COGNITIVE CONTROL OF EYE MOVEMENTS IN READING AND VISUAL SEARCH: EVIDENCE FROM FREQUENCY-BASED EFFECTS

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Experiments in this dissertation investigate the role of cognition in eye-movement behavior during scanning and reading. Shorter and fewer fixations on the more frequent and predictable words have been observed during reading, but not when scanning text for a target word, e.g., *zebra* (e.g., Rayner & Raney, 1996). Past research has employed these effects of *word frequency* and *predictability* to argue that cognition drives eye movements during reading, but not during scanning. Similarly, the present studies use effects of *stimulus frequency* and *predictability* to index cognitive control of eye-movement behavior. Experiments 1 and 2 focus on the frequency effects for non-word and word stimuli, respectively. Experiment 1 employed clusters of Landolt *C*s to examine how the gap size of and frequency of exposure to clusters affected eye movements during a scanning task. The findings demonstrated that, in parallel to word frequency effects observed in reading, more frequent clusters elicited fewer and shorter fixations. Experiment 2 compared eye-movement behavior on fully-crossed high- and low-frequency adjective-noun pairs embedded in paragraphs when participants were reading vs. scanning for a target word with an asterisk (e.g., “h*rse”), a word containing the letter "q" (e.g., “quilt”), or a word rhyming with "blue" (e.g., “shoe”). The results demonstrated that eye-movement measures are affected by frequency in the tasks requiring in-depth processing, such as reading and rhyme-judgment, but not in shallow-processing tasks like asterisk-detection. Experiments 3 and 4 focus on the frequency-based predictability effects for non-word and word stimuli, respectively. Experiment 3 employed similar materials to Experiment 1 and, in addition, manipulated frequency for pairs of clusters. The more predictable clusters in the repeating pairs elicited fewer fixations, providing tentative evidence of *transitional predictability* effects during scanning. Experiment 4 examined the effect of transitional probability in reading by increasing the frequency of co-occurrence for pairs of words (e.g., *tulip's blossoms*) in paragraphs of text. The more predictable words elicited shorter first fixation durations, suggesting that co-occurrence frequency may result in forming short-term predictions during reading. Cumulatively, the findings demonstrate that cognitive effects are not unique to reading, and afford a more sophisticated characterization of the cognitive-oculomotor coordination.

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1.0 INTRODUCTION

Reading is a complex activity that involves the careful coordination of many faculties, such as oculomotor control, visual processing, attention, and word identification. Certain aspects of the visual system constrain how reading proceeds: limitations of visual acuity (Bouma, 1973; Rayner & Morrison, 1981) force the reader to fixate almost every word and programming of saccadic shifts is slow (Abrams & Jonides, 1988; Salthouse & Ellis, 1980). Cognition further hinders forward movement of the eyes with slow lexical processing (Rayner & Pollatsek, 1989). In addition to these well-known constraints, the exchange of information between lower- and higher-order processes that is necessary for reading constrains the pace of information acquisition and task scheduling within each of these faculties, which in turn influences where and when the eyes move in text (Rayner, 1998; Reichle, Pollatsek, Fisher, & Rayner, 1998; Reichle, Rayner, & Pollatsek, 2003). The importance of this coordination becomes evident when it breaks down. Whereas normal reading seems like as a seamless gliding of the eyes across a page of text, when coordination breaks down a reader experiences a frustrating stop-and-go processing. This kind of breakdown may be encountered while reading a novel in a second language, or reading a student's paper with many spelling errors and run-on sentences, or, in a more serious and permanent case of reading dysfunction, could be the result of a neurological disorder, e.g., dyslexia. And yet what most readers do so well, and what most people are able to do (and to a very limited extent baboons, in Grainger, Dufau, Montant, Ziegler, & Fagot, 2012), is not an innate skill: readers are not born – they are made through extensive training that *usually* begins some time during their early childhood.

1.1 COGNITION AND EYE-MOVEMENT CONTROL

The fact that reading is an acquired skill has two important implications for the present research. First, the coordination of cognition and the visual system during reading must be somewhat based on the pre-existing settings for the visual system: a set of parameters and the range of values along which they can vary, which evolved while humans had to engage in a variety of visual search/scanning tasks critical to their survival. The emergence of coordination during reading is likely accomplished by the gradual changing/tuning of these parameters to the cognitive/processing demands of reading. One goal of the present research was to contrast eye-movement behavior during scanning and reading, in order to further specify the differences in how cognition and the visual system are coordinated in these tasks, and to understand what is special to this coordination during reading. The second implication is that this coordination must be *learned*, and hence evidence of this learning should be observed in the eye-movement record. A complementary goal of this research, therefore, was to observe the emergence of this coordination during scanning or reading. Acquiring skill in reading requires a reader to learn to time saccadic shifts so that they result in relatively short fixations (averaging approximately 200ms), while coordinating the functioning of the oculomotor system with lexical processing. There has been little direct observation of this learning. Reading researchers conduct most of their studies with adults performing tasks that they already know how to do well (e.g., reading) or that require little learning (e.g., scanning text for a perceptually easy-to-find target). An alternative approach has been to compare the eye-movement behavior of child and adult readers. Age-related changes in eye-movement behavior indicate a gradual optimization in the coordination of these processes: as readers age, their fixations and regressions become shorter and fewer, their saccadic amplitudes become larger and they have a greater probability of skipping words (for a review see Blythe & Joseph, 2011; Joseph & Liversedge, 2013). It is unclear, however, to what extent the observed differences in eye-movement behavior between adults and children may be attributed to the emergence of the cognitive/oculomotor coordination specific to the task of reading. An alternative reason for these differences and, in particular, what appears to be the less optimal coordination of these systems in children, may be that the cognitive/oculomotor systems in children are still in the process of growth and development, whereas in adults, we observe the mature *end-state*.

Moreover, the direct observation of how such coordination emerges will address an important debate in reading research, namely, which factors predominantly drive eye-movements during reading. This debate has given rise to two theoretical perspectives, which, at two extremes, view this coordination (1) the same as exists when the eyes are identifying various objects in a visual scene or scanning the scene for a particular target and (2) highly specialized for the cognitive demands of reading. On the one side of the theoretical spectrum, *oculomotor theories* claim that timing and location of fixations during reading are determined by limitations of visual acuity and oculomotor constraints (McDonald, Carpenter, & Shillcock, 2005; Yang & McConkie, 2001). On the other, *cognitive (processing) theories* claim that completion of some stage of word identification, i.e., lexical processing, determines when the eyes move forward (e.g., Starr & Rayner, 2001). As will be reviewed later in the introduction, there are many similarities between reading and scanning behaviors which appear to support the oculomotor perspective (e.g., Vitu, O'Regan, Inhoff, & Topolski, 1995). However, there are also differences between reading and scanning; for example, in reading, but not scanning, shorter and fewer fixations are observed on more frequent and predictable words. These effects have been claimed as evidence of cognition guiding eye-movement behavior during reading (e.g., Inhoff & Rayner, 1986). The strength of this evidence, however, has been tempered by the fact that evidence for these effects comes from "quasi-experimental" manipulations, meaning that word frequency is usually conflated with many other word properties that could also affect the number and duration of fixations (Kliegl, Nuthmann, & Engbert, 2006; *cf.* White, 2008). The current research will inform this debate because we will attempt to document the emergence of these effects dependent on an experimental manipulation of frequency.

To summarize, the present research attempts to identify the important parameters that undergo change to accommodate reading, and to demonstrate the tuning of these parameters during task-specific learning. It does so with experiments that (a) compare eye-movement behavior in a variety of scanning tasks and reading, and (b) investigate the effects of learning on eye-movements in these tasks. Specifically, Experiments 1-3 employ a variety of scanning tasks with word and non-word stimuli and demonstrate that the depth of processing required by a task (e.g., Craik & Lockhart, 1972; Craik & Tulving, 1975) predicts the degree to which eye-movements in scanning tasks resemble reading behavior. Experiments 1, 3, and 4 demonstrate learning effects by manipulating the frequency of exposure to single and pairs of word and non-word stimuli and observing associated changes in eye-movement behavior.

Table 1

Overview of the presented studies

Stimuli	Investigated Effects	
	Frequency	Predictability
Landolt-C clusters	Experiment 1: Frequency of individual *Landolt-C* clusters	Experiment 3: Frequency of individual *Landolt-C* clusters and frequency of pairs of *Landolt-C* clusters
Words	Experiment 2: Frequency of words in a variety of scanning tasks, compared to reading.	Experiment 4: Frequency of word pairs in reading.

Next I will briefly review the literature that has compared eye movements in visual search to reading, before addressing how statistical learning fits in the context of this research. I will then summarize the hypotheses of the presented studies and the experimental manipulations therein. A more detailed review of the relevant literature for each study will be presented separately in the chapters that follow. Finally, a conclusion section will summarize the implications of these findings for future research and discuss some remaining open questions.

1.2 EYE MOVEMENTS IN VISUAL SEARCH AND READING

The comparison of eye movements during scanning and reading has primarily supported cognitive/processing theories of eye-movement control during reading. During reading, high frequency and more predictable words are associated with shorter fixation durations, fewer fixations, and higher skipping rates (Balota, Pollatsek, & Rayner, 1985; Ehrlich & Rayner, 1981; Henderson & Ferreira, 1990; Inhoff & Rayner, 1986; Morris, 1994; Rayner, 1998; Rayner, Ashby, Pollatsek, & Reichle, 2004; Rayner, Reichle, Stroud, Williams, & Pollatsek, 2006; Rayner & Well, 1996; Schustack, Ehrlich, & Rayner, 1987). These effects are absent, however, during scanning for a particular word (Rayner & Fischer, 1996; Rayner & Raney, 1996). Given that word identification is critical to reading, word frequency and predictability effects on eye movements suggest that the accessibility of mental representations is an important determinant of eye-movement behavior in this task.

Past findings can speak to which aspect of lexical processing drives eye movements only in a very limited way: it may be having to process words for meaning, or more generally engaging in memory retrieval. Also, although past findings suggest that the coupling of cognition and the visual system may be specific to reading, they do not rule out the possibility that cognitive effects may also be observed during scanning. The present research investigates an alternative hypothesis, namely that the necessity of accessing any aspect of a memory representation during task performance, e.g., a word's phonological code or a non-word's orthographic code, should result in cognitive effects on eye movements. That is, if the retrieval of task-specific information from memory leads to a faster rejection of a distractor or a faster recognition of a target than engaging in feature-by-feature perceptual discrimination, then having a tight link between cognition and oculomotor system may be advantageous even during a scanning task. Experiments 1-3 investigate this possibility by obliging participants to engage in scanning tasks that may be performed efficiently by accessing underlying mental representations of word and non-word stimuli. The present studies, therefore, test the prediction that eye-movement behavior will resemble reading in these tasks.

The present research will attempt to address another open question regarding the characterization of the link between the cognitive and oculomotor systems. In the present studies, I hope to provide evidence that the magnitude of the cognitive effects in a task corresponds to the cognitive demands of the task, rather than to the proportion of time that cognition is engaged during the task. In this way, the present research will extend *cognitive/processing theories* of eye-movement control during reading (e.g., Just & Carpenter, 1980). There is already tentative evidence that the degree to which cognition and eye movements are coupled may be modulated by a task's cognitive demands. Thus, for example, cognitive variables like word frequency and predictability have been demonstrated to have considerable effects on duration and number of fixations made on a word during normal reading or proofreading for errors (e.g., Kaakinen & Hyönä, 2010; Reichle, Vanyukov, Laurent, & Warren, 2008), but when subject's attention wavered from the text and his mind began to wander, the magnitude of these effects diminished (Reichle, Reineberg, & Schooler, 2010). Smaller cognitive effects during *mindless reading* could possibly reflect reading for meaning a proportion of the time and non-cognitively driven scanning behavior the remainder of the time (Reichle et al., 2010). If this is the case, the larger cognitive effects observed during proofreading than reading (Kaakinen & Hyönä, 2010) could counter-intuitively suggest that cognition is engaged more frequently during proofreading than during reading. By using a variety of scanning tasks with word and non-word stimuli, the current experiments will attempt to provide clearer support for a link between cognitive effects and the access of memory representations, rather than specifically processing for meaning. This evidence will be used to argue for a continuous, rather than dichotomous, characterization of the cognitive-oculomotor link. Like earlier research, the current experiments employ effects of stimulus frequency and predictability to index the coordination between cognition and vision, but also attempt to demonstrate how these effects emerge as a result of manipulating frequency of exposure to individual stimuli and pairs of stimuli, i.e., implicating memory and the effects of accessibility of memory representations in eye-movement behavior.

1.3 STATISTICAL LEARNING

Although the main focus of the present work is on the development of the coordination of eye-movement behavior and cognition that is required for reading, it also addresses the question of which learning mechanism accomplishes this coordination. Specifically, the present research explores the possibility that one possible candidate is *statistical learning*, or learning via repeated exposure to stimuli and combinations of stimuli. The characterization of this mechanism is consistent with the putative interpretation of word frequency effects, i.e., that these effects index a reader's expertise with a word or the accessibility of its memory representation (Ans, Carbonnel, & Valdois, 1998; Reichle & Perfetti, 2003). Statistical learning mechanisms also afford learning of a range of patterns, from simple co-occurrence of two adjacent items to more complex patterns. Hence, this mechanism is hypothesized to underlie probabilistic predictability as described by *surprisal*-based theories of sentence-processing difficulties during reading (Hale, 2001; Levy, 2008). Although it has been frequently implicitly assumed that word frequency effects and probabilistic predictability emerge from statistical learning, there has been no direct demonstration that the eyes can become gradually attuned to frequencies of individual stimuli and patterns of stimuli. The present research, therefore, would provide initial support that the same domain-general learning mechanism that aids in the learning of patterns in linguistic input in other modalities may play an important role in reading (e.g., Gómez & Gerken, 2000).

There is indirect evidence that eyes may be sensitive to simple co-occurrence relationships between words, i.e., the effects of transitional predictability, as well as more complex statistical co-dependencies. This evidence comes from examining the *final state* of the coordination between cognition and eye movements, i.e., expert readers. Generally, studies have estimated the statistical predictability of words from large corpora, and demonstrated that there is an association with eye-movement characteristics, while controlling for other factors (e.g., Boston, Hale, Kliegl, Patil, & Vasishth, 2008; Wang, Pomplun, Chen, Ko, & Rayner, 2012). Some researchers appear to find evidence of statistical predictability effects in the eye-movement record during reading (e.g., McDonald & Shillcock, 2003a, 2003b), but these claims have been challenged because it is difficult to disassociate these effects from contextual predictability (Frisson, Rayner, & Pickering, 2005). The findings from studies conducted on the Potsdam and Dundee corpora demonstrate that mismatches to readers' high-probability predictions result in longer first-fixation, single-fixation gaze durations and overall reading time, as well as greater probabilities of a regression (Boston et al., 2008; Demberg & Keller, 2008). Importantly, the present research will provide evidence of the on-line learning of statistical dependencies in eye-movement behavior; this demonstration has been outside the scope of past studies. Specifically, Experiments 1, 3 and 4 will provide evidence that frequency and statistical predictability effects result from repeated exposure to single stimuli and pairs of stimuli while participants are reading or scanning.

1.4 SUMMARY OF EXPERIMENTS

The primary goals of this research, therefore, are a) to specify which parameters are necessary for the coordination of cognition and eye movements during reading; and b) to demonstrate changes in these parameters due to on-line learning while scanning and reading. The secondary goals of the proposed research are to demonstrate a limited set of statistical learning effects on eye movement behavior; these include the effects of repeated exposure to single items and to pairs of items. Observations of changes in eye-movement behavior contingent on the frequency manipulations will provide evidence of cognitive control in eye movement behavior and, specifically, of the role it plays in inducing word frequency and frequency-based predictability effects. **Experiment 1** tests the hypothesis that frequency of exposure to individual letter clusters modulates eye movement behavior, such that processing time as indexed by fixation durations and number of fixations should decrease with increasing number of exposures. **Experiment 2** investigates the effects of word frequency as a function of task, i.e., reading versus scanning for target words. **Experiment 3** tests the hypothesis that increasing frequency of exposure to pairs of clusters will result in shorter and fewer fixations on the second cluster, i.e., a prediction will be formed. Finally, **Experiment 4** investigates whether frequency of exposure to word pairs will result in shorter and fewer fixations on the "predicted" word in the pair.

2.0 EXPERIMENT 1: THE EMERGENCE OF FREQUENCY EFFECTS IN EYE MOVEMENTS

The extent to which oculomotor and cognitive factors influence eye movements in reading is widely debated (Starr & Rayner, 2001). *Oculomotor* theories contend that the timing and location of fixations are predominantly determined by visual acuity and oculomotor constraints (e.g., McDonald, Carpenter & Shillcock, 2005; O'Regan, 1990; Yang & McConkie, 2001). *Cognitive* (*processing*) theories (e.g., Just & Carpenter, 1980; Reichle et al., 1998; Reilly & Radach, 2006) argue that cognitive processes like word identification largely drive eye movements, as evidenced by *word-frequency effects*, or the finding that higher frequency words receive shorter fixations and are skipped more often than lower frequency words (e.g., Inhoff & Rayner, 1986).

To determine cognition's involvement in eye-movement guidance during reading, eye movements during reading have been compared to eye movements during tasks presumed to minimally engage cognition, such as searching for a target word in a text or performing z-string "reading" (Rayner & Fischer, 1996; Rayner & Raney, 1996; Vitu et al., 1995). In these tasks, the word-frequency effects that are ubiquitous in reading are absent. Assuming that word-frequency effects arise because more exposures make a word's representation in memory easier to access, as posited by several episodic models of printed word identification (e.g., Ans et al., 1998; Reichle & Perfetti, 2003), this may be evidence that eye movements are guided by the demands of accessing lexical representations from memory during reading, but not during tasks that don't require full lexical retrieval.

The current experiment investigates how manipulating the frequency of orthographic patterns in a visual-search task affects eye movements. Demonstrating frequency effects in a non-reading task would provide strong evidence that cognition rapidly influences eye movements and address the etiology of word-frequency effects in reading. Because associations between word frequency and fixation durations are inherently correlational, some have argued that the causal nature of this relationship remains conjectural (cf. Kliegl et al., 2006; Rayner, Pollatsek, Drieghe, Slattery & Reichle, 2007). The current experiment directly tests the hypothesis that frequency effects arise from frequency of exposure by manipulating the latter to determine *if* and *how* eye-movement measures are affected.

We used a paradigm from Williams and Pollatsek (2007; see also Corbic, Glover, & Radach, 2007), in which participants scanned lines of *Landolt-C* clusters, or circles with a missing segment of varying size and orientation, to locate clusters containing an *O*, i.e., targets. In Williams and Pollatsek (2007), the number of pixels in the missing segments, or the *gap size*, was held constant within a given cluster, but manipulated between clusters. Their results indicated that fixation durations on the non-target or *distractor* clusters were related to the gap size of the fixated cluster, but not to the gap sizes of neighboring clusters. Furthermore, gaze durations on clusters during scanning were nearly equivalent to reaction times for target present-absent judgments on the same clusters in isolation. Because these results parallel the finding that gaze durations on words in reading correlate with the identification times of those same words displayed in isolation (Schilling, Rayner & Chumbley, 1998), Williams and Pollatsek argued that eye movements in their task were also driven by identification processes, and thus cognition.

However, given that gap-size manipulations directly affect *C-O* discriminability, gap-size effects are likely to be influenced by perceptual fluency. Even more compelling evidence for cognitive effects would be provided by a demonstration that the accessibility of individual clusters' memory representations affects eye movements.

Our study extends Williams and Pollatsek (2007) by manipulating the number of times a cluster appeared in the experiment. We predict an inverse relationship between the number of encounters and fixation durations on the distractor clusters. This finding would suggest that the accessibility of a cluster's representation in memory (as determined by frequency of exposure) influences how long that cluster must be processed and thus how long the eyes stay on it. This would provide stronger evidence of cognition influencing eye movements and would exemplify how the mind-eye link may develop in tasks like reading.

2.1 METHOD

2.1.1 Participants

Sixteen University of Pittsburgh undergraduates with normal or corrected vision received partial course credit in an introductory psychology course for their participation.

2.1.2 Procedure

Each trial began with participants viewing a dot on the leftmost side of the screen. Participants initiated the trial with a button press, which displayed the stimuli for 12 seconds. Participants were instructed to scan a horizontal row of clusters from left to right and to identify any targets, i.e., a cluster containing a letter *O* (see Figure 1). When their gaze shifted to the right of the line, the stimuli disappeared and were replaced by a question mark. Participants pressed joystick buttons to make a target present/absent response. Performance feedback was provided for all trials.

Figure 1. Example target present trial (target is located in the 3rd letter cluster).

2.1.3 Experimental design and materials

Participants completed four blocks of 29 trials. The order of blocks was counterbalanced across participants. In each block, eight trials contained a single target. Targets appeared with equal probability in any cluster position. Clusters were 4-characters long with gap sizes of 2-, 4-, 6-, and 8-pixels. Gap size was constant within a cluster but gap orientation (left, right, top, or bottom) was randomized to create eight unique exemplars for each of the three frequency categories: 10, 25, or 50 encounters. All other clusters occurred only once, resulting in total of 896 distractors. The assignment of distractors to trials was randomized, with each block containing two tokens of each frequency category and 54 unique clusters. This allowed frequency of exposure to be dissociated from practice.

2.1.4 Equipment

Participants viewed the stimuli binocularly on a 23-in. monitor 63 cm from their eyes with approximately 3.5 letters per degree of visual angle. An EyeLink 1000 eye-tracker (SR Research

Ltd.) recorded the gaze location of the right eye. The eye-tracker had a spatial resolution of 0.01° and sampled gaze location every millisecond. Task presentation was done using E-Builder software (SR Research Ltd.).

2.2 RESULTS

2.2.1 Behavioral results

Participants' mean accuracy on the search task was greater than 90%. The average hit rate was 87%, the false alarm rate less than 1.5%, and there was only one failure to respond within 12 seconds.

2.2.2 Eye-movement results

Analyses focus exclusively on distractor clusters because only distractor frequency was manipulated. The following eye-movement measures were examined on a given cluster: (a) *first-fixation duration*, or the duration of the initial fixation during first-pass scanning; (b) *gaze duration*, or the sum of all first-pass fixation durations; (c) *total-viewing time*, or the sum of all fixations; (d) *number of fixations* during the first pass; (e) *spill-over,* or the first-fixation duration on cluster $n + 1$ after leaving cluster n (Rayner & Duffy, 1986). We also investigated *parafovea-on-fovea effects*, or the influence of cluster $n + 1$ on the processing of cluster n (Kennedy & Pynte, 2005; Kliegl et al., 2006). For parafovea-on-fovea analyses, we excluded clusters that preceded a target, appeared at the end of a line, or occurred before a skipped cluster, thereby omitting 18% of the data.

Participants fixated the majority of clusters, skipping less than 7.4%. Based on individual participants' fixation-duration distributions, we excluded fixations outside of *Q1* – (3 × semi-interquartile) and *Q3* +(3 × semi-interquartile) range as outliers. Because the data were right-skewed, we performed a logarithmic transform to make the distributions more normal. This meant that on average, fixations shorter than 82 *ms* and longer than 898 *ms* were removed, resulting in the loss of approximately 1.4% of the data. Data were analyzed using a linear mixed-effects (*lme*) model with participants and blocks (to separate the variance associated with the assignment of particular clusters to blocks) as random effects. *p*-values were estimated using Markov chain Monte Carlo sampling. Regression weights cannot be directly interpreted as effect sizes because analyses were performed on log-transformed measures; to increase transparency, estimated effect sizes and the means in Table 2 are from lme analyses of untransformed data. A backward model selection procedure was used to determine which interaction terms (if any) should be included as predictors, as necessary re-fitting reduced models and making comparisons using log likelihood ratio tests. Only the results of models selected by this procedure are reported here.

Table 2

Estimated means for eye-movement measures on distractor clusters (fixation durations in ms)

	1st exposure				50th exposure			
	Gap size 2	Gap size 4	Gap size 6	Gap size 8	Gap size 2	Gap size 4	Gap size 6	Gap size 8
First fixation	332	325	318	310	330	323	316	309
Gaze duration	792	719	645	571	756	683	609	535
Total-viewing time	866	784	703	622	828	746	665	584
Number of fixations on first pass	2.7	2.4	2.2	2.0	2.6	2.3	2.0	1.8
Spill over	343	346	349	352	350	345	341	336
Parafovea-on-fovea effects (gap size is of upcoming cluster)	1st trial				116th trial			
Gaze duration	641	658	676	694	624	616	607	598
Total-viewing time	718	726	733	741	643	637	631	625
Number of fixations on first pass	2.2	2.3	2.3	2.4	2.1	2.1	2.1	2.0

We examined whether first-fixation duration on a cluster was affected by number of exposures, gap size, and practice in the task (i.e., ordinal trial number). First-fixation durations were not reliably affected by the number of exposures (b = -0.04, SE = 0.08, p = .94) or practice (b = -0.03, SE = 0.03, p = .48). However, they decreased with increasing gap size (b = -3.62, SE = 0.52, p < .01).

Gaze duration decreased with more exposures (b = -0.73, SE = 0.17, p < .01), with the predicted change being approximately 1 *ms* for every additional exposure. Gaze duration also decreased with larger gap sizes and more practice in the task [gap size: (b = -36.83, SE = 1.15, p < .01); practice: (b = -0.51, SE = 0.07, p < .01)]. Similarly, total-viewing time decreased with more exposures (b = -0.78, SE = 0.18, p < .01), wider gaps (b = -40.66, SE = 1.17, p < .01), and more practice (b = -0.85, SE = 0.08, p < .01).

The number of fixations on a cluster during first-pass scanning showed no main effect of number of exposures (b = 0.0007, SE = 0.001, p = 0.64), but participants made fewer fixations on clusters with wider gaps (b = -0.12, SE = 0.008, p < .01) and with more practice in the task (b = -0.003, SE = 0.0006, p < .01). A gap size × number of exposures interaction (b = -0.0006, SE = 0.0003, p < 0.05) indicated that repeated exposure to clusters with wider gaps was associated with a greater decrease in the number of fixations than clusters with narrower gaps. A gap size × practice interaction (b = 0.0003, SE = 0.0001, p < 0.01) demonstrated that for wider gaps the effect of practice was associated with a smaller decrease in the number of fixations.

We examined whether characteristics of the preceding cluster affected first-fixation durations on the next cluster, i.e., spillover. Spillover was unaffected by the number of exposures (b = 0.29, SE = 0.20, p = .06), however there was a main effect of gap size (b = 1.57, SE = 0.78, p < .05), with longer fixations after clusters with wider gaps. This main effect was qualified by gap size × number of exposures interaction (b = -0.08, SE = 0.04, $p < .05$), indicating that repeated exposure to clusters with wider gaps, but not narrower gaps, was associated with decreases in spillover. There was also a main effect of practice (b = -0.10, SE = 0.04, $p < .01$), with more practice in the task associated with less spillover.

