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UNIVERSITY OF CALIFORNIA, SAN DIEGO

Preview benefit: Coordinating vision and language to speak and read

A dissertation submitted in partial satisfaction of the requirements for the degree

Doctor of Philosophy

in

Psychology

by

Elizabeth Roye Schotter

Committee in charge:

Professor Keith Rayner, Chair
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2013

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University of California, San Diego

2013

DEDICATION

I dedicate this dissertation to my parents because all of me is them.

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Chapter 2, in full, has been submitted for publication of the material as it appears in 2013, Schotter, E.R., Jia, A., Ferreira, V.S., Rayner, K. Preview benefit in speaking occurs regardless of preview timing or awareness. The dissertation author was the primary investigator and author of this paper.

Chapter 3, in full, is a reprint of the material as it appears in Schotter, E.R., Ferreira, V.S. & Rayner, K. (2013). Parallel object activation and attentional gating of information: Evidence from eye movements in the multiple object naming paradigm. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 39, 365-374. The dissertation author was the primary investigator and author of this paper.

Chapter 4, in full, has been submitted for publication of the material as it appears in 2013, Schotter, E.R. Synonyms provide semantic preview benefit in English but other semantic relationships do not. The dissertation author was the sole investigator and author of this paper.

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- Schotter, E.R.**, & Rayner, K. (2013). Eye movements in reading. In E. Perego (Ed.), *Eye Tracking in Audiovisual Translation* (pp. 83-104). Rome: Aracne.
- Ferreira, V.S. & **Schotter, E.R.** (2013). Do verb bias effects on sentence production reflect sensitivity to comprehension or production factors? *Quarterly Journal of Experimental Psychology* (online first)
- Rayner, K., Angele, B, **Schotter, E.R.**, & Bicknell, K. (2013). On the processing of canonical word order during eye fixations in reading: Do readers process transposed word previews? *Visual Cognition*, *21*, 353-381.
- Rayner, K. & **Schotter, E.R.** (2013). Eye movements during reading. In H. Pashler (Ed.), *Encyclopedia of the Mind*. (pp. 338-340). Los Angeles: SAGE Publications, inc.
- Wang, H.-C., **Schotter, E.R.**, Angele, B., Yang, J., Simovici, D., Pomplun, M., & Rayner, K. (2013). Using singular value decomposition to investigate the configuration of Chinese characters: Evidence from eye movements during reading. *Journal of Research in Reading*, *36*, S35-S50.
- Schotter, E.R.**, Angele, B., & Rayner, K. (2012). Parafoveal processing in reading. *Attention, Perception & Psychophysics*, *74*, 5-35.
- Schotter, E.R.**, Blythe, H.I., Kirkby, J.A., Rayner, K., Holliman, N.S. & Liversedge, S.P. (2012). Binocular coordination: Reading stereoscopic sentences in depth. *PLoS ONE*, *7*.
- Schotter, E.R.**, Gerety, C. & Rayner, K. (2012). Heuristics and criterion setting during selective encoding in visual decision-making: Evidence from eye movements. *Visual Cognition*, *20*, 1110-1129.
- Schotter, E.R.**, & Rayner, K. (2012). Eye movements and word recognition during reading. In J. Adelman (Ed.), *Visual Word Recognition Volume 2: Meaning and Context, Individuals and Development* (pp. 73-101). New York: Psychology Press.
- Rayner, K., Pollatsek, A. & **Schotter, E.R.** (2012). Reading: Word identification and eye movements. In A. Healy (Ed.) *Handbook of Psychology, Volume 4: Experimental Psychology* (pp. 548-577). Hoboken: Wiley.
- Schotter, E.R.** (2011). Eye Movements as an index of linguistic processing in language production. *Studies of Psychology and Behavior*, *9*, 16-23.
- Slattery, T., **Schotter, E.R.**, Berry, R. & Rayner, K. (2011). Parafoveal and foveal processing of abbreviations during reading: Making a case for case. *Journal of Experimental Psychology: Learning Memory and Cognition*, *37*, 1022-1031.

Schotter, E.R., Berry, R., McKenzie, C., & Rayner, K. (2010). Gaze bias: Selective encoding and liking effects. *Visual Cognition, 18*, 1113-1132.

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Schotter, E.R., Bicknell, K., Howard, I., Levy, R., & Rayner, K. (under invited revision). Task effects reveal cognitive flexibility responding to frequency and predictability: Evidence from eye movements in reading and proofreading. *Cognition*

Schotter, E.R. (under invited revision). Synonyms provide semantic preview benefit in English but other semantic relationships do not. *Journal of Memory and Language*

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Schotter, E.R., Tran, R., & Rayner, K. (in prep). Reading comprehension is supported by information obtained during regressions: Evidence from the trailing mask paradigm.

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Schotter, E.R. & Rayner, K. (2012). Semantic preview benefit may be observed in English: The importance of initial letter capitalization (and display change delay). *Meeting of the Psychonomic Society, Minneapolis, MN*

Angele, B., Rayner, K., **Schotter, E.R.,** & Bicknell, K. (2012). Do readers obtain preview benefit from transposed words in English? *Meeting of the Psychonomic Society, Minneapolis, MN*

- Schotter, E.R.**, Bicknell, K., Levy, R. & Rayner, K. (2012). The effects of task on frequency and predictability effects. *CUNY Conference on Human Sentence Processing, New York, NY*
- Angele, B., Rayner, K., **Schotter, E.R.**, & Bicknell, K. (2012). Do readers obtain preview benefit from transposed words in English? *CUNY Conference on Human Sentence Processing, New York, NY*
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- Wang, H.-C., Angele, B., **Schotter, E.R.**, Yang, J., Simovici, D., Pomplun, M., & Rayner, K. (2011). Singular value decomposition is a valid predictor of stroke importance in reading Chinese. *European Conference on Eye Movements, Marseille, France.*
- Angele, B., Slattery, T.J., Chaloukian, T.L., **Schotter, E.R.**, & Rayner, K. (2011). Dissociating effects of parafoveal preprocessing from effects of the sentence context. *CUNY Conference on Human Sentence Processing, Palo Alto, CA*
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ABSTRACT OF THE DISSERTATION

Preview benefit: Coordinating vision and language to speak and read

by

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Doctor of Philosophy in Psychology

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In this dissertation I address how we coordinate perceptual (visual) and linguistic processing to perform common tasks like speak about our environment or read a text. This is important because perception provides the input the linguistic system requires to activate relevant internal representations. Using eye tracking and *gaze-contingent display change paradigms* I assessed *preview benefit*—facilitated processing of a *target* when an item previously in its location (the *preview*) was related compared to unrelated. Preview benefit indexes the success of visual-linguistic coordination, indicating that one had (1) obtained information from an item before fixating it and (2) used that information to speed processing, upon fixation.

In Studies 1 (Schotter, Jia, Ferreira & Rayner, under review) and 2 (Schotter, Ferreira & Rayner, 2013), a target object was revealed when the speaker fixated it; before, it was masked and then a preview object (representing the same or a different concept as the target) appeared briefly in its location. Processing of the target was unaffected by the timing of the preview or subjects' awareness of it (Study 1), suggesting that speakers access information from upcoming objects opportunistically (i.e., whenever the preview is available). Furthermore, preview benefit was provided by previews in to-be-named locations but not by previews in to-be-ignored locations (Study 2), suggesting that speakers do not access information from non-fixated objects indiscriminately.

In Study 3 (Schotter, under revision), I investigated how the linguistic system uses this information to address a debate over whether semantic information is obtained from upcoming words. Research in German and Chinese has found semantic preview benefit but research in English has not. This may be due to the deep orthography of English delaying semantic access due to more effortful phonological decoding. Supporting this idea, semantic preview benefit occurred in English when the preview and target were synonyms but not when they were associatively related, possibly because associated words have looser connections in semantic networks than synonyms.

Together, these studies imply that we achieve efficient reading and speaking via sophisticated (opportunistic but not indiscriminate) access of visual information in service of the linguistic system to activate appropriate mental representations.

CHAPTER 1:
INTRODUCTION

Part of what makes human cognition so remarkable is the ability to coordinate multiple cognitive subsystems to support efficient processing. While not always obvious, humans constantly synchronize vision and linguistic processing, demonstrating the capability of the human mind to coordinate these systems to serve a unified goal: efficient communication. In language production (e.g., dialogue), the perceptual information obtained from the environment provides the speaker (1) the content about which to speak (sometimes) and (2) a referential anchor to which both speaker and listener can ground the conversation. In language comprehension, the environment constitutes (1) the linguistic input itself (e.g., the text in silent reading), (2) the referential anchor (as with auditory speech comprehension; e.g., the visual world paradigm), or both (e.g., in movies with subtitles).

In this dissertation, I investigate how perceptual processing (vision) and linguistic processing support each other when naming objects and reading sentences and the constraints those systems impose on these processes, addressing the following questions: How (with what time-course) do we obtain visual information from upcoming items (Study 1)? Can access of visual information be restricted from an item that is irrelevant to the task at hand (Study 2)? How does the linguistic system impose constraints on the way this visual information is used (Study 3)?

Constraints on accessing input from the environment: The perceptual span.

