relevance on electrophysiological response. The main independent variable was item type, with the levels consisting of targets, triggers, target distractors, and neutrals. Table 1 defines all of these item types. The dependent variable was the mean amplitude of the ERP component of concern after collecting EEG data from participants. Three ERP components were examined: the anterior P2a/N2 complex, the central P3b, and the posterior N1. The possibility of hemispheric main effects or interactions was examined alongside item type (and ruled out) at each scalp region before examining each scalp region alone.

Table 1
Definitions of the Six Categories of Response Phase Items in the RITL Sequential Dependency Task

Item type	Definition
Trigger	An item with the instructed trigger feature which validly cues the target
Target	An item with the instructed target feature which appears subsequent to a trigger
Trigger distractor	An item with the instructed trigger feature which does not validly cue the target
Target distractor	An item with the instructed target feature which does not appear immediately following a trigger
Neutral	An item without an instructed trigger or target feature that does not appear subsequent to a trigger distractor
Facilitated neutral	An item without an instructed trigger or target feature appearing subsequent to a trigger distractor

Materials

Computer task apparatus and stimuli. A Windows 7 computer was used for stimulus presentation using E-Prime 2 Professional version 2.0.8.90 (see Appendix A1 for code). This computer used a 24 inch BenQ monitor with a 1920 x 1080 resolution at 100 Hz. All response stimuli for the RITL sequential dependency task were constructed as combinations of nine colours (red, orange, yellow, green, blue, purple, pink, grey, and black) and nine shapes (circle, hexagon, oval, rectangle, square, cross, star, trapezoid,

and triangle), with each stimulus' dimensions being approximately 8.55 x 8.55 cm (see Appendix A2). Task rules were in the form of "If A then B", where 'A' was the trigger feature, 'B' was the target feature, and 'A' and 'B' were either item colours or shapes, but not both (i.e., if 'A' was a colour then 'B' could not be a shape, and vice versa; see Figure 1 for an example task rule). The entire pool of task rules was created from the 9x8 possible combinations from either shapes or colours (i.e., 72 shape rules and 72 colour rules; see Appendix B). In this way, 144 task rules were created, each designating trigger or target status to certain response phase items within a trial block (see Figure 1 for an example). Crucially, to be designated target status, a response phase item needed to satisfy both the feature criterion (i.e., possession of the target 'B' feature) and the sequential dependency criterion (i.e., appearing immediately following an item with the trigger 'A' feature). Other item types that were also included were target distractors, facilitated neutrals, and neutrals.

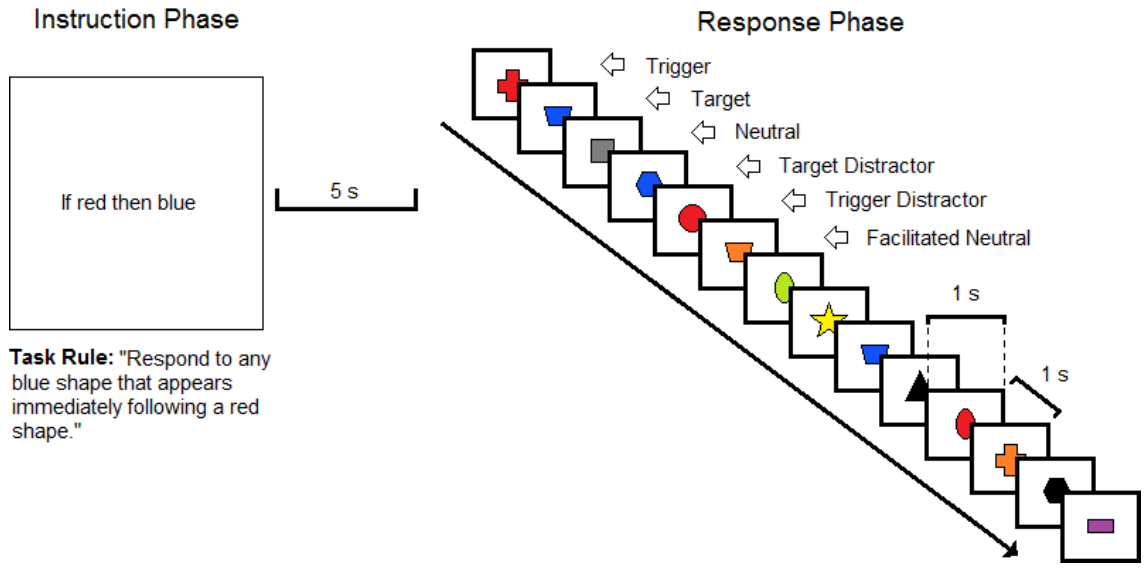

Figure 1 An example of the experimental paradigm for a one-target block using a colour rule (i.e., "If red then blue") and listing examples of all item types.

EEG Apparatus. EEG data acquisition was conducted using a Macintosh OSX version 10.6.8 with a Net Station interface package version 2.0.0.88. EEG data were obtained using a Sensor Net with 128 electrodes using the vertex as the online reference and recorded with Net Station 4.5.4 (digitised at 1 kHz; impedances less than 100 kΩ; Electric Geodesic, Eugene, USA) then down-sampled to 250 Hz.

Procedure

Testing was conducted on the Murdoch University campus in a quiet, air-conditioned, well-lit room. Participants were fitted with a Sensor Net soaked in a potassium chloride and shampoo solution, connected to the EEG, before being given general instructions on the computer task before beginning the trial blocks. These instructions specified the general design of each trial block (Figure 1). That is, a sequence of items would be presented after a task rule, and participants would be required to respond to targets (which fulfilled both task rule requirements) by pressing the space bar as quickly as possible, as well as withhold responses for all other items (which did not match both rule requirements; see Appendix C). They also were asked to keep as quiet and as still as possible during each trial block. The experimental paradigm (Figure 1) involved a computerised RITL sequential dependency task divided into two phases per trial block: the instruction phase and the response phase. During the instruction phase, one of the 144 task rules was presented centrally on-screen for 1 s. This was followed by a 5 s delay, after which the response phase would begin. During the response phase, 14 items were sequentially and centrally presented on the computer screen. All response phase stimuli were presented for 1 s each (or until participants responded, whichever occurred first) with inter-item intervals at 1 s each.

There were 144 blocks, each beginning with its own task rule and presenting 14 response phase items. Each block contained two distractor targets and two distractor triggers. For each block, genuine trigger-target pairs had equal probabilities of appearing once, twice, or not at all. This was to avoid intra-block order effects for attentional maintenance: zero-target blocks ensured no increase in attentional maintenance toward the end of a block due to the expectation of a trigger-target pair, whereas two-target blocks ensured no decrease in attentional maintenance after responding to the first target of a block. All other items in a block were composed of

neutrals, with trigger-target pairs from two-target blocks being separated by at least one neutral. Trigger-target pairs also had equal probabilities of appearing within four portions of a given block: the first two items, the first three to seven items, the first eight to 12 items, or the last two items. This also encouraged participants to maintain their attention for every item from first to last, to prevent intra-block order effects. All blocks were ordered randomly by rule type (i.e., colour or shape rule), number of targets, and position of appearance within the block. All neutral items were randomised for colour and shape, and all other items were randomised for their task-irrelevant dimension. Each task rule was only used once per participant to avoid practice effects. The duration of each session was approximately 80 minutes, with optional breaks available between trial blocks and a mandatory five minute break administered at the half-way point of each session.