Finally, we investigated whether characteristics of the upcoming cluster affected processing on the current cluster, i.e. *parafovea-on-fovea effects*. Gaze duration and the number of fixations on a cluster both increased with the gap size of the following cluster (GD: b = 9.08, SE = 2.39, $p < .01$; fixation count: (b = 0.03, SE = 0.01, $p < .01$). This effect was qualified by gap size × practice interaction in both measures (GD: b = -0.12, SE = 0.04, $p < .01$; fixation count: b = -0.0004, SE = 0.0001, $p < .01$), such that practice reduced the effect of the upcoming cluster's gap size. The effect of gap size was not reliable for the first-fixation duration or total-viewing time (FFD: b = -0.09, SE = 0.57, p = .06; TT: b = 0.47, SE = 1.24, p = .56).

2.3 DISCUSSION

This study investigated the role of cognition in eye-movement behavior in a visual search task. Distractor clusters that were encountered more often had shorter gaze durations and total-viewing times, and received fewer fixations. These findings parallel word-frequency effects in reading (Inhoff & Rayner, 1986) and have several important theoretical implications. First, the effect of whole-cluster frequency indicates that participants did not solely engage in letter-by-letter discrimination, but processed the clusters more holistically (McClelland & Rumelhart, 1981; Reicher, 1969). This is similar to a shift in word-processing associated with reading expertise: whereas novices may assemble words letter-by-letter, expert readers appear to process words as wholes (e.g., Ans et al., 1998). Second, these data suggest that frequency effects may emerge as a result of repeated exposure to a cluster, and more specifically, indicate a causal relationship between the number of exposures and the timing of saccadic programming. We hypothesize that the trigger to initiate saccadic programming in our experiment and reading corresponds to the access of information about a particular cluster or word from memory. In the current experiment, the to-be-accessed information is whether a cluster contains a target letter; in reading, it may correspond to a word's pronunciation and meaning. After only a few encounters, a cluster or word is only weakly represented in memory and its form and/or meaning is difficult to access, leading to longer saccadic latencies. But with more encounters, a cluster or word's representation becomes stronger and easier to access, leading to shorter saccadic latencies. This finding is therefore consistent with episodic theories of lexical access, according to which each encounter with a word increases its representational strength (Ans et al., 1998; Craik & Tulving, 1975; Goldinger, 1998; Reichle & Perfetti, 2003). The finding is also consistent with models of eye-movement control in which lexical access is the primary determinant of when the eyes move from one word to the next (Just & Carpenter, 1980; Reichle et al., 1998).

It is important to note that the current experiment's frequency effects arose from form frequency. This means that they should be similar to orthographic frequency effects, but smaller than word-frequency effects (cf. White, 2008). This is because word representations have multiple components (e.g., phonology, orthography, and semantics) and richer representations are accessed more quickly and successfully from memory (Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001; Seidenberg & McClelland, 1989; Plaut, McClelland, Seidenberg & Patterson, 1996).

The present study replicated Williams and Pollatsek's (2007) gap-size effects on the fixated cluster, but additionally found spillover effects. These included a main effect of gap size and an interaction between gap size and the number of exemplars, which indicated that repeated exposures to clusters with wider gaps reduced spillover. This could indicate that participants engaged in a strategic trade-off between perceptual discrimination and memory access. That is, participants may have initially engaged in letter-by-letter discrimination for clusters with wider gaps because *C* versus *O* discrimination is relatively easy with wide gaps. This strategy is slow, however, and affords little parafoveal processing, thereby resulting in spillover[1]. As a cluster was encountered more often and its representation became stronger, participants may have relied more on memory access, thereby reducing spillover.

Similarly, the finding that practice reduced parafovea-on-foveal effects of gap size provides further evidence that participants began to gradually treat clusters as holistic units. The finding that fixations were longer and more numerous when the upcoming cluster was *easier* to process (i.e., had wider gaps) appears to contradict the finding of longer fixation durations with *increased* parafoveal processing difficulty (e.g., Kliegl et al., 2006). A possible explanation for the current finding is that some parafoveal *C* and *O* discrimination may be possible for clusters with wide gaps; in these cases, participants may have adjusted their attentional window to process the current and upcoming clusters simultaneously. Under these conditions, attentional resources would be divided and processing slowed. The interaction with practice could indicate that this divided-attention strategy was relatively inefficient and became less likely with practice.

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[1] This account predicts the same interaction in gaze duration; analyses indicated such an interaction was marginally reliable (p = .092).

Some previous visual search studies have observed *no* effect of word frequency on eye movements across distractor words (Rayner & Fischer, 1996; Rayner & Raney, 1996). However, in those studies, target-distractor discrimination only required detecting surface-level perceptual differences (e.g., the target word *zebra* can be discriminated from most other words on the basis of its initial letter). In our task, the stimuli's homogeneity and high similarity to the target likely forced in-depth processing. This could have made strategies relying on memory access, and thus cognition, more effective and led to the observed reading-like eye movements. This explanation is consistent with other findings that the more deeply a scanning task engages cognition, the more similar eye-movement behavior is to reading (Kaakinen & Hyönä, 2010; Rayner, 1998; Reichle et al., 2008). It also complements findings that when readers are mind-wandering and thus not engaging cognition, fixations tend to be longer and less affected by cognitive variables, e.g., word frequency (Reichle et al., 2010).

Some have argued that word-frequency effects arise from perceptual tuning to familiar visual stimuli (McDonald et al., 2005), rather than as a consequence of memory access during lexical processing. The results of the current study do not rule out a perceptual tuning account, if tuning for specific exemplars becomes more precise with repeated encounters. However, the mechanisms of perceptual tuning are not well-specified in the literature, and within the context of many episodic word-processing models (e.g., Ans et al., 1998; Reichle & Perfetti, 2003), perceptual tuning and memory access are difficult, if not impossible, to dissociate. The current experiment brings us a step closer to demonstrating cognitive effects on eye movements by showing effects of memory accessibility in addition to effects of stimulus discriminability. Future research may provide more compelling evidence for the role of cognition in eye movement behavior by demonstrating predictability effects in this paradigm.

3.0 EXPERIMENT 2: EFFECTS OF WORD FREQUENCY AND PROCESSING DEPTH ON EYE MOVEMENTS IN READING AND VISUAL SEARCH

The precise nature of the link between cognition and eye-movement behavior during reading continues to be debated (Reichle, 2006). According to *oculomotor theories,* visual acuity and oculomotor constraints primarily determine both the timing and location of fixations (e.g., McDonald et al., 2005; O'Regan, 1990; Suppes, 1994; Yang, 2006; Yang & McConkie, 2001). In contrast, *cognitive* (*processing*) *theories* (e.g., Engbert, Nuthmann, Richter, & Kliegl, 2005; Just & Carpenter, 1980; Reichle et al., 1998; Salvucci, 2001) posit that moment-to-moment cognitive processes like word identification largely determine the timing of fixations during reading.

One piece of evidence for a tight coupling between cognition and eye movements is that readers make more and longer fixations on words that are infrequent and thus more difficult to process (e.g., Inhoff & Rayner, 1986; Just & Carpenter, 1980; Kliegl, Nuthmann, & Engbert, 2006; Rayner & Duffy, 1986; Schilling et al., 1998). Importantly, the presence of these *word-frequency effects* hinges on the task being performed. For example, although frequency effects are almost always present in reading for comprehension, they are absent when participants scan text for a target word (Rayner & Fischer, 1996; Rayner & Raney, 1996). This is consistent with the hypothesis that lexical processing, which is essential to reading, is linked to moment-to-moment "decisions" about when to move the eyes. However, these findings only support a simple characterization of this linkage, i.e., one in which cognition is either fully engaged and influences when the eyes move, or not.

The present study aims to provide more compelling evidence for an eye-mind link and refine our understanding of cognitive effects on eye movements by testing the following hypothesis: the strength of the link between eye movements and cognition depends on the degree to which the reader or scanner is currently engaging cognition. To encourage participants to differentially engage cognition, operationalized here as lexical processing, we manipulated task-processing depth (Craik & Lockhart, 1972; Craik & Tulving, 1975; see also Reichle et al., 2008). If word-frequency effects in reading reflect differences in the availability of lexical representations for high- and low-frequency words (e.g., Perfetti & Hart, 2001; Reichle & Perfetti, 2003), then the amount of lexical processing a task induces will predict the degree to which word frequency affects eye movements in that task. Specifically, tasks that induce deeper lexical processing (e.g., determining the meanings of words) should elicit larger word-frequency effects than tasks that induce shallow lexical processing (e.g., detecting the presence of a particular letter). Two recent findings support this prediction. First, Kaakinen and Hyönä (2010) observed larger word-frequency effects in an orthographic proofreading task than in reading for comprehension. This is consistent with our prediction, assuming that detecting errors in the proofreading task required more detailed lexical processing than reading for comprehension. Second, Reichle et al. (2010) observed larger word-frequency effects during normal reading than during periods when readers ‘zoned out’ and failed to generate a meaning for the text, i.e., mindless reading. The current study extends these prior findings with a task-depth manipulation that will allow us to more rigorously characterize the relationship between cognitive processing and eye movements.

This study also addresses a second question: are the attentional resources required for lexical processing distributed differently across tasks that require different amounts of cognitive processing? There are currently two theoretical perspectives on attention allocation in reading. The first is that attention is allocated serially, to support lexical processing of one word at a time (for a review, see Reichle, 2011). The second is that attention is allocated as a gradient, to support the concurrent lexical processing of multiple (typically 3 or 4) words (Engbert et al., 2005; Reilly & Radach, 2006; Engbert & Kliegl, 2011). To inform this debate, we investigated task effects on eye-movement measures collected from pairs of spatially adjacent high- and low-frequency words (i.e., adjective-noun pairs).

In reading, fixations on word *n* are typically longer if word *n - 1* is low frequency rather than high frequency, a phenomenon called the *foveal-load effect* (Henderson & Ferreira, 1990). This study investigates whether foveal-load effects appear in scanning tasks and — if so — whether there is a positive relationship between their magnitude and the depth of lexical processing induced by the tasks. The findings could discriminate between the two attention-allocation accounts. The attention-gradient account attributes foveal-load effects to a the narrowing of attention on the currently fixated word caused by the increase in that word's processing difficulty due to its low frequency (e.g., *SWIFT*: Engbert et al., 2005; Kliegl, Nuthmann & Engbert, 2006). If processing effort increases on word *n – 1*, then there will be less parafoveal processing of and longer fixations on word *n*. This prediction should generalize to search tasks, and predicts a positive relationship between the size of foveal-load effects and depth-of-processing. The serial-attention account attributes foveal-load effects to differences in the timing of attention shifts from low- and high-frequency words (e.g., *E-Z Reader*; Reichle et al., 1998). If lexical processing takes longer on word *n – 1*, then the attention shift from *n – 1* to *n* will be delayed, resulting in less parafoveal processing of and longer fixations on word *n*. The serial-attention account predicts foveal-load effects in visual search if attention and saccadic programming are coordinated similarly in reading and search tasks. However, recent simulations suggest that this coordination is tighter in search tasks than reading (Reichle, Pollatsek, & Rayner, 2012). If this is so, the serial-attention account predicts no foveal-load effects in search tasks.

Finally, although both parallel and serial theories predict foveal-load effects during reading, only parallel accounts predict effects of word *n* + 1 on word *n* (e.g., *SWIFT:* Engbert et al., 2005; *Glenmore:* Reilly & Radach, 2006). If words *n* + 1 and *n* are processed concurrently, increasing the difficulty of processing word *n* + 1 should reduce the attention available for processing word *n* and inflate fixation durations on it. Notably, the existence of such *parafoveal-on-foveal effects* in reading is highly contested (Drieghe, 2011; Rayner, White, Kambe, Miller, Liversedge, 2003; Reichle & Drieghe, 2012). Although these effects have been observed in some corpus studies (e.g., Kennedy & Pynte, 2005; Kliegl et al., 2006), they have rarely been observed in experimental studies (e.g., Rayner & Juhasz, 2004; White, 2008).

In contrast to reading, there is robust evidence for parallel processing in visual-search studies using certain types of non-word stimuli (e.g., Thornton & Gilden, 2007; Treisman & Gelade, 1980). This evidence is consistent with the possibility that shallower processing may encourage a wider spatial distribution of attentional resources, whereas deeper processing may encourage a tighter focusing of those resources. By employing scanning tasks that engender shallower versus deeper processing, the present study lends itself well to testing this prediction. It is important, however, to point out a potential confound: although shallow tasks may lead to more distributed processing and a greater likelihood of observing parafoveal-on-foveal effects, shallower processing may reduce the processing load difference between low and high frequency words, thus reducing the size of any potential parafoveal-on-foveal effects. However, to the extent that word-frequency effects are observed in the current experiment's shallow tasks, the presence or absence of concurrent parafoveal-on-foveal effects will inform the debate about attention allocation in tasks involving lexical processing.

In summary, the present study investigates the relationship between the depth of lexical processing induced by different tasks and eye movements in those tasks. To this end, we compared participants' eye movements on fully-crossed high- and low-frequency adjective-noun pairs embedded in paragraphs when participants were reading for comprehension versus engaged in one of three visual-search tasks: (1) *asterisk detection*, or scanning for words containing an asterisk (e.g., “h*rse”); (2) *letter detection*, or scanning for words containing the letter "q" (e.g., “quilt”); and (3) *rhyme judgment*, or scanning for words rhyming with "blue" (e.g., “shoe”). We predicted that the relatively shallow asterisk-detection task would not engage lexical processing and therefore not elicit word-frequency, foveal-load, or parafoveal-on-foveal effects. In contrast, the letter-detection, rhyme-judgment, and reading-comprehension tasks were expected to engage lexical processing, which should lead to word-frequency effects, possibly accompanied by foveal-load and/or parafoveal-on-foveal effects. Importantly, the size of the word-frequency effects should be related to the amount of cognitive processing that the tasks engage. Given that letter-detection emphasizes orthographic information, whereas rhyme-judgment necessitates the generation and retrieval of phonological information from orthographic codes, we predicted larger word-frequency effects in the rhyme-judgment than letter-detection task. The reading-comprehension task will allow a direct comparison between the visual search findings and normal reading. Although it is not immediately clear where reading falls along the depth-of-processing continuum, it is reasonable to assume that it requires significantly more lexical processing than simple letter-detection.

3.1 METHOD

3.1.1 Participants

Eighteen undergraduate psychology students at the University of Pittsburgh received partial course credit for their participation. They had either normal or corrected vision. The data of three participants were excluded from analysis due to low accuracy (below 70%).

3.1.2 Materials

Eighty-four passages of approximately 134 words were used in the study. Sixty-four of these passages contained two critical adjective-noun pairs that were positioned towards the middle of two different lines. Critically, none of these 64 passages contained targets for any of the search tasks. Four versions of 64 passages were created to counter-balance word frequency across these pairs, as shown in the example paragraphs in Table 3. A single participant saw only one version of each paragraph. The critical pair-containing paragraphs were randomly assigned to four lists, which were rotated through each of the following conditions using a Latin-square design: (1) reading for comprehension, (2) asterisk-detection, (3) letter-detection, and (4) rhyme-judgment.

The adjectives and nouns in the critical word pairs were either high frequency (HF) or low frequency (LF), with this frequency manipulation being fully crossed. The HF and LF words were either synonyms or semantically similar near-synonyms (e.g., *whimsical-fantastic*, *vehicle-chariot*) to minimize meaning differences across versions of a paragraph. The critical words were selected using the English Lexicon Project (Balota et al., 2007). HF words had log HAL frequencies of 8 or greater (mean = 9.39) and LF frequency words had frequencies of 7 or less (mean = 5.78) (Burgess & Livesay, 1998; Lund & Burgess, 1996). All words were between 5-9 characters long, and HF and LF words were matched for length as closely as possible (mean length HF = 6.97; LF = 6.79).

3.1.3 Experimental design

Tasks were blocked, with each block consisting of 21 trials, 5 of which contained a target in the search tasks or were followed by a "*true*" true/false (T/F) statement in the reading-comprehension task. Task blocks were presented in random order. Between blocks, participants took short breaks and the eye-tracker was recalibrated.

3.1.4 Procedure

At the beginning of each task, participants were told to read for comprehension or search for a particular target. In the search tasks, they were instructed to scan the passages line by line, from left to right. After completing a passage, participants pressed a button to replace it with a screen requesting either a target present/absent response or, in the reading-comprehension task, a response to a T/F statement.

Table 3

Four versions of a sample paragraph illustrating the counter-balancing of word frequency across the two adjective-noun pairs

Written language is not just something one encounters on paper or etched in stone. The penchant for writing dwells in every man's heart. The urge is so powerful that the content does not always matter. Sometimes, it is just a curse, a venomous cry, an obscenity thrown at the heavens. The graffiti on the walls and on the bridge is very representative of the ***extensive writings*** **(HF-HF)** left behind by an unknown but steady hand all over the city. Writing appears in the strangest and darkest places where there is no one that can read it. Even in the infernal depths of the subway tunnel some scribe leaves that ***hackneyed memento*** **(LF-LF)** of love as reflected in the pairing of names, souls, or more likely, bodies: "Alice loves Michael." Where is Alice now? Has she remained faithful? Has this love endured?

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3.1.1 Equipment

Participants viewed the stimuli binocularly on a 23-in. monitor 63 cm from their eyes with approximately 3 letters per 1° of visual angle. An EyeLink 1000 eye-tracker (SR Research Ltd.)

recorded gaze location of participants' right eyes (although viewing was binocular) and sampled gaze location every millisecond.

3.2 RESULTS

3.2.1 Behavioral results

Overall accuracy was approximately 90%. There were significant differences in accuracy by task [$F(1,13) = 14.75$, $p < .01$], with the lowest accuracy in the rhyme-judgment task [vs. asterisk-detection: $t(13) = 5.58$, $p < .01$; vs. letter-detection: $t(13) = 3.82$, $p < .05$], but similar accuracy across the other tasks (all *p*s > .05).

3.2.2 Eye-tracking results

Analyses focused exclusively on non-target trials because only they contained the adjective-noun frequency manipulation. Two eye-movement measures were examined on each word of each critical pair, conditional on it not being skipped: *first-fixation duration* (*FFD*), or the duration of the initial fixation during first-pass scanning, and *gaze duration* (*GD*), or the sum of all first-pass fixation durations.

Fixations shorter than 80 ms and longer than 1200 ms were trimmed prior to analysis, resulting in the loss of approximately 1.4% of the data. Data were analyzed using linear mixed-effects (*lme*) models with *p*-values estimated using Markov-chain Monte-Carlo sampling. Because the analyses were performed on log-transformed measures, regression weights cannot be directly interpreted as effect sizes; estimated effect sizes and means (see Figures 2 and 3) are therefore reported from lme analyses of untransformed data.

All models specified participants, items, and trial number as crossed random effects. When the lengths of the currently fixated and next word were included as predictors, the effects were in the expected direction (e.g., longer words were fixated longer than shorter words). However, because these two factors were not manipulated, they were specified as crossed random effects in the reported models to simplify the reporting of the results. Only directly manipulated factors (*task type, word frequency*) are reported here. A backward model-selection procedure determined which interaction terms (if any) should be included as predictors, re-fitting the reduced models and making comparisons using log-likelihood ratio tests as necessary. Only the results of models selected by this procedure are reported.

For the word-frequency analyses described below, data for adjectives and nouns was pooled. This was done despite a significant interaction of task type × part of speech [FFD: $F(3, 2616) = 4.0$, $p < .01$; GD: $F(3, 2613) = 5.96$, $p < .05$][2] which indicated that, although adjectives and nouns were on average fixated for approximately the same amount of time ($p > .05$), in the reading-comprehension task fixations on adjectives were shorter than on nouns ($b < 12.72$, $p < .05$). Notwithstanding this observed interaction, the data for adjectives and nouns were combined because the model comparisons indicated that the three-way interaction (i.e., task type × frequency × part of speech) was unreliable (FFD and GD *p*s > .05), and because the effect of

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[2] A mixed-effects model [*lmer()* or *lme*() in *R*] does not generate regression coefficients corresponding to the Type III of fixed effects for the predictors that are categorical variables with three or more levels (e.g., task type in the present study). Therefore, to make the reporting of our results more complete, Analysis of Variance (*ANOVA*) was performed on the corresponding *lme* model with categorical variables recoded for effect coding [*anova.lme(lme_model_name, type = "marginal", adjustSigma = F)*].

frequency was in the same direction for both parts of speech. Part of speech was specified as a random effect in all analyses in which the adjective and noun data were pooled.

3.2.2.1 Word-frequency effects

3.2.2.2 First-fixation durations

The results for first-fixation durations are summarized in Panel A of Figure 2. There was a main effect of frequency on first-fixation durations ($b = 17.84$, $SE = 3.53$, $p < .01$), with shorter fixations on HF than LF words. There was also an effect of task: first fixations were shortest in asterisk-detection (vs. letter-detection: $b = 11.12$, $SE = 2.58$, $p < .01$; vs. rhyme-judgment: $b = 21.84$, $SE = 2.52$, $p < .01$; vs. reading-comprehension: $b = 23.88$, $SE = 2.5$, $p < .01$), intermediate in letter-detection (vs. rhyme-judgment: $b = 9.61$, $SE = 2.32$, $p < .01$; vs. reading-comprehension: $b = 10.93$, $SE = 2.31$, $p < .01$), and longest and of similar duration in the rhyme-judgment and reading-comprehension tasks ($b = 1.75$, $SE = 2.28$, $p = .59$). There was no reliable interaction of frequency and task on first-fixation durations ($p > .05$).

3.2.2.3 Gaze durations

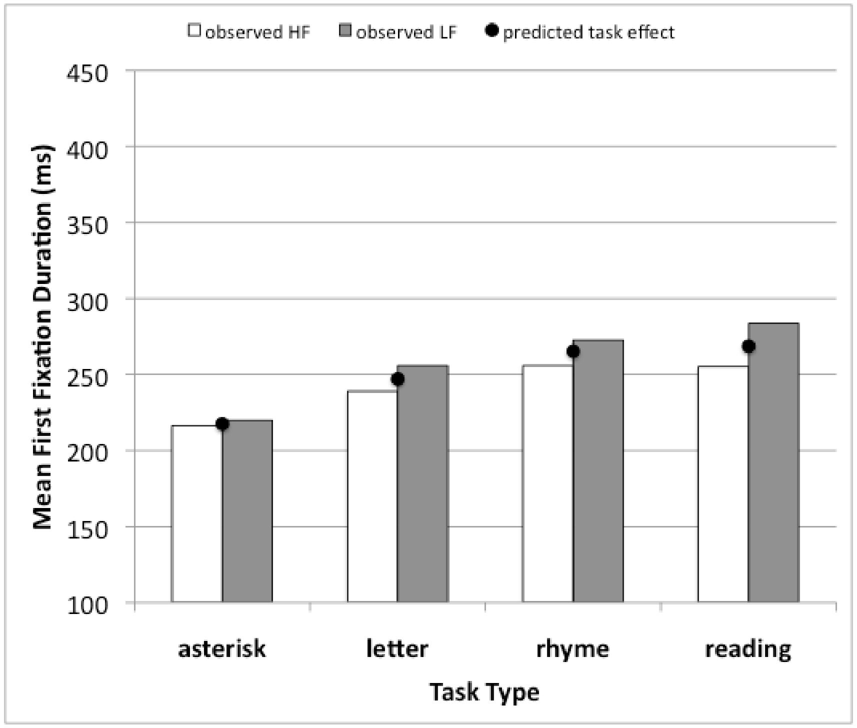
The results for gaze duration are summarized in Panel B of Figure 2. Gaze duration showed the same main effect of frequency as first-fixation duration ($b = 32.19$, $SE = 3.39$, $p < .01$), and also the same effect of task. Gaze durations, like first-fixation durations, were shortest in the asterisk-detection task (vs. letter-detection: $b = 22.86$, $SE = 4.82$, $p < .01$; vs. rhyme-judgment: $b = 63.23$, $SE = 4.61$, $p < .01$; vs. reading-comprehension: $b = 51.28$, $SE = 4.66$, $p < .01$), intermediate in the letter-detection task (vs. rhyme-judgment: $b = 33.97$, $SE = 4.31$, $p < .01$; vs. reading-comprehension: $b = 24.32$, $SE = 4.33$, $p < .01$), and marginally longer in rhyme-judgment than reading-comprehension tasks (*b* = 9.18, *SE* = 4.27, *p* = .05). The interaction of task type × frequency was also reliable [$F(3, 2613) = 8.28$, $p < .05$]. Although gaze durations showed no effect of frequency in the asterisk-detection task ($p > .05$), they did in the other tasks, with the size of the frequency effect increasing with the depth-of-processing; i.e., gaze durations were approximately 14 ms longer for LF than HF words in letter-detection (*b* = 14.39, *SE* = 6.48, $p < .01$), and this difference increased to 52 ms in rhyme-judgment (*b* = 51.88, *SE* = 6.18, $p < .01$) and 40 ms in reading-comprehension (*b* = 39.75, *SE* = 6.2, $p < .01$).

3.2.2.4 Foveal-load and parafoveal-on-foveal effects

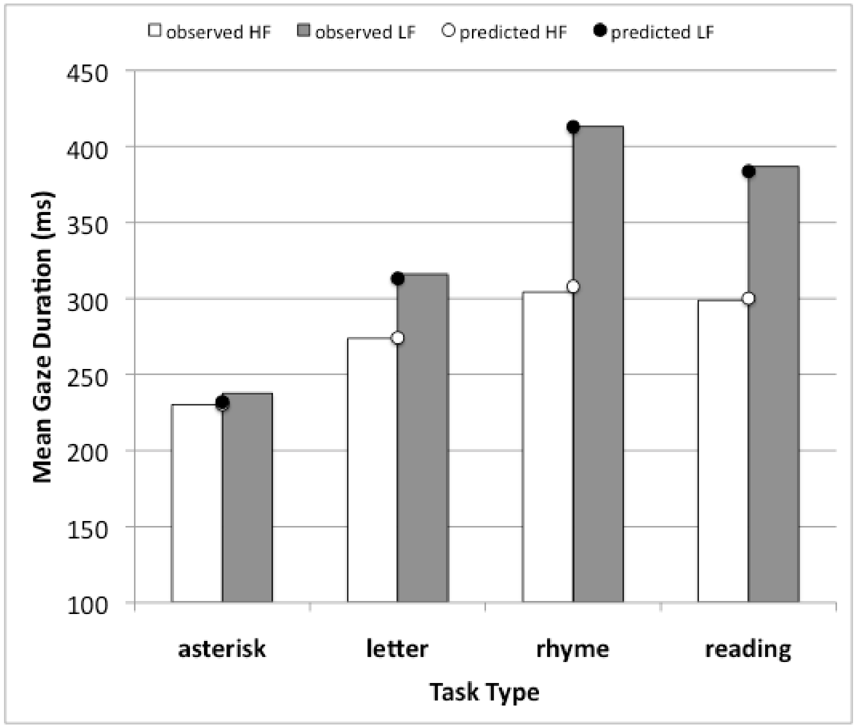
To investigate foveal-load effects, we examined first-fixation durations on the nouns as a function of the following variables: (1) task, (2) frequency of the currently fixated noun, and (3) frequency of the previously fixated adjective. Estimated and observed means are shown in Figure 3. First fixations showed the same effects of task [$F(3, 1103) = 21.21$, $p < .01$] and frequency of the currently fixated noun [$F(1, 1103) = 14.52$, $p < .01$] as the previous reported analyses, but also reliable interactions of task type × noun frequency [$F(3, 1103) = 3.61$, $p < .05$] and adjective frequency × noun frequency [$F(1, 1103) = 4.49$, $p < .05$]. Contrast analyses indicated that the participants' first-fixation durations were shorter on nouns preceded by HF adjectives only in the reading-comprehension task (*b* = 16.76, *SE* = 4.82, $p < .01$), with all other comparisons being non-significant (all *p*s > .05). The interaction of adjective frequency × noun frequency indicated that the foveal-load effect in the reading-comprehension task was present only for HF nouns (*b* = 11.11, *SE* = 3.69, $p < .01$). We tested for parafoveal-on-foveal effects by including noun frequency as a predictor for eye-movement measures on the adjective. This predictor was not reliable for either first-fixation or gaze durations (both *p*s > .05).