This research focuses on a balancing act between processing in the *fovea* (the center of vision with the highest *acuity*—resolution) and non-foveal areas of the visual field (the *parafovea* and *periphery*, areas with lower acuity). Undoubtedly, because acuity (and consequently, the fidelity of visual information *entering* the processing system) is higher, information processing is more efficient inside than outside the fovea (see Rayner, 1998, 2009; Schotter, Angele, & Rayner, 2012). It is for this reason that humans make eye movements—to bring to the center of vision the stimulus that one wishes to process with the highest efficiency. Consequently, where the eyes fixate and where the mind attends are highly correlated at any given moment (Just & Carpenter, 1976). It is important to note that, just because the center of vision constitutes the area of highest acuity and highest priority in processing, stimuli (objects or words) lying outside the fovea are visible and available for processing, to some degree (i.e., within the *perceptual span*; see Rayner 1998, 2009; Schotter et al., 2012 for reviews with regard to reading and Schotter, 2011 for a review with regard to speech production and comparisons to reading). How and to what extent is this information accessed and how is it used to facilitate ongoing processing? To investigate this, researchers have turned to eye tracking and gaze-contingent display change paradigms.

Eye movements as an index of cognitive processing: Preview benefit in the gaze-contingent boundary paradigm and the multiple object-naming paradigm.

Because fixation location constitutes an important indication of both overt attention and covert attention (see Rayner, 1998, 2009), all the studies reported

here use eye movement behavior as the dependent measure to assess whether and how information is obtained and used from upcoming items. The logic underlying these studies follows from earlier work in the reading literature using the *gaze-contingent boundary paradigm* (Rayner, 1975) and hinges on the idea of *preview benefit*—that information is accessed from a stimulus before it is fixated and used to facilitate processing upon fixating it (see Rayner, 1998, 2009; Schotter et al., 2012 for reviews). In the boundary paradigm, the subject reads a sentence while his/her eye movements are monitored and the display from which the subject is reading is manipulated based on where he/she is looking. As the reader fixates words before a critical, manipulated word, it is replaced with a different letter string—the *preview*. Once the reader makes an eye movement to that word and his/her eyes cross an invisible boundary located at the beginning of the space before it, the preview disappears and is replaced with the *target*—the actual word that appears in the sentence. What is manipulated in these experiments is the relationship between the preview and the target. In general, the more similar to the target the preview is, the faster processing of the target will be (i.e., preview benefit will be larger; e.g., Mielliet & Sparrow, 2004; Pollatsek, Lesch, Morris & Rayner, 1992; see Schotter et al., 2012). Preview benefit is measured as the difference between processing time on the target when the preview was related compared to a baseline condition, in which the preview is either an unrelated word or letter string (e.g., a sequence of x's or random letters).

While originally designed to study parafoveal preprocessing in reading (as in Study 3), the boundary paradigm has been adapted to study language production as well (Pollatsek, Rayner, & Collins, 1984), and has been extended to the *multiple object-naming paradigm* (Morgan & Meyer, 2005; Studies 1 and 2). The logic is largely the same as for reading, but the task obviously differs. In this paradigm, several (generally 2-4) objects are presented simultaneously on a computer screen, separated by blank space, and the subject is instructed to name them in a prescribed order. As in the reading version of the paradigm, one object is selected as the target of manipulation and changes from a preview to a target during the saccade to it. As in reading, preview benefit is measured as faster processing of the target when the preview was related compared to unrelated.

With these paradigms, researchers can precisely map out not only what *type* of information the speaker or reader accesses from upcoming items (using different types of preview conditions, as in Study 3), but also the time-course of preprocessing (as in Study 1) by presenting the preview at different time intervals (*stimulus onset asynchronies; SOAs*). The logic behind the use of different SOAs relies on the fact that perceptual information can only be accessed from an item while it is present. Thus, different SOA timings are used to present the preview of the upcoming item at particular times during processing of the current item (early vs. late). Again, preview benefit is measured, but here the critical comparison is the magnitude of preview benefit at different SOAs. If preview benefit is not modulated by the timing of the preview it would suggest that speakers had, to some extent,

always allocated attention to it, rather than only prior to an eye movement to that location.

Differences between processing demands on speaking and reading.

The reader's task is in some ways similar but in many ways different from the task of speaking. Most notably, information flows in opposite directions in the two tasks. Speakers start with conceptual representations and end with the phonological form they produce. Readers start with orthographic input and must end with a conceptual representation of what that orthographic form represents. The consequence of this is that, whereas speakers start with a meaning and attempt to *convey* it, readers must *recover* the meaning intended by the writer. An important part of this recovery of meaning is that word order (especially in languages that are not case marked, and thus have no other way to denote a words' syntactic role) is extremely important (Rayner, Angele, Schotter, & Bicknell, 2013; Rayner, Pollatsek, Liversedge, & Reichle, 2009; Reichle, Liversedge, Pollatsek, & Rayner, 2009; Schotter et al., 2012). From this view, it may seem that readers should not even attempt to preprocess upcoming words in order to avoid identifying them out of order (potentially leading to a misunderstanding of the sentence). However, as with speaking, preprocessing of words during reading has been robustly demonstrated, at least in terms of their visual properties (e.g., word length), orthography, and phonology. Preprocessing of the meaning (semantics) from an upcoming word is debated (see Rayner, 1998, 2009; Schotter et al., 2012; see below). One final difference between speaking and reading is how the sequence of eye movements is

determined. Because speakers must combine exploration and apprehension of their environment with speaking about it (Griffin & Bock, 2000), the sequence and location of their fixations is mostly unconstrained and it is likely that they distribute processing broadly across the environment (at least in part) in order to determine where they should move their eyes next. In reading, on the other hand, because the order of fixations is highly constrained by the text, readers may distribute processing differently, possibly in a more discrete way.

Accessing meaning: Linguistic organization and semantic networks.

While the research mentioned above suggests that speakers and readers use perceptual processing to *access* information from multiple items simultaneously, it does not reveal how they *use* that information, once it is obtained. Within the reading literature there is a debate over the existence of semantic (meaning-based) preview benefit, with different findings across different languages (see below). Thus, it is clear that properties of the language affect how readers are able to use the information obtained through perceptual processing to read for comprehension.

It is possible that readers may temporally stagger processing of words, waiting to process the upcoming word until some requisite processing of the current word has transpired. This, in fact, is the operating principle underlying the E-Z Reader model (Reichle, Pollatsek, Fisher, & Rayner, 1998; Reichle, Pollatsek, & Rayner, 2006; Reichle, Rayner, & Pollatsek, 2003; Reichle, Warren, & McConnell, 2009), a serial attention shift model of eye movements in reading. In this model,

word identification occurs serially, one word at a time, allowing for word order to be properly maintained. Thus, while perceptual processing may occur across multiple words, the opportunity to access lexical-semantic information from perceptual information is restricted to a serial process. This processing principle stands in contrast to the SWIFT model (Engbert, Longtin, & Kliegl, 2002; Engbert, Nuthmann, Richter, & Kliegl, 2005; Schad & Engbert, 2012), in which word identification occurs on multiple words simultaneously, distributed as a gradient with the currently fixated word having the highest priority. These two models—the most prominent models of eye movements during reading—have been argued to make different predictions about the presence of semantic preview benefit—whether semantic information is obtained from the upcoming word during reading. Semantic preview benefit is argued to naturally fall out of SWIFT but many assume that it poses a problem for E-Z Reader. In fact, semantic preview benefit has been debated over the past decade or so, with studies showing positive effects in German (Hohenstein & Kliegl, 2013; Hohenstein, Laubrock, & Kliegl, 2010) and Chinese (Yan, Richter, Shu & Kliegl, 2009; Yang, Wang, Tong, & Rayner, 2010) but negative evidence in English (Altarriba, Kambe, Pollatsek & Rayner, 2001; Rayner, Balota & Pollatsek, 1986; see Hohenstein & Kliegl, 2013; Schotter et al., 2012 for discussion of other research showing negative evidence). The work in Study 3 investigates the linguistic constraints on semantic preview benefit, attempting to explain these cross-language differences.

The ideas detailed above suggest that humans take advantage of the perceptual information provided by the environment to facilitate efficient language processing. Additionally, this process is subject to constraints imposed on it by properties of the visual system (e.g., acuity differences across the visual field) and the linguistic system (e.g., properties of the language involved). The studies in this dissertation explore these constraints further, addressing how humans obtain visual information from upcoming items (Study 1), whether access of that information can be restricted when irrelevant (Study 2), and how visual information obtained from upcoming items is used by the linguistic system (Study 3).

Study 1

Recently, many studies have shown that speakers can process more than one object simultaneously (Malpass & Meyer, 2010; Meyer & Dobel, 2003; Meyer, Ouellet, & Hacker, 2008; Morgan & Meyer, 2005; Morgan, van Elswijk, & Meyer, 2008; Pollatsek et al., 1984; for reviews see Meyer, 2004; Schotter, 2011). These findings then raise the issue of *how* the language processing system successfully achieves simultaneous activation of multiple objects. It may seem logical to manage this by delaying processing of the upcoming object until some processing of the current object is complete.

To test this, in Study 1 (Schotter, Jia, Ferreira, & Rayner, under review) I combined the multiple object naming paradigm with an SOA manipulation, varying when the preview appeared: 50 or 250 ms after fixation on the first object (the

preview was always displayed for 200 ms). If speakers only access information from the upcoming object shortly before they move their eyes to it, preview benefit would be absent or diminished at the early SOA compared to the late SOA. An interaction between SOA and preview type would suggest that speakers access information from upcoming objects discretely, in a way that is temporally separated from processing of other objects. On the other hand, a lack of an interaction would suggest that speakers access this information opportunistically, continuously and concurrently with other objects, as soon as it is available.