Results

Data Pre-processing and Analysis Overview

Data were pre-processed with MATLAB using the EEGLAB toolbox (Delorme & Makeig, 2004). This involved a 1-30 Hz forward-reverse (zero-phase) FIR band-pass filter, epoching trials from -100 to 600 ms around stimulus onset, correcting baselines from 100 ms before stimulus onset, deleting artifacts and bad channels, and re-referencing voltages to the average reference. Artifact rejection was conducted automatically on epochs with amplitude values greater than or equal to 85 μV. Bad channels were automatically deleted if they gave voltage values that were more than five standard deviations from other channels.

ERPs were extracted from MATLAB (see Appendices D1-D3) by clustering electrodes for all participants into 2x3 topographical regions according to hemisphere (i.e., left or right) and region (i.e., anterior, central, and posterior; Figure 2). This was so that hemispheric interactions with item type could be tested for (and ruled out as a confounding factor) while investigating the three ERP components of interest: the

anterior P2a/N2 complex, central P3b, and posterior N1**.** The time windows of extraction of per participant mean amplitude scores for these components were, respectively, 225-300 ms, 300-400 ms, and 150-200 ms post-stimulus onset. After extraction, all scores were winsorised at 2.5 standard deviations from their condition mean prior to analysis to reduce the effect of outliers without eliminating extreme values altogether (Field, 2013; see Appendices E1-E2). Except where noted, all data sets observed univariate normality by achieving non-significant Shapiro-Wilk's test statistics ($\alpha = .01$; see Appendices F1-F4) and all statistical tests were two-tailed.

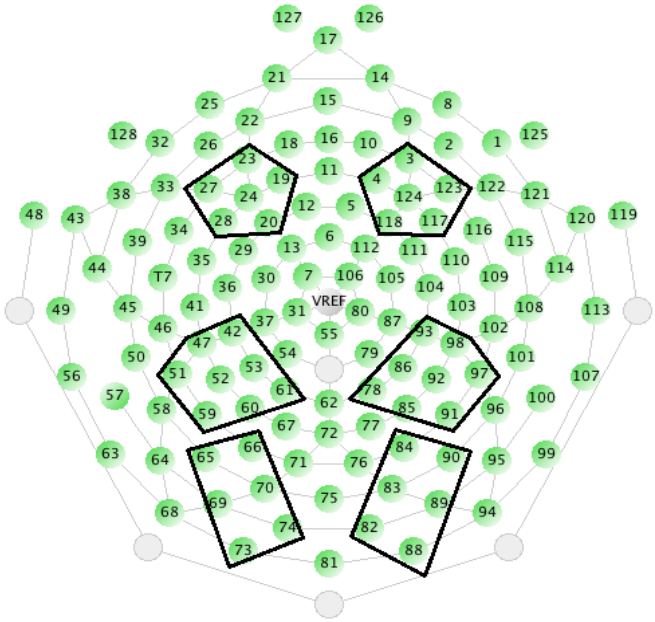

Figure 2 A map of electrodes used to gather EEG data, showing the six electrode clusters included in ERP analysis: anterior left (19, 20, 23, 24, 27, 28), anterior right (3, 4, 117, 118, 123, 124), central left (42, 47, 51, 52, 53, 59, 60, 61), central right (78, 85, 86, 91, 92, 93, 97, 98), posterior left (65, 66, 69, 70, 73, 74), and posterior right (82, 83, 84, 88, 89, 90).

Anterior P2a/N2

Winsorisation of per participant mean amplitudes altered 2.27% of this dataset. Table 2 displays the descriptive statistics for this time window, showing that overall mean amplitudes were all negative, except in targets.

Table 2
Means (Standard Deviation in Brackets) of Per Participant Mean Amplitudes (in Microvolts) Extracted from Anterior Regions 225-300 ms Post-Stimulus Onset

		Hemisphere	
Item Type	Overall Amplitude	Left	Right
Target	0.259 (0.610)	0.204 (0.674)	0.326 (0.696)
Trigger	-0.044 (0.476)	-0.198 (0.440)	-0.123 (0.520)
Target Distractor	-0.187 (0.430)	-0.209 (0.502)	-0.164 (0.386)
Facilitated Neutral	-1.09 (0.769)	-1.10 (0.887)	-1.08 (0.709)
Neutral	-0.563 (0.560)	-0.641 (0.696)	-0.485 (0.479)

Inspections of the anterior ERP graph (Figure 3) supported these observations, confirming the presence of an anterior N2 for every item type except targets (which exhibited the expected P2a component) 225-300 post-stimulus onset.

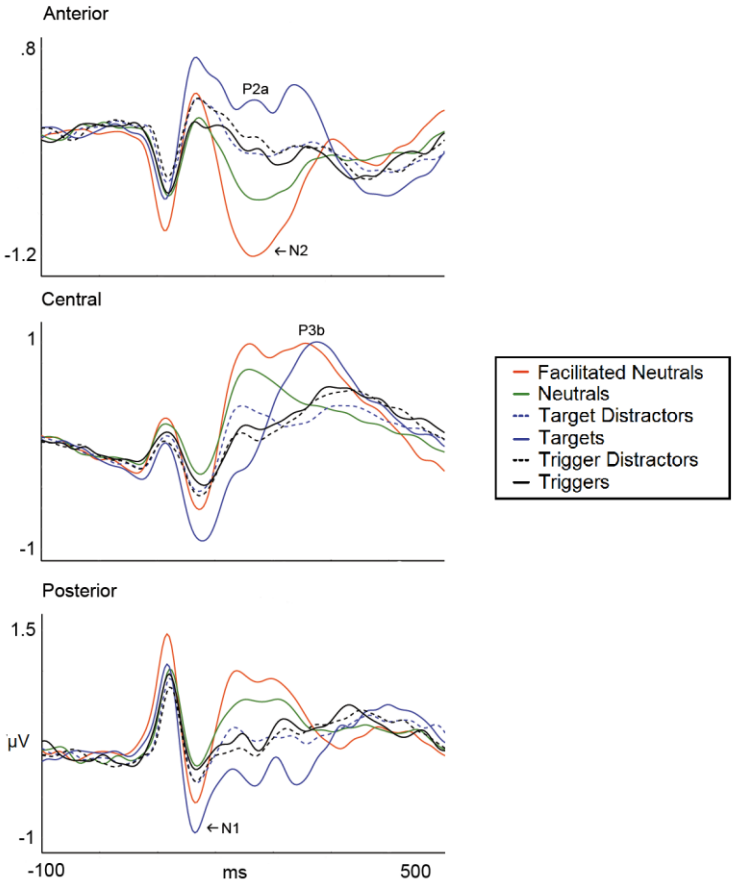

Figure 3: ERP graphs taken from all participants (n = 22) for each item type at anterior, central, and posterior regions (with left and right hemispheres collapsed). ERP components of interest are labelled. Stimulus onset occurred at 0 ms.

Shapiro-Wilk's test detected non-normality in facilitated neutrals (*Skew* = -1.23, *Kurtosis* = 2.76; see Appendix F1). A two-tailed 2x5 repeated-measures ANOVA (α =

.05) using Greenhouse-Geisser epsilon corrections was conducted to identify any main effects of interactions between the independent variables of hemisphere (i.e., left and right) and item type (i.e., targets, triggers, target distractors, neutrals, and facilitated neutrals). No hemispheric main effect ($F(1, 21) = 1.55$, $p = .23$, $\eta_p^2 = .07$) or interaction ($F(2.90, 60.80) = 0.49$, $p = .69$, $\eta_p^2 = .02$) was found. Only a main effect for item type was found ($F(2.18, 45.76) = 35.93$, $p < .001$, $\eta_p^2 = .63$).