Figure 2. Observed means and estimated means from lmer models for eye-movement measures on target-absent trials (fixation durations in *ms*).[3]

Panel A. First-fixation durations.



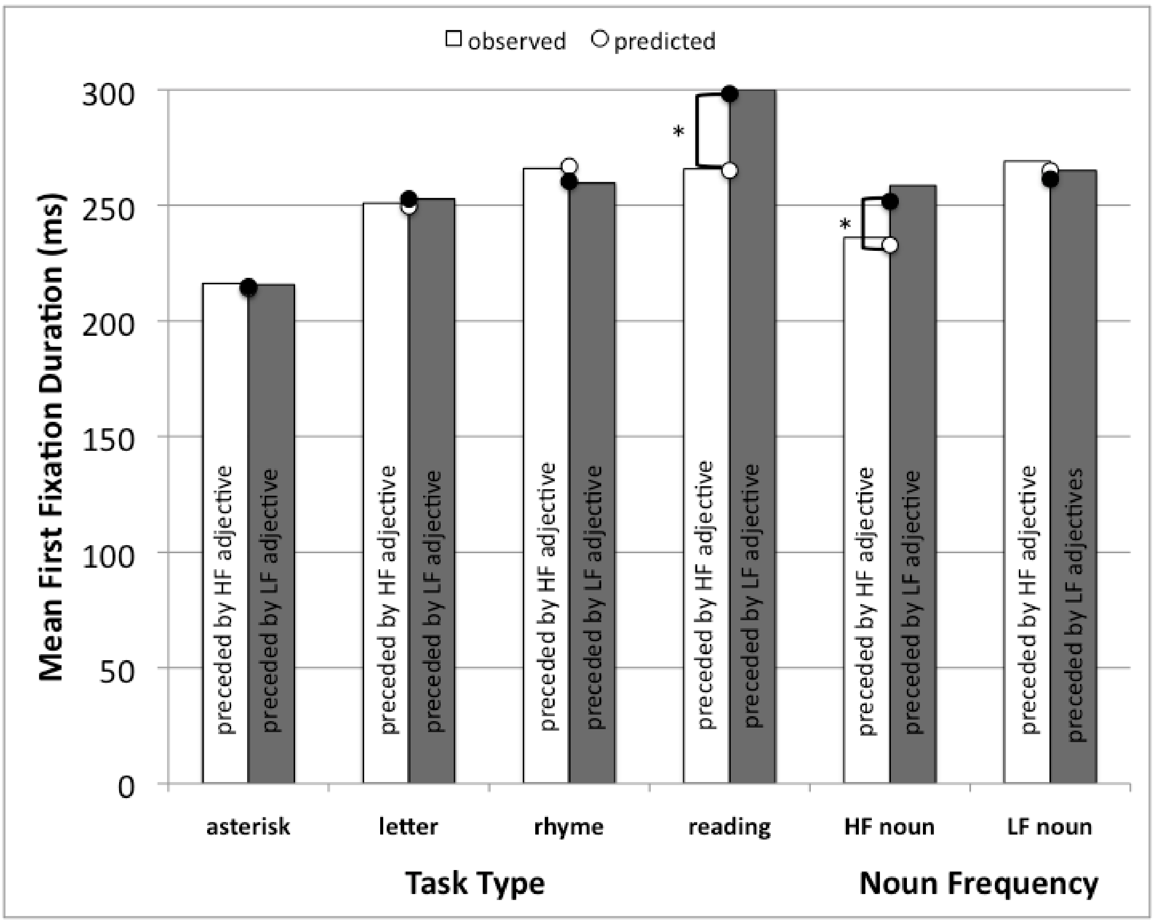
Panel B. Gaze durations.



[3] Note that the graph for first fixation durations only displays the predicted task effect means. The predicted difference for HF vs. LF words per each task condition is not shown because the interaction of task type × frequency was not reliable for first fixation durations. The predicted difference between HF vs. LF words (main effect of frequency) is reported in the text.

Figure 3

Effects of foveal load: Observed means and estimated means from lmer models of first-fixation durations on nouns as a function of task type and adjective frequency, and as a function of noun frequency and adjective frequency.



3.3 DISCUSSION

To summarize the current findings, the word-frequency manipulation had no effect in the asterisk-detection task, a 14-ms effect in letter-detection, a 52-ms effect in rhyme-judgment and a slightly smaller 40-ms effect in reading for comprehension. There were no foveal-load effects in any visual-search task and only modest foveal-load effects on high-frequency nouns during normal reading. There was no evidence of parafoveal-on-foveal effects in any task.

These results provide compelling evidence for an eye-mind link and refine our understanding of cognitive effects on eye movements. As anticipated, the magnitude of word-frequency effects across tasks was positively related to the predicted amount of lexical processing within each task. Although the letter-detection task could have been performed via a series of character-by-character discriminations, the presence of small word-frequency effects in this task suggests that participants did activate lexical representations when looking for a “q”. At the other extreme, the rhyme-judgment task, which requires one to retrieve and/or generate phonology from an orthographic code and then compare that information to the phonological representation of the target word “blue”, generated the largest word-frequency effects. The fact that the word-frequency effects observed in normal reading were smaller than in the rhyme-judgment task is consistent with the hypothesis that reading comprehension may have been occasionally only ‘good enough’, and not engaged lexical processing as fully as the rhyme-judgment task (e.g., Ferreira & Patson, 2007; Sandford & Sturt, 2002; Sturt, Sanford, Stewart & Dawydiak, 2004). Alternatively, participants may have lapsed into intervals of mindless reading, during which lexical processing would be expected to become more superficial (Reichle et al., 2010). The overall pattern of findings indicates that lexical processing influences decisions about when to move the eyes, and that the deeper the lexical processing, the more pronounced are the differences in timing of saccades from low- versus high-frequency words, consequent to those decisions.

The results of Experiment 1 and the current study suggest that mechanisms of memory access and retrieval, of which lexical processing may be a special instance (e.g., Ans et al., 1998; Kwantes & Mewhort, 1999; Reichle & Perfetti, 2003), can manifest themselves in the eye-movement record. Experiment 1 demonstrated that the frequency with which non-word distractor stimuli are encountered across a search task affects fixation durations on those stimuli. In that experiment the visual features of distractors and targets were very similar; discrimination presumably necessitated in-depth processing. The retrieval from memory of the fact that a fixated stimulus was a previously rejected distractor facilitated this otherwise time-consuming discrimination and influenced saccadic programming.

It is worth noting that the absence of word-frequency effects in previous visual-search experiments (e.g., Rayner & Fischer, 1996; Rayner & Raney, 1996) is not inconsistent with either the current findings or those of Experiment 1. The searches in these previous studies may have failed to engage lexical processing, like our asterisk-detection task. For example, the word "zebra" (a target in previous studies) can be found by looking only at the first letter of each word because its presence is highly diagnostic of target presence (see Kaakinen & Hyönä, 2010). In contrast, the letter-detection and rhyme-judgment tasks are different from these simple search tasks because efficient performance of these tasks is not possible by simply examining the first letter of each letter string, and as such the tasks encourage participants to more deeply engage in lexical processing and to access lexical representations.

The findings reviewed so far provide evidence of important similarities in eye-movement behavior in reading and non-reading tasks; in contrast, the foveal-load effects highlight important differences. We observed foveal-load effects only during reading, and only for high-frequency nouns (cf. Henderson & Ferreira, 1990). This finding is consistent with previous research showing larger parafoveal preview for high-frequency words (e.g., Inhoff & Rayner, 1986). One explanation for the absence of foveal-load effects in the letter-detection and rhyme-judgment tasks is suggested by the results of recent simulations using the E-Z Reader model of eye-movement control in reading to examine a variety of non-reading tasks (Pollatsek, Reichle, & Rayner, 2006; Reichle et al., 2012). According to E-Z Reader, saccadic programming and attentional shifts are decoupled during normal reading: saccadic programming is triggered by the completion of an early stage of lexical access, whereas attention shifts are triggered by the completion of lexical access. This means that attention often moves to the next word ahead of the eyes, which allows the model to account for parafoveal preview in reading. Interestingly, recent E-Z Reader simulations of non-reading tasks were most successful when saccadic programming and shifts of attention were synchronized (Reichle et al.), suggesting that the relationship between overt and convert attention may be qualitatively different during reading and non-reading tasks. The current findings are consistent with this hypothesis—even if the non-reading tasks required lexical processing. Our findings do not, however, rule out the possibility that the nouns may have been more contextually predictable from high- than low-frequency adjectives during reading. Contextual predictability would not be expected to play a role when searching for a word with a particular letter or rhyming with blue, which also may have led to the differences of foveal load effects between the two categories of tasks.

An alternative, but less plausible, explanation of the observed pattern of foveal-load effects is that fine-grained information (e.g., the specific features for the target letter "q") may be less accessible in parafoveal vision because of visual acuity limitations, thereby eliminating any interaction between foveal load and parafoveal preview. This explanation, however, contradicts numerous earlier findings indicating that both phonological and orthographic codes can be extracted from the parafovea (e.g., Ashby & Rayner, 2004; Ashby, Treiman, Kessler, & Rayner, 2006; Chace, Rayner, & Well, 2005; Miellet & Sparrow, 2004; for an extensive review of parafoveal processing, see Schotter, Angele & Rayner, 2012).

Finally, no parafoveal-on-foveal effects were observed in this experiment. Although attention-gradient models (e.g., Engbert et al., 2005) predict these effects in reading, empirical attempts to find such effects have often failed (e.g., Rayner & Juhasz, 2004; White, 2008). One possible explanation for these failures is that the difficulty of lexical processing during reading may often limit the gradient of attention to a single word. By this account, one would expect more parallel processing of words in a task like letter-detection, where smaller effects of word frequency indicate more superficial lexical processing than in reading. However, there were no parafoveal-on-foveal effects in this task. This pattern of data is therefore more consistent with models of eye-movement control in which attention is allocated serially during lexical-processing tasks (e.g., Reichle, Liversedge, Pollatsek & Rayner, 2009).

In conclusion, the present study provides support for cognitive theories of eye-movements by demonstrating that word-frequency effects are only present in tasks that require some degree of lexical processing. Importantly, the magnitude of these effects was modulated by the depth-of-processing across the tasks, suggesting that cognitive involvement is determined by the degree to which a task necessitated lexical processing. This finding is important because it suggests that, although the decisions about when to move the eyes are largely under local cognitive control, global aspects of the performed task (e.g., searching for letters vs. generating and comparing phonological representations) can also modulate the overall rate at which the eyes progress through the text. Elaborating on how the local control of eye movements is modulated by global task constraints remains a challenge for theories of eye-movement control during reading.

4.0 EFFECTS OF TRANSITIONAL PREDICTABILITY IN VISUAL SEARCH AND READING: LEARNING FROM FREQUENCY OF CO-OCCURRENCE

There is considerable evidence that contextually predictable words, i.e. those that are assigned high values in a *cloze* task, receive shorter fixations, are more likely to be skipped, and are less likely to be refixated (Balota et al., 1985; Ehrlich & Rayner, 1981; Morris, 1994; Rayner, 1998; Rayner et al., 2004; Rayner, Slattery, Drieghe, & Liversedge, 2011b; Rayner & Well, 1996; Schustack et al., 1987). Several sources of predictability, e.g., semantic, syntactic, and/or probabilistic, likely combine to drive the effects in the cloze task. The current chapter presents the findings of two experiments that investigate the extent to which a text's statistical properties contribute to the predictability of upcoming words and influence eye-movement behavior. Specifically, the experiments test the hypothesis that if readers form expectations about upcoming words based on the frequency of words' co-occurrence, then a match in this expectation should reduce the duration and number of fixations on the "predicted" word. Experiment 3 investigated whether eye movements were affected by statistical predictability resulting from the repeated exposure to pairs of non-linguistic stimuli in a reading-like task. Experiment 4 extended the results of Experiment 3 to reading, by observing whether increased exposure to co-occurring word pairs can influence eye-movements on the second or "predicted" word in a pair.

The present research investigates whether statistical properties of language, thought to help support language acquisition (for a review, see Gómez & Gerken, 2000), may continue to play a role during reading and affect eye-movement behavior. There is evidence that the visual system can become sensitive to statistical predictability of stimuli, but a direct demonstration that statistical patterns in text can elicit effects in eye-movement behavior has been lacking. For example, statistical learning of spatial-temporal patterns has been demonstrated to shorten fixation durations when there is a match between expectations based on learning, and the experimental stimuli (Kirkham, Slemmer, & Johnson, 2002; Kirkham, Slemmer, Richardson, & Johnson, 2007). With regard to statistical patterns in text affecting the processing of language, it has also been suggested that mismatches in probabilistically-based expectations may explain difficulties in comprehension during reading (e.g., Hale, 2001; Levy, 2008). For example, self-paced reading experiments find longer reading times on syntactic constructions that are more improbable given preceding linguistic input (e.g., Reali & Christiansen, 2007a, 2007b; Roland, Mauner, O'Meara, & Yun, 2012). In addition, statistical predictability estimates derived from corpora (sometimes combined with empirically-derived measures of predictability, i.e., from cloze tasks) account for some of the variability in eye-movement behavior (e.g., Wang et al., 2012). The findings from studies like this conducted on the Potsdam sentence and Dundee corpora demonstrate that mismatches to readers' high-probability predictions result in longer first-fixations, single-fixations, gaze durations, and overall reading time, as well as greater probabilities of a regression (Boston et al., 2008; Demberg & Keller, 2008). These studies, however, can address only to a limited extent two important and related questions: what readers were probabilistically predicting about an upcoming word and when during processing this information became relevant.

One important limitation of the past findings is that the purported effects of probabilistic predictability are conflated with other sources of variability, e.g., semantic association. The present research attempts to address this limitation by manipulating statistical predictability directly. Specifically, we investigate whether eye movements can learn to track a simple statistical pattern, namely, the conditional probabilities (or *transitional predictability*) of both linguistic and non-linguistic stimuli. A direct manipulation of statistical predictability can also begin to address another question left open by past research. Namely, past findings conflate the different probabilistic predictions a reader may be making about the characteristics of upcoming text: the upcoming word's meaning, its syntactic category, the shape and/or length of the upcoming word, or all three. This variability in the type of predictions could partially underlie the lack of consistency in the reported findings about which eye-movement measures are affected by probabilistically-based predictability. Some studies report influences on "early" processing measures, e.g., first fixation duration but not total reading time (McDonald & Shillcock, 2003a, 2003b; Wang et al., 2012). Others observe effects on the full range of eye-movement measures, including total reading time and regressions (e.g., Demberg & Keller, 2008). Hence, by focusing on a simple pattern like conditional predictability and by directly manipulating the frequency of co-occurrence, the present research can (a) provide evidence that the eyes can indeed track some statistical information and (b) provide a more careful investigation of what type of information is being predicted. The current experiments do so by exposing participants to pairs of co-occurring stimuli during visual search and reading. Over time, repeated exposure should result in increasing statistical predictability of the second stimulus in the pair. The present studies investigate whether the predicted stimulus will become easier to process and, hence, whether it will receive shorter and fewer fixations.

The experiments in this chapter focus on the eye-movement effects of transitional predictability. At present, evidence for such effects comes almost entirely from large corpora studies; there is only one such experimental study. In this study, McDonald and Shillcock (2003a) experimentally manipulated transitional predictability by using nouns that predicted a target verb with high/low probability, and observed a small (11-12 ms) effect on first fixation durations on the target verbs. In addition, their 2003b corpus study found that transitional predictability was a reliable predictor of first fixation durations, gaze durations and skipping rates. However, Frisson et al. (2005) showed that transitional predictability was conflated with contextual predictability in these studies. Frisson et al. also caution that estimated transitional predictability is often correlated with word frequency. Cumulatively, the findings of Frisson et al. highlight the challenge of demonstrating that transitional predictability makes an independent contribution to predictability in context without a proper experimental manipulation. More recently, Wang et al., (2010) controlled for contextual predictability by including a measure of latent semantic analysis (LSA; Landauer & Dumais, 1997) as one of the predictors and still observed effects of transitional predictability on first fixation durations in Chinese. To the degree that LSA overlaps with contextual predictability, these findings may indicate that transitional predictability effects make an independent contribution from predictability that is based on semantic association between words. In the experiments in this chapter, we attempt to capture the effects of learning transitional predictabilities by observing how eye movements change as a function of co-occurrence frequency. Because we manipulate co-occurrence frequency in the context of the present studies, we can with greater certainty demonstrate the contribution of probabilistic predictability effects to contextual predictability.

4.1 EXPERIMENT 3: CO-OCCURRENCE EFFECTS IN VISUAL SEARCH

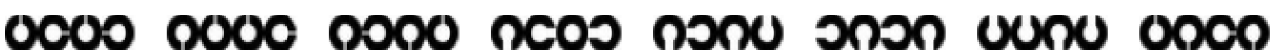
Experiment 3 investigates the effects of co-occurrence frequency using the paradigm from Experiment 1 (see also Corbic et al., 2007; Williams & Pollatsek, 2007). In addition to the previously tested manipulation of individual cluster frequency, the present study manipulates the frequency of pairs of clusters. We observe whether episodic learning due to repeated exposure to these pairs affects eye movements. The novel prediction for the current study is that as the number of encounters with the pair increases, we should also observe shorter and fewer fixation durations on the second (predicted) cluster in the pair. Similar to Experiment 1, in the present study participants scanned lines of Landolt-C clusters, or circles with a missing segment of varying size and orientation, to locate clusters containing an O, i.e., targets. The number of pixels in the missing segments, the gap size, was held constant within a given cluster, but manipulated between clusters. In this way the perceptual difficulty of identifying a cluster as a non-target varied with the gap size, and, accordingly, distractor clusters with larger gap sizes receive shorter and fewer fixations (e.g., Experiment 1; Williams & Pollatsek, 2007). In parallel to Experiment 1, the manipulation of gap size was employed in the current study as a way to separately demonstrate the influence of perceptual processing difficulty from the influence of presumed cognitive variables, e.g., frequency of a single cluster. Because processing differences due to the perceptual difficulty of clusters have already been replicated, and are not this study's primary concern, we employed only two gap sizes (the largest and the smallest from the previous study). Similarly to Experiment 1, we predict that fewer and shorter fixations will be associated with clusters with larger gaps and with more encounters with a single cluster. Importantly, we attempt to disassociate the effects of co-occurrence frequency from that of the frequency of the individual clusters, by having the clusters in the repeating pairs occur equal number of times throughout the experiment. Note that we do not use a direct measure of transitional predictability because this measure would not capture the effects of learning to predict from co-occurrence of the stimuli. For example, in the case where at every occurrence a cluster *X* was preceded by the same cluster *Y*, the conditional probability (or transitional predictability) of *X* would be equal to one throughout the entire experiment. Hence, the measure of the conditional probability would not reflect the updating of one's expectations based on repeated exposure to a pair of stimuli.

4.1.1 Method

4.1.1.1 Participants

Seventeen undergraduate psychology students at the University of Pittsburgh received either partial course credit or were paid $15.00 for their participation. Participants scanned lines of eight clusters of Landolt Cs in search of one containing an O. They all had either normal or corrected vision and were naive concerning the purposes of the study.

Figure 4. Example target-present trial (target is located in the 4th letter cluster).



4.1.1.2 Experimental design and materials

Fifty-six of 295 total trials contained a single target (i.e., a cluster with an O). An example target present trial is provided in Figure 4. Targets appeared with equal probability in any cluster position. Distractor clusters were 4-characters long with small (2-pixels) or large (8-pixels) gap sizes. Gap size was the same within a cluster but gap orientation (left, right, top, or bottom) was randomized to create unique exemplars. Four pairs of exemplars with gap size fully crossed were created for each of the five transitional predictability categories (0, .25, .50, .75, and 1). Each cluster in each pair appeared 40 times across the experiment for all transitional predictability categories except 0. When transitional probability was zero, the second cluster was repeated 40 times but was always preceded by a unique cluster. For pairs in the transitional probability category of 1.0, the second cluster was preceded by the first cluster 40 times across the experiment, whereas for pairs in the transitional probability category of .75, the second cluster was preceded by the first 30 times and by other unique clusters 10 times. The assignment of pairs to trials was randomized. No manipulated pairs occurred after a target on a line to maximize the probability of fixation on the clusters of interest.

4.1.1.3 Procedure

The procedure was the same as in the Experiment 1. Each trial began with participants viewing a dot on the leftmost side of the screen to verify that their gaze (and scanning) would proceed from left to right. Participants initiated the display of stimuli with a button press, after which a horizontal line of Landolt-C clusters appeared for 12 seconds. Participants were instructed to scan the stimuli from left to right. When their gaze shifted to the right of the line, the stimuli were replaced by a question mark. Participants pressed one joystick button if they located a target and another button if they did not. Performance feedback was provided for all trials.

4.1.1.4 Equipment

Participants viewed the stimuli binocularly on a 23-in. monitor 63 cm from their eyes with approximately 3.5 letters per degree of visual angle. An EyeLink 1000 eye-tracker (SR Research Ltd.) recorded the gaze location of the right eye. The eye-tracker had a spatial resolution of 0.01° and sampled gaze location every millisecond. The task presentation was done using E-Builder software (SR Research Ltd.).

4.1.2 Results

4.1.2.1 Behavioral results

Overall, participants' mean accuracy on the visual search task was greater than 95%. Participants had a mean hit rate of 79.9% and a mean false alarm rate of less than 0.4%. One participant was excluded from the eye-tracking analyses because of low accuracy (hit rate of 30.35%, false alarm rate of 8.79%, and overall accuracy less than 80%).

4.1.2.2 Eye-movement results

The following eye-movement measures were considered: (a) *first-fixation duration*, or the duration of the initial fixation on a cluster during first-pass scanning; (b) *gaze duration*, or the sum of the durations of all fixations on a cluster during first-pass scanning; (c) *number of fixations* on a cluster during first-pass scanning. Analyses focus exclusively on participants' eye-movements on the second clusters of the manipulated distractor pairs. Participants fixated the majority of distractor clusters, with approximately 4.0% being skipped. Fixations shorter than 80 ms and longer than 1000 ms were removed, resulting in a loss of 1.6% of the data.

We examined the effects of the following predictors: the gap sizes of the preceding and current clusters, the number of times the current cluster was seen by a participant, the number of times the current cluster was seen preceded by the preceding cluster (to reflect the learning to predict the current cluster from co-occurrence frequency of the pair), and the trial number. The effects of trial number were in the expected direction, i.e., shorter and fewer fixations were observed with more practice in the task.

Data were analyzed using a linear mixed-effects (lme) model with participants and items as crossed random effects to reflect the variability due to participants and items. All non-categorical predictors were centered to minimize collinearity among variables and their interactions. The *p*-values were estimated using Markov-Chain Monte Carlo sampling. The regression weights cannot be directly interpreted as effect sizes because the analyses were performed on log-transformed measures; an inverse logistic transformation was performed on the parameter estimates for the measures reported in Table 4, and estimated effect sizes from lme analyses on the untransformed data are reported in text. A backward model selection procedure was used to determine which interaction terms (if any) should be included as predictors, as necessary re-fitting reduced models and making comparisons with the larger models using log likelihood ratio tests. Only the results of the models selected by this procedure are reported.

4.1.2.3 First-fixation durations

Contrasts to examine the main effect of the current cluster's gap size indicated that shorter first fixation durations were associated with large gaps (b = -23.87, SE = 0.97, $p < .01$). Post-hoc contrasts for the interaction of gap size of cluster n × gap size of cluster $n - 1$ indicated that an increase in the preceding cluster's gap size resulted in shorter fixation durations on currently fixated clusters with large gaps (b = -5.94, SE = 1.41, $p < .01$), but did not did not affect processing of currently fixated clusters with small gaps ($p > .05$).