Study 2

In addition to the issue addressed in Study 1, prior research showing that speakers access information from non-foveal objects raises another issue: speakers now require a way to ensure that they do not say the word for the upcoming object when intending to speak about another object. That is, how do speakers avail themselves of the information obtained during preview, but not become inundated with a potentially overwhelming amount of incoming information? This is of particular concern in natural environments, which can include dozens of features that could be verbalized. If a speaker wishes to name one object in that environment, how might access to information from all the other nameable items be managed? One way to accomplish this information management could be to restrict information from objects that are task-irrelevant. To investigate this, in Study 2 (Schotter, Ferreira, & Rayner, 2013) I used a different modification of the multiple object-naming paradigm. In Experiment 1, four objects were presented on the

screen and the subject only needed to name three of them—the object in the other location was always to be ignored. Previews appeared in the target location and the unnamed location while the subject fixated the first object and preview benefit was measured, comparing preview benefit from relevant (to-be-named) or irrelevant (to-be-ignored) locations. In Experiment 2, the previews appeared in the target and the third-to-be-named location, comparing preview benefit between two relevant (to-be-named) locations. To address concerns about differences in display complexity between the first two experiments, in Experiment 3, the previews appeared in the target and third location (as in Experiment 2), but the third location was to-be-ignored (as in Experiment 1). If speakers access information indiscriminately, preview benefit would be observed from both a preview in a to-be-named location (the target location in all experiments and the third-to-be-named location in Experiment 2) and from a preview that appears in a location that is never to-be-named (the unnamed location in Experiments 2 and 3). If, on the other hand, speakers access information from non-foveal objects selectively, in a way that is sensitive to the demands of the task (task-relevance—whether the object must be named) we would observe preview benefit from previews that appear in the to-be-named locations, but not from a preview that appears in the to-be-ignored location.

Together, Studies 1 and 2 investigate how speakers take advantage of perceptual input in order to speak efficiently. But speech production is only one side of the language processing coin. In order to gain a complete understanding of how efficient language processing is achieved one must understand how perception and

linguistic processing are coordinated in both production and comprehension. Therefore, in Study 3 I examine how this is achieved during reading.

Study 3

In Study 3 (Schotter, under review), I addressed the debate on semantic preview benefit in reading, assessing whether its presence depends on constraints imposed by linguistic factors (orthography of the language and the organization of conceptual representations). One reason why semantic preview benefit may be difficult to observe in English is because these factors may limit its magnitude. That is, because English has a deep orthography, phonological processing requires more time and resources. Thus, any semantic information that is obtained from the preview may be accessed so late that little information has had time to permeate the readers' associative semantic network. This account makes a very specific prediction: In English, semantic preview benefit should be unlikely to be observed from semantically associated words (because activation would need to travel too far between representations) but should be observed for synonyms (because their meanings are so similar, accessing one would almost immediately activate the other). To test this, I used the gaze-contingent boundary paradigm (explained above; Rayner, 1975) and compared reading times on a target word (e.g., *curlers*) when the preview was the same as the target (e.g., *curlers*), a synonym of the target (e.g., *rollers*), or a semantically related word (e.g., *styling*; in Experiment 2 only) to when it was an unrelated word (e.g., *suffice*).

Summary

Together, the following studies address the issue of how successful language processing (object naming and reading) is achieved. In Study 1 I investigate how speakers access information from objects they intend to name, simultaneously with the object they are attempting to name currently. Study 1 addresses whether access of information from upcoming objects is discrete (i.e., occurs only briefly during current object processing) or is opportunistic (i.e., occurs whenever perceptual information is available). In Study 2 I investigate whether speakers can manage the potentially overwhelming amount of incoming perceptual information, selecting which objects they wish to process while ignoring irrelevant objects. Study 2 addresses whether access of information from perceptually available objects is selective or indiscriminant. In Study 3 I investigate what constrains a readers' ability to access lexico-semantic information from upcoming words. Study 3 addresses whether the presence of semantic preview benefit in reading depends on constraints imposed on the process by linguistic factors (depth of orthography and semantic organization).

References

- Altarriba, J., Kambe, G., Pollatsek, A., & Rayner, K. (2001). Semantic codes are not used in integrating information across eye fixations in reading: evidence from fluent Spanish-English bilinguals. *Perception & Psychophysics*, *63*, 875-890.
- Engbert, R., Longtin, A., & Kliegl, R. (2002). A dynamical model of saccade generation in reading based on spatially distributed lexical processing. *Vision Research*, *42*, 621-636.
- Engbert, R., Nuthmann, A., Richter, E. M., & Kliegl, R. (2005). SWIFT: A dynamical model of saccade generation during reading. *Psychological Review*, *112*, 777-813.
- Griffin Z. & Bock J.K. (2000). What they eyes say about speaking. *Psychological Science*, *11*, 274-279.
- Hohenstein, S., & Kliegl, R. (2013). Semantic preview benefit during reading. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, in press.
- Hohenstein, S., Laubrock, J., & Kliegl, R. (2010). Semantic preview benefit in eye movements during reading: a parafoveal fast-priming study. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *36*, 1150-1170.
- Just, M.A. & Carpenter, P.A. (1976). Eye fixations and cognitive processes. *Cognitive Psychology*, *8*, 441-480.
- Malpass, D. & Meyer, A. (2010). The time course of name retrieval during multiple-object naming: Evidence from extrafoveal-on-foveal effects. *Journal of Experimental Psychology: Learning, Memory and Cognition*, *36*, 523-537.
- Meyer, A., (2004). The use of eye tracking in studies of sentence generation. In J. M. Henderson & F. Ferreira (Eds.), *The interface of language, vision, and action: Eye movements and the visual world* (pp. 191-211). New York: Psychology Press
- Meyer, A. & Dobel, C. (2003). Application of eye tracking in speech production research. In J. Hyönä , R. Radach, and H. Deubel (Eds.), *The mind's eye: Cognitive and applied aspects of eye movement research* (pp 253-272). Amsterdam: North Holland.
- Meyer, A., Ouellet, M., & Hacker, C. (2008). Parallel processing of objects in a naming task. *Journal of Experimental Psychology: Learning, Memory and Cognition*, *34*, 982-987.

- Miellat, S., & Sparrow, L. (2004). Phonological codes are assembled before word fixation: Evidence from boundary paradigm in sentence reading. *Brain and language, 90*, 299–310.
- Morgan, J. & Meyer, A. (2005). Processing of extrafoveal objects during multiple-object naming. *Journal of Experimental Psychology: Learning Memory and Cognition, 31*, 428-442.
- Morgan, J., van Elswijk, G., & Meyer, A. (2008). Extrafoveal processing of objects in a naming task: Evidence from word probe experiments. *Psychonomic Bulletin & Review, 15*, 561-565.
- Pollatsek, A., Lesch, M., Morris, R. K., & Rayner, K. (1992). Phonological codes are used in integrating information across saccades in word identification and reading. *Journal of Experimental Psychology: Human Perception and Performance, 18*, 148-162.
- Pollatsek, A., Rayner, K., & Collins, W. (1984). Integrating pictorial information across eye movements. *Journal of Experimental Psychology: General, 113*, 426-442.
- Rayner, K. (1975). The perceptual span and peripheral cues in reading. *Cognitive Psychology, 7*, 65-81.
- Rayner, K. (1998). Eye movements in reading and information processing: 20 years of research. *Psychological bulletin, 124*, 372–422.
- Rayner, K. (2009). The Thirty-fifth Sir Frederick Bartlett Lecture: Eye movements and attention in reading, scene perception, and visual search. *The Quarterly Journal of Experimental Psychology, 62*, 1457–1506.
- Rayner, K., Angele, B, Schotter, E.R., & Bicknell, K. (2013). On the processing of canonical word order during eye fixations in reading: Do readers process transposed word previews? *Visual Cognition, 21*, 353-381.
- Rayner, K., Balota, D. A., & Pollatsek, A. (1986). Against parafoveal semantic preprocessing during eye fixations in reading. *Canadian Journal of Psychology, 40*, 473–483.
- Rayner, K., Pollatsek, A., Liversedge, S.P. & Reichle, E. D. (2009). Eye movements and non-canonical reading: Comments on Kennedy and Pynte (2008). *Vision Research, 49*, 2232-2236.
- Reichle, E. D., Liversedge, E.D., Pollatsek, A., & Rayner, K. (2009). Encoding multiple

- words simultaneously in reading is implausible. *Trends in Cognitive Science*, 13, 115-119.
- Reichle, E. D., Pollatsek, A., Fisher, D. L., & Rayner, K. (1998). Toward a model of eye movement control in reading. *Psychological Review*, 105, 125–157.
- Reichle, E. D., Pollatsek, A., & Rayner, K. (2006). EZ Reader: A cognitive-control, serial-attention model of eye-movement behavior during reading. *Cognitive Systems Research*, 7(1), 4–22.
- Reichle, E. D., Rayner, K., & Pollatsek, A. (2003). The E-Z Reader model of eye movement control in reading: Comparisons to other models. *Behavioral and Brain Sciences*, 26, 445–476.
- Reichle, E. D., Warren, T., & McConnell, K. (2009). Using E-Z Reader to model the effects of higher-level language processing on eye movements during reading. *Psychonomic Bulletin & Review*, 16, 1–20.
- Schad, D.J. & Engbert, R. (2012). The zoom lens of attention: Simulated shuffled versus normal text reading using the SWIFT model. *Visual Cognition*, 20, 391-421.
- Schotter, E. (2011). Eye movements as an index of linguistic processing in language production. *Journal of Psychology and Behavior*, 9, 16-23
- Schotter, E.R. (under review). Synonyms provide semantic preview benefit in English but other semantic relationships do not. *Journal of Memory and Language*
- Schotter, E. R., Angele, B., & Rayner, K. (2012). Parafoveal processing in reading. *Attention, Perception, & Psychophysics*, 74, 5–35.
- Schotter, E.R., Ferreira, V.S. & Rayner, K. (2013). Parallel object activation and attentional gating of information: Evidence from eye movements in the multiple object naming paradigm. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 39, 365-374.
- Schotter, E.R., Jia, A., Ferreira, V.S., Rayner, K. (under review). Preview benefit in speaking occurs regardless of preview timing or awareness. *Psychonomic Bulletin & Review*
- Yan, M., Richter, E. M., Shu, H., & Kliegl, R. (2009). Readers of Chinese extract semantic information from parafoveal words. *Psychonomic bulletin & review*, 16, 561.