To conduct pair-wise comparisons of item types in isolation, scores for all item types were averaged across the left and right hemisphere. Table 2 shows the descriptive statistics for these averaged scores. Six two-tailed paired t-tests using Holm-Bonferroni corrections to alpha levels (Holm, 1979) were conducted on all planned comparisons, with only triggers versus target distractors failing to reach significance ($t(21) = 0.33$, $p = .74$, $\alpha = .05$, $d = 0.07$; targets versus facilitated neutrals: $t(21) = 7.72$, $p < .001$, $\alpha = .017$, $d = 1.65$; targets versus target distractors: $t(21) = 3.43$, $p = .002$, $\alpha = .025$, $d = .73$; targets versus neutrals: $t(21) = 5.37$, $p < .001$, $\alpha = .013$, $d = 1.14$; triggers versus neutrals: $t(21) = 4.45$, $p < .001$, $\alpha = .01$, $d = .95$; target distractors versus neutrals: 5.74, $p < .001$, $\alpha = .008$, $d = 1.22$).

Central P3b

Winsorisation of per participant mean amplitudes altered 1.36% of these scores. Table 3 displays the descriptive statistics of this data set, showing positive scores.

Table 3
Means (Standard Deviation in Brackets) of Per Participant Mean Amplitudes (in Microvolts) Extracted from Central Regions 300-400 ms Post-Stimulus Onset

Item Type	Overall Amplitude	Hemisphere	
		Left	Right
Target	0.811 (0.398)	0.777 (0.470)	0.844 (0.430)
Trigger	0.374 (0.340)	0.349 (0.362)	0.400 (0.381)
Target Distractor	0.253 (0.265)	0.213 (0.276)	0.293 (0.323)
Facilitated Neutral	0.923 (0.527)	0.984 (0.546)	0.862 (0.558)
Neutral	0.450 (0.212)	0.481 (0.236)	0.412 (0.256)

Once again, the two-tailed 2x5 repeated-measures ANOVA (α = .05) using Greenhouse-Geisser epsilon corrections only found a main effect for item type (F(2.21, 46.31) = 20.32, p < .001, η_p^2 = .49), with no main effect for hemisphere (F(1, 21) = 0.003, p = .96, η_p^2 < .001) or interaction (F(2.38, 49.98) = 2.47, p = .09, η_p^2 = .11) achieving significance. After averaging scores across the two hemispheres (see Table 3 for descriptive statistics), six two-tailed paired t-tests using Holm-Bonferroni corrections to alpha levels (Holm, 1979) reached significance in three planned comparisons: targets versus target distractors (t(21) = 5.26, p < .001, α = .01, d = 1.12), targets versus neutrals (t(21) = 4.08, p = .001, α = .013, d = 0.87), and target distractors versus neutrals (t(21) = -4.62, p < .001, α = .008, d = -0.98). All other pairs failed to reach significance (targets versus facilitated neutrals: t(21) = -0.81, p = .43, α = .05, d = -0.17; triggers versus target distractors: t(21) = 2.47, p = .022, α = .017, d = 0.53; triggers versus neutrals: t(21) = -1.37, p = .19, α = .025, d = -0.29).

Posterior N1

Winsorisation of per participant mean amplitudes altered 1.36% of these scores. Table 4 displays the descriptive statistics of this data set. All item types had negative amplitudes except for neutrals, which expressed weakly positive mean amplitudes overall.

Table 4
Means (Standard Deviation in Brackets) of Per Participant Mean Amplitudes (in μV) Extracted from Posterior Regions 150-200 ms Post-Stimulus Onset

Item Type	Overall Amplitude	Hemisphere	
		Left	Right
Target	-0.674 (0.853)	-0.754 (0.900)	-0.594 (0.852)
Trigger	-0.166 (0.799)	-0.250 (0.834)	-0.083 (0.794)
Target Distractor	-0.177 (0.708)	-0.266 (0.724)	-0.088 (0.754)
Facilitated Neutral	-0.257 (0.914)	-0.312 (0.967)	-0.201 (0.904)
Neutral	0.028 (0.792)	-0.051 (0.817)	0.106 (0.806)

The two-tailed 2x5 repeated-measures ANOVA (α = .05) using Greenhouse-

Geisser epsilon corrections found a main effect for item type ($F(2.93, 61.44) = 13.67$, $p < .001$, $\eta_p^2 = .39$) and hemisphere ($F(1, 21) = 4.50$, $p = .046$, $\eta_p^2 = .18$), with the left hemisphere (M = -0.33 µV, SD = 0.17 µV) attaining greater mean amplitudes than the right (M = -0.17 µV, SD = 0.16 µV). No interaction was found ($F(2.69, 56.48) = 0.43$, $p = .71$, $\eta_p^2 = .02$) so planned comparisons were conducted on scores averaged across the two hemispheres, and descriptive statistics for these scores are displayed in Table 4. Shapiro-Wilk's test detected non-normality in difference scores of targets versus target distractors (see Appendix F3). Six two-tailed paired t-tests using Holm-Bonferroni corrections to alpha levels (Holm, 1979) reached significance for all planned comparisons except triggers versus target distractors ($t(21) = 0.16$, $p = .87$, $\alpha = .05$, $d = 0.35$; targets versus facilitated neutrals: $t(21) = -3.45$, $p = .002$, $\alpha = .013$, $d = -0.74$; targets versus target distractors: $t(21) = -4.44$, $p < .001$, $\alpha = .01$, $d = -0.94$; targets versus neutrals: $t(21) = -6.24$, $p < .001$, $\alpha = .008$, $d = -1.33$; triggers versus neutrals: $t(21) = -2.55$, $p = .019$, $\alpha = .025$, $d = -0.54$; target distractors versus neutrals: $t(21) = -2.77$, $p = .012$, $\alpha = .017$, $d = -0.59$).

Correlational Analyses

Table 5 displays the three sets of exploratory correlational analyses which were conducted to examine any relationships between the per participant mean amplitudes of all examined component pairs for each of the five item types. As mentioned above, Shapiro-Wilk's test detected non-normality in facilitated neutrals for the P2a/N2 complex (see Appendix F4).

Table 5
Pearson's r Correlations Between Per Participant Mean Amplitudes of Different ERP Components for each Item Type

	Targets	Triggers	Target Distractors	Neutrals	Facilitated Neutrals
P2a/N2 – P3b	.13	-.51*	-.26	-.60**	-.64**
P2a/N2 – N1	-.40	-.57**	-.46*	-.60**	-.59**
P3b – N1	-.06	.20	.34	.19	.28

Across item types, negative relationships were generally found between the

anterior N2 versus the posterior N1, with a relationship between the P2a and N1 for targets approaching significance (p = .07) but failing to reach it. Negative relationships were also found between anterior N2 versus central P3b for triggers, neutrals, and facilitated neutrals, but not for targets or target distractors. No relationships for N1 versus P3b were found for any item type. All significant relationships were considered to be strong, with the exception of the moderate relationship found between N2 versus N1 mean amplitudes for target distractors (Cohen, 1988).