Repeated encounters with the cluster and with the cluster in the pair inflated first fixation

Table 4

Parameter estimates for fixed effects on eye-movement measures for the predicted cluster

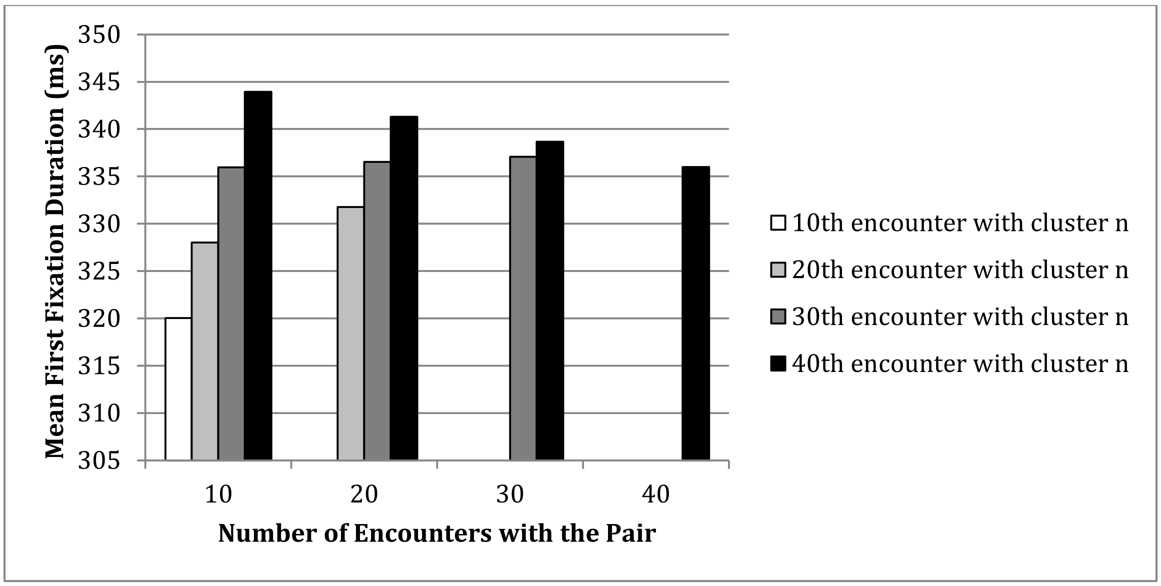
Effect	First Fixation Duration	Gaze Duration	Number of Fixations
Intercept	318.30**	636.83**	2.31**
Current cluster (*n*) gap size	-30.52**	-158.16**	-0.44**
Preceding cluster (*n* – *1*) gap size	3.52	-8.79	-0.09**
Number of encounters with cluster *n*	0.96**	-0.51	-0.002*
Number of encounters with the pair	0.64†	0.45	-0.007**
Gap size of cluster *n* × gap size of cluster *n - 1*	-14.72**	-30.68**	n/a
Gap size of cluster *n* × number of encounters with *n*	-0.32†	0.57	n/a
Gap size of cluster *n* × number of encounters with the pair	-0.46†	-2.29**	n/a
Gap size of cluster *n* – *1* × number of encounters with cluster *n*	-0.42*	0.13	n/a
Gap size of cluster *n* – *1* × number of encounters with the pair	0.74**	-0.45	n/a
Number of encounters with cluster *n* × number of encounters with the pair	-0.03**	n/a	0.0003**
Gap size of cluster *n* × gap size of *n* – *1* × number of encounters with *n*	n/a	-2.16**	n/a
Gap size of cluster *n* × gap size of *n* – *1* × number of encounters with the pair	n/a	2.87*	n/a

Note: * $p < .05$, ** $p < .01$, † $p < .08$

durations (0.96 ms and 0.64 ms, respectively). We performed stratified analyses (within each level of gap size) to further investigate how perceptual processing difficulty interacted with these two factors of interest. These analyses suggested repeated encounters with a cluster inflated first fixation durations more when the preceding and current clusters had small gaps (preceding cluster with a small gap: $b = 0.68$, $SE = 0.16$, $p < .01$ vs. preceding cluster with a large gap: $b = 0.24$, $SE = 0.16$, $p < .01$; the current cluster with a small gap: $b = 0.58$, $SE = 0.18$, $p < .01$ vs. current cluster with a large gap: $b = 0.30$, $SE = 0.14$, $p < .01$). In contrast, repeated encounters with a pair inflated first fixation durations only when the preceding cluster had a large gap ($b = 1.14$, $SE = 0.42$, $p < .01$; no effect for preceding clusters with small gaps: $p > .05$), or for current clusters with a small gap ($b = 0.98$, $SE = 0.47$, $p < .05$; no effect for current clusters with a large gap: $p > .05$). These interactions and the stratified analyses, therefore, suggest that the visual system may have been adjusting flexibly to perceptual processing difficulties associated with gap size by utilizing frequency and predictability information to a different degree for each type of pair. In order to better understand the implications of these adjustments, we also analyzed first fixation durations for each type of preceding and current cluster pairs separately, i.e., for pairs with small-small, small-large, large-small and large-large gaps. These analyses confirmed the patterns reported earlier. Namely, repeated encounters with a cluster resulted in inflated first fixation durations on the current cluster in all but large-large gap pairs (small-small: $b = 0.81$, $SE = 0.26$, $p < .01$; small-large: $b = 0.61$, $SE = 0.19$, $p < .01$; large-small: $b = 0.58$, $SE = 0.23$, $p < .01$; large-large: $p > .05$). Repeated encounters with the pair, however, inflated first fixation durations only for those pairs in which the preceding cluster had a large gap (large-small: $b = 0.94$, $SE = 0.32$, $p < .01$; large-large: $b = 0.83$, $SE = 0.53$, $p = 0.08$; small-small and small-large: ps $> .05$). Finally, the interaction of the number of encounters with a cluster × the number of encounters with a pair indicated that repeated encounters with a cluster were associated with diminishing increases in first fixation durations due to repeated encounters with the pair (Figure 5).

Figure 5

Estimated mean first-fixation durations as a function of the number of encounters with a cluster in the pair and number of encounters with a cluster.



4.1.2.4 Gaze durations

The main effect of the current clusters' gap size on gaze duration paralleled the results for the first fixation durations: gaze durations were shorter on current clusters with large gaps (b = -97.29, SE = 2.04, p < .01). Post-hoc contrasts indicated that an increase in the gap size of the preceding cluster resulted in shorter gaze durations only on current clusters with large gaps (b = -9.61, SE = 3.10, p < .01; other p > .05). There was a three-way interaction of gap size × number of encounters with a cluster × number of encounters with a pair for both preceding and current clusters (Figure 6). It indicated that the perceptual processing difficulty of preceding and current clusters may have also modulated the effects of these variables on gaze durations. Hence, we investigated the effects of these factors for each pair type separately. These analyses indicated that repeated encounters with a cluster resulted in shorter gaze durations only in pairs where both clusters had large gaps (b = -1.36, SE = 0.37, $p < .01$), whereas repeated encounters with the pair resulted in shorter gaze durations only for pairs in which the preceding cluster had a small gap and the current cluster had a large gap (b = -1.52, SE = 0.51, $p < .01$). All other comparisons were unreliable (ps > .05).

4.1.2.5 Number of fixations

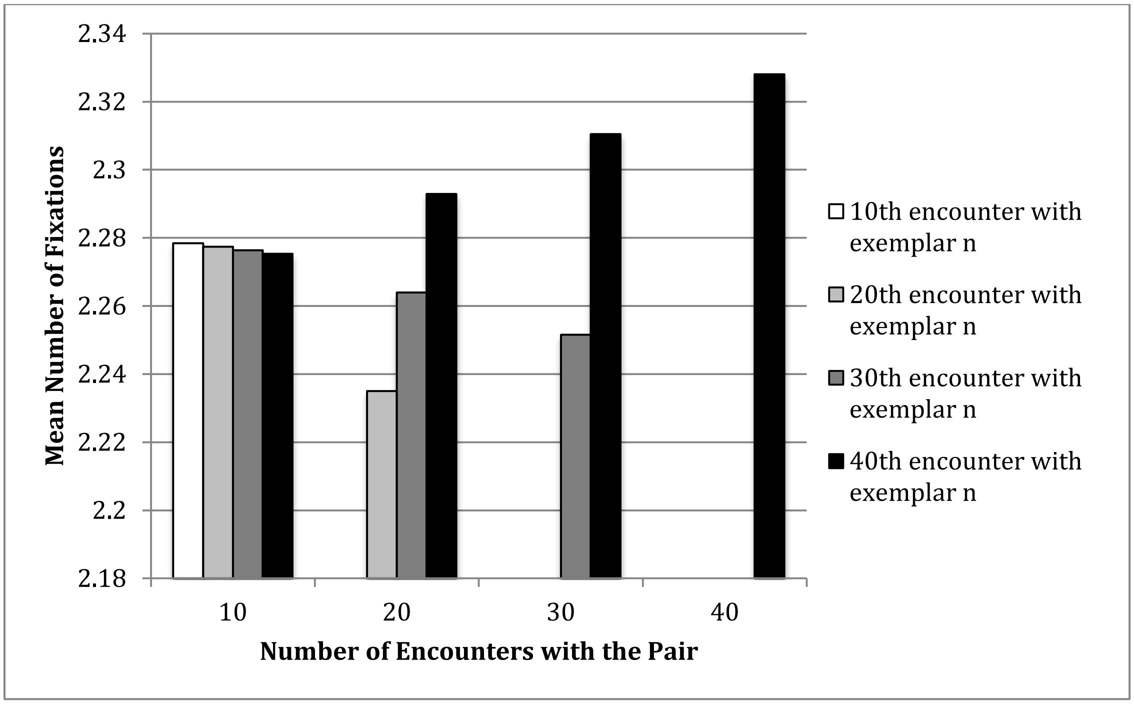
The main effects of the preceding and current clusters' gap size on the number of fixations paralleled the results reported for fixation durations: fewer fixations were observed on preceding and current clusters with large gaps (b = -0.03, SE = 0.007, $p < .01$; b = -0.22, SE = 0.006, $p < .01$, respectively). There were main effects of the number of encounters with a cluster (b = -0.002, SE =0.0007, $p < .05$) and of the number of encounters with the pair (b = -0.007, SE = 0.002, $p < .05$). The interaction of number of encounters with a cluster × the number of encounters with the pair (Figure 7), however, qualified these main effects. Figure 7 indicates that repeated encounters with the pair reduced the number of fixations on clusters that had been encountered fewer times (e.g., see 10^{th}-30^{th} encounters with a cluster), but the direction of this effect was gradually reversed as participant's experience with a particular cluster increased.

Figure 6. Estimated mean gaze durations as a function of the pair type (gap sizes of the preceding and current clusters) and number of encounters with a cluster (A) and number of encounters with a pair (B).

A.

B.

Figure 7. Estimated mean number of fixations as a function of the number of encounters with a cluster and number of encounters with a pair.



4.1.3 Discussion

Experiment 3 investigated the effect of probabilistic predictability on eye movements in a visual search task. Specifically, we investigated whether the eyes can become sensitive to a very simple statistical pattern of co-occurrence for pairs of stimuli. Presumably, the learning of such co-occurrence patterns would form the basis of the effects of transitional predictability. The critical findings from the experiment are as follows. First, the effects of cluster and pair frequencies were at odds for the different fixation duration measures. Surprisingly, repeated encounters with clusters or with pairs of clusters resulted in longer first fixation durations. This counter-intuitive finding will be addressed later in the discussion. Consistent with Experiment 1 we observed decreases in gaze durations and number of fixations associated with cluster frequency.

Consistent with predictability effects observed during reading (e.g., Ehrlich & Rayner, 1981; Rayner & Well, 1996), we also observed decreases in gaze durations and number of fixations associated with pair frequency for clusters occurring in certain types of pairs. Second, we found that the perceptual processing difficulty of current and preceding clusters modulated the degree to which eye-movement measures were affected by cluster and pair frequencies. Finally, although repeated encounters with a cluster or a pair were associated with fewer fixations, a simultaneous increase in frequency of both the cluster and the pair appeared to reverse this effect, resulting in more fixations on the more frequent clusters in the more frequent pairs. Cumulatively, our results provide tentative evidence that participants were predicting the upcoming cluster in the frequently co-occurring pairs, but also indicate that the predicted information was not employed in such a way as to make fixating the predicted cluster unnecessary, nor did it always reduce the processing time for the predicted cluster.

We will address the findings regarding the effects of perceptual processing difficulty first, because these effects may shed light on the more complex effects of repeated exposure to individual cluster and pairs. Similarly to Experiment 1, shorter and fewer fixations were associated with clusters with large gaps. These results may not be surprising, because they indicate that C's with large gaps are easier to discriminate from the target letter 'O'. However, the interactions of gap size with the variables that index participant's experience with a cluster or a pair suggest that perceptual processing difficulty may also affect the quality of encoding and/or retrieval of task-relevant information about a cluster from memory. These interactions will be discussed in greater detail below, but here we will review some preliminary evidence from reading in support of this hypothesis. In parallel to the current results, the findings from reading demonstrate that a decrease in perceptual processing difficulty for words results in faster word identification. Specifically, words with small increases in interletter spacing are identified faster when presented one at a time (Perea & Gomez, 2012a) and also receive shorter first fixations during normal reading (Perea & Gomez, 2012b). Perea and Gomez (2012a and b) argue that this processing advantage is due to two factors: less lateral masking from the neighboring letters and less letter position uncertainty in the letter string. A similar explanation may apply to results for current clusters with large gaps, suggesting that memory representations for these clusters may be more accessible. For example, Experiment 1 demonstrated larger effects of repeated exposure to clusters with large gaps. This explanation, however, is insufficient to explain the complete pattern of current data, because the findings described below also demonstrate that the visual system was flexibly adjusting to the perceptual processing demands due to preceding and current clusters' gap sizes resulting in the effects of repeated encounters with a cluster and a pair only for clusters in some pairs.

Our results are partially consistent with the hypotheses that (a) perceptual processing difficulty modulated the learning of the individual clusters and (b) that the strength of memory representation for individual clusters in a pair in turn modulated the effects of probabilistic association for these clusters. For example, as we suggested earlier, clusters with small gap sizes may have been less well encoded, resulting in noisier and weaker memory representations as compared to clusters with large gaps. This conjecture is partially supported (also see Experiment 1): the greatest decrease in gaze durations, associated with the number of encounters with the individual cluster, was observed on clusters with large gaps, but only when also preceded by clusters with large gaps, and absent for clusters in the other pairs. These results may indicate that effortful processing on the small-gapped cluster limited the amount of processing that could be done in the parafovea, therefore, mitigating any processing advantage due to the large-gapped cluster's frequency. This interpretation relies on the phenomenon also observed in reading, where more effortful processing on the current word, or greater *foveal load*, inflates the duration of processing on the next word because of reduced parafoveal preview (Henderson & Ferreira, 1990). The second related hypothesis is that the noisy representations of poorly-encoded clusters could also result in more noisy, and therefore, less informative, predictions. That is, one may expect better learning to occur for those pairs in which the preceding cluster has a large gap or in which the current cluster has a large gap. Our findings also support this latter conjecture only partially: the decrease in gaze durations, associated with number of exposures to a pair, was driven by the pairs in which the current clusters had large gaps and the preceding clusters had small gaps, and was absent for pairs in which both clusters had large gaps. Note that this result contradicts the pattern described earlier, in which no frequency effects were observed for current clusters in the small-large pairs, potentially indicating that frequency and predictability information are being used by the visual system in very different ways. For example, it is possible that perceptual processing difficulty of clusters with small gaps presents a particular challenge to the visual system: no frequency effects for individual clusters were also observed in small-small and large-small pairs. Predictability information may then be employed to compensate for the fact that preceding small-gapped clusters afford no parafoveal processing on the current clusters in small-large pairs. In contrast, predictability information may be unnecessary if the both preceding and current clusters have large gaps, because the second (current) cluster can be processed partially in the parafovea. Lastly, an auxiliary hypothesis would suggest that repeated encounters with a cluster should also increase the strength of its memory representation and result in better learning of pairs with the more frequent clusters. The current study, however, does not provide evidence in support of this last speculation. Although first fixation durations diminished for the more frequent clusters with repeated encounters in a pair, the number of fixations appeared to increase.

The degree to which different eye-movement measures were affected by the frequency of pairs is relevant to the question raised earlier in the introduction of what is being predicted about an upcoming stimulus and/or how the probabilistic information was being used. Most of the clusters were fixated and therefore overall skipping rates were too low to observe effects of frequency or co-occurrence frequency. There were no reliable main effects of co-occurrence frequency on fixation durations (until separate analyses were conducted for the different pair types), but the number of fixations reliably decreased with co-occurrence frequency. Thus, it could be that the predicted information was employed in orthographic pre-processing of the upcoming cluster. This type of information may then be used to target a saccade to a location within an upcoming cluster from which cluster-relevant information can be more easily retrieved from memory, making additional refixations within that cluster unnecessary. That is, our data suggest that similar to words in reading, a cluster may have an optimal/preferred viewing position from which it can be processed more effectively (e,g., McConkie & Zola, 1984; Rayner, 1979; Vitu & O'Regan, 1988, 1991; Vitu, O'Regan, & Mittau, 1990), and a higher predictability gave an advantage in targeting this location. This strategy can be contrasted with the potentially less accurate and less effective method of employing degraded parafoveal information to target the most informative location in the upcoming cluster, i.e., the location that appears most likely to contain an “O”. One may argue that because all clusters employed in our study were of the same length (4 characters), the pre-processing advantage for the predicted clusters should not have differentiated them from the unpredicted clusters. However, Plummer and Rayner (2012) recently demonstrated that orthographic pre-processing of the parafoveal word affected saccadic targeting independent of word length, influencing initial eye landing positions. The authors manipulated parafoveal information, which was either a target word or a visually similar non-word with orthographically legal or illegal initial letters. They found that having orthographically similar information to the target word in the parafovea resulted in fewer refixations once the word was foveated. The current results, therefore, may be demonstrating that the matching prediction is providing “accurate” information in the parafovea that is necessary for planning and executing the saccade. Other studies have not found contextual predictability effects on landing positions (Rayner, Binder, Ashby, & Pollatsek, 2001; Rayner et al., 2011). Some potential explanations for this disagreement in findings may be because (a) these studies used longer words as compared to the short letter-clusters employed here, and/or (b) because the current study is measuring predictability effects that contribute to but do not fully comprise the contextual predictability effects in reading.

The present study also replicated some of the findings of Experiment 1 demonstrating that a decrease in gaze durations was associated with more exposures to a cluster. Experiment 3’s findings also indicated, however, that the change in the way gap size was manipulated in the current experiment (employing only the two most extreme gap sizes from Experiment 1) may have had important implications for scanning behavior and resulted in several differences between the two studies. It is unclear whether exclusion of intermediate gap sizes in the current study may have mitigated or intensified the effect of frequency on the different eye-movement measures as compared to Experiment 1. For example, the size of the frequency effect observed in the current study was somewhat smaller than in Experiment 1 a decrease of 0.51 ms in gaze duration for each additional exposure, compared to 0.73 ms. However, in the current study we observe a frequency effect on the number of fixations, whereas Experiment 1 did not.

Furthermore, the current study observed spillover effects of the preceding cluster's perceptual processing difficulty on fixation durations for the currently fixated cluster that were in the opposite direction to Experiment 1. Experiment 3's results indicated that clusters with large gaps were processed faster when preceded by clusters with large versus small gap sizes. The current experiment's finding is more consistent with the *foveal-load effects* observed in reading where fixations on words tend to be shorter when a preceding word is of high versus low frequency (Henderson & Ferreira, 1990). Hence, participants may be attempting to process two clusters simultaneously when perceptual processing difficulty of both is low, or shifting visual attention earlier to the next cluster when the preceding cluster has a large gap. It is important to note, however, that related findings indicated that shifts of attention and saccadic programming are more likely to be synchronous during visual scanning (e.g., Reichle et al., 2010). While we remain agnostic as to whether several clusters can be processed in parallel or one-at-a-time, limitations in visual acuity may mitigate the processing advantage gained due to easier-to-process preceding clusters for current clusters with small gaps.

Finally, in Experiment 3 we observed a reliable effect of cluster and pair frequency on first fixation duration, but in the direction opposite to that predicted: first fixation durations appeared to increase with repeated encounters with a cluster and a pair. This is an interesting and counter-intuitive result. First, this result contrasts with the observed effects of cluster and pair frequency on gaze durations and number of fixations in the current study. Second, the effect of cluster frequency on first fixation durations was not observed in Experiment 1. We propose that these effects may be evidence of a *familiarity preference* for stimuli and pairs that are frequent and, therefore, appear more informative/surprising, than the other previously unseen distractors. Generally, familiarity effects are thought to reflect statistical learning of the stimuli (e.g., Fiser &

Aslin, 2002). Consistent with our explanation, these effects have been observed in other modalities to result sometimes in increased looking time for more familiar stimuli (Fiser & Aslin, 2002), possibly reflecting that the familiar stimuli have not yet been completely encoded, and other times in decreased looking time (Fiser & Aslin, 2001), possibly reflecting habituation to familiar stimuli. Kidd, Piantadosi & Aslin (2012) propose an explanation for this phenomenon in infant attention allocation, which they refer to as *goldilocks effect*, suggesting that infants allocate their attention to the most surprising stimuli, and avoid looking at stimuli which are either too predictable or too unexpected given previous input. Importantly, the familiarity preference effects are predicted to arise when the representations for stimuli have not yet been consolidated, as is the case of the clusters in the current study. Hence, it is possible that with more exposures to clusters we would begin to observe decreases in first fixation durations, marking habituation to these stimuli.

This last speculation also presupposes that first fixations and gaze durations may sometimes index the duration of distinct cognitive processing stages. Reingold and Rayner (2006) present evidence that may be consistent with this supposition, demonstrating that some manipulations of stimulus presentation (e.g., decreasing the contrast between a word and the background) affect first fixation durations but not gaze. There is not strong evidence for these distinct influences during reading, because attention shifts are presumed to precede saccades in many cases (Reichle et al., 1998) and, therefore, first fixations are not necessarily quantitatively linked to the beginning of word processing. However, as already noted, attention shifts and saccades may be coordinated differently during scanning, therefore, the first fixation duration on the cluster may be more tightly linked to the beginning of processing for that cluster. If first fixation durations index an early processing stage for the Landolt-C clusters, then our results may indicate that the more frequent stimuli elicit a stronger early familiarity signal. The specific formulation of the familiarity signal employed here is consistent with the episodic memory models (e.g., Hintzman, 1984). The familiarity signal is stronger when memory contains more traces similar to the probe. In the current study, the strength of the signal may be boosted both due to the repeated encounters with these particular stimuli and the pairs, as well as because of previously encountered (similar) Landolt-C clusters. This effect may be akin to the visual system recognizing that a cluster is a "word", i.e., may contain important task-relevant information. Shorter gaze durations for more frequent clusters and/or pairs would index the accessibility of specific clusters representations and reflect the time it takes to retrieve this information for these stimuli. Another alternative to explaining the unusual pattern for first fixation durations, also highly speculative, may be that fixations before refixations are on average shorter than single fixations, in parallel to findings in other visual search tasks (Hooge & Frens, 2000; Klein & MacInnes, 1999). Our findings also indicate that repeated encounters with a cluster in the more frequent pairs resulted in more fixations on these clusters, hence, increasing the probability of a refixation on a cluster, which, consistent with this explanation, may have resulted in the pattern of inflated first fixation durations. More recently, Rayner, Juhasz, Ashby, and Clifton (2003) found evidence of this phenomenon in reading, specifically, for fixations that preceded regressions to earlier words.

4.2 EXPERIMENT 4: CO-OCCURRENCE EFFECTS IN READING

Experiment 4 extends the findings of Experiment 3 to eye-movements in reading. Experiment 3 attempted to demonstrate that learning from frequently co-occurring pairs of clusters gives rise to transitional predictability effects. The results suggested a potential role of co-occurrence frequency in contributing to predictability effects. The strength of our findings, however, may have been tempered by the fact that memory representations for individual clusters were not yet established at the time of exposure to pairs of clusters. Because words are already part of the mental lexicon, it is possible that it would be possible to observe stronger and more immediate co-occurrence frequency effects on eye movements during reading. In order to test this hypothesis, Experiment 4 manipulated the frequency with which certain pairs of words appeared in text. In addition, Experiment 4 attempted to parse out the different contributions to contextual predictability that may originate from frequency of co-occurrence: structural/syntactic predictability versus semantic association between words.

In the three conditions of this experiment, participants read passages of text followed by test sentences in which a critical pair of words was embedded. We were primarily interested in the eye-movement behavior on the second word of the critical pair as a function of the type of passage that preceded the test sentence. In the co-occurrence condition, which we will refer to as structural-linguistic (SL), the passage contained several occurrences of the target word (*witticism* in the example below) in a Saxon genitive construction, e.g., *deacon's witticism*. If frequency of co-occurrence leads participants to form a probabilistic association between these two words, then encountering the first word of the pair (*deacon*) again in the test sentence should diminish the processing time on the second or predicted word (*witticism*). However, any observed effect of predictability in the SL condition could be related to either the semantic association resulting from the words' occurrence in the same passage or an artificially inflated transitional predictability for the target word. In order to distinguish between these effects, we used a linguistic (L) condition in which the Saxon genitives from the SL condition were replaced by prepositional genitives e.g. *witticism of the deacon*, which were identical in meaning to the Saxon genitives and used the same content words, but ordered them differently. The SL and L passages were followed by the same test sentence, with the target word in a Saxon genitive. This design meant that semantic association between the two words should be similar in the SL and L conditions, but the SL condition should result in increased predictability of the critical word due to its transitional predictability that has been experimentally inflated. Finally, processing of the target word in SL and L conditions was contrasted with the high-frequency-synonymous (HF) condition. The HF condition was designed to serve as a baseline condition in order to index the reading times on the target word in the absence of probabilistic association between the target and the preceding word. In this condition, the passage had the same number of occurrences of the target word *witticism* as the other two conditions, but it was neither preceded nor followed by *deacon*. Hence, the first time the reader would see the target word *witticism* preceded by *deacon* would be in the test sentence. However, in this case the processing of the target word could potentially be put at an additional processing disadvantage, because it would be preceded by a low-frequency word (i.e. *deacon*). In contrast, in the SL and L conditions the preceding word's frequency had been artificially inflated by its repetition in the preceding passage. Thus, in order to equate the influence of the preceding word's frequency between the HF and other conditions, *deacon* was replaced by a high-frequency synonym, e.g., *bishop*, which also did not occur in the preceding passage. The difference in reading times on the target word in HF compared to the SL and L conditions will, therefore, depend on two considerations: (a) how similar is the processing of high base-frequency (HF) and high contextual-frequency (SL and L) of the preceding words and (b) whether the processing advantage resulting from greater predictability of the target word in SL and L conditions is greater than or equal to the predictability of the target word in HF condition. Regarding the first of the two considerations, Rayner, Raney, and Pollatsek (1995) demonstrated that repeated exposure to the same high or low frequency words in the same passage reduced fixation times on the repeated words, with the effect being more pronounced for low frequency words. Hence, early fixation measures on the target word in L and SL conditions (e.g., first fixation durations) may be approximately the equal to or less than in HF condition, because of the similar processing of the pre-target words resulting in approximately the same parafoveal preview benefit of the target word (Inhoff & Rayner, 1986). However, the increase in the probabilistic predictability of the target word in SL condition may result in additional processing advantage for the target word, which we may observe as differences in later processing measures, i.e., shorter gaze durations in SL versus HF.[4]

4.2.1 Method

4.2.1.1 Participants

Thirty-nine undergraduate psychology students at the University of Pittsburgh received either partial course credit or were paid $15.00 for their participation. They all had either normal or corrected vision and were naive concerning the purposes of the study.

4.2.1.2 Experimental design and materials

This was a single-factor within-subjects design with three conditions. The experimentally manipulated materials consisted of 18 paragraphs of approximately 161 words each, which were

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[4] The second consideration would be best addressed by verifying with a separate set of participants, whether the *cloze* predictability of the target word from HF synonym in the test sentence is approximately less than or equal to its predictability in the SL and L conditions. This verification was outside of the current study's scope.

followed by test sentences for which participants had to make true/false judgments. Items were counterbalanced across three presentation lists, so each participant saw one condition of each item with six items per condition. Conditions were counterbalanced across three presentation lists using a Latin square design.

Structural-linguistic (SL) paragraphs contained five repetitions of the critical Saxon genitive (e.g., *deacon's witticism*). Linguistic (L) paragraphs contained five repetitions of a PP genitive with the same content words (e.g., *witticism of the deacon*). High-frequency-synonymous (HF) paragraphs contained five repetitions of the second word in the pair (*witticism*), and no occurrences of the predictor. The SL and L conditions were followed by a test sentence that included the Saxon genitive as below:

1. The congregation thought the deacon's witticism was very amusing.

The HF condition was followed by a test sentence in which the pre-target noun was replaced by a high frequency synonym:

2. The congregation thought the bishop's witticism was very amusing.

These 18 experimental items were combined with 60 filler items (paragraphs and sentences). All sentences following target paragraphs required a "yes" response. 36 fillers were followed with yes/no comprehension sentences and half of these required a "yes" response. The presentation order for the paragraphs was randomized.

Eye-movements were measured only on the test sentence, specifically, on the target word (*witticism*) and the pre-target region (*the deacon's* or *the bishop's*). Target words were mean length = 7.22 (5-9 characters) and mean HAL log frequency = 6.08 (4.16-6.94). Pre-target words were mean length = 7.33 (5-11 characters) and mean HAL log frequency = 5.91 (3.6- 6.9). High frequency synonyms of pre-target words were mean length = 6.5 (5-9 characters) and mean HAL log frequency = 9.57 (7.73-12).

4.2.1.3 Procedure

The experiment lasted approximately 80-120 minutes. Participants were instructed to read normally, for comprehension, and were told that some passages will be followed by a true/false sentence. Participants read one passage at a time and pressed a button when finished. When a passage was followed by a true/false sentence, the display of the sentence was terminated when participants looked at a dot in a lower right corner of the screen. Participants made their yes/no response on the next screen.