Yang, J., Wang, S., Tong, X., & Rayner, K. (2010). Semantic and plausibility effects on preview benefit during eye fixations in Chinese reading. *Reading and Writing, 25*, 1031-1052.

CHAPTER 2:
PREVIEW BENEFIT IN SPEAKING OCCURS REGARDLESS OF PREVIEW TIMING OR
AWARENESS

Abstract

Speakers are able to access information from objects they are about to name, but have not looked at yet. This suggests that speakers distribute attention over multiple objects, but does not reveal the time course of the concurrent processing of a current and to-be-named object. Using the *multiple object-naming paradigm* with a *gaze-contingent display change* manipulation, we addressed the issue of the time course of pre-processing the next-to-be-named object. We manipulated the latency of the onset of the preview (SOA) and whether the preview represented the same concept as (but a different visual token of) the target or an unrelated concept. Results revealed that preview benefit was robust, regardless of the latency of the preview onset (SOA) or the latency of the saccade to the target (the lag between preview offset and fixation on the target). Preview benefit was also observed regardless of subjects' self-reported awareness of the preview. Together, these data suggest that speakers continually distribute attention over multiple objects they intend to name, facilitating efficient language production.

Part of what makes speaking so efficient is our ability to pre-process upcoming, to-be-named objects (Meyer & Dobel, 2003; Meyer, Ouellet, & Hacker, 2008; Morgan & Meyer, 2005; Pollatsek, Rayner, & Collins, 1984; Schotter, Ferreira & Rayner, 2013; for reviews see Meyer, 2004; Schotter, 2011). This ability for simultaneous processing then raises the issue of how processing and management of information from multiple objects is achieved. Do speakers continuously process all objects in their visual field or is preprocessing of the upcoming object restricted to a brief amount of time—before the speaker has moved his/her eyes to that object—but when attention is shifted to its location?

When describing multiple objects in their environment, it may seem most advantageous for speakers to restrict pre-processing of an upcoming object to only a short time before they eyes move to it; otherwise they may risk prematurely accessing and saying the wrong word. However, such narrow deployment of attention may be difficult for speakers because the order in which they can inspect their environment is unconstrained (in comparison to reading, in which the sequence of fixations is constrained by the order of the words in the text; see Rayner, Angele, Schotter, & Bicknell, 2013; Reichle, Liversedge, Pollatsek, & Rayner, 2009; Schotter, Angele, & Rayner, 2012). Therefore, a process in which speakers fully process one object and then shift attention to pre-process the next object before they move their eyes to it may not be a viable strategy. Rather, because speakers combine exploration of their visual environment with the task of speaking (Griffin &

Bock, 2000), it may be more likely that they distribute attention and processing resources over the entire scene.

In the present study, we investigated whether speakers distribute attention over multiple objects continuously, employing the *multiple object-naming paradigm* (Morgan & Meyer, 2005) with a *gaze-contingent display change* manipulation (Pollatsek et al., 1984; Rayner, 1975). In this paradigm speakers see three objects on the screen and are asked to name them in a prescribed order. During the trial, the *target* (the object in the second to-be-named location) is replaced with a *preview* (a different object) while the speaker looks at and names the first object. When the speaker makes an eye movement to the target location, the preview is replaced by the target. *Preview benefit*—faster processing of (shorter gaze durations on¹) the target when the preview was related to it compared to when it was unrelated—suggests that speakers had processed the preview and used that information to facilitate processing of the target. Preview benefit in object naming has been demonstrated for visually similar objects (Henderson & Seifert, 2001; Pollatsek et al., 1984; Schotter et al., 2013), objects that represent the same concept (Meyer & Dobel, 2003; Pollatsek et al., 1984), and homophones (Meyer, Ouellet, & Hacker, 2008; Morgan & Meyer, 2005; Pollatsek et al., 1984; see Schotter, 2011). In all these studies, however, the timing of the preview was not manipulated. Therefore, it is unclear *when* the preview benefit arises—during the entire time the subjects fixate

¹ As noted by Schotter et al. (2013), *gaze duration* (the sum of all fixations on the object before

the preceding object or only later, shortly before the eyes make a saccade to the target.

In the present study we manipulated the timing of the preview (i.e., its onset relative to the start of fixation on the preceding object) to assess whether preview benefit diminishes when the preview is only available very early during prior object processing. If so, it would suggest that speakers only process the upcoming object shortly before they move their eyes to it. Conversely, if the preview benefit remains relatively stable regardless of when the preview was available, it would suggest that speakers continuously process upcoming objects. To ensure that the preview benefit we observe is due to cognitive-linguistic processing of objects (Meyer & Dobel, 2003; Meyer, Ouellet & Hacker, 2008; Morgan & Meyer, 2005), as opposed to more visually-based processing (Henderson & Siefert, 2001; Pollatsek et al., 1984; Schotter et al., 2013) the related previews were the same concept as the target, but a different visual token (see Figure 1).


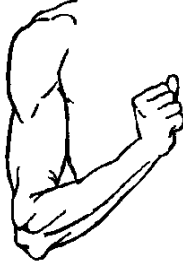
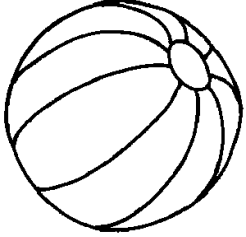

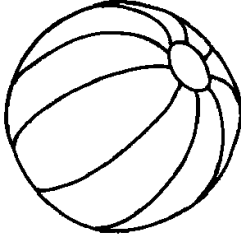
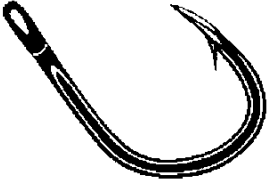
	Target	Preview	
		Same Concept	Different Concept
Example 1: arm			
Example 2: ball			

Figure 1. Example stimuli used in the experiment.

Method

Subjects. Fifty-two students from the University of California, San Diego (ages 18-24) participated in this experiment for course credit or \$10. Five subjects were excluded because excessive blinking led to excessive track loss. All subjects were native speakers of English with normal or corrected-to-normal vision and were naïve concerning the purpose of the experiment.

Apparatus. Eye movements were recorded via an SR Research Ltd. Eyelink 1000 eye tracker in remote setup (no head restraint, but head position was monitored) with a sampling rate of 500 Hz. Viewing was binocular, but only the right eye was monitored. Following calibration, eye position errors were less than 1°. Subjects were seated approximately 60 cm away from a 20" Sony Trinitron CRT monitor with 1280 x 1024 pixel resolution and an 85 Hz refresh rate.

Materials and Design. One hundred and forty-four line drawings of objects (48 target pictures, 48 pictures for the first location, and 48 pictures for the third location) were selected from the International Picture Naming Project database (IPNP; E. Bates et al., 2003) with similar selection criteria as used in Schotter et al. (2013; monosyllabic names, a large proportion of usable responses, high name agreement, and fast response times). Forty-eight other line drawings were taken from web searches to create same-concept previews. For each target, one picture was selected that represented the same concept as the target but with a different visual token of that concept (see Figure 1). To create the different-concept preview, the same-concept previews were shuffled across targets so that the target and preview were not semantically or phonologically related. Because the same items were used both as same-concept and different-concept previews, any idiosyncratic effects of the visual or linguistic characteristics of those objects are controlled for across conditions.

There were three object locations on the screen (see Figure 2), and subjects were instructed to name first the image on the top left (the first object), then the image on the top right (the target object), and then the bottom image (the third object). Objects were black line drawings on a white background (on average, they subtended approximately 5°) and arranged so that the distance between the midpoints of any two objects was 21° . The experiment used a 2 x 2 design between preview type (same vs. different concept) and stimulus onset asynchrony (SOA; 50 vs. 250 ms).