Discussion

This study aimed to investigate the effect of task relevance on ERP amplitudes, with particular attention being paid to task feature identification and the sequencing of task components. It was hypothesised that for all ERP components of interest, targets, triggers, and target distractors would each elicit greater amplitudes than neutrals (i.e., the neutral item comparisons), target distractors would elicit lower amplitudes than targets and triggers (i.e., the target distractor item comparisons), and that targets would elicit higher amplitudes than facilitated neutrals (i.e., the facilitation comparison).

Task Feature Identification

Except for the non-significant pair-wise comparison between triggers versus neutrals at central P3b, all neutral item comparisons found significantly different mean amplitudes for targets, triggers, and target distractors compared to neutrals at all ERP components of interest. At N1, neutrals consistently elicited lower mean amplitudes than the three other item types, whereas at the P2a/N2 complex, neutrals exhibited greater N2 amplitudes than triggers and target distractors, and a different component altogether compared to targets, which evoked a P2a (the behaviour of P3b is discussed below in its own section).

One interpretation of these results could be that these modulations reflect early stimulus-driven perceptual processes. Although the assignment of an item to a specific item type was done so on the basis of its stimulus features, this stimulus feature (and its

modality) changed randomly with each trial block. Thus, a systematic effect for bottom-up processing can be ruled out because the only commonality between all items within a specific item type is their relevance to the active task rule. Hence, it is far more likely that these modulations reflect task-driven, rather than stimulus-driven processes. The fact that these processes were found even in posterior N1 is evidence for early top-down processing of task relevance (Gazzaley, 2011). This phenomenon has been observed in previous studies in the area (Gazzaley, 2011; Gazzaley et al., 2005; Zanto & Gazzaley, 2009; Zanto et al., 2011) and supports the biased competition model of visual selective attention insofar as these findings exemplify task-driven enhancement of the processing power of task-relevant stimuli (i.e., targets, triggers, and target distractors) relative to task-irrelevant stimuli (i.e., neutrals; Desimone & Duncan, 1995). Furthermore, the moderate-to-strong relationship found for all non-target items between N1 and N2 mean amplitudes provides some supporting evidence for the involvement of the frontoparietal network and secondary visual areas in task relevance processing for visual task execution, which has been observed in previous visual attention studies (Kastner & Ungelieder, 2000; Murray & Wojciulik, 2004; Pasternak & Greenlee, 2005; Reynolds & Desimone, 2003; Stokes, 2011).

However, the lower amplitudes exhibited by triggers and target distractors compared to neutrals tends to refute the notion that these items experience enhanced processing due to their task relevance compared to task-irrelevant items, as described by the biased competition model (Desimone & Duncan, 1995). Potts (2004) argues that the P2a/N2 complex tends to elicit P2as for task-relevant items and N2s for task-irrelevant items in Go/No-go response paradigms (such as ours), so perhaps the behaviour of these item types reflects the partial fulfilment of the task rule as well as the need for response suppression in both item types. Partial fulfilment would explain why mean amplitudes for both item types are more positive than the neutral N2s and more negative than target P2as. Response suppression would explain the negative mean amplitudes for both item

types. Also, the interaction of both phenomena would explain why the ERP graphs for both item types do not exhibit perfectly defined anterior N2 waves (nor the expected P2a waveform for target distractors), but perhaps each show an overlap with a small, positive component. If this is the case, this would both support and expand Cole et al.'s (2012) compositional theory of RITL. This interpretation would be testable via source localisation analyses so that the presence of simultaneous positive and negative components could be established, but for now remains a speculation. In any case, it is clear that Desimone and Duncan's (1995) biased competition model is insufficient for a complete understanding of the visual selective attentional processes involved in RITL execution of visual tasks.

Target distractor item comparisons consistently found greater amplitudes for targets versus target distractors in all ERP components of interest, and consistently failed to find any significant differences between target distractors versus triggers. As mentioned previously, target distractors and triggers both exhibited greater amplitudes than neutrals in N1, and showed evidence for complex activation in the P2a/N2 complex, which both indicate the involvement of task relevance processes. The failure to find significant differences between target distractors and triggers is perhaps due to the fact that both item types involve the isolated identification of a task-relevant feature in the absence of cue facilitation; triggers possess the trigger feature, target distractors possess the target feature, and neither complete the active task rule. If so, this would again provide support for Cole et al.'s (2012) compositional theory by demonstrating that stimuli possessing a single task-relevant feature elicit equivalent amplitude sizes (and perhaps also cognitive processes) during task relevance processing in N1 and N2, reflecting the additive nature of rule compositionality. Extending this logic to overall task set formation, stimuli possessing no task-relevant features (i.e., neutrals) elicit smaller N1 amplitudes and more negative N2 amplitudes than stimuli possessing a single feature (i.e., triggers and target distractors; as mentioned in the previous section),

and crucially, stimuli possessing all task-relevant features (i.e., targets) elicit the greatest N1 amplitudes and a more complete P2a component than stimuli possessing zero or one task-relevant feature. This explanation is consistent with all observed pair-wise comparisons in N1 and the P2a/N2 complex and provides further support for a compositional understanding of RITL execution (Cole et al., 2012). Furthermore, the fact that these phenomena are observed in N1 is evidence that these compositional mechanisms operate under early top-down processes (Gazzaley, 2011).

Task Component Sequencing

It is possible that of the neutral item comparisons, targets elicited larger amplitudes than neutrals and target distractors due to cue facilitation, rather than due to task relevance processes. This is a possibility in the case of the central P3b component where the facilitation comparison failed to reach significance, but this is not a likely explanation for the N1 component where significantly larger mean amplitudes for targets than for facilitated neutrals were found. Nor is this a likely explanation in the case of the P2a/N2 complex, not only because the facilitation comparison here was significant, but also because targets and facilitated neutrals elicited components that were opposite in polarity (i.e., P2a for targets and N2 for facilitated neutrals). These findings suggest that target-specific processes are uniquely present in N1 and P2a, even after accounting for cue facilitation. It is tempting to suggest that the same target-specific process is at work in both of these components, however drawing this conclusion is impeded by the fact that targets failed to exhibit a relationship between N1 and P2a, which suggests that any target-specific processes found reflect separate, unrelated processes in these two areas. This relationship did approach significance, so it may be possible that this study simply lacked the statistical power to detect this relationship using 22 data points. Although, a better interpretation would be that the target-specific processes in N1 reflect early, basic target feature identification, whereas the target-specific processes in P2a reflect higher-order task relevance processes in the

executive regions. For this interpretation to be complete, it would require an explanation as to why targets elicited a P2a component whereas all other item types elicited an N2 within the same time window and scalp region. The two main differences between targets and all other item types is (1) their need for a motor response, and (2) their simultaneous fulfilment of both the feature criterion (i.e., possession of the target feature) and the sequential dependency criterion (i.e., their appearance subsequent to a trigger). However, these two differences are not easily separable, because the latter is a requirement for the former. The fulfilment of both task-relevant criteria likely created a P2a wave for targets which became more positive with cue facilitation. As well as this, neutral status (i.e., the total non-fulfilment of any task-relevant criteria) likely created the N2 wave seen for neutrals, which became more negative with cue facilitation for facilitated neutrals. This observation is supported by previous research claiming that the P2a/N2 complex is central to task relevance processing, with P2as being elicited for targets and N2s being elicited for neutrals (Potts, 2004; Potts et al., 2003; Potts, Martin, Burton, & Montague, 2006) as well as studies linking the N2 wave with response selection and suppression (Falkenstein, Hoorman, & Hohnsbein, 1999; Folstein & Van Petten, 2008; Mathalon et al., 2003) from similar cortical regions. Therefore, the specific evocation of P2a for targets probably reflects higher-order matching processes of all task-relevant features. Early top-down processes may simply have a stronger influence on the rejection of a non-target item, than on the higher-level processes for matching a target item, which would make a relationship between N1 and P2a for targets more difficult to detect at lower statistical powers. In any case, these higher-level processes for matching a target item likely underlie the main (or at least the earliest) mechanism by which humans can sequence instructions in the correct order, which means that task component sequencing probably involves a process whereby stimuli are matched to an attentional template held in working memory before being identified as a target (Potts, 2004; Potts et al., 2003; Potts & Tucker, 2001). Attentional template

matching explanations of the P2a/N2 complex are not new, but these findings suggest that matching underlies task component sequencing, and that the role of early top-down modulation is more apparent in eliminating mismatches than in identifying matches. Future research would likely benefit from further investigations of the P2a/N2 complex to elaborate its role in task component sequencing.