Comprehension rates were high (mean = 77.36%, SD = 6.56). Fixations shorter than 80 ms and longer than 1000 ms were removed by the data analysis software, resulting in the loss of approximately 1.2% of the data.

4.2.1.4 Equipment

Participants viewed the stimuli binocularly on a 23-in. monitor 63 cm from their eyes with approximately 3 letters per 1° of visual angle. An EyeLink 1000 eye-tracker (SR Research Ltd.) recorded gaze location of participants' right eyes and sampled gaze location every millisecond.

4.2.2 Results

4.2.2.1 Eye-tracking results

Analyses were done on correct trials only. Three standard eye-movement measures were examined on the pre-target and target words, conditional on them not being skipped: first-fixation duration, or the duration of the initial fixation during first-pass scanning, gaze duration, or the sum of all first-pass fixation durations, and number of fixations on the first-pass.

Data were analyzed using linear mixed-effects (lme) models with p-values estimated using Markov-chain Monte-Carlo sampling. Because the analyses were performed on log-transformed measures and thus regression weights cannot be directly interpreted as effect sizes, estimated effect sizes and means (see Figure 8) are reported from lme analyses of untransformed data for conceptual transparency.

All models specified participants, items, and trial number as crossed random effects. The frequency of the word preceding the target was not included as the predictor because it is conflated with the condition. The length of the currently fixated and next word were included as predictors and often had effects in the direction expected (longer words were processed for more time). However, because these two factors were not manipulated, they will not be discussed any further. Only the directly manipulated factor (condition) is reported here.

Pre-target region

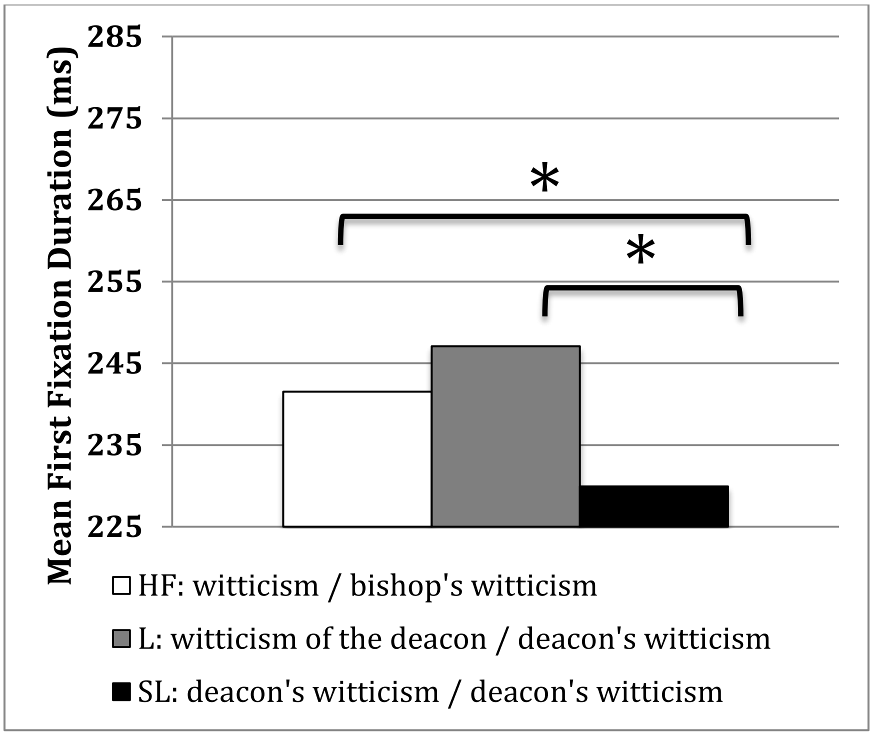
First fixation durations on the pre-target word in all conditions were approximately the same (all *p*s > .05). Gaze durations on the pre-target word were longer in the HF than in L and SL conditions (L: $b = 29.81$, $SE = 14.28$, $p < .05$; SL: $b = 20.1$, $SE = 14.27$, $p = .08$). There was no difference in gaze durations on pre-target word in SL and L conditions ($p > .05$). No differences between the conditions were found for the number of fixations (ps > .05).

Target region

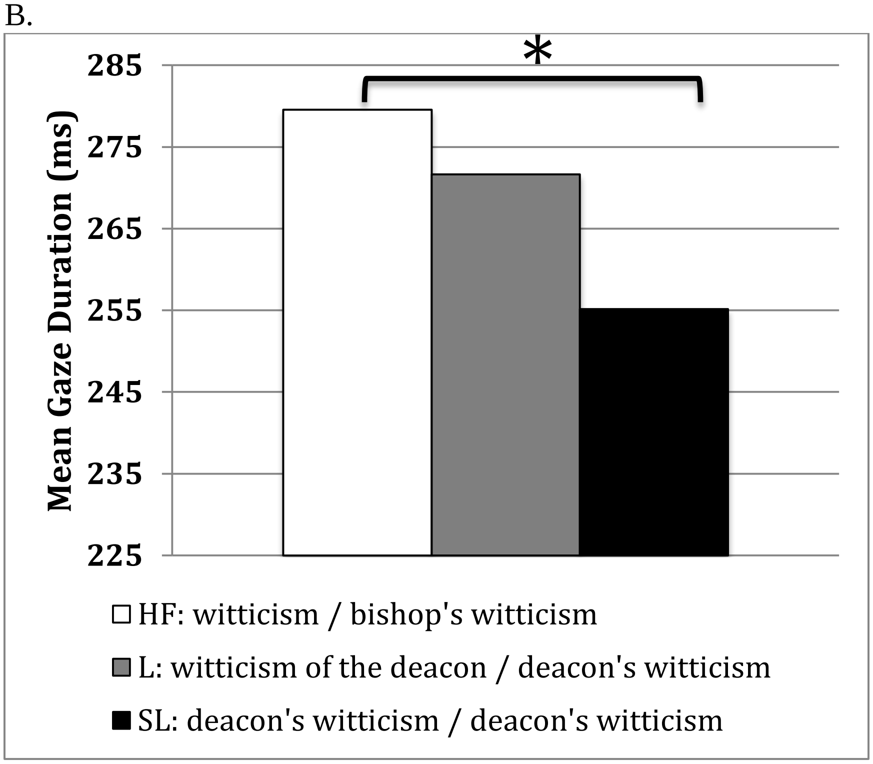
Figure 8 summarizes the results. There was a main effect of condition on first fixation duration [$F(2, 419) = 3.43$, $p < .05$] and gaze durations [$F(2, 419) = 3.16$, $p < .05$], but not on number of fixations [$F(2, 419) = 1.19$, $p > .05$]. First fixation durations were shortest in the SL condition (vs. L: $b = -14.43$, $SE = 8.49$, $p < .05$; HF: $b = -4.56$, $SE = 9.16$, $p = 0.08$), and approximately the same in the HF and L conditions ($p > .05$). Gaze durations were not reliably different in SL and L ($p > .05$), but shorter in SL than in HF ($b = -23.99$, $SE = 13.48$, $p < 0.05$), and approximately the same in the HF and L conditions ($p > .05$). There were no reliable differences for the number of fixations among the three conditions (all ps > .05). There was no evidence that condition influenced skipping rates on the target word (all ps > .05), or the spillover on the next word (all ps > .05).

Figure 8. Mean first fixation (A) and mean gaze durations (B) on the target word (*witticism*) as a function of the condition type.

A.



B.



4.2.3 Intermediate Discussion

The results of the Experiment 4 can be summarized as follows: we observed an early effect of probabilistic predictability for the first fixation durations on the target word, consistent with previous findings (McDonald & Shillcock, 2003a and b; Wang et al., 2010). The processing advantage was approximately 14.4 ms for the SL versus L conditions. Although statistically unreliable, a similar numerical pattern was also observed for gaze durations. These results suggest probabilistic predictability reduces processing time over and above that of contextual predictability, which was equivalent in these two conditions. The processing advantage in the SL condition was also greater than in the HF condition in both early and late measures (although more pronounced for gaze durations). We observed no differences for the early (first fixation durations) or later (gaze durations) processing measures between the HF and L conditions. There may be several possible explanations for the lack of differences in these two conditions. A longer parafoveal preview of the target word in the HF condition may be afforded because the pre-target word, in contrast to the L condition, was of high frequency (Inhoff & Rayner, 1986). However, as noted earlier, the pre-target word in the L condition had its frequency artificially inflated in the preceding passage, and therefore may have also afforded a parafoveal preview of the target word of an equal duration (Rayner, Raney, & Pollatsek, 1995). In addition, the processing advantage afforded by the increase in contextual predictability of the target word in L condition resulting from its semantic association with the low-frequency pre-target word could also have made the processing of the target word more similar to the HF condition.

4.3 GENERAL DISCUSSION

The findings of Experiments 3 and 4 presented in this chapter lend tentative support for statistical predictability effects on eye-movement behavior in reading. Experiment 3 demonstrated that the frequency of co-occurrence of non-linguistic stimuli affected eye-movement measures: gaze duration and number of fixations on the predicted stimuli decreased with repeated encounters with a pair. The learning of the frequency of co-occurrence should give rise to the transitional predictability effects between stimuli. As already noted, although the observed effect of co-occurrence frequency on first fixation durations was in the direction contrary to expected, it may be an artifact of learning and consolidating the memory representations for the Landolt-C clusters at the time of exposure. In addition, our findings provided evidence that co-occurrence frequency effects may be modulated by the strength of the representation for the individual stimuli in the pair. In the context of Experiment 3, the strength of the representation was modulated by the gap size within a cluster. Tentatively, the results from Experiment 3 would suggest that if contributions of transitional predictability to contextual predictability are to be observed during reading, these effects should be most pronounced for words with high representational strength, e.g., words with high quality representations (e.g., Perfetti & Hart, 2001). Experiment 4 extended the findings of Experiment 3 to reading and, as a consequence, to stimuli for which learning and consolidation of memory representations had already occurred. In Experiment 4 an increase in TP for a target word resulted from the inflated frequency of co-occurrence of target word and the pre-target word in the preceding short passages. Experiment 4 demonstrated that this increase resulted in shorter first fixation durations and a similar trend in gaze durations, but did not affect the number of fixations on the target word. Although the words in Experiment 4 were not specifically chosen to have high representational strength (they were longer and of low frequency to maximize the likelihood of fixations), TP effects were observed after many fewer exposures to repeating pairs than in Experiment 3. This evidence is consistent with the hypothesis that TP effects should be more pronounced for stimuli with established memory representations. Experiment 4 provides a demonstration that TP can indeed contribute to contextual predictability of words in text.

The direction of TP effects and which eye movement measures it affected were different in the two experiments: the increase in first fixation durations was followed by decreases in gaze durations and number of fixations in Experiment 3, whereas a decrease in first fixation durations was followed by a similar quantitative pattern on gaze durations in Experiment 4. These observed differences may be attributed to the differences in the representational strength of the two types of stimuli employed: Landolt-C clusters versus words. The homogeneity of Landolt-C clusters may also make it more difficult to make predictions regarding the precise identity of an upcoming cluster. Instead, we argued that the observed TP effect on the number of fixations may indicate that the predicted information is used in orthographic pre-processing of the upcoming cluster. It is possible that during reading, the predicted information about an upcoming word is of better quality, resulting in more immediate and more pronounced effects. In addition, the differences in the locus and the direction of TP effects could be related to differences in the coordination of the saccadic programming and attention shifts in visual search and in reading (Reichle et al., 2012; Reichle et al., 2010; Experiment 2). Evidence from earlier studies suggests that in visual search, attentional shifts are synchronous with saccades, whereas during reading attention may shift ahead of the saccade. Hence, in reading, attentional shifts afford a processing advantage for the upcoming word, otherwise known as *parafoveal preview benefit* (see Rayner, 1998 for a review). If, similarly to scanning, one type of predictability information afforded by

TP also aids in the orthographic pre-processing of the upcoming word, then it is possible that this advantage is cancelled by the attentional shifts occurring for both predicted and unpredicted words. Thus, if TP effects are strong enough during reading, then the locus of these effects would be more likely observed on the eye-movement measures indexing word identification, i.e., fixation durations, rather than number of fixations. The findings of Experiment 4 also raise an important question about the stability (or longevity) of transitional predictability effects. Given that the effects in our study came about through the artificial inflation of the co-occurrence frequency, the findings may suggest that the visual system flexibly adjusts to statistical distributions of words and word sequences specific to the currently read text. Hence, it is unclear whether transitional predictability, as estimated from corpora, would have an effect on eye movements.

It is important to consider the mechanism via which transitional predictability might contribute to contextual predictability. Stanowich and West (1979) proposed that contextual predictability of words may result from an automatic spreading activation in semantic memory, i.e., associative priming, and a conscious prediction of words due to their expectancy. It seems likely that these two mechanisms are not exclusive. Notably, the cloze task via which contextual predictability of words is measured may turn automatic activation into a conscious prediction of the word that is most likely to continue a sentence. Although limited evidence has been found for intralexical priming in reading (Camblin, Gordon, & Swaab, 2007; Carroll & Slowiaczek, 1986; Traxler, Foss, Seely, Kaup, & Morris, 2000), co-occurrence frequency may influence the degree to which a word can prime another (McKoon & Ratcliff, 1979; Zeelenberg, Pecher, & Raaijmakers, 2003). Abbott and Rayner (2012) have recently demonstrated in a series of experiments that learning of word pairs shown in isolation reduced reading times of the pair in sentences. In particular, second words in the pair received shorter gaze and total time durations, when compared to unlearnt combinations. Moreover, mismatches in the expectation for the second word resulted in greater likelihood of regressions to the first word in the pair. The present experiments demonstrated that these associative links between tokens can be formed while scanning and reading. The scope of the current experiments, however, was limited to demonstrating that TP effects may contribute to contextual predictability and, therefore, our results cannot speak to whether the generated predictions from TP are conscious or automatic.

The findings of Experiments 3 and 4 are also limited to demonstrating predictability effects for a pair of tokens. However, readers' expectations could also be based on longer and potentially more complex sequences of tokens. This conjecture follows from *surprisal*-based theories (Hale, 2001; Levy, 2008), which posit that probabilities of words conditional on the preceding sentential context determine the relative ease of word processing, so that highly improbable words are more difficult to process. Empirical evidence from German demonstrates that reading times are shorter on those verbs for which an expectation has been formed earlier in a sentence (Konieczny, 2000; Konieczny & Döring, 2003; Levy & Keller, 2012). The importance of probabilistic information to forming expectations may not be confined to grammatical continuations of sentences. Claims have also been made that co-occurrence frequencies underlie semantic associations and representations (e.g., Latent Semantic Analysis theory: Landauer & Dumais, 1997; Featural and Unitary Semantic Space: Vigliocco, Vinson, Lewis, & Garrett, 2004). In accordance with these claims, studies have also found that semantically unexpected words as indexed by LSA are associated with longer fixation durations (Pynte, New, & Kennedy, 2008; Wang et al., 2012). Surprisal and LSA measures are correlated with cloze task values, providing prima facie evidence that probabilistic variability underlies contextual predictability (Wang et al., 2012). A related phenomenon has been observed in research on *lexical bundles*, or high-frequency word sequences (*e.g.*, *I think that* or *becoming increasingly clear that*). It has been claimed that these highly predictable sequences of words, frequency of ten times per million or at least five times per million, may be processed differently because their meaning is attached to the entire sequence (Conklin & Schmitt, 2008; Schmitt & Underwood, 2004; Underwood, Schmitt, & Galpin, 2004). There is evidence that these word sequences are associated with faster self-paced reading times and better recall (Jiang & Nekrasova, 2007; Tremblay & Baayen, 2010; Tremblay, Derwing, Libben, & Westbury, 2011). Event-related potential studies demonstrate that the magnitude of the N1 component, known to be reduced when reading high versus low frequency words, is also reduced for these word sequences. Some researchers argue that both words, parts of a sequence, and sequences of words may be stored in the mental lexicon (Bod, Scha, & Sima'an, 2003). Lexicalization of entire sequences of words may result in much different visual processing of these sequences. For example, it is possible that, visual acuity limitations aside, these sequences are also processed more holistically with visual attention allocated to the entire sequence rather than to a single word at a time. These questions should be addressed by future research.

Finally, the findings of Experiments 3 and 4 do not mean that statistical predictability is the sole source of predictability effects in reading. However, a test of whether statistical properties of language contribute to predictability effects in eye movements is important, because it provides further evidence that a domain-general learning mechanism may also be employed in reading. Research demonstrates that this mechanism is engaged in statistical learning of patterns in linguistic input in other modalities. Probabilistic effects on eye-movement behavior would therefore cohere with findings suggesting that language learners (for a review see Gómez & Gerken, 2000), comprehenders (Astheimer & Sanders, 2011; Hale, 2001; Jurafsky, 1996; Staub & Clifton, 2006), and speakers (Bell, Brenier, Gregory, Girand, & Jurafsky, 2009; Bell et al., 2003; Demberg, Sayeed, Gorinsky, & Engonopoulos, 2012; Jaeger, 2010) are sensitive to statistical properties of language. In particular, the learning of adjacent dependencies, like transitional predictability, is thought to aid in parsing of continuous speech (e.g., Saffran, Newport, & Aslin, 1996), in learning syntax (Gómez & Gerken, 1999; Saffran & Wilson, 2003), and in determining phrase boundaries (e.g., Saffran, 2001, 2002). The current research provides preliminary evidence that the adjacent dependencies between words in text may have similar learning effects on eye-movement behavior.

5.0 CONCLUSION

The primary goal of the presented experiments was to shed light on the coordination of cognition and eye-movement behavior during reading and visual search. Cumulatively, these experiments provide evidence that cognition influences eye movements during reading and support cognitive/processing theories of eye-movement control in reading (e.g., Just & Carpenter, 1980; Starr & Rayner, 2001). These findings extend past research by providing evidence for several key phenomena. First, they provide evidence for a unified framework of eye-movement control during scanning and reading: Experiments 1-3 elicit cognitive influences during scanning and in this way demonstrate that the link between cognition and the eyes is not exclusive to reading. Second, the findings afford a more sophisticated characterization of cognitive-oculomotor coordination: The magnitude and the locus of cognitive effects is demonstrated to vary across a range of scanning tasks and with stimuli that require different degrees of lexical and non-lexical processing. Third, this research shows the development of cognitive-oculomotor coordination over the course of a task: Experiments 1, 3, and 4 demonstrate that repeated exposure to single and/or pairs of stimuli results in emergence of eye-movement effects. In this way, these three studies also provide evidence of learning from repeated exposure in eye-movement behavior, i.e., *effects of statistical learning*. Experiments 1 and 3 provide evidence of learning from repeated exposure during scanning, whereas Experiment 4 provides tentative evidence of learning from repeated exposure during reading. The next sections elaborate on the implications of these findings.

5.1 BRIDGING THE GAP BETWEEN VISUAL SEARCH AND READING

Past research has relied on the differences in characteristics of eye movements between scanning and reading to argue for cognitive control of eye-movements during reading but not during scanning (e.g., Rayner & Fischer, 1996; Rayner & Raney, 1996). Those experiments demonstrated that there were no effects of word frequency or predictability during scanning for a target word (e.g., *zebra*), whereas reading for meaning resulted in such effects. These findings were taken to support the argument that cognitive processes, i.e., word identification, primarily determine when the eyes move during reading. However, given that the coordination of cognitive-oculomotor systems guiding eyes during reading is founded on the same architecture that evolved to accomodate scanning behavior, the assumption of cognitive involvement that exists *only* during reading does not respect the property of parsimony. The *oculomotor* perspective has, therefore, argued that the visual and oculomotor constraints, which predominantly determine eye-movement behavior during scanning, should also be sufficient to explain the variability of eye-movement behavior in reading (e.g., Nuthmann & Engbert, 2009). According to the oculomotor perspective, cognitive influences in reading are limited to impeding the movement of the eyes forward in text in cases when comprehension fails. In parallel, it has also been argued that word frequency effects may be epiphenomenal to the set of non-cognitive word properties, e.g., orthographic familiarity and length (cf. White, 2008). Similarities between *z*-string scanning, which requires no lexical processing, and reading have also been used in support of this perspective (Vitu et al., 1995). The answer to the question of what drives the eyes forward in text, therefore, hinges on how *unique* is cognitive involvement in eye-movement behavior, and on bridging the gap between visual search and reading.

The present work has instead used the similarities in eye-movement behavior in scanning and reading to argue that cognitive control of eye movements does not categorically depend on *reading for meaning*. The reported findings offer a more sophisticated characterization of cognitive involvement in eye movements by demonstrating that cognition is involved to the extent that the task performance can benefit from engaging memory. That is, the current experiments provide evidence that whenever memory representations underlying the stimuli could inform task performance, the accessibility of the task-related information in memory influences eye-movement behavior. The present experiments provide such evidence by demonstrating that cognitive effects, i.e. effects of stimulus frequency and predictability, are present during both scanning and reading. In particular, Experiment 2 compared eye-movement behavior in three types of scanning tasks to reading for comprehension on the same passages of text. Our findings indicated that effects of word frequency were in fact present in two of the scanning tasks: when participants looked for a word containing the character “q” and a target word rhyming with “blue”. These results extend the findings of previous research in showing that *reading for meaning* does not necessarily elicit the largest cognitive effects. For example, Experiment 2 demonstrated that rhyme-judgment task elicited larger effects of word frequency than reading for comprehension. This finding parallels the results of Kaakinen and Hyönä (2010) which show that word frequency effects are larger during proofreading (searching for errors), than during reading. (The next section will elaborate on how accessibility of task-related information in memory may determine the size of the cognitive effects in eye-movement behavior.) Furthermore, the findings of Experiments 1 and 3 empirically linked the frequency of the stimuli with the effects of frequency on eye-movements, providing tentative evidence for cognitive effects during scanning of the non-word stimuli. In parallel to the word frequency effects observed in reading, repeated encounters with stimuli resulted in shorter and fewer fixations, with a minor inconsistency observed for first fixation durations in Experiment 3. Experiment 3 provided tentative evidence that predictability effects also affect eye movements during scanning, by showing that repeated encounters with a pair of stimuli over time resulted in fewer fixations on the second stimulus. This pattern of data parallels *contextual* predictability effects observed during reading, where more predictable words are also less likely to be refixated (e.g., Rayner et al., 2004).

Our findings also indicated that reading for meaning may affect processing in parafovea in ways different from scanning. During reading, increased processing difficulty of the foveated word, *i.e., foveal load*, has been shown to inflate fixation durations on the next word (Henderson & Ferreira, 1990; Inhoff & Rayner, 1986; Experiment 2). Experiment 2 suggests that this is not the case for scanning tasks. In Chapter 3 we offered two interpretations for these findings, but will focus on one suggested by the simulations using *E-Z Reader* model of eye-movement control in reading (e.g., Reichle et al., 2003). In E-Z Reader, attention is serially allocated to one word at a time. More importantly, saccadic and attentional shifts are decoupled during normal reading: saccadic programming is triggered by the completion of an early stage of lexical access, whereas attention shifts are triggered by the completion of lexical access. This means that on occasion, attention may shift to the next word, while the eyes remain on currently fixated word. When this happens, some processing of this word in parafovea can occur, resulting in *parafoveal preview benefit* (for a review see Schotter et al., 2012). A delayed covert attentional shift is the putative reason for inflated fixation durations on the next word when the foveated word increases in processing difficulty, e.g., switched from a high- to a low-frequency word. The absence of foveal load effects during scanning in Experiment 2 suggest that covert attentional shifts may be more synchronized with saccades during scanning than reading. These findings are consistent with the results of recent simulations adapting the E-Z Reader architecture to examine a variety of non-reading tasks: *z*-string reading, target-word search, and visual search of Landolt *C*s in linear and circular arrays (Reichle et al., 2012). In parallel to the results in Experiment 2, the model fit the behavior during scanning tasks best when saccadic programming and shifts of attention were synchronized. Reichle et al. suggest the de-coupling of attention and saccadic programming may have been a cognitive-visual systems' adaptation to reading: an attempt to optimize task performance when slow saccadic programming is coupled with slow lexical processing. By signaling the completion of an early lexical processing stage, which indicates that access to a word's memory representation is imminent, the visual system can start programming a saccade to the next word while completing processing on the currently foveated word. Hence, the synchrony of attentional shifts and saccades during scanning tasks in Experiment 2 may either be due to the lack of practice in these tasks, or, alternatively, may suggest that the two-stage lexical processing is only induced by processing for word's meaning. More will be said about the model's simulations in the last section of this chapter.

5.2 CHARACTERIZATION OF THE EYE-MIND LINK

Up to this point, we have been employing terms such as "link", "coupling", and "cognitive engagement" when discussing cognitive-oculomotor coordination. We interpreted evidence of larger cognitive effects to claim that cognition was engaged more, and, conversely, interpreted smaller cognitive effects to mean that cognition was engaged less. These terms gloss over an important question: What does it mean when cognition is engaged more or less by a task?

There are two possible ways of characterizing the degree of cognitive engagement. First, in tasks with smaller cognitive effects, participants may be engaging in lexical processing only on a proportion of words. The rest of the time participants may be scanning, which primarily depends on oculomotor factors and not access of memory representations, e.g., character-by-character perceptual discrimination. According to this perspective, when searching for a word with a letter "q", participant may be performing a kind of cognitive sampling of every other word, rather than consistently engaging in lexical processing of every word. An alternative characterization may be that cognition is engaged throughout the performance of the task and that the type of information to-be-accessed determines the magnitude of the cognitive effects. That is, if the task performance depends on retrieving fine-grained information that is specific/unique to a particular stimulus, e.g., in parallel to proofreading, then (a) this information will take longer to access and (b) the characteristics of eye movements will be more closely associated with the frequency of that particular stimulus. If, however, the task performance may be accomplished by accessing coarse-grained information, e.g., scanning for a word among non-words, then the characteristics of eye movements will not be as closely associated with the frequency of that particular word. In parallel to the observed latencies in word recognition, these characteristics may instead depend on some combination of factors, like the word frequency, its orthographic neighborhood size, and the frequency of its neighbors, etc. (e.g., Andrews, 1989, 1992, 1997). The present data may be insufficient to rule out the possibility that smaller cognitive effects during some of the scanning tasks (e.g., looking for character "q" in Experiment 2) are due to cognition being engaged only some of the time. Accepting this interpretation, however, would also entail that cognition must be engaged only some of the time also during reading, because larger cognitive effects were observed in the rhyme-judgment task (Experiment 2). Hence, our findings provide evidence that tentatively supports characterizing the eye-mind link in terms of intensity, rather than the sampling rate.