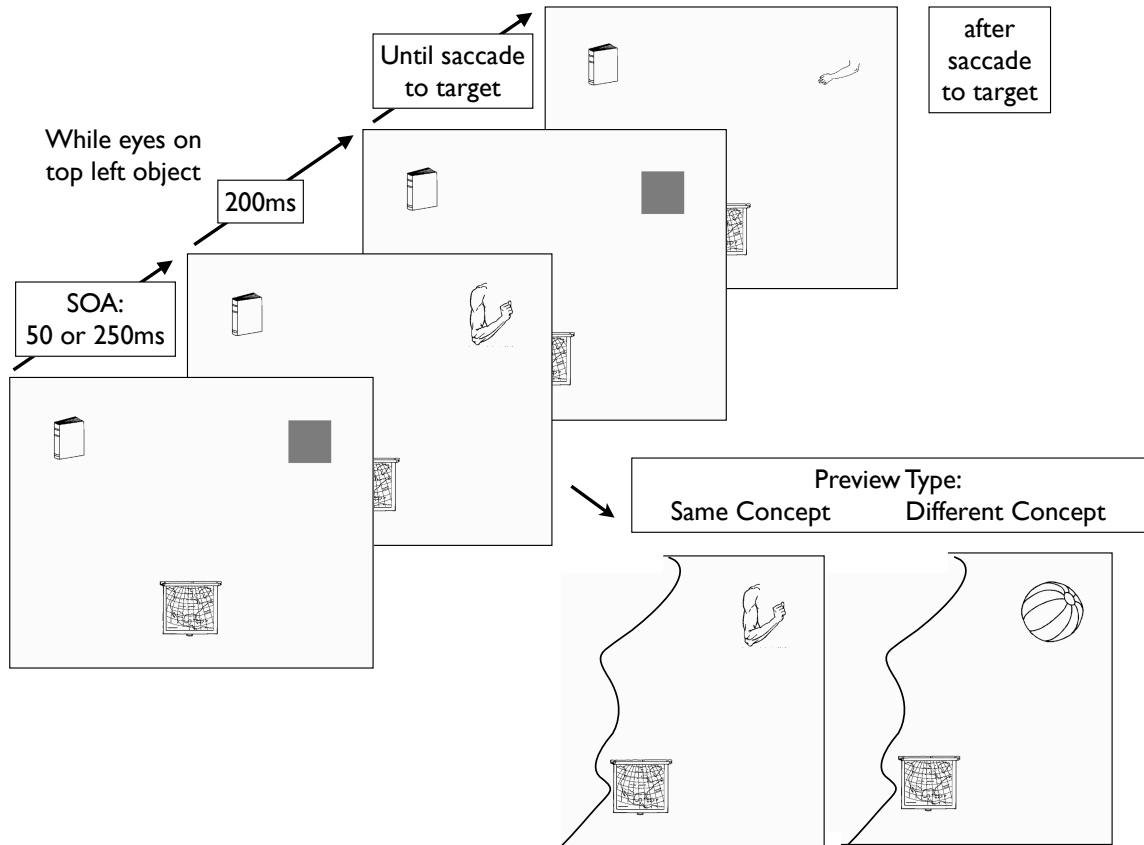


Figure 2. The display during a trial in the experiment. Subjects are to name the top-left object, then the top-right object, then the bottom object. On a correct trial, a subject would say “book, arm, map.” During fixation on the first object (the book), the second object location appears as a gray box. After either 50 or 250 ms (SOA) the preview appears in the second location. The preview is either the same concept (with a different visual token) or a different concept as the target. Once the subject makes a saccade to the second object location the target appears there.

Procedure. To ensure subjects used the correct names for the objects, the experiment began with a training session in which all line drawings, including the preview objects, were presented individually at the center of the computer screen. Subjects were instructed to name each object as it appeared, and naming errors were corrected (all intended object names were monosyllabic and common terms for the objects). The objects were displayed until the correct response was made or until the experimenter corrected the subject.

After training, the subject put on a headset microphone and a target sticker was placed on the subject's forehead to monitor head movements. To record movements of the eye in both the x- and y-axes, the eye tracker was calibrated using a 9-point calibration. At the start of each trial, the subject saw a fixation point in the center of the screen. If the eye tracker was accurately calibrated, the experimenter pressed a button, causing the fixation point to disappear and a black box to appear in the top left quadrant of the screen (the location of the first object to ensure that the subject was looking in that location when the trial started). Once a fixation was detected in this region, images appeared in all locations, with objects appearing in the first and third locations and a gray box appeared in the second (target) location.

Depending on the SOA condition, the preview appeared in the second location either 50 or 250 ms after trial onset (fixation on the black box that triggered the objects to appear). The preview was displayed for 200 ms before reverting to a gray box. When the subject's eyes crossed an invisible boundary located to the right of the first object, the target appeared in place of the gray box. This occurred regardless of whether the display changes of the preview objects were complete. The display change (which took, on average, 15 ms) occurred during a saccade (when vision is suppressed) that took approximately 50-60 ms to complete. The three objects remained in view until the subject named them all. The experimenter then pressed a button to end the trial and code naming accuracy of the first and second objects. Subjects were not informed of the display changes in the instructions. However, at the end of the experiment, they were asked if they were

aware of the display changes and to report the approximate percentage of the time they could identify what the preview object was. The experiment lasted approximately 30 minutes.

Results and Discussion

Data were excluded if subjects (a) misnamed or disfluently named the first or target object (i.e., the first word in the utterance was not the target name; 2% of the data), (b) there was track loss on the first or target object (16% of the data), or (c) the target object was not fixated (<1% of the data). There were 7177 observations remaining after these exclusions (78% of the original data).

We report inferential statistics based on generalized linear mixed-effects models (LMMs). In the LMMs, preview type (same vs. different concept) and SOA (50 vs. 250 ms) were centered and entered as fixed effects, and subjects and items were entered as crossed random effects (Baayen, Davidson, & Bates, 2008) with the maximal random effects structure (Barr, Levy, Scheepers, & Tily, 2013). In order to fit the LMMs, the lmer function from the lme4 package (Bates, Maechler, & Bolker, 2011) was used within the R Environment for Statistical Computing (R Development Core Team, 2012). We report regression coefficients (b) that estimate the effect size (in milliseconds) of the reported comparison, standard errors, and the t-value of the effect coefficient (for which a value greater than or equal to 1.96 indicates an effect that is significant at approximately the .05 alpha level).

Gaze Duration on the First Object. Gaze duration on the first (pre-target) object was unaffected by preview type ($t < .49$) because, at this time, the subject did not know whether the preview was related or unrelated to the target (which had not yet appeared). There was a significant effect of SOA ($b = 22.96$, $SE = 8.33$, $t = 2.75$), with longer gaze durations on the pre-target picture when the preview appeared later (i.e., closer to the saccade). There was no interaction between preview type and SOA ($t < .09$).

Gaze Duration on the Target Object. There was a significant effect of preview type ($b = 20.37$, $SE = 5.29$, $t = 3.86$) with shorter gaze durations on the target when the preview was the same concept as the target than when it was unrelated. There was also a significant effect of SOA ($b = 12.13$, $SE = 6.12$, $t = 1.98$) with longer gaze durations on the target when the preview appeared at the later SOA². There was no interaction between preview type and SOA ($t < 0.31$) suggesting that the magnitude of the preview benefit was unaffected by when, relative to trial onset, the preview appeared (Figure 3).

² This is may be due to a psychological refractory period effect (Pashler, 1994; Welford, 1952). Later previews appear closer in time to the onset of target fixation. If there is a refractory period due to processing of the preview, this will be more likely for later than for earlier previews to extend into the period of the target gaze duration.

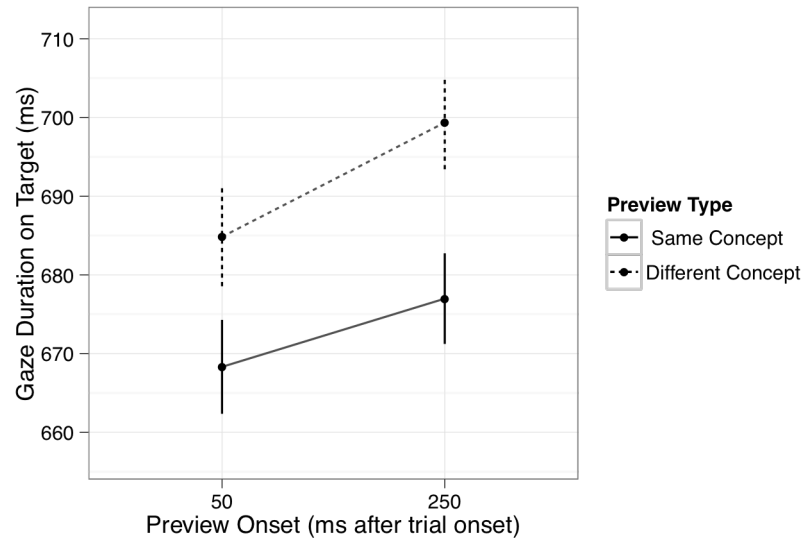


Figure 3. Gaze duration on the target object as a function of preview type (same vs. different concept) and SOA (50 vs. 250 ms after trial onset).

The Effect of Saccade Latency on Preview Benefit. The above data suggest that information is always obtained from the preview, regardless of when it appeared. However, it is possible that the latency between the offset of the preview and the saccade to the target influences preview benefit. That is, it is possible that preview benefit may be larger when the preview appeared briefly before the subject moved his/her eyes to the target. If saccade latency influences the time course of preview benefit we would expect to see an interaction between preview type and preview offset-to-saccade latencies such that preview benefit is larger at shorter latencies (when the preview would coincide with an attention shift to that location). If an interaction were not observed it would suggest that speakers continually processed that location and had benefitted from a same concept preview, regardless of when it appeared.

To investigate the influence of saccade latency, we ran an additional model on all the data in which, instead of SOA, the continuous variable of the latency from preview offset to the saccade to the target (binned in 100 ms intervals)³ was centered and entered as a predictor (both in the fixed effects and random effects). In this model, the effect of preview was significant ($b = 18.08$, $SE = 5.38$, $t = 3.36$). The effect of latency was also significant ($b = .05$, $SE = .02$, $t = 2.50$). Again, there was no interaction between preview type and preview offset-to-saccade latency ($t < .77$), suggesting that the magnitude of the preview benefit was the same, regardless of saccade latency.

Taken together, these data suggest that preview benefit during multiple object naming is fairly stable, and does not depend on the timing of the preview relative to the saccade to the target. This indicates that speakers do not restrict preprocessing of the upcoming object to a restricted time before the saccade to it. Rather, speakers continually (to some extent) distribute attention across multiple objects they intend to name (for further discussion see Schotter et al., 2013). Neither the experimental manipulation of preview SOA nor the latency between preview offset and the saccade to the target modulated the magnitude of preview benefit in our task (preview benefits were a fairly stable, regardless of these variables; Figure 4).