Central P3b

Specific comments on the P3b component are necessary due to its unexpected behaviour. As mentioned above, no significant differences were found between targets versus facilitated neutrals or between triggers versus neutrals despite these differences occurring in the other components. Furthermore, no relationship was found between the N1 versus the P3b components across item types and only three relationships were found between the N2 versus the P3b components (i.e., for triggers, neutrals, and facilitated neutrals), which is in contrast with the consistent relationship between N1 and N2 amplitudes for non-target items. Previous studies have generally found P3b to be related to the explicit working memory processes involved in target identification (Barceló, Muñoz-Céspedes, Pozo, & Rubia, 2000; Polich, 2007) or at least response selection processes (Dien, Spencer, Donchin, 2004; Verleger, 2008). A non-significant facilitation comparison may indicate the involvement of identical processes for targets and facilitated neutrals, which tends to contradict previous studies of P3b because (1) target identification processes should be present in targets and not in facilitated neutrals, and (2) the response selection processes should differ between targets (which require a motor response) and facilitated neutrals (which require withholding a motor response). Following this logic, either target-specific processes are absent in P3b or the response selection processes are identical for both items, perhaps implying a high rate of false alarm responses. If the former explanation is correct, it would explain the absence of a relationship between P3b and N1, because N1 would be involved in task-relevant feature processing (as mentioned above) whereas P3b would not. However, if this is the

case, it would be difficult to explain the strong relationships between P3b and N2 for item types without a target feature (i.e., triggers, neutrals, and facilitated neutrals) in a way that also explains the similarity between the P3b amplitudes for targets versus facilitated neutrals. If instead the similarity of targets and facilitated neutrals in mean amplitude reflected a high rate of false alarm responses for facilitated neutrals, this would explain their elicitation of the classic P3b component, whereas the other item types seemed to elicit a waveform that more resembles the late positive complex (LPC). The LPC is generally involved in response or perceptual conflict (Chen, Bailey, Tiernan, & West, 2011; Larson, Clawson, Layson, & South, 2009; Li, Wang, Duan, & Zhu, 2013), which could explain the strong relationships between P3b and N2 for items without a target feature (but not completely, because the LPC was also elicited by target distractors). However, this explanation cannot be verified without the analysis of behavioural data, which has been a design feature included in several previous ERP studies in this area (Gazzaley, 2011; Gazzaley et al., 2005; Zanto & Gazzaley, 2009; Zanto et al., 2011). Also, it would be difficult to explain why a high rate of false responses is occurring for facilitated neutrals when the earlier ERP components mentioned had been able to distinguish between targets and facilitated neutrals (particularly in the P2a/N2 complex).

A more parsimonious and complete explanation would be that this time window only reflects the allocation of attentional resources to explicit working memory operations in the anterior regions, as found in previous studies (Barceló, Muñoz-Céspedes, Pozo, & Rubia, 2000; Dien et al., 2004; Polich, 2007), but is not related to target identification specifically. This would mean that the non-significant facilitation comparison simply reflects the presence of cue facilitation in targets and facilitated neutrals in this time window. The manifestation of the LPC for other item types would then reflect the aforementioned response or perceptual conflict processes in the absence of cue-facilitated processing. However, this still does not explain the significantly lower

mean amplitudes of target distractors compared to neutrals in this time window. This is difficult to explain, because an explanation involving task-relevant feature identification would require a significant trigger versus neutral comparison, whereas an explanation involving specific suppression of target distractor amplitudes would require a significant trigger versus target distractor comparison—evidently, we have neither. It is worth mentioning that the triggers versus target distractors comparison was very close to reaching significance, and should it have done so, the second explanation would be an interesting example of attentional suppression, a phenomenon which has been argued for in several studies of early top-down modulation (Gazzaley, 2011; Gazzaley et al., 2005; Zanto & Gazzaley, 2009; Zanto et al., 2011). But even if there were the case, no relationship was found between the P3b of target distractors and any other ERP component examined, so it would be difficult to relate target suppression in the parietal regions to any other cognitive process. In any case, the finding that target distractors elicited lower amplitudes than neutrals tends to refute the biased competition model, which predicts greater ERP amplitudes than usual for items closely resembling targets due to selective processing (Desimone & Duncan, 1995). Future RITL studies should exercise caution in selecting the central P3b as a component for investigating task relevance processes, or at least employ experimental designs that can more thoroughly investigate and explain the behaviour of P3b in task relevance processing.

Conclusion

It seems that the general picture of task relevance processing in RITL is much clearer for the earlier components than for the later ones. Early top-down modulation clearly manifested in posterior P1 and has a moderate-to-strong relationship with the rejection of non-target items in the P2a/N2 complex, but perhaps has less involvement in the higher-order processes specific to target identification within this time window. Evidence for compositional representation of individual task-relevant features was found in these two time windows, particularly when examining target distractors and

triggers and comparing their amplitudes to targets or neutrals. These comparisons were distinguishable even in N1, suggesting the presence of early top-down modulation of task relevance processes for non-target items in the form of compositionality. Although, it seems that some of this empirical support for Cole et al.'s (2012) compositional theory was obtained at the cost of empirical support for Desimone and Duncan's (1995) biased competition model, particularly in the P2a/N2 complex and the P3b component, suggesting that biased processing does not completely explain RITL execution of a visual task. Furthermore, the findings of this study suggest that task component sequencing relies on anterior attentional template matching processes in the P2a/N2, with evidence of compositionality affecting this process being found in triggers and target distractors. The pattern of results for P3b was difficult to interpret, but overall they suggest a general lack of involvement in task relevance processing and perhaps reflect attentional resource allocation processes. However, it is important to note that all of these interpretations would strongly benefit from the examination of behavioural data and source localisation analyses, so it is recommended that future research seeking to investigate these explanations include these analyses in their studies. Despite these limitations, the findings of this study have very interesting implications for understanding RITL execution and task relevance processing. Preliminary ERP evidence has been found for a compositional understanding of RITL execution (Cole et al., 2012). Clear evidence for early top-down modulation of items based on task-relevance has been found, and it is likely that these processes influence later attentional template comparison processes in the anterior regions. All of these findings have helped advance an understanding of the ways that task-relevant feature identification and task component sequencing occur in RITL.