5.3 DEVELOPMENT OF THE EYE-MIND LINK

Another question that remains only partially addressed by the current studies is what causes the development of cognitive-oculomotor coordination over time in the task like scanning of *Landolt-C* clusters? The findings provide evidence that statistical learning, or learning from repeated exposure, played an important role in the emergence of cognitive-oculomotor coordination. However, the account of factors that trigger a gradual switch from character-by-character processing to the more holistic processing of clusters in Experiments 1 and 3 remains opaque. For example, in the beginning of Experiments 1 and 3, participants had to engage in character-by-character perceptual discrimination, because of their lack of familiarity with the Landolt-C clusters. However, it would appear that for the frequency-based effects to emerge during the scanning tasks, cognition had to be engaged always. Repeated exposure to visually highly similar stimuli may have indicated to the cognitive systems that the stimuli are potentially meaningful and resulted in the construction and consolidation of memory representations for Landolt-C clusters in Experiments 1 and 3. The results of these studies also indicate that the strength of the frequency and predictability effects intensified over time, suggesting that the strength of memory representations intensified with repeated exposure to the clusters. These findings would be consistent with episodic theories of lexical access, according to which each encounter with a word increases its representational strength (Ans et al., 1998, Craig & Tulving, 1975, Reichle & Perfetti, 2003).

Importantly, our findings provide tentative evidence that the *informativeness* of the non-word stimuli may change over the course of the task. Some of this evidence comes from pilot studies that have not been reported here. In the pilot studies, some of the clusters were allowed to repeat up to one hundred times during the experiment (as opposed to the maximum of fifty times in Experiment 1 and forty times in Experiment 3). This repetition resulted in increased looking times on these clusters after approximately the seventy-fifth occurrence. Note that in the reported studies, the number of exposures to a cluster was limited to 50 or less occurrences, which is, perhaps, why this effect is not observed in Experiments 1 and 3. However, we did observe that repeated encounters with a cluster and a pair in Experiment 3 inflated first fixation durations. Chapter 4 speculated that these effects may be evidence of a *familiarity preference* for clusters and pairs that are frequent and, therefore, appear more informative/surprising, than the other previously unseen distractors. In the domain of statistical learning, studies observed that preference for the more familiar stimuli increased when memory representations were in the process of being consolidated (Fiser & Aslin, 2002) and decayed after the consolidation (Fiser & Aslin, 2001). Kidd, Piantadosi and Aslin (2012) proposed an explanation for this phenomenon in infant attention allocation, which they refer to as *goldilocks effect*, suggesting that infants allocate their attention to the most surprising stimuli, and avoid looking at stimuli which are either too predictable or too unexpected given previous input. Interestingly, the results of Experiment 3 may also be providing tentative evidence that participants are in the process of creating memory representations of the stimuli that are more complex than a single cluster, by demonstrating familiarity-preferences effects to frequently occurring pairs.

5.4 IMPLICATIONS FOR THEORETICAL AND COMPUTATIONAL FRAMEWORKS OF EYE-MOVEMENT CONTROL

Cumulatively, the present findings have important implications for theoretical and computational frameworks of eye movements. Provided that the coordination of oculomotor and cognitive systems for reading builds on the pre-existing settings for scanning behavior, further evidence that cognitive demands modulate eye-movement behavior across these tasks highlights the importance of developing a unified framework for eye-movement control. The current data indicates that this framework should be able to flexibly handle different degrees of cognitive involvement in eye movements between tasks (e.g., Experiment 2), but also accommodate the emergence of cognitive effects within a task (e.g., Experiments 1, 3, and 4). As noted earlier, Reichle et al. (2012) made an attempt to describe eye-movement behavior in scanning tasks with E-Z Reader. In order to replicate the attenuation of word frequency and foveal load effects during scanning, several parameters had to be adjusted from model's defaults specified for reading. Simulations indicated that a better fit to the scanning data was provided by a shorter duration of an early stage of lexical access, which indexed general familiarity with stimuli. In addition, the durations of a later stage of lexical access and post-lexical processing had to be set to zero. Although the adjustments made to model's parameters made it possible to replicate these phenomena, the present data also hinted at some limitations in the model's framework that may need to be addressed in future simulations.

In view of the present findings, one notable limitation is that the model's behavior describes the end state of the cognitive-oculomotor coordination, leaving open the question of how cognitive effects can emerge over a course of one experiment, e.g., Experiments 1 and 3. This is because the model's computational framework does not elaborate on the contents of the different cognitive or oculomotor modules, e.g., lexical processing, and focuses instead on the interactions between these modules (Reichle et al., 2003). For example, in the simulations described above, the new parameter settings for the durations of various stages of lexical access were determined by data fitting, rather than by an endogenous mechanism which would correspond to the processes of memory access and retrieval. Hence, the model's implicit assumption is that these durations do not change over a course of a single task, whereas the present results provide evidence to the contrary. Another limitation may be the model's assumption that attention can only be allocated to a single stimulus at a time. The results from Experiment 1 suggest that there may be effects on the currently fixated stimulus of its neighbors' processing difficulty at least initially during scanning of Landolt-C clusters. These findings may provide evidence favoring a model that employs instead an attention gradient (e.g., *SWIFT:* Engbert et al., 2005). This gradient of attention may encompass initially several stimuli when scanning unfamiliar stimuli, but with practice in the task quickly adjusts to encompass a single stimulus. One may even speculate that it is the gradual consolidation of memory representations for stimuli over the course of the task that signals to adjust the size of the attention gradient to a single cluster. We did not, however, find evidence favoring the attention-gradient hypothesis during the word-processing tasks (e.g., Experiment 2). This is consistent with the idea that attention has to be focused on a single word at a time, in order to retrieve information about this word's memory representation.

APPENDIX A

MATERIALS FOR EXPERIMENT 2

A.1 LIST 1

But in practice so many populations have wandered back and forth across the area now called Germany during the thousand years between Germania and the emergence of a sort of old Germany that the people talked about by Tacitus cannot be called German in any but the vaguest sense. One example would be the marauding but *practical/willful tribes/vandals* that migrated from Poland and then arrived in Spain. We will never know how much impact they had on the other nationalities. Throughout their travels, however, their *brutal/barbaric actions/antics* imprinted their name on several languages. Some of them must have spoken a sort of proto-German, but only alongside numerous other peoples and any number of evil-smelling incomers carving their bearded ways in the supposedly impenetrable forests.

And so they set off on their journey across the countryside. They stopped in villages along the way and gave some lively performances, many of which were improvised on the spot. While there were many traveling vagabonds, this *unusual/offbeat group/troupe* of musicians, poets and clowns enjoyed greater success because of their unscripted dialogue. Sometimes, though their performances flagged because of the internal conflicts between the eldest member of the theater and the rest. It was not uncommon that they would cancel the performance because of the *angry/irate actress/thespian* throwing yet another tantrum and locking herself in her carriage. Only after much persuading and substantial amounts of wine she would finally calm herself. Although the actors lost a lot of time and money, the old actress remained part of their traveling theater.

Ten years ago the Johnsons found an unsigned painting in their attic. They were very excited about this work of art. The fact that the painting lay for so many years discarded and covered with dust did not perturb them. Still they hung this stupendous treasure in their otherwise *elegant/classy apartment/veranda* to be displayed prominently. The rare, and still becoming rarer, guests of the couple were invariably shocked by its depiction of a reclining nude with a *bright/lurid apple/apricot* in its mouth. The painting was very realistic. However, for someone at rest, the nude had an incongruously animated facial expression. Also, its arms and legs were folded at odd angles. A work of art may be provocative but this one triggered a feeling of repugnance and extreme distress.

It had been three hours, and all Bob could think about was leaving the stadium. The cold metal seat made his back hurt and the game turned against his team. Making matters even worse, the crowd was still chanting loudly. He started thinking about his clean and *silent/roomy house/domicile* and felt like he should go back home. He made his way out of his seat, and started looking for the elevator. The roar of the stadium made him disoriented and the signs in the garage were very confusing. He stared for awhile at an *unclear/abstruse banner/placard* hanging overhead which had many arrows and symbols. Still he could identify neither his own nor the location of the car. The next morning, Bob was back at the stadium parking lot. He retrieved his car and made it just in time for work.

There was a long discussion during the meeting about balancing the workload of graduate studies and research. The students complained that the program demands were unreasonable but the higher-ups in the administration were not that interested in improving the students' lives. In particular, the students demanded that their *trivial/deficient earnings/stipends* should be increased because of the rising costs of living in the city. They also demanded more clear guidelines for their vacation time. It was lunch soon and the administration was becoming impatient. But, in keeping appearances, the *dishonest/insincere chair/provost* made some pledges that he obviously would not keep. The same thing happened the previous year when the administration promised students a lounge in the building. There was no doubt on the part of the students that this year they lost another battle.

The old lady was taking her tea in her rooms, enjoying her solitude. She asked that she would not be disturbed by anyone during this time. Of course, when her butler tripped and fell over the pile of firewood in the hallway, she asked what that *atrocious/wretched noise/ruckus* was all about. Upon finding out that there appeared the makings of the bonfire in the hallway, she was more amused than annoyed. The culprit was found in kitchen, rummaging for matches in the closet. A moment later, the boy was brought in and the old lady was presented with the *foolish/obtuse criminal/arsonist* looking rather embarrassed with his head hung low. Lady

Paltridge giggled over her cup of tea and suggested that more thorough preparation may be necessary for his next devious plot.

The jungle was all around us. It moved, breathed. There was a ringing of bird calls, the creaking of trees, the swishing of wings. There was not a moment of silence. Even though we were many kilometers away from the village we could still hear the *distant/faraway sound/cadence* of drums that called the gatherers for their supper. Our guide led us down some tortuous paths but eventually we found an opening. This is where we expected that the rare pheasants would nest. One of these birds was there now, standing at the very edge of the opening. The feathers formed a kind of a *sheer/gauzy crown/tiara* around the bird's head, which shone iridescent in the golden glow. It was very busy looking around for food and did not notice us at first.

The overseer of the theater could not understand the reason for the unwholesome noises coming from the audience. There were whistles and *ignorant/boorish laughter/guffaws* that shook the very walls of the building. Even stranger was the loud stomping on the stage, completely unexpected during what should have been the graceful performance of the Swan Lake. When he looked behind the curtains he understood why. In the middle of the stage was a bear dressed in a pink skirt, apparently having the time of its life. This rather ungraceful and *heavy/portly dancer/ballerina* was also making pirouettes and tiny hops. At every bear's jump and turn, the audience would burst in another paroxysm of laughter and would encourage the bear by cheering him on and throwing treats on the stage.

The girls loved playing with their huge dog. Because of his size and compliant nature, he acted as their pony. Lucy, the smallest one, would climb inside the baby carriage, which was decorated with garlands. This carriage was somehow connected with the dog's collar. All afternoon this *fantastic/whimsical vehicle/chariot* would be seen driving around the grounds and on the gravel pathways of the garden. The guests were much amused. Unfortunately, the dog's demise abruptly ended this *wonderful/blissful enjoyment/commotion* and the girls were very distraught. They tried playing with the dolls and other toys but these inanimate creatures were not nearly as fun. Slowly, they started circling the bunnies' cage. It was then that the bunnies realized that they must escape at all cost.

We have not seen each other in years. I did not think I would recognize her. I expected that she had changed a great deal. At the end of the alley a tiny figure appeared, clothed in a cobalt coat against which glowed a red ribbon. I was startled by the acute feeling of recognition. Time did not dampen the *eternal/immutable rhythm/staccato* of her tiny heels on the pavement. When she approached, however, there was no doubting that the 20 years left their toll. The wrinkles, the sharp lines at the corners of her mouth were carved by the unmistakable *deadly/menial knife/cleaver* of Time. Yet when she smiled, again I was startled by how much she looked like the photograph I have kept. She extended her gloved hand. I held it gently. The soft suede felt like her skin.

There comes a time in most peoples' lives when they take stock and decide whether they're on the right track. Such is the case for Li Fisher, for whom the sad loss of her father brings the chance of a lifetime. She trades *difficult/tiresome students/pupils* and French lessons for the bohemian lifestyle of an art student, complete with a student's love life. In the meantime, she must fill the time before term starts, and what better way than by temping as a translator for a company specializing in boiler installation. The only problem is one *hostile/inimical owner/trustee* of the company, the rugged but seemingly thoughtless Joe Delaney. He crashes Li’s car on the way home from a work trip and breaks his arm for four weeks. When Li has no choice and becomes his driver, seeing how dislike on both sides evolves and becomes attraction is delightful.

The heads of state gathered together. They conferred about the discord taking place among the people in their countries. There was much disagreement about its causes. On the one hand, they felt that the media of the democratic regimes had incited the *desperate/vehement violence/mutiny* that broke out on the streets of their cities. Their subjects were tempted with freedom and riches. On the other hand, there were some voices in the crowds that spoke with *intense/ardent passion/fervor* for another kind of tyranny. These voices came from representatives of extreme groups that felt that their countries’ decline was caused by people turning away from religion. Hence, they argued for the establishment of a state ruled entirely by religion.

He grieved for a long time and spent most of it isolated in a tiny room. There were no sounds in his home except for the creaking of floorboards. The winter storms that raged outside of his window made the *terrible/woeful burden/adversity* weighing on him seem even heavier. The experiment had gone terribly wrong and soon he would become a terrifying and repulsive creature, like the rest. He was apprehensive about attending gatherings of his colleagues. He feared that the news of this *horrible/odious prospect/prognosis* had somehow reached them as well. As the darkness fell, he lit another candle and continued scribbling. His papers covered every inch of the room. The mice made nests in the neglected piles.

The mention of the king's mistress in the song angered the proud monarch. She interrupted the feast and walked out in high dudgeon. Everyone hushed and all looked at the king for his reaction. The king ordered the *nervous/tremulous performer/minstrel* that he should proceed with his song. He seemed unperturbed by this scene of family discord. From this moment on, Catherine's influence in the court was greatly diminished. Displays of impertinence by the lowliest subjects became not uncommon. Catherine's pride was deeply wounded by the *shallow/frivolous remarks/chatter* she would overhear from her subjects. They gossiped and snickered in her presence. She was also unpopular with the people of England. She felt isolated and asked for help from her allies overseas.

The country was almost on the brink of internal war and being threatened by enemies from the outside. The ministers asked the oracle for his advice. Their king was a *passive/apathetic leader/tyrant*, more decisive about executing his personal vendettas than assuring the stability of his rule. The oracle demanded that a human sacrifice be brought for appeasing the ancestors. He also predicted that unless the army, led by the king, was gathered immediately at the border, the land would be burnt and looted by barbarians. The oracle delivered his *dramatic/dismal sentence/ultimatum* at the big festival when the king and his subjects celebrated the beginning of harvest. The king was very displeased that the festivities were interrupted by the ill tidings. He punished his ministers and ordered oracle's execution that same evening.

Herbs are mainly used for flavoring meats, stews, soups, fish, vinegars, bread, and often used along with lamb, tomatoes and eggs. A lot of them have medicinal purposes and some are very common. For example, the fields near my grandmother's home were overgrown with the *purple/mauve plants/thyme* containing a very special oil in their leaves. One could use this oil for treating many bacterial, fungal and viral infections. It was even used by some villagers for treatment of dental decay, sore throats and dandruff. I remember that it had a very *strong/pungent smell/aroma*, which was because of a chemical called "thymol" located in the leaves of the plant. My grandmother told me that in the middle ages, in Europe, it was placed beneath pillows. This supposedly aided sleep.

A.2 LIST 2

But because of the ongoing war with France, the spies were everywhere. The minister favored by his mother told Philip curtly that he could not travel openly in his gilded ship, unless he valued his vanity more than his own safety. Unpleasant as it was, the young king followed the recommendation of his *arrogant/haughty servant/vassal* and ordered for himself a much smaller vessel. Before leaving the city, the king met with the French ambassador and discussed a possibility of a peace treaty. All this had put him in a foul mood. He saw his mother after the state dinner. Their exchange of the usual affections became a very *formal/frigid liturgy/ceremony* during which the young king did not hide his scowl of displeasure. He resented being treated like a child. He resented the control of his mother over his affairs. He wished for independence and for the rest of the evening sulked in his rooms.

Enter almost any cemetery in eastern Massachusetts that was in use during the seventeenth and eighteenth centuries. Inspecting the stones and the designs carved at their tops, one will find that around the eighteenth century the grim death's head has been replaced by a *depressed/mournful angel/cherub* perched in various locations on the gravestone. This design also undergoes a gradual simplification of form with time. If the cemetery is in a rural area, one may also see a sculpture of a reclining figure draped in *light/wispy fabric/shroud* that sometimes also covers her face. By the late 1700's or early 1800's, again depending on where one is observing, these are sometimes replaced by stones decorated with a willow tree overhanging a pedestaled urn.

The Strand — about twenty miles long and five miles wide — is an explosion of flora and fauna across swamps, islands of tropical hardwood hammocks, and pine rock lands. Black bears and panthers live here. This jungle houses the *crimson/maroon snake/mamba*, the slinky bobcats, a white-tailed deer, minks, and diamondback terrapins. During the dry season, ponds are abound with alligator snouts. If one is fortunate one may also spy the *secret/furtive flowers/blossoms* of the ghost orchids and several other species of rare blooms. With more than 20,000 documented species, orchids are the most diverse family of plants on earth. Over millions of years they have adapted brilliantly. Initially growing in soil, they now grow on the trunks, branches and canopies of trees, rocky outcroppings, and even in water.

Although an onlooker may have thought Rome as glorious as a century ago, the Roman Empire was actually in its last throes. And the more perspicacious could discern the cracks in its very foundation. The hallways of palaces still echoed with the *empty/vacuous beauty/splendor* of speeches praising empire's past accomplishments. While outside the palatial walls, the country was a smoldering fire-bed, brewing with wars and unrest. Many in the governing elite were so ensconced in the *corrupt/decadent fortune/affluence* accumulated over centuries by their ancestors that the chaos outside barely distracted them from their petty affairs. They spent nights and days feasting and wassailing, plotting and spreading sordid rumors. In less than a century, nothing would be left of them or the memory of their noble families.

American violinist Hilary Hahn comes across as the charming and amiable girl next door. Now nearing her 30s, she could easily pass for a teen, with her wide-set eyes, porcelain skin, and elfin features. She is in the habit of peppering her speech with words like "wow", "gosh", and "neat". Hahn exudes a kind of *brilliant/luminous energy/euphoria* both on and off the stage. Her love of music is evident. Yet her activities off stage are hardly a picture that jibes with the image of the studious and *humble/demure genius/virtuoso* that spends her days practicing scales and her nights performing on concert stages. For example, earlier this summer she went white-water rafting for three weeks in Arctic Canada, and before that she took in Brit electronic rockers Goldfrapp at Radio City Music Hall.

There are rare instances of people overcoming adversity as impressive as John Stringer. Born in a tiny town in rural Illinois, he had an uneasy childhood. At the age of six, he became very sick. Among one of the symptoms of this *strange/atypical illness/malady* was that he could not bear the sunlight. He stayed indoors all the time. He started reading everything he could get his hands on as a way of distracting himself. He particularly liked volumes on legal matters, as these let him test out his formidable logical reasoning skills. A local law firm heard about the boy, and arranged it so that one *smart/brainy lawyer/jurist* should visit the boy. He was so impressed with John's accomplishments that as follow-up he sent him some complicated legal briefs. The boy returned them with pages of useful notes. In time, John recovered and became a judge on Illinois' Supreme Court.

Fortunately, one of us found that he had got with him in his hunting pouch the means of kindling a fire. So after some discussion, another of the party led the way, and crawled, with his comrades behind him, on his hands and knees inside the nearest passage, holding the torch in one hand, and with the other cautiously pushing forward his revolver. The narrow path led inside a *large/spacious chamber/grotto* whose vaulted roof rested on three irregular pillars. Here, large masses hung from the roof in the form of stalactites. Our flashlights sought out the *sensitive/irritable lizard/gecko* we found in the other cave. We found him in the corner on top of the rocks but again, as our flashlights fell on him, with a hiss he scurried underneath the pile. Where he went, curiously-perforated fragments rose from the floor.

There is one particular professor that my friends remember with much fondness. He taught history of the ancient world. He spoke with an unidentifiable accent making it seem that he was also one of the ancients. One was intrigued by the *bizarre/eccentric character/charisma* of his dress as he walked jauntily with cane in one hand, a long cape in the other and a feathered orange beret perched on his head. Students followed him involuntarily, like a mad Pied Piper. But it was his teaching style that was most memorable. He had a very *sincere/candid manner/demeanor* when teaching that engaged the students. He inspired our conversations afterwards. We would talk about historical personae that were long dead and gone with such avidness as if they were our contemporaries.

While spinach was making a superman of Popeye, my mother put her faith in good old Numol. Every day we were fed a tablespoonful of the brown, *sweet/syrupy medicine/elixir* out of the putty-colored jar kept in the preserves cupboard. While my brothers screwed up their features and winced at the taste, I enjoyed the stuff so much that my spoon was invariably licked clean. “Digestive and appetizing for kids and adults’’ was the *brief/terse message/advert* on the label of the Numol jar. In the end I relished my daily dose of Numol like a sailor would his rum ration. Nearly sixty years have slipped by since I was reared on Numol. But I could almost taste it again the other day when I came across a dust-covered stone jar tucked away in a corner of the cellar.

The window was open wide in the library. The springtime air flowed inside the room and ruffled the pages of books on the tables. One could hear the ringing of bicycles outside and joyful voices. The sunlight was pouring in and the dust specks swirled in its rays. With another gust of wind the curtains of almost *invisible/ethereal cotton/rayon* hovered over the table like bird wings. The librarian was dusting off the shelves with the collection of some prehistoric tools. He noticed that there was a *foreign/deviant object/specimen* among them that was not there before. It looked like an end of a prehistoric spear but was made out of a shiny gray metal. The spear end lay on the very edge of the shelf. It appeared very sharp. When the librarian extended his hand and touched it, he was surprised that the spear felt icy cold.

The day at the courthouse was very long. The jury deliberated for hours. By the late afternoon, the journalists arrived. Some men from the company gathered in the *simple/austere entrance/vestibule* of the court's building waiting for the judge's decision. The farmer's daughter was also here and she was talking with some of the journalists about the extent of the damage made by the plane. The news reports that appeared shortly after the suspension of the overly *confident/brash pilot/aviator* were divided. Some thought that he was not at fault for the plane's mechanical failure. Others thought that the pilot should not have tried a novel and dangerous trick with an old plane. The company covered most of the damages and rebuilt the barn. The pilot's reputation, however, was sallied by this episode.

Although the state promised the same distribution of goods among its citizens, there were still some that received more than others. Not by because of talent or effort but because of higher ranking in the party. Although, they also owned nothing and what they had could have been taken away in the blink of an eye, they enjoyed the kind of *cheap/specious wealth/opulence* that was the envy of their inferiors. Instead of huddling together in a communal flat, they had three rooms for a single family. Meanwhile, famine raged in the countryside. As televisions were showing the *peaceful/pastoral scenery/panorama* of rolling wheat fields and content farmers, many were carried away by disease brought on by destitution and hunger. There were reports that these disasters were caused by the enemies of the state. The guilty were of course found and executed in public displays of justice.

I remember how once my mother and I went inside a grocery store in Moscow. In the middle of the store, there stood an old lady surrounded by piles of old books and records. My mother bought a book from her out of sympathy. As it happens, this old brochure was a *ancient/recondite source/fount* of various information on the mixing of paints and the preparation of canvasses. The ingredients for some of the paints included things like egg and honey. There was also a drawing of a *primitive/rustic table/easel* for painters in the 18th century and instructions for its construction. We could not make use of any information in the book but it became a kind of souvenir of that turbulent time. I brought it along with me when we came here and may still have it somewhere among my things.

By the 19th century, Bapaume was no longer regarded as a fortified town. In 1847 the dismantling of the fortifications was therefore undertaken. It was conducted by the Army as part of maneuvers and the testing of explosives. The walls and the fortresses were blown-up and the moats were filled in. Recently, the underground galleries were restored and their entrance made more accessible at the *medieval/dormant fortress/bastion* of Dauphin near the river. Some of the graffiti and the stonework were also restored. In spite of these restoration efforts, however, only the *massive/colossal tower/spire* and part of the underground tunnels are still intact. These were used as underground shelter during both world wars.

The wait had been long, but Phil suspected that it would be worth it. The boss had finally signaled that this was the right time for their nefarious plan. Together they came up with the idea of the *tricky/shrewd theft/caper*, which would net enough money for their entire gang. Phil did his part, cutting off the security system, while someone else cracked the safe and stole the jewels. Although it was hard to believe then, now, imprisoned for many years, he no longer doubted the *obvious/salient truth/verity* of his boss's betrayal. When he arrived at the agreed upon meeting place, he was greeted by a bevy of police cars. May be, he missed the signs of treachery then because he was so eager for his share of the proceeds.

Timothy was a spiritual guide for Franciscan Seculars, and for several years was Chaplain at the local Council of the Knights of Columbus. He never let his heart condition bother him or distract him from his work. He found strength and joy working with the many groups associated with the Parish. They were very happy with this *pleasant/amicable priest/friar* as the spiritual moderator or organizer. He gladly accompanied the nuns on outings far and wide. He was a very devoted councilor and aided many newlyweds. Once he even accompanied them for a *casual/cheery weekend/excursion* in the wetlands and conducted free couple therapy sessions at the camping site. Only when his heart condition became critical in 1955, the cheerful Friar ended up in the hospital. Needing constant care and bed rest, he remained a good-natured host when other monks visited him. One night he died in his sleep.

A.3 LIST 3

For many years the mistress of the magical mountain kept Evan as her slave locked under lock and key. She provided him with the precious stones he needed for his creations. In turn he labored tirelessly and satisfied her every caprice. He became so adept in making his statues that they seemed alive if motionless. But it was her final wish of a bell-flower carved from malachite that tested the skill of the *gentle/docile master/artisan* and almost proved his downfall. Evan worked on it day and night but remained unsatisfied. One evening, in frustration he hit the stone with his chisel and this *fortunate/opportune accident/mishap* suddenly made the malachite come alive. Evan was very moved by what he thought his best creation yet. He felt that he would betray his craft by letting the sculpture remain in the mistress's possession. But because he could take it with him, he destroyed it instead.

The Saugus Public Library recently got rid of a very old and senile library guard that on regular basis harassed the students, because of the following incident. College student Lauren McLean was caught unaware last month around midnight when she looked up from an engrossing study session and noticed she was alone in the library. After taking stock of her situation, McLean gathered her things and exited the building. At the library's exit she was met with the *infamous/witless guardian/custodian* and he arrested her. The guard explained that he thought that she was a burglar. He also told the authorities that the student was dressed in some *dirty/shabby clothing/apparel*, which made him suspicious. Fortunately, the police were aware of the guard's history of harassment and they let the student go right away. She filed a complaint the next with the school and the whole matter was resolved.

Before the holidays it is imperative that one cleans one's home thoroughly. Everything must be put away, all surfaces dusted, all laundry folded. Before starting this rather *boring/banal activity/chore* of house-cleaning, a glass of red wine is strongly recommended. It will improve one's spirits and make the cleaning go faster. The preparation of the guest bedrooms and bathrooms will likely demand nothing short of *infinite/grandiose courage/fortitude* from the hostess, especially if these rooms have been neglected for the entire year. Fully armed with a broom and a sponge, one can already anticipate the spirit of the holidays by brushing away spider webs, clearing from under the beds, and dusting the surfaces.

Even in the 19th century, duels were still being fought left and right. A duel may be brought on by any insignificant insult. It was a deadly sport that claimed the lives of many young men. At this time most fighters no longer employed weapons like the *swift/nimble sword/rapier* and preferred instead dueling pistols. This actually meant that more duels ended in wounding the opponent rather than killing him. The introduction of pistols meant that duels no longer entailed the *romantic/glamorous display/luster* of skill and bravery from the fighters, thus, diminishing the duel's appeal. Laws and regulations also started taking their effect and in this way the practice of dueling had been completely wiped out.