³ The pattern of data and significance tests show the same pattern when the data are not binned and raw latency values are used.

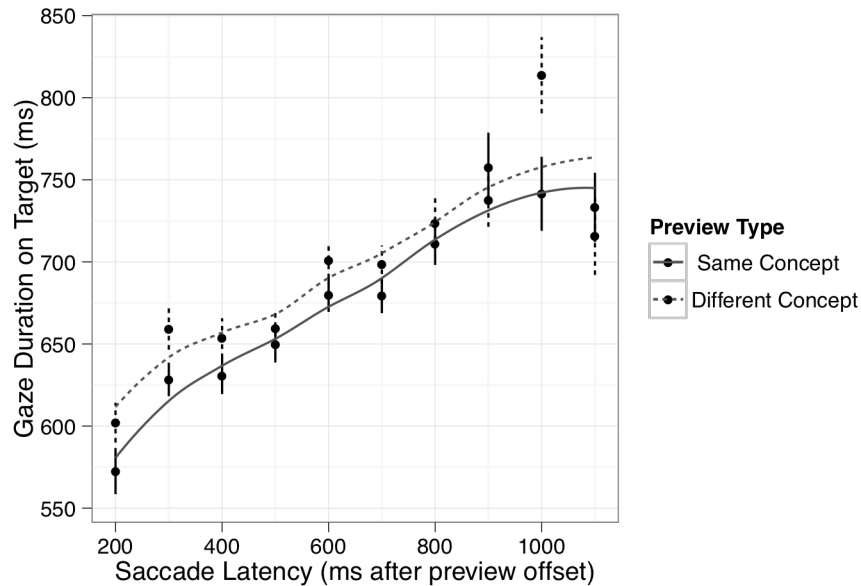


Figure 4. Gaze duration on the target as a function of preview type and preview offset-to-saccade latency (binned by 100 ms). Only saccade latencies between 200 and 1200 ms are included in the figure for clarity, because data at more extreme latencies are much noisier (note the greater variability of the data points above 800ms in the figure). All data points were used in the statistical model.

The Effect of Preview Awareness on Preview Benefit. It is also possible that, rather than preprocessing the upcoming object continuously, subjects processed the preview because the sudden visual onset attracted their attention. If this were the case, we would expect to see that subjects who were more aware of the display changes (i.e., those who reported identifying the preview a large proportion of the time) would exhibit larger preview benefits than subjects who were unaware or less aware. To test this, we categorized subjects into three groups: unaware (those who reported identifying less than 2% of the previews- 11 subjects), less aware (those who reported identifying 2-65% of the previews- 25 subjects) and more aware (those who reported identifying more than 65% of the previews- 10 subjects). We then entered this factor in the analyses (both as a fixed effect and a

random effect for items with interactions with the other factors). This analysis revealed a main effect of preview ($b = 30.12$, $SE = 12.18$, $t = 2.47$), but neither the effects of SOA ($t = 1.31$) nor awareness group, nor any of the interactions were significant (all t s < 1 ; Figure 5).

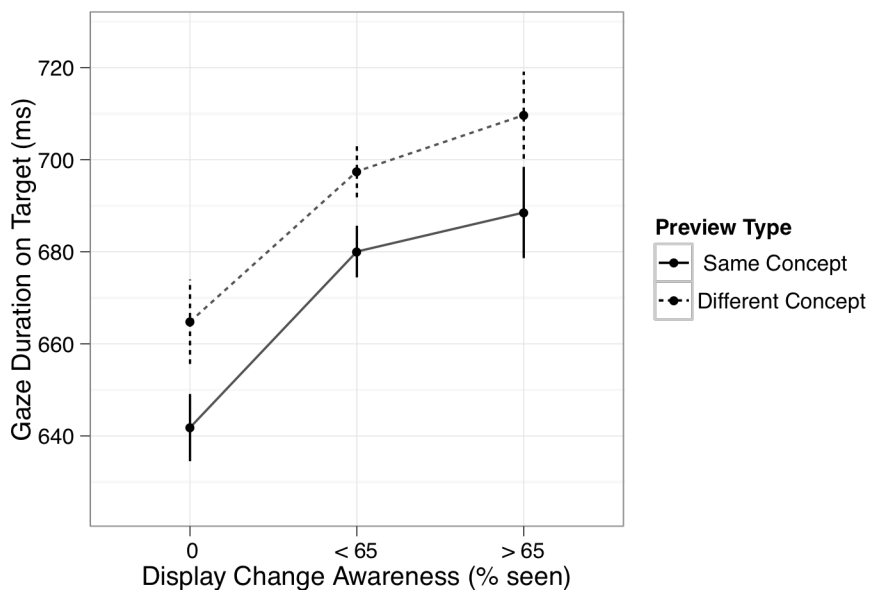


Figure 5. Gaze duration on the target as a function of preview type and subjects' awareness of the display changes.

Conclusion

The data reported here add to a growing body of research suggesting that speakers access information from to-be-named objects concurrently as they fixate preceding objects (see also Meyer & Dobel, 2003; Meyer et al., 2008; Morgan & Meyer, 2005; Schotter et al., 2013; for a review see Schotter, 2011). Crucially, though, the present study provides evidence that conceptually-driven preview benefit is relatively stable, regardless of the latency of the preview relative to the onset of processing the prior object (our manipulation of SOA) or the latency of the

saccade to the target location (which, under the assumption that preprocessing is restricted to an attention shift before an eye movement to the target, should show a negative relationship with preview benefit). This suggests that speakers distribute attention over multiple objects they intend to name. This may be a natural part of the speaking process. In general, although in this task the order of inspection was pre-determined, speakers combine speaking about their environment with visual inspection of it (Griffin & Bock, 2000). For this reason, it may be advantageous for speakers to distribute attention broadly in order to allow apprehension of the scene.

One of the consequences of the fact that speakers promiscuously process multiple objects simultaneously is that the linguistic processing system now requires a way in which to regulate the potentially overwhelming amount of incoming information. Other related research (Schotter et al., 2013) reveals that speakers restrict this processing to only those objects they *intend* to process, such that only to-be-named objects show preview benefits. This suggests that one way speakers avoid potentially accessing and naming the wrong object is by restricting the set of processed objects to only those that are intended.

Chapter 2, in full, has been submitted for publication of the material as it appears in 2013, Schotter, E.R., Jia, A., Ferreira, V.S., Rayner, K. Preview benefit in speaking occurs regardless of preview timing or awareness. The dissertation author was the primary investigator and author of this paper.

References

- Baayen, R., Davidson, D., & Bates, D. (2008). Mixed-effects modeling with crossed and random effects for subjects and items. *Journal of Memory and Language*, 59, 390-412.
- Barr, D.J., Levy, R., Scheepers, C., & Tily, H.J. (2013). Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of Memory and Language*, 68, 255-278.
- Bates, D. M., Maechler, M., & Bolker, B. (2011). Lme4: Linear mixed-effects models using S4classes. R package version 0.999375-42. <http://CRAN.R-project.org/package=lme4>.
- Bates, E., D'Amico, S., Jacobsen, T., Szekely, A., Andonova, E., Devescovi, A., Herron, D., Lu, C. C., Pechmann, T., Pleh, C., Wicha, N., Federmeier, K., Gerdjikova, I., Gutierrez, G., Hung, D., Hsu, J., Iyer, G., Kohnert, K., Mehotcheva, T., Orozco-Figueroa, A., Tzeng, A., & Tzeng, O. (2003). Timed picture naming in seven languages. *Psychonomic Bulletin & Review*, 10, 344-380.
- Griffin Z. & Bock J.K. (2000). What they eyes say about speaking. *Psychological Science*, 11, 274-279.
- Henderson, J.M. & Siefert, A. (2001). Types and tokens in transsaccadic object identification: Effects of spatial position and left-right orientation. *Psychonomic Bulletin & Review*, 8, 753-760.
- Meyer, A., (2004). The use of eye tracking in studies of sentence generation. In J. M. Henderson & F. Ferreira (Eds.), *The interface of language, vision, and action: Eye movements and the visual world* (pp. 191-211). New York: Psychology Press
- Meyer, A. & Dobel, C. (2003). Application of eye tracking in speech production research. In J. Hyönä , R. Radach, and H. Deubel (Eds.), *The mind's eye: Cognitive and applied aspects of eye movement research* (pp 253-272). Amsterdam: North Holland.
- Meyer, A., Ouellet, M., & Hacker, C. (2008). Parallel processing of objects in a naming task. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 34, 982-987.
- Meyer, A. & van der Meulen, F. (2000). Phonological priming effects on speech onset latencies and viewing times in object naming. *Psychonomic Bulletin & Review*, 7, 314-319.