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Instructions to authors submitting to Cognitive, Affective, and Behavioral Neurosciences

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Statistical Guidelines

The Psychonomic Society's Publications Committee and Ethics Committee and the Editors in Chief of the Society's six journals worked together (with input from others) to create these guidelines on statistical issues. These guidelines focus on the analysis and reporting of quantitative data. Many of the issues described below pertain to vulnerabilities in null hypothesis significance testing (NHST), in which the central question is whether or not experimental measures differ from what would be expected due to chance. Below we emphasize some steps that researchers using NHST can take to avoid exacerbating those vulnerabilities. Many of the guidelines are long-standing norms about how to conduct experimental research in psychology. Nevertheless, researchers may benefit from being reminded of some of the ways that poor experimental procedure and analysis can compromise research conclusions. Authors are asked to consider the following issues for each manuscript submitted for publication in

a Psychonomic Society journal. Some of these issues are specific to NHST, but many of them apply to other approaches as well. We welcome feedback regarding these guidelines via email to stats@psychonomic.org with the Subject heading "Statistical Guidelines."

1. It is important to address the issue of statistical power. Statistical power refers to the probability that a test will reject a false null hypothesis. Studies with low statistical power produce inherently ambiguous results because they often fail to replicate. Thus it is highly desirable to have ample statistical power and to report an estimate of a priori power (not post hoc power) for tests of your main hypotheses. Best practice when feasible is to draw on the literature and/or theory to make a plausible estimate of effect size and then to test a sufficient number of participants to attain adequate power to detect an effect of that size. There is no hard-and-fast rule specifying "adequate" power, and Editors may judge that other considerations (e.g., novelty, difficulty) partially offset low power. If a priori power cannot be calculated because there is no estimate of effect size, then perhaps the analysis should focus on estimation of the effect size rather than on a hypothesis test. In any case, the Method section should make clear what criteria were used to determine the sample size. The main points here are to (a) do what you reasonably can to attain adequate power and (b) explain how the number of participants was determined.

2. Multiple NHST tests inflate null-hypothesis rejection rates. Tests of statistical significance (e.g., t-tests, analyses of variance) should not be used repeatedly on different subsets of the same data set (e.g., on varying numbers of participants in a study) without statistical correction, because the Type I error rate increases across multiple tests.

A. One concern is the practice of testing a small sample of participants and then analyzing the data and deciding what to do next depending on whether the predicted effect (a) is statistically significant (stop and publish!), (b) clearly is not being obtained (stop, tweak, and start a new experiment), or (c) looks like it might become significant if more participants are added to the sample (test more participants, then reanalyze; repeat as needed). If this "optional stopping rule" has been followed without appropriate corrections, then report that fact and acknowledge that the Type I error rate is inflated by the multiple tests. Depending on the views of the Editor and reviewers, having used this stopping rule may not preclude publication, but unless appropriate corrections to the Type I error rate are made it will lessen confidence in the reported results. Note that Bayesian data analysis methods are less sensitive to problems related to optional

stopping than NHST methods.

B. It is problematic to analyze data and then drop some participants or some observations, re-run the analyses, and then report only the last set of analyses. If participants or observations were eliminated, then explicitly indicate why, when, and how this was done and either (a) report or synopsize the results of analyses that include all of the observations or (b) explain why such analyses would not be appropriate.

C. Covariate analyses should either be planned in advance or be described as exploratory. It is inappropriate to analyze data without a covariate, then re-analyze those same data with a covariate and report only the latter analysis as confirmation of an idea. It may be appropriate to conduct multiple analyses in exploratory research, but it is important to report those analyses as exploratory and to acknowledge possible inflations of the Type I error rate.

D. If multiple dependent variables (DVs) are individually analyzed with NHST, the probability that at least one of them will be "significant" by chance alone grows with the number of DVs. Therefore it is important to inform readers of all of the DVs collected that are relevant to the study. For example, if accuracy, latency, and confidence were measured, but the paper focuses on the accuracy data, then report the existence of the other measures and (if possible) adjust the analyses as appropriate. Similarly, if several different measures were used to tap a construct, then it is important to report the existence of all of those indices, not just the ones that yielded significant effects (although it may be reasonable to present a rationale for why discounting or not reporting detailed results for some of the measures is justified). There is no need to report measures that were available to you (e.g., via a participant pool data base) but that are irrelevant to the study.

3. Rich descriptions of the data help reviewers, the Editor, and other readers understand your findings. Thus it is important to report appropriate measures of variability around means and around effects (e.g., confidence intervals around means and/or around standardized effect sizes).

4. Cherry picking experiments, conditions, DVs, or observations can be misleading. Give readers the information they need to gain an accurate impression of the reliability and size of the effect in question.

A. Conducting multiple experiments with the same basic procedure and then reporting only the subset of those studies that yielded significant results (and

putting the other experiments in an unpublished “file drawer”) can give a misleading impression of the size and replicability of an effect. If several experiments testing the same hypothesis with the same or very similar methods have been conducted and have varied in the pattern of significant and null effects obtained (as would be expected, if only due to chance), then you should report both the significant and the non-significant findings. Reporting the non-significant findings can actually strengthen evidence for the existence of an effect when meta-analytical techniques pool effect sizes across experiments. It is not generally necessary to report results from exploratory pilot experiments, such as when pilot experiments were used to estimate effect size, provided the final experiment has high power. In contrast, it is not appropriate to run multiple low-powered pilot experiments on a given topic and then report only the experiments that reject the null hypothesis.

B. Deciding whether or not to report data from experimental conditions post hoc, contingent on the outcome of NHST, inflates the Type I error rate. Therefore, please inform readers of all of the conditions tested in the study. If, for example, 2nd, 4th, and 6th graders were tested in a study of memory development then it is appropriate to report on all three of those groups, even if one of them yielded discrepant data. This holds even if there are reasons to believe that some data should be discounted (e.g., due to a confound, a ceiling or floor effect in one condition, etc.). Here again, anomalous results do not necessarily preclude publication (after all, even ideal procedures yield anomalous results sometimes by chance). Failing to report the existence of a condition that did not yield the expected data can be misleading.

C. Deciding to drop participants or observations post hoc contingent on the outcome of NHST inflates the Type I error rate. Best practice is to set inclusion/exclusion criteria in advance and stick to them, but if that is not done then whatever procedure was followed should be reported.

5. Be careful about using null results to infer “boundary conditions” for an effect. A single experiment that does not reject the null hypothesis provides only weak evidence for the absence of an effect. Too much faith in the outcome of a single experiment can lead to hypothesizing after the results are known (HARKing), which can lead to theoretical ideas being defined by noise in experimental results. Unless the experimental evidence for a boundary condition is strong, it may be more appropriate to consider a non-significant experimental finding as a Type II error. Such errors occur at a

rate that reflects experimental power (e.g., if power is .80, then 20% of exact replications would be expected to fail to reject the null).

6. Authors should use statistical methods that best describe and convey the properties of their data. The Psychonomic Society does not require authors to use any particular data analysis method. The following sections highlight some important considerations.

A. Statistically significant findings are not a prerequisite for publication in Psychonomic Society journals. Indeed, too many significant findings relative to experimental power can indicate bias. Sometimes strong evidence for null effects can be deeply informative for theorizing and for identifying boundary conditions of an effect.

B. In many scientific investigations the goal of an experiment is to measure the magnitude of an effect with some degree of precision. In such a situation a hypothesis test may be inappropriate as it only indicates whether data appear to differ from some specific theoretical value. Sometimes stronger scientific arguments can be made with confidence intervals (of parameter values or of standardized effect sizes). Moreover, some of the bias issues described above can be avoided by designing experiments to measure effects to a desired degree of precision (range of confidence interval).