The cartoon is uproariously funny and its depictions of the Wild West locales are absolutely hilarious. The story starts with the three cowboys arriving in town. Of course, they first visit a *filthy/musty casino/saloon* where they are greeted with unfriendly stares of the locals. A fight ensues, literally, over some spilled milk. The animals in the cartoon are probably the funniest characters. There are the moody ponies that throw off their drivers and the *selective/finicky eagle/buzzard* that cannot eat the blind mouse on account of its old age. There is the pugnacious pug that plays the sheriff's assistant. There is the parrot that cannot ask for a cracker because of his bad stutter. Audiences of all ages should enjoy this terrific romp.

Many disciplines hold competitions worldwide, both at the local and the international levels. Most shows run several days, sometimes longer for major, all-breed competitions or national and international championships in a given discipline or breed. Before each show, the breeders assess the nature of the animals presented. They prefer the *mature/placid horses/steeds* rather than the very young and hyper ones. Most shows consist of a variety of performances, called classes, wherein animals with similar training or characteristics compete against one another for awards. Thus, horses from very *different/disparate grades/tiers* of breeding can participate in the same show. Some are bred for running, others for show jumping, and yet others for performing more strenuous exercises.

The movie takes place in south of France, during the 18th century. In the film, the young man marries a *righteous/virtuous woman/damsel* that has led a cloistered life in the company of her aging aunt. During a conversation the aunt has with the young man, the audience learns of his involvement with a sultry Spanish mistress. The young man tells the aunt that he will leave his mistress, but he instead maintains a relationship with both women, making them suffer. In the end, the audience sees his *miserable/morose lover/courtesan* throwing herself at his feet, just as the young wife learns of the affair. The movie ends very sadly for all. The young wife miscarries and the tempestuous Spaniard suddenly leaves the young man and returns home.

There was a lot of discord during the meeting, which delayed the decision about the movie premier. Someone forgot the vegetarian orders. The coffee was repugnant. The negotiations were taking hours. When the design team brought in the poster for the movie, it was the last straw and the *emotional/sullen director/publicist* stormed out of the room. Not only did the poster have the name of one of the actors misspelled but the name of the director was not even mentioned. He later complained that this *blatant/flagrant mistake/omission* demonstrated just how much everyone cared about this movie in the first place. Fortunately, the designers corrected the error just in time for the premier. The movie did not get glowing reviews but it did make a bit of money at the box office. It was later replayed on television. Strangely enough, it even became somewhat of a cult classic.

The flat was in great disrepair. The wallpaper hung tattered on the walls, exposing the gray cement beneath it. The furniture lay broken. The handles of doors were missing. The bathroom stunk like a *gross/rancid lemon/mango* mixed with baby powder. This unorthodox combination of aromas scared away prospective renters more than the gaping hole in one of the walls, from which the tendrils of electric wiring hung limply. It was clear that our *former/bygone neighbors/tenants* led tumultuous lives filled with many celebratory occasions. The vodka bottles stacked neatly in the corner suggested that they did enjoy some semblance of order in their lives. The place would need a lot of work before we could make any use of it.

The last four adventures had been a breeze and I was really hoping that stealing the red dragon's treasure would be as challenging as the oracle had said: After crossing the river of fire and triumphing over the troll, I would solve a *complex/onerous puzzle/conundrum* that would lead me inside the dragon's lair. I crossed the river on the back of a passing fire beetle, and easily bested the troll. I climbed a spiral staircase and saw a door with no handle. Lying in front of me were some thirty *ordinary/prosaic pieces/shards* of glass that clearly fit together like a child's jigsaw puzzle. Some challenge! I put it together with no trouble and the door magically opened, revealing the loot I had sought. While the gold certainly kept me warm and well-fed, I was disappointed that another adventure ended so abruptly.

Life at court of 18th century France was licentious and dangerous, particularly so, for women. Having no rights in the society of yesteryear they were often coerced by more powerful men. In literary works, there are many mentions of court jesters and the role they play in the *immoral/unsavory events/intrigues* taking place behind the scenes. Often, jesters were irreverent figures. They were permitted many liberties at the court that a nobleman would not be. Their unpredictability and temperamental personality made them dangerous enemies. A well-known fresco inside one of the palaces depicts a jester with an *insane/impish smile/grimace* and in his three-pronged hat with bells beating a courtier with a long stick. The history of the jester is one of the reasons why his image became part of the card deck. The jester card is symbolizes both the luck and the misfortune one may encounter at the king's court.

Written language is not just something one encounters on paper or etched in stone. The penchant for writing dwells in every man's heart. The urge is so powerful that the content does not always matter. Sometimes, it is just a curse, a venomous cry, an obscenity thrown at the heavens. The graffiti on the walls and on the bridge is very representative of the *extensive/prolific writings/screeds* left behind by an unknown but steady hand all over the city. Writing appears in the strangest and darkest places where there is no one that can read it. Even in the infernal depths of the subway tunnel some scribe leaves that *universal/hackneyed testament/memento* of love as reflected in the pairing of names, souls, or more likely, bodies: "Alice loves Michael." Where is Alice now? Has she remained faithful? Has this love endured?

Disney has long traded on this appealing idea, albeit mostly in animated form. 1995's "Babe" - which relied on live-action talking animals - furthered the art form, which is demonstrated again in the hilarious and satisfying "Racing Stripes." The Warner Brothers film, which opens nationwide today, centers on a *brave/plucky horse/zebra* that becomes a race pony. The story begins when a baby animal is accidentally left behind by a traveling circus in Kentucky. It is discovered by a farmer and brought home, where he is adopted by the farmer's daughter. "Racing Stripes" emphasizes *familiar/pervasive themes/motifs*, like "Nothing good ever comes easy," as Tucker tells Stripes. The filmmakers also pit technology against ingenuity—as in how the thoroughbreds use the latest gadgetry while Stripes must rely on Farmer Nolan's earthy, makeshift training tools.

There are 600 species of insects on the British isles all of which are carnivores. In the garden one may find a number of critters, especially during the months of autumn. Some of these can be very colorful and some can be very dangerous. The one that lives underneath the leaves of the oak tree is an *typical/exemplary spider/arachnid* with four pairs of short hairy legs. The spider waits in the center or at the edge of the web until the vibration of the ensnared prey is picked up by sensors in its front pair of legs; then it approaches the prey and wraps it in silk. The spider does not consume its food directly. It first injects a *thick/viscous venom/toxin* and immobilizes the creature. Then it injects the digestive juices which partially dissolve the organism. The spider then sucks out the resulting meal, leaving a carcass of undigested remains still wrapped in silk.

This was one of those imbecilic fantasy flicks that one could not avoid seeing because it starred a popular young starlet. The movie was about some successful politician running for governor. His campaign is complicated by a *gorgeous/seductive witch/vixen* with romance and revenge on her mind. Coincidentally, throughout the entire movie the leading lady sounded like she had a cold and was completely incoherent. The actor playing the politician had zero chemistry with her. He appeared both startled and repulsed each time he heard her *rough/hoarse voice/murmur* or when she would hug or kiss him. It would have been a really dull experience, if it was not for rambunctious company of people in the front that made fun of the movie. Eventually, we ended up watching their tomfoolery more than whatever was happening on the screen.

As youngsters we enjoy funny stories about frightening characters. One such story told of a *wicked/grumpy goblin/gremlin* that lived in a tiny swamp near a sea. Like in most swamps there were many gnats and similar bugs. A funny illustration in the story depicted how this creature battled an entire cloud of these bugs. The story described very amusingly how, piercing the swarm like a *cruel/fretful warrier/matador* with a gnarly branch for a weapon, he would hop in exasperation. One day a princess comes upon his shack in the swamp but she is not greeted with much hospitability. She aids the monster so that they can build a hovel in another area near the sea. The bugs follow them but are blown away by the wind. The creature and the princess live happily ever after near the sea.

A.4 LIST 4

Before telecommunications, citizens could use pamphlets for mass communications. Thomas Paine was a political pamphleteer over 230 years ago. If he were alive today, he would not be a glam television anchor. He would not be a *severe/abrasive analyst/pundit* on a cable news channel. No, if Thomas Paine could be among us, he would be one of us. Thomas Paine would most assuredly be a blogger. Blogging permits the expression of one's views without being interrupted by either *sudden/abrupt applause/ovations* from an adoring audience or being booed off the stage. Sometimes it might feel like speaking in a vacuum but weblogs are bringing about a real revival of citizen pamphleteering.

The afternoon was lazy. The guests gathered outside on the grounds of the manor. Women entertained themselves with the recent gossip. The young and impassioned atheist philosopher was talking with the *patient/serene bishop/deacon* about the nature of divine. The nanny was watching the kids. They were enjoying their vacation from studies. The smallest one, Ellen, was of that age when one is very interested in how things work. Even now she was standing underneath a pear tree, studying the wings of a *little/miniscule cricket/locust* she found in its branches. The nanny stopped Ellen's interest in the Nature's mysteries very sternly. Ellen asked her if insects have souls. Nanny said she did not know but she was certain of where Ellen's would end up if she continued playing with insects.

The teacher interrogated the boy and he betrayed the other students. Although Mary knew of his treachery, she could not tell on her friend and took the blame for his cowardly act.

Throughout the movie, Mary waits for his admission of guilt, but not only is it not forthcoming, he actually joins the other kids when they ostracize her. The girl suffers many an *abusive/vitriolic nickname/epithet* inside the school walls and is even attacked in her home. One afternoon, when she is walking from school alone, she is captured by the *merciless/vicious children/urchins* and brought inside an old and dilapidated churchyard. There they continue to torment her and even then her friend does not protect her. Mary is deeply hurt by his betrayal.

The centuries-old Wieliczka Salt Site in Poland, which has already earned itself a place on the UNESCO World Cultural Heritage list, is now the place for a pilgrims' trail - 100 meters under the earth. The route takes visitors alongside the numerous underground chapels built by the *religious/devout workers/miners* from the 17th century. A cross was fixed wherever a miner perished, and regular services were conducted in underground chapels. These demonstrate the importance of the faith of laborers faced with the *constant/incessant danger/peril* of working underground. The hazardous job escalated the Poles native religiosity. The one for Saint Kinga is Wieliczka's most incredible sight, with religious statues, the artistic bass relief of The Last Supper, and crystal-dripping chandeliers - all made of salt.

Shlomo was born in Hungary. Like many Jewish families in Eastern Europe, they were a Chassidic family. Shlomo’s father was an *famous/eminent singer/cantor,* as were all of his brothers, and the family held positions in some of Hungary's most famous synagogues. Given his background, the young Shlomo received a thorough and musical education but strangely was not taught singing. Once a renowned scholar was visiting the synagogue and Shlomo insisted that he would sing for him. He was very anxious and stuttered during his performance. The rabbi, however, was not at all upset by this *awful/ghastly disaster/calamity* and instead congratulated him on his soft and yet rich timbre. The family felt encouraged by this praise. In late fall, Shlomo arrived in Vienna and started his training as a singer at one of the most prestigious musical academies.

Mervyn Johns was one of the soundest and most sincere of actors. His roles were victims usually, reticent always, and never less than authentic: petty crooks, modest bank clerks, henpecked husbands, *polite/diffident priests/clerics* that were almost all Welsh and as obliging and as real as can be. He could muster an other-worldly air of almost celestial insight or stand in front of the audience and deliver some *absurd/asinine discourse/sermon* of a dejected drunkard. This was John's great and sometimes touching trait. He was himself short of build, but the secret of his acting was not so much a matter of height as of depth - of getting under the very skin of the role he played.

The night fell fast and the palace's doors were already closed. The guards changed. The room in which the painting hung was dark but there were some windows still lit. This operation was very dangerous and demanded a lot of planning. There was even a web camera that the *careful/vigilant criminals/burglars* set up on the banister that overlooked the courtyard. The camera's feed was monitored by an accomplice in a van three streets over. In the darkness one of the guards asked another for a cigarette. For a moment, the flash of the lighter exposed the black rope hanging rather incongruously on the *beautiful/ornate exterior/façade* of the old building. But the guard's back was turned and it went unnoticed. The rope was found the next day in the bushes near the window. The painting's theft still went unnoticed until the evening.

Upon hearing the news of the latest victories at the front, it became clear that the war was ending soon. The troops' morale vacillated sharply between extreme exasperation and impatience, and the *innocent/artless happiness/optimism* brought on by the victories of their brothers-in-arms. One evening a truck arrived in the camp. Its windshield was completely covered with the dirt of spring roads. Someone in a gray trench jumped out. The next moment the shouts were heard all over, spreading the news that war was officially over. Everyone was overjoyed and even the face of the *serious/solemn general/corporal* cracked in a crooked grin. The soldiers started packing their things, gathering their letters, folding their tents. They were finally going home.

With the exceptions of courting individuals and mothers with their young, the bear is a solitary animal. He is generally diurnal, but may also be active during the night or twilight. During the long winters this *furry/slovenly veteran/hermit* of the woods uses shelters such as caves and burrows as his den for a long period of sleep. It has been suggested that the bear is still in the process of evolving from a carnivorous diet and may eventually assume a predominantly herbivorous diet. This is particularly evident for anyone who has encountered a bear feasting on the *enjoyable/savory portion/ration* of honeycomb found inside the trees. All bears will feed on any food source that becomes available, and the nature of that varies seasonally. A study of black bears in Taiwan found that they would consume copious numbers of acorns when they were most common, and switch to animals in other times of the year.

Visitors in Ravenna may still see the stately sarcophagus of this Byzantine governor of fragments of Italy, which is placed in an alcove behind the church of S. Vitale. Upon the tomb is carved an inscription in rather halting Greek iambics, with a poor modern Latin translation. One can easily read in between the conventional phrases of the *naïve/vapid summary/eulogy* how unsuccessful the governor's rule had been. There is a mention of his wife but none about his battles. Had there been even some *minor/meager record/gleam* of victory over the Lombard army, the inscription would have mentioned it. As it is, the utmost that can be said of him is that he "kept Rome and the West unharmed", but if our reading of his history be correct, he probably kept the lovely Riviera unravaged by surrendering it.

The artist felt strangely moved by the performance this afternoon. He looked at his paintings that filled the flat. The painting he was working on the night before lay stretched out on the table. Its fresh coat of paint glistened in the moonbeam. There was a time when he thought that were this seemingly *permanent/indelible fragment/remnant* of himself found in the attic in some remote future, it could tell a story of the entire generation. Now, he was no longer certain whether this was an important enough story. His supper waited for him on that same table. It consisted of a piece of a *green/mouldy salmon/sturgeon* and a loaf of buttered bread. He considered burning his paintings but he just did not have the strength. He took a jar of white paint and splattered it over the canvas.

After the war, the family had no news of John. Their own letters went unanswered. The army was thinly spread out and did not have the most current information about the units overseas. One evening their mother received in the mail a *tragic/ominous letter/missive* from a friend of her husband's. They were fighting together at the front lines. The family learnt that their father was wounded and was now languishing in a tiny hospital somewhere in Italy. Several months later, this man appeared at their doorstep. It was evident that his visit was brought on by a *unhappy/somber business/errand* which made him very uncomfortable. He told them that during his convalescence, John fell in love with an Italian nurse. John was not coming back. They never heard of their father again, except once, many years later a postcard from Italy arrived. It said only "with love" and was not signed.

The sanctuary at Sepilok is famed worldwide for its work in rehabilitating a variety of animals and then releasing them, so that they would lead their life in the wild. For the majority of travelers no trip in Borneo is complete without seeing the *fabulous/majestic elephant/orangutan* and watching his playful romp. Although the park is densely covered in jungle there is a feeding platform that the animals visit at set times of day and this greatly enhances your chances of seeing them. This animal's distinct vocalizations and its *mighty/stocky shape/girth* make it stand out even amidst the clamor and the chaos of the jungle. Generally speaking the afternoon feeding is much less busy. During a night safari along the raised platforms, one will see the creatures of the jungle at their most active.

There are very few parks where kids can play and the city bureaucrats are moving at a pace of a sloth. In the meantime, our kids play in the backyards (the lucky ones, that is), and the back alleys. The entire last year, at press conferences, the mayor made *worthless/sporadic promises/oaths* that he would change the face of our town and that there will finally be a place for a playground. What is most upsetting, however, are the disingenuous statements of the officials that they have not yet found a suitable place. Everybody knows that there is an *enormous/desolate stadium/airfield* near the river just sitting there unused. Or what about that garbage dump next to the school. I am sure that could become a very nice park. Until the mayor realizes how important this may be for his reelection, I don’t think this project will move along at all.

Some hooligans had climbed on the train as it turned round the bend. They now perched on top victoriously as if they subdued the great big dragon which huffed and puffed as it pulled in. A gust of wind almost made one *small/svelte rider/jockey* slip down on the ground, but he held on with a shrill cry. There was a band of the local musicians all prepared for playing a loud march. The mayor addressed a flock of school kids dressed in their Sunday best and mumbled on about the importance of education. He was distracted and no one listened as one *stupid/fatuous statement/platitude* followed another. Everyone watched the train in awe and anticipation of the great event. The meeting committee consisted of the town’s more successful businessmen: the barber, the undertaker and the local councilman.

I won't belabor the reader with the actual details of our stilted conversation. Not because of what the thin, earnest and bespectacled activist had said - I've absorbed more *bitter/acrid criticism/animosity* against Israel in the past - but the way that he wasn't really debating. Instead he talked in clipped sentences punctuated by tight-lipped smiles and the recurring challenge: "Why is that?" as if he really did not want a response from me, but somehow had known the facts all along and now was simply challenging me. After each remonstrance, he would gulp his drink. Each gulp was like a gesture of *savage/ferocious wrath/vehemence* that washed down the anger that frothed forth. As a form of distraction from this conversation, I asked him what he thought of what was being shown on the bar's television: the scenes of festivity on the streets of Washington following the president’s inauguration.

A.5 TARGET PARAGRAPHS FOR ASTERISK TASK.

Argüello was a sinewy, powerful fighter whose nickname was El Flaco Explosivo, the Explosive Thin Man. A brutal body puncher with a piston of a left jab and a darting overhand right, he won championships in the featherweight, junior lightweight and lightweight divisions, becoming, in 1981, the sixth fighter that won three distinct titles. In the game for his fourth title, he stepped up in weight class once again and took on a super lightweight, Aaron Pryor. In one of most fabled slugfests, the other box*r knocked out Argüello in the 14th round with a flurry of blows directed at his head, leaving him unconscious for several minutes. Ten months later he lost a rematch, and though financial problems brought him back inside the ring more than once, he never regained his championship stature.

It seemed like a well-planned bank robbery: A man armed with an imitation machine pistol goes inside a Greenwich Village bank, grabs thousands of dollars and then drives off in a waiting getaway car. But the would-be robber that tried it yesterday did not count on one hurdle every New York motorist faces -- rush-hour traffic. The suspect, a convicted felon, was arrested after he held up a Citibank branch on Fifth Avenue when his getaway li*ousine he had hired got caught in traffic. Later in the day, investigators discovered that the would-be robber was wanted in four other bank robberies. The suspect was arrested in the morning in the congestion caused by the lights of an intersection. The police were also helped by the incredibly slow traffic along another street.

This year, while promoting awareness of China's national heritage, the government introduced a free-admission policy at the country's public museu*s. Officially the cultural establishment greeted the news with smiles. But the look of anxious exasperation on the face of a curator watching as crowds of schoolchildren swarmed in a gallery of ancient ceramics here on a recent morning told another story. They touched every exposed surface, leaned on glass cases and smeared them with fingerprints. A running joke is that once only a handful of people came inside these institutions for the art exhibits; now many will come, not for the art but for the air-conditioning. Such are the growing pains of these institutions in a country that feels both older and newer than any place on the planet.

After eight years and so much frenzied anticipation, any ending would have been a letdown. Viewers seek a resolution, happy or sad, so it was fitting that this series that was neither comedy nor tragedy should defy expectations in its very last moments. The ending was a reminder of what made these series about New Jersey mobsters so distinctive from the beginning. There have been many good mafia movies and one legendary trilogy, but fans could not find comparable depictions of the complexity and inconsistencies of American family life. The finale last night was almost like a *rank, a mischievous dig at viewers that agonized over how television's most addictive series would finish. The suspense of the final scene in the diner was almost unbearable. As last night's episode showed one last time, a troubled marriage struggles on, intergenerational conflicts scab over but never heal, and power comes and goes.

Governments control the pipes through which all that information flows. This means they can block sites or, as Egypt has just apparently done, shut down the entire Internet and thus confuse everyone that relies on it. Technological tools can be used effectively by the masses, or by the man. One must be cautious about praising the impact of social media on social protest. For star*ers, it is not as though technology always favors the people in the streets. Nor is it the case that one should always favor the people in the streets. The other worrisome thing is how revolutions inspired by the Internet will change their countries. Movements that center around hash tags often don't center around leaders. Headless movements have advantages, but are the charismatic people that are leading protests really the people one wants leading the country after the government changes?

A.6 TARGET PARAGRAPHS FOR Q-DETECTION TASK

The company, whose most promising drug candidate failed in a clinical trial in October, is one of several biotech businesses that have been under pressure from investors recently. The investors argued that the company should liquidate after this setback. In the past, when one of its drugs failed, a biotechnology company typically would try another new drug. But with capital markets tight, investors are becoming less interested in that tradition. Avigen, based in California, had been resisting the efforts of the Biotechnology Fund, which started a proxy fight for replacing the company's board. But on Thursday, the company gave in, saying it would dissolve its finances — as long as the Biotechnology Fund nominees were not elected. At the same time, the company, saying it was not pursuing any more research, dismissed most of its employees.

Dr. Rae is a professor of aerospace engineering. He is interested in why a football flies the way it does. It turns out that the flight of a football is almost as complicated as the flight of an airplane but we know less about the football. Dr. Rae is one of a handful of engineers and physicists that study the physics of football and other sports. The main reason is that they want their students interested while learning about such complicated subjects as fluid dynamics of the forces that act on rotating bodies. Dr. Rae uses the flight of a football for demonstrating the gyroscopic torque and it turns out that it is more complicated than one would expect. In more than five years of looking at football dynamics, Dr. Rae has done computer simulations of the forces acting on a flying ball and developed mathematics explaining the interactions.

They have a long lease on four floors of a loft building in the flower district, which houses her workrooms, and they live upstairs, in a penthouse they renovated fifteen years ago. A dining room, furnished with a marble drafting table, leads outside. There is a balcony that overlooks what was once a lithography studio. They sleep on a mezzanine, under a ceiling splotched by a century of water stains, yellow scabs that sometimes reopen. Ruben covered most of the walls with a graffiti-like frieze of faces. The décor is, as he puts it, a crazy quilt of found objects: puppets, a birdcage, hula hoops, some hanging from the rafters. Friends contributed furniture, and, surrounded by art books, canvases, and stylized dress forms that Ruben designs for Pucci Mannequins, a woodworm-ridden Buddha sits on an odd-shaped table.

There were people that said at the time that there was nothing wrong in wearing a glove puppet at a board meeting as such, but there were more that disagreed. The matter was hotly disputed in every one of the company's offices and in the canteen. Mr. Ramsay was well-liked, even if everyone thought him ineffectual, so a lot of people stuck up for him, even if they thought the squirrel a bit odd. Mr. Ramsay did not have a reputation for eccentricity. He was a mild mannered man. Never said a word, usually. Let everybody walk all over him. Mr. Ramsay had also never before produced a glove puppet from underneath the table. He had never had a puppet sitting on his left hand during a presentation from any of the Board members, and he had never behaved as if nothing untoward was happening when it patently was.

Much of the attention in the recent collapse of the housing boom has focused on those in danger of losing their home or facing higher monthly payments in their adjustable mortgages. But the broader effect on the economy is from the much larger population of homeowners that can no longer count on rising home values for bolstering their finances. Marshall and his bride, Holly, exchanged vows on the grounds of a sumptuous private estate in the Napa Valley. They spent their honeymoon at a resort in Tahiti. But now, in the downturn of the national economy, Mr. Whittey has grown tight with his money. His home is worth far less than it was a year ago, and his equity has evaporated. And like many other involuntary adopters of a newly economical lifestyle, he can borrow no more.

A.7 TARGET PARAGRAPHS FOR RHYME-JUDGMENT TASK

Every older hospitalized person should undergo short but proper cognitive testing, since subtle delirium is often missed. Older patients should be aroused during rounds and evaluated daily for the hypoactive form of delirium, which is often overlooked. When clinicians search for the underlying cause of delirium, they should be aware of the possibility of uncharacteristic presentations of many diseases in the elderly, including myocardial infarction, infection, and respiratory failure, because delirium is often the sole manifestation of the underlying disease. All preadmission and current medications should be reviewed. If changes in long-term medications are appropriate after the indications and risk–benefit ratios have been carefully weighed, the hospital represents the ideal venue for making these changes.

This year, the 10th anniversary of the presentation of the first “Resonance Chronometer”, a mechanism by the Geneva-based watchmaker, coincided with an exceptional horology sale at Sotheby’s in Paris. In collaboration with the French auction company and the horology specialists, Sotheby’s held a sale this month of rarely seen historical items that included a planetarium, a double-dial pedestal regulator and a calendrical table regulator, all signed by the 18th-century French clockmaker Antide Janvier. Before becoming an horologer, Janvier was a mathematician consumed by astronomy,” said the watchmaker, at a conference held during the preview of the sale at Sotheby’s. It was Mr. Janvier’s mechanism that the watchmaker adapted for the “Resonance Chronometer” wristwatches that he began making 10 years ago, relying on the natural phenomenon of resonance for accuracy.

The tendency of reversing letters in words is thought of as characteristic of dyslexia but that image is untrue because such reversals are made by all kinds of readers. Kids with dyslexia make more errors overall so they make more reversals as well, but not proportionately more. Kids that have trouble with reading have trouble with language generally. 'When they see a word in print, they have difficulty pronouncing it and they have difficulties in writing sentences and paragraphs. One study involved kids from the time they entered kindergarten until they reached third grade. When the researchers independently tested the students, they found same numbers of boys and girls in both grades with reading difficulties. And, they found, fewer than half of youngsters referred for reading problems actually had them.

A big department store was making a fuss about delivering parcels. A girl called them and asked if they would deliver some camera film. They said they couldn't deliver just the film, because that wasn't a dollar's worth and they weren't delivering things less than a dollar. She said that in that case they could send her a bottle of hair shampoo. The film was delivered the next day but the other item arrived three days later. Each time the delivery was made, the store would pay extra, so actually the store lost more money this way. One of the managers at the store decided that this practice should be either cancelled or the store clerks should wait until they have the entire order and then combine the items in a single package.

Fifteen years ago, Filipinos braved tanks and threats in a "people power" revolution and brought down a dictator that had stolen an election. They restored democracy after three decades of martial law. Last month, huge crowds again forced a president from office. As before, it was an impassioned outpouring, with songs and raised fists. But if they expected cheers once again from around the world, they were instead hurt and infuriated was described by foreign commentators as a "mob rule." The man they overthrew, Joseph Estrada, was now a democratically elected president half way done with his six-year term. The turning point came when the armed forces chief informed Mr. Estrada that the military was withdrawing its support.