- Morgan, J. & Meyer, A. (2005). Processing of extrafoveal objects during multiple-object naming. *Journal of Experimental Psychology: Learning Memory and Cognition*, *31*, 428-442.
- Morgan, J., van Elswijk, G., & Meyer, A. (2008). Extrafoveal processing of objects in a naming task: Evidence from word probe experiments. *Psychonomic Bulletin & Review*, *15*, 561-565.
- Pashler, H. (1994). Dual-task interference in simple tasks: Data and theory. *Psychological Bulletin*, *116*, 220-244.
- Pollatsek, A., Rayner, K., & Collins, W. (1984). Integrating pictorial information across eye movements. *Journal of Experimental Psychology: General*, *113*, 426-442.
- R Development Core Team. (2012). R: A language and environment for statistical computing [Computer software]. Vienna, Austria: R Foundation for Statistical Computing.
- Rayner, K. (1975). The perceptual span and peripheral cues in reading. *Cognitive Psychology*, *7*, 65-81.
- Rayner, K., Angele, B., Schotter, E.R., & Bicknell, K. (2013). On the processing of canonical word order during eye fixations in reading: Do readers process transposed word previews? *Visual Cognition* (online first)
- Reichle, E.D., Liversedge, S.P., Pollatsek, A., & Rayner, K. (2009). Encoding multiple words simultaneously in reading is implausible. *Trends in Cognitive Science*, *13*, 115-119.
- Schotter, E. (2011). Eye movements as an index of linguistic processing in language production. *Journal of Psychology and Behavior*, *9*, 16-23
- Schotter, E. R., Angele, B., & Rayner, K. (2012). Parafoveal processing in reading. *Attention, Perception, & Psychophysics*, *74*, 5-35.
- Schotter, E.R., Ferreira, V.S., & Rayner, K. (2013). Parallel object activation and attentional gating of information: Evidence from eye movements in the multiple object naming paradigm. *Journal of Experimental Psychology: Learning, Memory and Cognition*, *39*, 365-374.
- Welford, A.T. (1952). The 'Psychological Refractory Period' and the timing of high-speed performance: A review and a theory. *British Journal of Psychology*, *43*, 2-19.

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CHAPTER 3:
PARALLEL OBJECT ACTIVATION AND ATTENTIONAL GATING OF INFORMATION:
EVIDENCE FROM EYE MOVEMENTS IN THE MULTIPLE OBJECT NAMING
PARADIGM

Abstract

Do we access information from any object we can see, or do we only access information from objects that we intend to name? In three experiments using a modified multiple object naming paradigm, subjects were required to name several objects in succession when previews appeared briefly and simultaneously in the same location as the target as well as at another location. In Experiment 1, *preview benefit*—faster processing of the target when the preview was related (a mirror image of the target) compared to unrelated (semantically and phonologically)—was found for the preview in the target location but not a location that was never to be named. In Experiment 2, preview benefit was found if a related preview appeared in either the target location or the third-to-be-named location. Experiment 3 showed the difference between results from the first two experiments was not due to the number of objects on the screen. These data suggest that attention serves to gate visual input about objects based on the intention to name them, and that information from one intended-to-be-named object can facilitate processing of an object in another location.

People do not perceive, think, and act on one object at a time. We can see multiple objects in our environments simultaneously, and we can describe them in sequence rapidly, fluently, and accurately. To do so, we must efficiently manage multiple pieces of information from multiple sources. But how do the mechanisms of visual perception and language production do so?

One line of evidence suggests that we activate linguistic information from visually presented objects, even though we intend to ignore them. However, activation of linguistic information from to-be-ignored objects only seems to arise when there is some uncertainty as to whether the object is, indeed, a distractor. For example, Morsella and Miozzo (2002) presented subjects with two superimposed pictures of objects, one red and one green, and had them name the green object while ignoring the red object—a *picture-picture interference paradigm* (Tipper, 1985). They found *phonological facilitation*—subjects named the target object faster when the distractor object was phonologically related than when it was unrelated (see also Navarrete & Costa, 2005; cf., Jescheniak, Oppermann, Hantsch, Madebach & Schriefers, 2009). Meyer and Damian (2007) found similar results regardless of the type of phonological relatedness (i.e., whether target-distractor pairs shared word initial, word final segments, or were homophones). An important aspect of these studies is that because the two objects were superimposed, naming the target object likely encouraged or required some processing of the distractor object as well. Relatedly, Navarrete and Costa (2005) showed that subjects named the color of a pictured object faster when the object name was phonologically similar to the color

name than when it was dissimilar; this shows activation of linguistic information when target and distractor appear in the same location.

Distractor objects do not need to superimpose targets to cause activation of their linguistic information. Humphreys, Lloyd-Jones, and Fias (1995) showed that when the target and distractor pictures are partially superimposed but the cue to which one should be named comes at a delay after the offset of the pictures, *semantic interference*—slower responses when the target and distractor were semantically related than unrelated—is observed. Thus, linguistic information about distractor objects can be activated even when the target and distractor pictures are not superimposed. This is most likely due to the fact that the subject does not know a priori which picture is the target and which picture is the distractor, and therefore some processing of both objects occurs.

Relatedly, in a picture-picture interference paradigm, Glaser and Glaser (1989; Experiment 6) presented subjects with two pictures of objects in different locations, separated by variable *SOAs* (stimulus onset asynchronies) and required them to name either the first or second object and ignore the other object. Subjects were not able to anticipate the location of the target and the distractor before the first stimulus onset. Results showed semantic interference. Here, the inability to distinguish target from distractor a priori likely leads to access of linguistic information from the distractor.

Finally, semantic interference (Oppermann, Jescheniak, Schriefers, & Gorges, 2010) and phonological facilitation (Madebach, Jescheniak, Oppermann, & Schriefers, 2010) effects from adjacent but not superimposed objects have been observed. In these experiments, subjects were cued to name one picture and told to ignore the other. However, the location of the pictures varied across trials so that subjects were not able to predict which object was the target and which was the distractor. This very likely encouraged processing of both target and distractor, thereby leading to activation of linguistic information from distractors. Furthermore, Oppermann, Jescheniak, and Schriefers (2008) showed that if target and distractor objects were part of an integrated scene (e.g., a mouse holding a piece of cheese next to a picture of cheese) distractor objects caused phonological facilitation, but not when the objects were not integrated (e.g., a picture of a finger next to a picture of cheese). One interpretation of these results is that integration into a thematically coherent scene, like superimposing of pictures and uncertainty of location, allows sufficient distractor processing to lead to activation of linguistic information.

In short, evidence for access of information from distractor objects has been observed, but distractor processing has only been observed when the distractor object cannot be excluded from processing a priori. The difficulty of excluding distractor objects can arise because (a) distractor pictures were superimposed on target pictures (Morsella & Miozzo, 2002; Navarette & Costa, 2005; Tipper, 1985), (b) subjects were unable to anticipate before trial onset which object is the target and which is the distractor because of spatial (Glaser & Glaser, 1989; Madebach et

al., 2010; Oppermann et al., 2010) or temporal (Humphreys, Lloyd-Jones, & Fias, 1995) uncertainty, or (c) targets and distractors were integrated into a thematically coherent scene (Oppermann et al., 2008).

One way to interpret this set of results is that the above-described factors that lead to linguistic activation from distractor objects corresponds to the allocation of attention¹ to those objects, as compelled by an intention to name them. This may operate through a mechanism that boosts propagation of information from sensory areas to language processing areas in the brain (see Strijkers, Holcomb, & Costa, 2011). When attention is not allocated to distractor objects – when they are not superimposed on targets and when their status as to-be-ignored is known a priori, linguistic activation from distractor objects is not observed (Opperman et al., 2008). The present study directly tests this idea: mainly, whether intention to eventually name a spatially, temporally, and conceptually distinct “distractor” object determines whether information is activated from it when all else is held equal.

The literature described thus far can be characterized as assessing whether exogenous factors (spatial overlap, spatial uncertainty, temporal uncertainty, and thematic integration) cause the influence of an intention to name the target object to

¹ There is a large literature on attention and many debates over what exactly attention is (Pashler, 1999). A discussion of these debates is beyond the scope of the paper and we do not intend this paper to make any conclusions bearing on such a debate. Therefore, for the purposes of this paper, we will use the term *attention* as an umbrella mechanism, with *intention to name* as one way of allocating attention, because object naming is not an automatic process (i.e., in order to name an object one must choose to do so and allocate attention to it and this process operates within conscious awareness and control).

be applied also to distractor objects, and thus causes linguistic activation from those objects. Here, we address whether endogenously allocated intention to name might also affect activation of linguistic information from visually perceived objects. That is, one useful way to regulate information efficiently is to only activate linguistic information for objects that speakers intend to name and not activate linguistic information for objects that they do not intend to name (but see Harley, 1984 for intrusions prompted by unintended but visually present environmental stimuli). If so, then we should observe facilitation effects from (spatially, temporally, or conceptually distinct) distractors only when subjects intend to ultimately name those objects and not from distractors that subjects never intend to name.

To assess whether intention to name gates the activation of information from objects, we used a variant of the *multiple object naming* paradigm (Morgan & Meyer, 2005) with a gaze-contingent display change manipulation (Pollatsek, Rayner, & Collins, 1984; Rayner, 1975). In the standard paradigm, three objects are presented simultaneously on a computer screen in an equilateral triangle, and the subject is instructed to name them in a prescribed order. The object of interest is the image in the second-to-be-named location. While the first image is fixated, the second image is a *preview* object that changes to the *target* (named object) when the subject makes a saccade to it. These studies report *preview benefit*—faster processing of the target when the preview was related compared to unrelated to the target. Preview benefit can be obtained from visually similar objects (Pollatsek et al., 1984), objects that represent the same concept (Meyer & Dobel, 2003; Pollatsek et al., 1984), and

objects with phonologically identical (homophonous) names (Meyer, Ouellet, & Hacker, 2008; Morgan & Meyer, 2005; Pollatsek et al., 1984); these studies thus provide evidence that visual, semantic, and phonological representations of the upcoming object are processed concurrently during fixation on the current object (for reviews see Meyer, 2004; Schotter, 2011). In all, this shows access of information from an object far from fixation in extrafoveal vision (approximately 15-20 degrees) that is eventually to be named and therefore should not be ignored, but is not the current target of production.