C. The Psychonomic Society encourages the use of data analysis methods other than NHST when appropriate. For example, Bayesian data analysis methods avoid some of the problems described above. They can be used instead of traditional NHST methods for both hypothesis testing and estimation.

Last Word. Ultimately, journal Editors work with reviewers and authors to promote good scientific practice in publications in Psychonomic Society journals. A publication decision on any specific manuscript depends on much more than the above guidelines, and individual Editors and reviewers may stress some points more than others. Nonetheless, all else being equal submissions that comply with these guidelines will be better science and be more likely to be published than submissions that deviate from them.

Resources. There are many excellent sources for information on statistical issues. Listed below are some that the 2012 Publications Committee and Editors recommend.

Confidence intervals.

Cumming, G. (2012). Understanding the new statistics: Effect sizes, confidence

intervals, and meta-analysis. New York, NY US: Routledge/Taylor & Francis Group. (see www.latrobe.edu.au/psy/research/projects/esci).

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Manuscript Style

Manuscripts are to adhere to the conventions described in the *Publication*

Manual of the American Psychological Association (6th ed.). See www.apastyle.org/ for information on APA style, or type "APA style" into a search engine to find numerous online sources of information about APA style. Here we highlight only the most fundamental aspects of that style.

Layout. All manuscripts are to be double spaced and have 1" margins with page numbers in the upper right corner of each page.

Title page. The title page must include the authors' names and affiliations and the corresponding author's address, telephone number, and e-mail address.

Abstract. There must be an abstract of no more than 250 words.

Sections. Manuscript should be divided into sections (and perhaps subsections) appropriate for their content (e.g., introduction/background, Method, Results, etc.), as per APA style.

Acknowledgments. The Author Note should include sources of financial support and any possible conflicts of interest. If desirable, contributions of different authors may be briefly described here. Reviewers and the Editor should not be thanked in the Author Note.

Figures and tables. Figures and tables are to be designed as per APA style.

Location of figures, tables, and footnotes. In submitted manuscripts, figures and tables can be embedded in the body of the text and footnotes can be placed at the bottom of the page on which the footnoted material is referenced. Note that this is a departure from APA style; if you prefer you can submit the manuscript with the figures, tables, and footnotes at the end, but it is slightly easier for reviewers if these elements appear near the text that refers to them. When a paper is accepted, in the final version that the author submits for production each figure and table must be on a separate page near the end of the manuscript and all footnotes must be listed on a footnote page, as per the APA Publication Manual.

Citations and References. These should conform to APA style.

Supplemental Material

Authors are encouraged to attach, in a separate file or files, supplemental material (e.g., data sets such as stimulus norms or raw data, demonstrations or pictorial, auditory, or video stimuli, additional information regarding methods, additional tables or figures, relevant program source code [excluding executable code] for modeling or stimulus generation, or supplementary analyses that are not central to the main thrust of an

article). The supplemental material will be reviewed along with the submitted article, or may be added at the time of acceptance in consultation with the Editor. Supplemental material will be published online, linked to the accepted article. The Editor makes decisions regarding supplemental material.

Color Figures

Authors are encouraged to use color in figures if they believe that doing so improves the clarity of those figures. With the approval of the Editor, color can be used in the online version of the journal at no cost to authors. Moreover, as of 2011, the Editor has a limited budget for printing hard copy articles with color figures at no expense to authors. The Editor makes the final decision as to whether or not an article will be printed in hard copy with color: The greater the scientific value of using color the more likely an Editor will approve its use. Also, authors can pay for printed production of their articles with color figures; the current fee is $1,100 per article (regardless of the number of color figures). Many of the articles submitted to CABN are ones that need to make use of color figures in order to most clearly present the data. As with most journals, we must charge for the publication of color pictures in the print version of articles. However, if authors wish, they may opt to publish a black and white version of pictures/tables in the print version (as long as they are understandable to readers) and publish color versions in the on-line versions of articles.

Whether used only online or both in print and online, color figures should (insofar as is possible) be designed such that grayscale versions are interpretable. This is important because readers may wish to print or photocopy articles in grayscale.

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Other Questions

If you have questions not answered above, please direct them to the Editor of the journal in question:

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dbarch@artsci.wustl.edu
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Box 1125
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St. Louis, MO 63130
Fax: 314-935-8790

Appendix B

Task Rules

If Triangle then Circle
If Grey then Black
If Purple then Yellow
If Star then Square
If Hexagon then Oval
If Red then Pink
If Red then Green
If Triangle then Oval
If Yellow then Green
If Rectangle then Square
If Oval then Triangle
If Black then Orange
If Pink then Red
If Hexagon then Cross
If Triangle then Hexagon
If Square then Oval
If Purple then Red
If Circle then Star
If Circle then Trapezoid
If Oval then Square
If Circle then Rectangle
If Black then Purple
If Triangle then Square
If Blue then Grey
If Triangle then Trapezoid
If Blue then Red
If Square then Trapezoid
If Oval then Hexagon
If Blue then Pink
If Pink then Grey
If Orange then Blue
If Trapezoid then Star
If Star then Rectangle
If Triangle then Cross
If Star then Triangle
If Rectangle then Oval
If Rectangle then Cross
If Black then Yellow
If Hexagon then Trapezoid
If Yellow then Purple
If Hexagon then Circle
If Trapezoid then Triangle
If Green then Pink
If Black then Blue
If Circle then Triangle
If Rectangle then Circle
If Cross then Rectangle
If Oval then Circle

If Trapezoid then Rectangle
If Hexagon then Rectangle
If Cross then Square
If Blue then Black
If Triangle then Rectangle
If Purple then Black
If Hexagon then Triangle
If Circle then Hexagon
If Yellow then Red
If Pink then Green
If Yellow then Grey
If Orange then Yellow
If Red then Black
If Oval then Star
If Yellow then Blue
If Cross then Trapezoid
If Grey then Red
If Grey then Orange
If Black then Green
If Trapezoid then Hexagon
If Hexagon then Square
If Pink then Purple
If Yellow then Black
If Purple then Green
If Blue then Orange
If Yellow then Pink
If Cross then Triangle
If Cross then Oval
If Black then Grey
If Circle then Cross
If Oval then Rectangle
If Circle then Square
If Hexagon then Star
If Star then Cross
If Trapezoid then Cross
If Purple then Blue
If Purple then Grey
If Orange then Black
If Star then Trapezoid
If Grey then Green
If Green then Red
If Square then Triangle
If Trapezoid then Oval
If Oval then Trapezoid
If Blue then Green
If Pink then Orange
If Orange then Grey
If Square then Rectangle
If Red then Purple
If Red then Grey
If Orange then Green
If Black then Pink
If Rectangle then Triangle

If Star then Circle
If Square then Cross
If Green then Blue
If Red then Blue
If Oval then Cross
If Orange then Purple
If Circle then Oval
If Rectangle then Hexagon
If Purple then Pink
If Purple then Orange
If Rectangle then Star
If Square then Star
If Red then Orange
If Cross then Star
If Green then Yellow
If Cross then Circle
If Green then Grey
If Black then Red
If Pink then Black
If Blue then Purple
If Green then Purple
If Star then Oval
If Grey then Purple
If Pink then Yellow
If Cross then Hexagon
If Trapezoid then Square
If Rectangle then Trapezoid
If Red then Yellow
If Grey then Pink
If Yellow then Orange
If Triangle then Star
If Grey then Yellow
If Orange then Pink
If Green then Orange
If Square then Hexagon
If Trapezoid then Circle
If Pink then Blue
If Blue then Yellow
If Green then Black
If Grey then Blue
If Orange then Red
If Star then Hexagon
If Square then Circle

Appendix C

General Instructions for the Computerised RITL Sequential Dependency Task

Each of the following sequences will begin with a set of task instructions followed by a 5-second blank screen. Then a series of coloured shapes will appear (upon which you may execute the instructed task).