A.8 TARGET PARAGRAPHS FOR COMPREHENSION TASK

The body rested in a fine mahogany coffin fitted with a plate of glass. The face, as it showed under the glass, was not disagreeable: it bore a faint grin, and as the death had been painless, had not been distorted beyond the repairing power of the undertaker. At two o'clock of the afternoon the friends assembled and paid their last tribute of respect. The surviving members of the family came severally every few minutes and wept above the composed features beneath the glass. This did them no good; it did John Mortonson no good; but in the presence of death, reason and philosophy are helpless. When the minister had finished his eulogy with prayer a hymn was sung and the pall-bearers took their places beside the bier. As the last notes of the hymn died away, the widow ran and cast herself upon the coffin and sobbed hysterically.

In the United States, trading in precious metals and other commodities is regulated and closely monitored by a federal agency, the Commodity Futures Trading Commission. In September, after receiving hundreds of complaints that silver future prices were being manipulated downward by companies, the commission’s enforcement division started an investigation. In November, an informant, described in the law suit only as an employee of Goldman Sachs and a 40-year industry veteran, approached the commission with tales of how the silver traders at JPMorgan were bragging about all the money they were making as a result of the manipulation, which entailed flooding the market with short positions every time the price of silver would creep upward. The idea was that by unloading its short positions like a time-released capsule, JPMorgan's traders were keeping the price of silver artificially low.

It was late morning when the soldiers came knocking on the door. Such a genteel knock. A bit like Mr. Marsden from the Pro did when he came and collected his money every month. "I'm here again," he would say, laughing. "Doesn't time fly!" And he would collect his half a crown which he would put inside the brown leather bag he carried around his waist before stooping down. He would then refit the bicycle clips around his skinny ankles, mount his sit-up-and-beg Raleigh and pedal off. He would knock on Mrs. Hutcheson's at number 143. Sixpence here, five bob there, a tanner from old Granny Baxter at number 79 for her funeral insurance! She was determined that she would have a good send off with ham sandwiches for all followed by biscuits and tea.

This week, Algeria's army installed a president, and issued a decree canceling the extension of the state of emergency in place since 1992. If one was perplexed why the change of heart, the recent fall of Arab and African autocratic regimes, and the approaching end for the one in Libya, Algeria's eastern neighbor, are the reason. The two fallen regimes, and the one in Libya, collapsed not only because of street defiance, or because the dictators suddenly became benevolent. In fact, the "balance of power" in each case was held by the military, which was persuaded by the people's revolt. It drove the final nail in the dictatorship's coffin, providing the push that turned into a shove. However, the problem in Algeria is that the military junta, which no doubt pulls the strings, purposely denied the victories of political parties it disliked in 1992. The Algerian military claimed that these parties are inherently extremist.

At number fourteen on a windy hilltop street Ed parked at the curb and walked down the drive. The building had been converted from a stable a hundred years before, sat well back from any other property, and commanded a view of Cleveland Circle. Ed could see most of the Reservoir, and behind that the Middle Campus of Boston College. The facade of the house was narrow, and two cars sat in the circular drive. A gray Toyota truck bore plates that Ed remembered were Eliza's - a gift last year from her father. The second car was a nasty bit of European speedcraft, crouching half on the grass and gleaming in its paint so that even the fallen leaves gave wide berth as they rustled past. Ed never slowed on his way as he came up at the front door. He reached it, found it locked, breathed deeply, and knocked.

APPENDIX B

MATERIALS FOR EXPERIMENT 4

Edith Stein was an old actress. Her agent suggested that she should write a book about her experiences in film and found her a publicist. Her neighbor, Anna Withers, decided she would write about her life as a vampire. Both books were soon finished. The ***(SL: thespian's publicist; L: publicist of the thespian; HF: publicist)*** tried to get some exposure for Edith's book. Anna's cousin, the butcher, knew people too and made some calls. Finally, the ***(SL: thespian's publicist; L: publicist of the thespian; HF: publicist)*** arranged for Edith to appear on a popular morning TV show. By coincidence, Anna was being interviewed during the same show about her book. The butcher and the ***(SL: thespian's publicist; L: publicist of the thespian; HF: publicist)*** ran into each other near the dressing rooms of their clients. Unlike the actress's memoirs, Anna's book was selling very well and the ***(SL: thespian's publicist; L: publicist of the thespian; HF: publicist)*** was interested in finding out how the butcher managed it. Anna was after all only a closeted vampire. The butcher was happy to share his secret with the ***(SL: thespian's publicist; L: publicist of the thespian; HF: publicist)***. He told him that Anna's book contained some very explicit scenes, which appealed to a certain type of audience.

Test sentences:

SL/L: The book promoted by the thespian's publicist was doing worse than Anna's novel about her adventures as a vampire.

HF: The book promoted by the actress's publicist was doing worse than Anna's novel about her adventures as a vampire.

Sally grew up in the old west, traveling the road as a cattle herder with her father and brothers. After an unfortunate accident, Sally was left alone until she came across the town of Wagon Wheel. At that time the law of the town was that women were not allowed to talk to men. So when Sally asked a man at the local post office for directions, the town-folk gasped at the ***(SL: cowgirl's defiance*** *for*; ***L: defiance of the cowgirl*** *for*; ***HF: defiance*** *of*) the local customs. The men of the town gathered to decide what penalty ***(SL:*** *the* ***cowgirl's defiance; L:*** *the* ***defiance of the cowgirl; HF:*** *this* ***defiance)*** deserved. Among the town's women the news of ***(SL:*** *the* ***cowgirl's defiance; L:*** *the* ***defiance of the cowgirl; HF:*** *this act of* ***defiance)*** spread quickly and instead of being angered they were inspired. Although Sally was unaware that she was doing something wrong, ***(SL:*** *the* ***cowgirl's defiance; L:*** *the* ***defiance of the cowgirl; HF:*** *her* ***defiance*** *of the local customs)* started a rebellion. In the end the man granted the women permission to speak whenever they liked. The women idolized Sally because without ***(SL:*** *the* ***cowgirl's defiance; L: the defiance of the cowgirl; HF:*** *her act of* ***defiance)*** they still wouldn't be speaking to men today.

Test sentences:

SL/L: The town's men were irritated by the cowgirl's defiance but the women were inspired by it.

HF: The town’s men were irritated by the woman’s defiance but the town’s women were inspired by it.

A couple hired two folk musicians to play at their wedding, but the couples’ parents had an argument. One family preferred the sound of a flute, whereas another claimed that there is no better instrument than a ***(SL: minstrel’s sitar; L: sitar of the minstrel; HF: sitar)***. The admirers of the flute claimed that its light sound was more appropriate for the wedding. The other family claimed that a ***(SL: minstrel’s sitar; L: sitar of the minstrel; HF: sitar)*** was more apt because it symbolizes how love plays on the strings of the heart. The flute’s music is too soothing and easy, whereas a ***(SL: minstrel’s sitar; L: sitar of the minstrel; HF: sitar)*** plays complex melodies on which one can meditate. The families asked the traveling musicians’ advice. After giving it some thought, they played a melody together. The flute sang of lasting happiness and the ***(SL: minstrel’s sitar; L: sitar of the minstrel; HF: sitar)*** repeated the melody quietly with a melancholy twang, as if reminding its partner that no union is so simple. When the flute seemed to tire and quiet down, the ***(SL: minstrel’s sitar; L: sitar of the minstrel; HF: sitar)*** would break into a joyous melody. The audience realized that both instruments complimented each other.

Test sentences:

SL/L: The families disagreed whether a minstrel’s sitar or a flute should play at the wedding.

HF: The families disagreed whether a musician’s sitar or a flute should play at the wedding.

Mary was an aid to a TV show host who was a renowned expert on politics. One day, her boss felt unwell and left mid-way through the show. The ***(SL: pundit's malady; L: malady of the pundit; HF: malady*** *of her boss)* allowed Mary to get some airtime. Next week, because of the ***(SL: pundit's malady; L: malady of the pundit; HF: malady),*** the channel invited another journalist to host the show, but the show's manager said that Mary could continue as a co-host at least until her boss's return. Mary was very excited about this opportunity. She was secretly hoping that the guest host would be inexperienced, and that the ***(SL: pundit's malady; L: malady of the pundit; HF: malady)*** would keep *(SL/L: him; HF: her boss)* at home for longer. Almost immediately, it became clear that her co-host monopolized airtime, making Mary's role redundant. Now her only hope was that the ***(SL: pundit's malady; L: malady of the pundit; HF: malady*** *of the old show host)* would be cured soon otherwise Mary was going to lose her new job. She visited her old boss and found him on the couch in front the TV. When he tried to stand up to greet her, it became clear that ***(SL:*** *the* ***pundit's malady; L:*** *the* ***malady of the pundit; HF: his malady)*** was more serious than previously thought – he could hardly walk.

Test sentences:

SL/L: Mary benefitted from the pundit's malady initially, but she soon wished for her boss's return.

HF: Mary benefitted from the expert's malady initially, but she soon wished for her boss's return.

Rumors of a plot reached the old queen. She turned for help to an attractive and intelligent woman who was a mistress to many powerful men. Few could escape her seductive ways. The queen had used her to learn all she could about her minister's ploys. In fact, the queen contributed to ***(SL:*** *the* ***courtesan’s affluence; L:*** *the* ***affluence of the courtesan; HF:*** *the* ***affluence*** *of her subject****)*** more than any of her suitors. The young woman, however, was indiscrete about her fortune and flaunted her wealth. The minister began to suspect that ***(SL:*** *the* ***courtesan’s affluence; L:*** *the* ***affluence of the courtesan; HF:*** *her* ***affluence)*** may be a sign of her betrayal. He threatened her and she told him the truth. The minister decided to use ***(SL:*** *the* ***courtesan’s affluence; L:*** *the* ***affluence of*** *his* ***courtesan; HF:*** *the* ***affluence)*** against the aging queen. The frightened woman made a deal with the minister to deliver false reports to the queen. The queen continued to give the young woman generous gifts, which increased still ***(SL:*** *the* ***courtesan’s affluence; L:*** *the* ***affluence of the courtesan; HF:*** *her* ***affluence)***. Soon the young woman had amassed a fortune that was enough to hire a small army of mercenaries to overthrow the queen. In the end, ***(SL:*** *the* ***courtesan’s affluence; L:*** *the* ***affluence of the courtesan; HF:*** *this* ***affluence)*** helped the minister to execute their plan.

Test sentences:

SL/L: The minister used his courtesan’s affluence to end the queen’s reign.

HF: The minister used his mistress’s affluence to end the queen’s reign.

The English professor was an eccentric who owned a lot of exotic animals. Each semester, he would bring one of his pets to class. Last semester, the ***(SL: academician’s flamingo ; L: flamingo of the academician; HF: flamingo)*** was chosen to accompany him. Initially, the bird was shy and stayed near the podium, but as the lecture went on it became bolder. While the professor read excerpts from Shakespeare, the ***(SL: academician’s flamingo ; L: flamingo of the academician; HF: flamingo)*** strutted around the lecture hall. It flew to the ceiling and danced in between the rows of seats. Then the students’ notebooks became objects of great interest to the ***(SL: academician's flamingo; L: flamingo of the academician; HF: flamingo)***, and the bird proceeded to peck at a few. Instead of paying attention to the lecture, the students were awfully distracted by the bird's antics. Some even fed the ***(SL: academician's flamingo; L: flamingo of the academician; HF: flamingo)*** snacks. At the end of the semester the students were asked what their favorite part of class was and most answered with the "***(SL: academician's flamingo; L: flamingo of the academician; HF: flamingo)***."

Test sentences:

SL/L: The students were amused by the *academician's flamingo* and its antics.

HF: The students were amused by the *professor's flamingo* and its antics.

Every spring the custodian, James, and the hospital's landscaping crew plant flowers around the hospital's grounds. The landscaper arranges flowerbeds in front the hospital's entrance, whereas James plants flowers outside every patient's window and in planters all around the building. He also has a good feeling for color, so that ***(SL:*** *the* ***custodian's blossoms ; L:*** *the* ***blossoms of the custodian; HF:*** *his* ***blossoms)*** always make a lasting impression on the patients. The landscaper does not take good care of the plants, but ***(SL:*** *the* ***custodian's blossoms ; L:*** *the* ***blossoms of the custodian; HF:*** *the* ***blossoms*** *that James plants**)*** are beautiful and he never lets a single weed grow. The hospital staff waits impatiently for ***(SL:*** *the* ***custodian's blossoms ; L:*** *the* ***blossoms of the custodian; HF:*** *the* ***blossoms)*** to emerge in late spring. *(SL/L: His; HF: The)* gentle nature and his devotion to gardening make *(SL/L: the janitor; HF: James)* the most beloved member of the hospital's staff. The cheerful and healthy look of the ***(SL: custodian's blossoms; L: blossoms of the custodian; HF: blossoms)*** helps patients heal faster. When they leave the hospital, the ***(SL: custodian's blossoms; L: blossoms of the custodian; HF: blossoms)*** inspire many to start a garden of their own.

Test sentences:

SL/L: When spring comes the custodian's blossoms make the patients and the staff very happy.

HF: When spring comes the guard's blossoms make the patients and the staff very happy.

A priest at St. Mary's church made an awkward joke during what was intended to be a solemn sermon after the death of the town's beloved mayor. The nervous laughter seized the audience and ***(SL: the deacon's witticism ; L: the witticism of the deacon; HF:*** *this unfortunate* ***witticism)*** ended up in the news. The congregation thought that, although an obvious blunder, the ***(SL: the deacon's witticism ; L: the witticism of the deacon; HF: witticism)*** was not a serious matter. The late mayor enjoyed a good joke and might have appreciated a more cheerful send-off. In contrast, his fellow clergymen thought the ***(SL: deacon's witticism; L: witticism of the deacon; HF: witticism)*** as inappropriately flippant and unprofessional. Some argued that the ***(SL: deacon's witticism; L: witticism of the deacon; HF: witticism)*** helped everyone pay attention during the services. Others had said that he should be fired from his post. The arguments continued for a week, but then a naked man was found in the town's bell tower and the ***(SL: deacon's witticism ; L: witticism of the deacon; HF: witticism)*** was forgotten.

Test sentences:

SL/L: The congregation thought the deacon's witticism was very amusing.

HF: The congregation thought the bishop's witticism was very amusing.

While cleaning his laboratory’s old supply closet, Dr. Bunsen Honeydew found a flask marked with a blue ballpoint pen. Inside was a greenish liquid with the density of honey. The ***(SL: specimen’s viscosity; L: viscosity of the specimen; HF: viscosity*** *of the liquid* ***)*** and its unusual color reminded the doctor that a newer batch of similar flasks just arrived in the mail. He asked his assistant, Beaker, to compare ***(SL:*** *this* ***specimen’s viscosity; L: the viscosity of the specimen; HF:*** *the* ***viscosity)*** with the ones they just received from a supplier. If Beaker found that the ***(SL: specimen’s viscosity; L: viscosity of the specimen; HF: viscosity*** *of the liquid inside the flask* ***)*** was too high, then a solution might be to dilute it. However, if ***(SL:*** *the* ***specimen’s viscosity; L:*** *the* ***viscosity of the specimen; HF:*** *its* ***viscosity)*** was too low, then he would have to drink it. In order to measure ***(SL:*** *the* ***specimen’s viscosity; L:*** *the* ***viscosity of the specimen; HF: viscosity)***, Beaker used a rheometer and found that both liquids were approximately the same.

Test sentences:

SL/L: The scientist measured the specimen’s viscosity with the help of his assistant.

HF: The scientist measured the sample’s viscosity with the help of his assistant.

A fisherman was out at sea when a terrible storm overturned his boat. The man did not sink but held on to a wooden plank, which was all that remained of his vessel. Suddenly he felt something grip his leg and tug on it. He tried to see what was in the water and thought he saw a ***(SL: octopus’s tentacle; L: tentacle of the octopus; HF: tentacle)*** around his ankle. The storm must have wakened some sea monster from its slumber. The fisherman tried to shake off the ***(SL: octopus’s tentacle; L: tentacle of the octopus; HF: tentacle)*** but only felt it gripping more tightly. He felt himself growing heavier and sinking into the water. He searched his pockets for some other means of detaching the ***(SL: octopus's tentacle; L: tentacle of the octopus; HF: tentacle)*** from his leg. All he could find was his tobacco pipe. He brought the sharp end of the pipe to where the ***(SL: octopus's tentacle; L: tentacle of the octopus; HF: tentacle)*** was. The pipe touched his ankle but found no slimy ***(SL: octopus's tentacle; L: tentacle of the octopus; HF: tentacle)*** to dislodge. The man looked more closely and saw that it was his boot that must have been tugging on his leg.

Test sentences:

SL/L: The fisherman feared that an octopus's tentacle was grasping his ankle.

HF: The fisherman feared that a creature's tentacle was grasping his ankle.

The nanny was left alone with the two girls. The youngest was three Katy was seven. The nanny read a storybook to the children. Whereas Katy interrupted the story to ask questions as always, the ***(SL: toddler's apathy; L: apathy of the toddler; HF: apathy*** *of the toddler****)*** during the story-telling time was unusual. When the nanny offered the girls their snacks, Katy was quick to grab her favorite cookies, but the ***(SL: toddler's apathy; L: apathy of the toddler; HF: apathy*** *of her sister****)*** was unremitting. The child also felt warm to the touch. When the girls' mother called, the nanny did not mention anything about the ***(SL: toddler's apathy; L: apathy of the toddler; HF: apathy*** *of the toddler****)***. She did not want to worry her. Later that evening, when the little girl was clearly feverish, the nanny called the hospital. The nurse said the ***(SL: toddler's apathy; L: apathy of the toddler; HF: apathy*** *of the young girl****)*** may be a symptom of a serious illness and that the child needed to be brought in for examination. In the hospital, a doctor examined the little girl. He was also disturbed by the ***(SL: toddler's apathy; L: apathy of the***

***toddler; HF: apathy** of the toddler)* and lack of protest when being examined. The doctor diagnosed the girl with the measles.

Test sentences:

SL/L: The nurse was alarmed by the toddler's apathy and asked for her to be brought to the hospital.

HF: The nurse was alarmed by the child's apathy and asked for her to be brought to the hospital.

University hired two new professors: Dr. James in mathematics department and Dr. Walker in (SL/L: humanities; HF: the economics' department). Both are very energetic and fitness-oriented. Dr. James walks from home to the department but the ***(SL: linguist's commute; L: commute of the linguist; HF: commute** of Dr. Walker**)*** is somewhat longer, so he bikes to work. Once, the ***(SL: linguist's commute; L: commute of the linguist; HF:** Dr. Walker's **commute)*** had taken him on a route through the park. He saw Dr. James on the side of the trail and slowed down to chat. The mathematician told him that he was considering buying a house outside of the city. In a month, Dr. James bought the house and now the ***(SL: linguist's commute; L: commute of the linguist; HF: commute** of Dr. Walker**)*** was much shorter by comparison. The following summer, the city was fixing the roads and a number of routes were closed. The ***(SL: linguist's commute; L: commute of the linguist; HF: commute** of Dr. Walker**)*** was not affected by these closings, but *(SL/L: the mathematician; Dr. James)* could not get to work on time. He asked Dr. Walker if he could stay once a week at his home and his colleague agreed. Now the two of them could sometimes bike to work together and the ***(SL: linguist's commute; L: commute of the linguist; HF: commute)*** seemed shorter with a companion.

Test sentences:

SL/L: The mathematician knew that the linguist’s commute was shorter in comparison.

HF: The mathematician knew that the economist’s commute was shorter in comparison.

The restaurant owner was asked by his patrons to do something about a ***(SL: waitress’s cologne; L: cologne of the waitress; HF: cologne*** *of one of his employees* ***)***. The smell of this perfume overwhelmed the aroma of the customers’ meals. That evening the owner asked his wife for advice on how to approach this situation regarding the ***(SL: waitress’s cologne; L: cologne of the waitress; HF****: smell of* ***cologne)***. His wife said that it was strange that so many complained about the ***(SL: waitress’s cologne; L: cologne of the waitress; HF: cologne of his employee)*** but not about his own, since they both wore the same one. The next day the owner noticed his waitress’s bag on a chair next to the bar, emitting the very same smell of the perfume. The bottom of the bag was moist and he guessed that the ***(SL: waitress’s cologne; L: cologne of the waitress; HF: cologne)*** must have spilled inside it. He mentioned it to the young woman and she quickly amended the situation. The customers did not have to complain about the ***(SL: waitress’s cologne; L: cologne of the waitress; HF:*** *smell of* ***cologne)*** again.

Test sentences:

SL/L: The restaurant owner liked his waitress’s cologne and wore it himself.

HF: The restaurant owner liked his server’s cologne and wore it himself.

Mary preferred going to the small grocery store rather than to the supermarket, because the shop *(SL/L: owner; HF: proprietor)* grows some of the fruit himself. In particular, ***(SL:*** *this* ***grocer’s mangoes; L:*** *the* ***mangoes of the grocer; HF:*** *his* ***mangoes)*** are known to be the freshest in the city. Mary prepared a wonderful sorbet out of this exotic fruit. She went last Sunday as usual to the store but the clerk told her that they were all out of the (***SL: grocer's mangoes; L: mangoes of the grocer; HF:*** *the* ***locally grown mangoes)*** and instead offered the imported fruit, which was not yet ripe. Mary is very stubborn and she insisted that she had to buy the ***(SL: grocer's mangoes; L: mangoes of the grocer; HF:*** *local* ***mangoes)*** and no other. An argument ensued between her and the clerk. The clerk claimed that the imported fruit, once ripened, was just as good as ***(SL: the grocer's mangoes; L: the mangoes of the grocer; HF: the mangoes of his boss)*** but Mary would not budge. His boss overheard the argument and was very flattered by Mary's persistence. He went into his garden and found ripe fruit. Mary was very glad to go home with a basket full of (SL: grocer's mangoes; L: mangoes of the grocer; HF: his mangoes), rather than imported ones.

Test sentences:

SL/L: The store ran out of the grocer's mangoes and instead the clerk offered Mary the ones imported from Morocco.

HF: The store ran out of the owner's mangoes and instead the clerk offered Mary the ones imported from Morocco.

An old friar set out on a pilgrimage to an ancient and holy city. On the second day of his travels, a traveling merchant joined him on his path. After a day of walking, the men were exhausted and camped for the night on the side of the road. The ***(SL: pilgrim's satchel; L: satchel of the pilgrim; HF: satchel*** *of the friar)* was placed side by side with the merchant's wares. During the night the ***(SL: pilgrim's satchel; L: satchel of the pilgrim; HF: satchel)*** was stolen but the merchant's bag was left untouched. Both men were surprised. The merchant's purse was filled with spices and silks, whereas the ***(SL: pilgrim’s satchel; L: satchel of the pilgrim; HF: satchel)*** was filled with holy books. The thief must have taken the ***(SL: pilgrim’s satchel; L: satchel of the pilgrim; HF: satchel)*** because it was heavier than the merchant’s purse. Although the loss of his books was discouraging, the monk decided to continue his journey. The next night, the thief returned the ***(SL: pilgrim’s satchel; L: satchel of the pilgrim; HF: satchel)*** with its contents intact and did not touch the merchant’s purse. In the morning, the merchant asked his companion why he thought this was so. The friar took out a book from his bag and by chance it opened on a verse that chided against stealing.

Test sentences:

SL/L: The thief confused the pilgrim’s satchel with the merchant’s bag full of wares.

HF: The thief confused the priest’s satchel with the merchant’s bag full of wares.

Unlike the rose, the ***(SL: tulip’s petals; L: petals of the tulip; HF: petals*** *of the tulip* ***)*** are oblong and fewer in number, only six. One also becomes aware that ***(SL:*** *the* ***tulip’s petals; L:*** *the* ***petals of the tulip; HF:*** *these* ***petals)*** are harder and smoother than those of a rose, which makes it more resistant to colder climates and pests. It is as if this spear-headed flower is covered by a thin layer of lacquer. ***(SL:*** *The* **tulip’s petals; *L:*** *The* **petals of the tulip; *HF:*** *Its* ***petals)*** are more varied in color than those of other flowers, sometimes featuring color combinations reminiscent of exotic birds’ wings. These feathered patterns on the ***(SL: tulip’s petals; L: petals of the tulip; HF: petals)*** are due to a virus, which also causes them to become more fragile. Poets have written many a verse praising this flower and Dutch paintings are more likely to show a table littered with ***(SL: tulip’s petals*** *than any other flower* ***; L: the petals of the tulip*** *than any other flower* ***; HF: petals*** *of this blossom).*

Test sentences:

SL/L: The multi-colored patterns on the tulip's petals are caused by a virus.

HF: The multi-colored patterns on the flower's petals are caused by a virus.

The zoo keepers just finished their monthly check-up of the petting zoo. The rabbits, the ferrets, and the ponies seemed alright, but the ***(SL: zebra's obesity; L: obesity of the zebra; HF: obesity*** *of the zebra****)*** was giving the custodians trouble. There is a sign that warns the children and their parents not to bring food inside the petting zoo, but the ***(SL: zebra's obesity; L: obesity of the zebra; HF: obesity*** *of the zebra****)*** seemed to indicate that it might be sneaking snacks anyway. The main custodian invited the vet to see if ***(SL:*** *the* ***zebra's obesity; L:*** *the* ***obesity of the zebra; HF:*** *this* ***obesity)*** could be a sign of another health problem. The vet looked over *(SL/L: the animal; HF: zebra),* but apart from ***(SL:*** *the* ***zebra's obesity; L:*** *the* ***obesity of the zebra; HF:*** *its* ***obesity)***, it seemed perfectly happy and healthy. It was then that the vet noticed a pile of candy wrappers near *(SL/L: the animal's; HF: its)* shed. No one knew how the candy got there, or who was the culprit, but that probably explained the ***(SL: zebra's obesity; L: obesity of the zebra; HF: obesity*** *of the zebra****)***.

Test sentences:

SL/L: The reason for the zebra's obesity was unknown until the arrival of the vet.

HF: The reason for the animal's obesity was unknown until the arrival of the vet.

Animal tests showed that a new type of aloe-based medication may potentially alleviate many of the discomforts associated with various skin problems. Initially, the new treatment did not appear effective for the type of ***(SL: macaque's eczema; L: eczema of a macaque; HF:***

macaque's ***eczema)*** that parallels closely the skin condition in humans, but alleviated some rash-related symptoms for other tested animals. After a modification of the topical treatment with the addition of steroids, the ***(SL: macaque's eczema; L: eczema of the macaque HF:*** *macaque's* ***eczema)*** showed improvement. The medication needed repeated application, however, because the animal would sometimes remove the bandage with the treatment. With the modifications to the procedure, the ***(SL: macaque's eczema; L: eczema of the macaque; HF: eczema)*** was almost gone by the third day of treatment. The researchers concluded that while the ***(SL: macaque's eczema; L: eczema of the macaque; HF:*** *macaque's* ***eczema)*** was treatable with the combination of aforementioned medications, it was still too early for human trials. This was because while the affected areas were almost healed, the ***(SL: macaque's eczema; L: eczema of the macaque; HF: eczema)*** appeared to migrate to other parts of the animal.

Test sentences:

SL/L: Researchers concluded that the macaque's eczema was completely cured by the medication.

HF: Researchers concluded that the monkey's eczema was completely cured by the medication.

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