The set of instructions changes with every sequence, but will always come in the form of "If A then B". "A" and "B" can be either colours or shapes. You will need to press the space bar every time you see a "B" that appears directly after the "A" for that sequence.

e.g., if you are given the instructions "If pink then green", then for the entirety of that particular sequence, you should press the space bar every time you see a GREEN shape... but only if it appears immediately after a PINK shape. Hence, “If pink then green”.

This exercise should take somewhere between 70-80 minutes, during which it is ideal that you keep any talking or bodily movements to an absolute minimum (there will be breaks between each sequence if you need to stretch or ask questions).

Appendix I

Ethics Approval

Murdoch
UNIVERSITY

Division of Research & Development
Research Ethics and Integrity Office

Chancellery Building
South Street
MURDOCH WA 6150
Telephone: (08) 9360 6677
Facsimile: (08) 9360 6686
human.ethics@murdoch.edu.au

www.murdoch.edu.au

Thursday, 05 June 2014

Dr Bethanie Gouldthorp
School of Psychology and Exercise Science
Murdoch University

Dear Bethanie,

Project No. 2014/061
Project Title Frontal Lobe Modulation of Task-Relevant and Task Irrelevant Features in Rapid Instructed Task Learning

Thank you for addressing the conditions placed on the above application to the Murdoch University Human Research Ethics Committee. On behalf of the Committee, I am pleased to advise the application now has:

OUTRIGHT APPROVAL

Approval is granted on the understanding that research will be conducted according the standards of the ***National Statement on Ethical Conduct in Human Research*** **(2007), the *Australian Code for the Responsible Conduct of Research*** **(2007)** and **Murdoch University policies** at all times. You must also abide by the **Human Research Ethics Committee's standard conditions of approval (see attached).** All reporting forms are available on the Research Ethics and Integrity web-site.

I wish you every success for your research.

Please quote your ethics project number in all correspondence.

Kind Regards,

Dr. Erich von Dietze
Manager
Research Ethics and Integrity

cc: Rebecca Cooper

Appendix J

Information Letter

Dear Participant

We invite you to participate in a study testing top-down modulation of task-relevant and task-irrelevant features during rapid instructed task learning. This study will form part of my Honours Degree in Psychology, and is supervised by Dr Bethanie Gouldthorp, a lecturer at Murdoch University.

Please note that in order to participate in this study you must meet the following criteria:

- You must be 18 years of age and over
- Have normal or corrected-to-normal eyesight
- Have no known motor/neurological disorders
    - (e.g., epilepsy, Parkinson's disease, Alzheimer's disease, etc.)
- Not be taking any psychoactive medications or drugs
    - (no caffeine or nicotine 3 hours prior to the study)
- Not be wearing any hearing aids

Nature and Purpose of the Study

Rapid Instructed task learning (RITL) is the human ability to rapidly understand and perform a new set of instructions, usually on the first attempt. People do this every time they follow a new recipe or use the instructions to play a new game. Often the individual steps are familiar, but the combination of them into a specific step-by-step sequence is totally new.

My hypothesis is that when regular people are given a set of novel instructions, different parts of the brain bias themselves towards responding to anything that seems to resemble what the instructions ask for. I think the findings of this experiment could help people understand how instruction-following works and improve educational settings where instruction-following is used.

What the Study Will Involve

Basic phases. After giving informed consent and agreeing to participate in the study, you will be asked to complete the following:

1. A very short demographic survey asking about your age, gender, etc.;
2. Two tests measuring your fluid intelligence and your working memory abilities, lasting about 20 minutes in total;
3. A 70-80 minute computerised task you'll perform while wearing an EEG cap (to measure your brain waves).

Fluid intelligence and working memory task procedures. You will be asked to complete two short tests: Cattell Culture Fair Test (measuring fluid intelligence) and the Digits Backwards test (measuring working memory capacity). The Cattell involves looking at a series of pictures and picking from the options the picture that best completes the series. The Digits Backwards test involves looking at series of numbers and repeating them backwards.

Having the EEG. You will be asked to wear an electroencephalography (EEG)

cap which will measure the electrical activity across your scalp during the computerised task mentioned above. You might feel like you're wearing a wet bonnet, and you'll be asked to remove any earrings and makeup beforehand. There are bathrooms on the premises to cater for this. Participants are advised to attend the session with minimal hair product and that participants do not attend a session if they have dyed their hair within two weeks of it (to avoid staining the EEG nets). It is advised that no caffeine or nicotine be taken 3 hours prior to the study.

Please be aware that the use of the EEG in this experiment is purely for research measurement, and no diagnostic information about your brain activity will be recorded. Further, since all data will be anonymous, data patterns will not be able to be matched to a specific participant.

Voluntary Participation and Withdrawal from the Study

Your participation in this study is entirely voluntary. You may withdraw at any time without discrimination or penalty. All information is treated as confidential and no names or other details that might identify you will be used in any publication arising from the research. If you withdraw, all information you have provided will be destroyed.

If you consent to take part in this research study, it is important that you understand the purpose of the study and the procedures you will be asked to undergo. Please make sure that you ask any questions you may have, and that all your questions have been answered to your satisfaction before you agree to participate.

Benefits of the Study

While it is possible that there may be no direct benefit to you from participating in this study, if you are a psychology student then it is likely you will be able to apply the knowledge gained from participation to your academic career, and your fourth year project (should you go on to study further in this field). This study also has potential theoretical and practical implications for the wider community. For example, the results could benefit future neuropsychological rehabilitation and education program development.

If you are willing to consent to participation in this study, please complete the Consent Form. If you have any questions about this project please feel free to contact either the student researcher, Rebecca Cooper, at email ribzqueen@gmail.com, or Chief investigator, Dr Bethanie Gouldthorp, at b.gouldthorp@murdoch.edu.au.

We are happy to discuss any concerns you may have about this study.

You can expect to receive feedback in December 2014, by accessing the Murdoch School of Psychology website (http://www.psychology.murdoch.edu.au), under 'Current Research Results.'

Thank you for your assistance with this research project.

Sincerely

Rebecca Cooper

Appendix K

Consent Form

Top-Down Modulation of Task Features in Rapid Instructed Task Learning

1. I agree voluntarily to take part in this study.

2. I have read the Information Sheet provided and been given a full explanation of the purpose of this study, of the procedures involved and of what is expected of me. The researcher has answered all my questions and has explained the possible problems that may arise as a result of my participation in this study.

3. I understand I am free to withdraw from the study at any time without needing to give any reason.

4. I understand I will not be identified in any publication arising out of this study.

5. I understand that my name and identity will be stored separately from the data, and these are accessible only to the investigators. All data provided by me will be analysed anonymously using code numbers.

6. I understand that personal information provided by me is treated as confidential and will not be released by the researcher to a third party unless required to do so by law.

7. I understand that information collected during this study may be used in future research provided that the data is not individually identifiable.

Signature of Participant: _____ Date: ……/……/…….
(Name)

Signature of Investigator: _____ Date: ..…../……/…….
(Name)