The question then is whether activation of information from these extrafoveal objects in the multiple-object naming paradigm is determined by the intention to name those objects. One possibility is that intention-to-name does not gate information activation, so that any item within view affects production-relevant behavior. If this were the case, we would expect to see an effect of previews of objects in any location (regardless of whether they were to-be-named or ignored) on processing of a target object. Alternatively, objects may only have information activated about them if they are relevant to the task at hand—an object that needs to be named. If this were the case, we would expect to see an effect on processing of a target object of previews of objects only in locations that subjects anticipate needing to name. To test these possibilities, we modified the multiple object naming paradigm to determine whether information about objects that can be completely excluded from the task affect processing of objects that are intended to be processed.

Experiment 1

In Experiment 1, we tested whether unnamed objects are processed and if so, whether the information obtained from unnamed objects can affect processing of an object in another location. In this experiment, there were four objects on the screen, but only three were to be named. The unnamed object was always in the same location throughout the entire experiment and subjects were told at the outset that they were never to name it. Fifty milliseconds after trial onset, while the subject was looking at the first object, previews appeared in the target (second) location and in the unnamed location for 200 ms; the relationship between those previews and the target was manipulated. Previews in both locations were either related (a mirror image of the target) or unrelated (a different object), yielding a 2 (preview-target relationship) x 2 (location) design. We used a mirror image preview so that the related preview had the greatest opportunity to cause a preview benefit even from the unnamed locations, but so that there would be a visual difference between the preview in the second location and the target on all trials (thus, if preview benefit were obtained for the preview in the second location but not the preview in the unnamed location it could not be due to complete visual overlap). Mirror image previews produce preview benefits almost as large as those obtained from identical previews (Henderson & Siefert, 1999; cf., Pollatsek et al., 1984)².

² It is worth noting that because the mirror image preview shares almost all information [except orientation] with the target, this experiment will not pinpoint which level of representation can cause any observed preview benefit. However, given our goal of determining whether information is activated at all from never-to-be-named objects, it was appropriate to use previews that were most likely to cause a preview benefit that was not solely due to visual properties of the object.

Some previous studies of object naming have reported naming latencies when the eyes start on a fixation cross and the target object is named first (Morgan & Meyer, 2005; Pollatsek et al., 1984). However, when subjects name a sequence of objects, and the object of interest is not the first to-be-named object (as here), then it is difficult to precisely measure the voice onset time of a noun when it is embedded between other words. Instead, *gaze duration* (the sum of all fixations on the object before moving to another object) has been used as the primary index of processing difficulty (Meyer et al., 2008; Morgan & Meyer, 2005). Gaze durations are sensitive to many properties of objects in production studies, such as visual degradation (Meyer, Sleiderink & Levelt, 1998), word frequency (Meyer et al., 1998), word length (Zelinsky & Murphy, 2000), codability (Griffin, 2001), and phonological properties (Meyer & van der Meulen, 2000). Given that fixation times are diagnostic of production effects, in the present experiments, gaze durations on the target are reported instead of naming latencies³.

Based on prior multiple-object naming research, preview benefit should be observed from previews at the second (target) location. If there were a significant preview benefit from the unnamed object preview, it would suggest that information is not gated by attention as implemented by intention-to-name. On the other hand, if the unnamed location preview does not provide preview benefit to

³ We investigated naming latencies on a subset of the subjects from Experiment 2. There were no effects of our manipulation on naming latencies. We expect that this lack of an effect could be, for the most part, due to the target object being named after the first object, which could influence naming latencies in that the subject cannot start to say the name of the second object before they have finished naming the first.

processing the target it would suggest that that object was excluded from processing altogether, presumably because the subject did not need to name it.

Method

Subjects. Twenty-four members of the University of California, San Diego community participated in the experiment. All were native English speakers who were naïve concerning the purpose of the experiment. They all had normal or corrected-to-normal vision. In all experiments, subjects' ages ranged from 18 to 27.

Apparatus. Eye movements were recorded via an SR Research Ltd. Eyelink 1000 eye tracker in remote setup (so that there was no head restraint, but head position was monitored, as well) with a sampling rate of 500 Hz. Viewing was binocular, but only the right eye was monitored. Following calibration, eye position errors were less than 1°. Subjects were seated approximately 66 cm away from the monitor, a 19 in Viewsonic VX922 LCD monitor (Viewsonic Corporation, Walnut, CA).

Materials and Design. One hundred and ninety-two line drawings of objects with monosyllabic names were selected from the International Picture Naming Project database (IPNP, Bates et al., 2003). Using measures listed in the database⁴, we selected objects that had a large proportion of usable responses from the IPNP ($M = .98$, $SD = .03$), high name agreement for the dominant name ($M = 2.58$

⁴ For descriptions of these measures see <http://crl.ucsd.edu/experiments/ipnp/method/getdata/uspnvariables.html>

alternative names, $SD = 1.64$), and fast response times ($M = 931$ ms, $SD = 161$). Object names ranged in log transformed CELEX frequency from 0 to 7.40 ($M = 3.32$, $SD = 1.38$) and object images ranged in complexity (as assessed by the jpg file size) from 3730 bytes to 48626 bytes ($M = 15758$ bytes, $SD = 7720$). These objects consisted of 48 target items, paired with mirror image and 48 unrelated preview objects, as well as 48 objects that appeared in the first location and 48 that appeared in the third location. Unrelated objects were chosen so that they were not semantically or phonologically related to the target and mirror image previews were created by flipping the target across the vertical midline (so that the right side of the image was on the left and vice versa). Target and unrelated items did not differ significantly in terms of percent usable responses, log frequency, or visual complexity (all $ps > .2$).

In this experiment, there were four object locations on the screen (see Figure 1) and subjects were instructed to name the top left, then the top right, and then the bottom left image. Previews appeared in the second and unnamed locations (location 4) and were either related (mirror image) or unrelated to the target that appeared when the subject made a saccade to the second location. When the subject's saccade crossed an invisible boundary located two degrees to the right of the right-hand edge of the first object, the target appeared. The same unrelated object was used in both the second and unnamed locations for each target. The relationship between the preview-target relationship and location yielded a 2x2 design. Previews appeared in both locations to ensure that the same visual and

timing manipulations were implemented on the screen across all trials, and so the only difference across conditions was the relationship between the preview in a given location and the target.

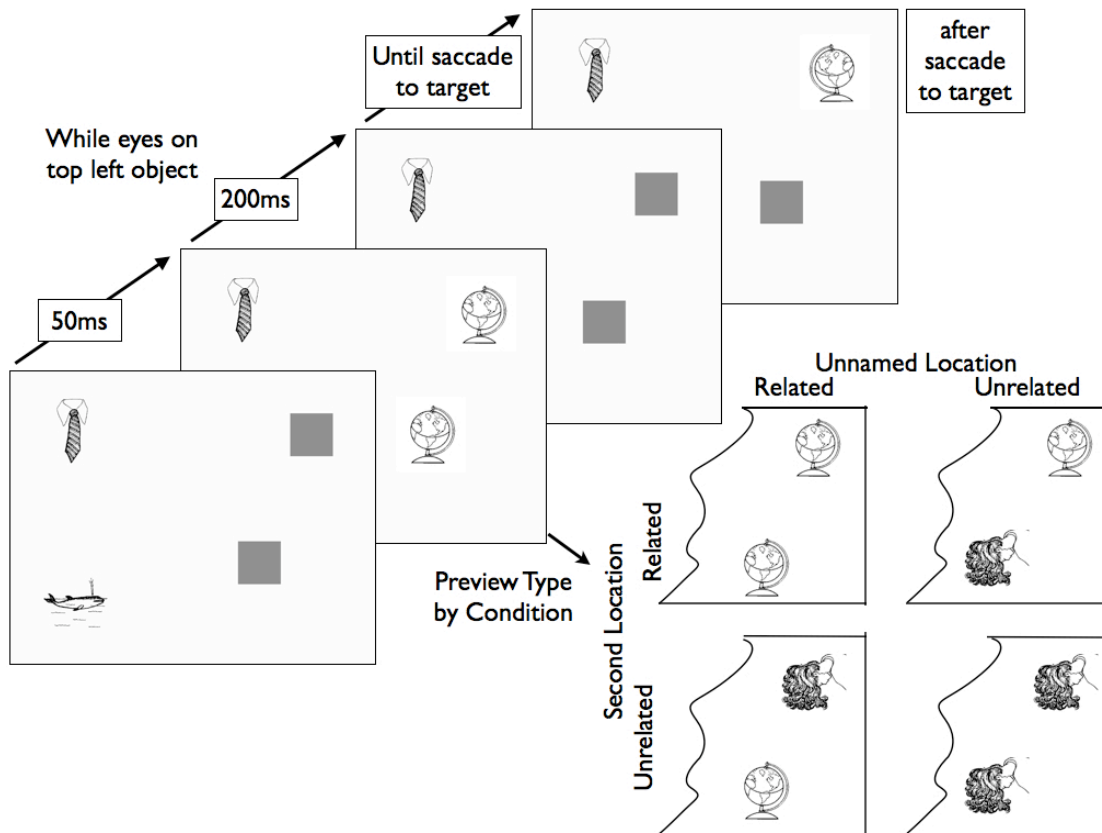


Figure 1. The display during a trial in Experiment 1. Subjects are to name the top-left object, then the top-right object, then the bottom-left object; the bottom-right object is never named. During fixation on the first (top left) object, previews appear in both the second and unnamed locations. Once the subject makes a saccade to the second object the target appears there. On a correct trial, a subject would say “Tie, globe, whale.” The bottom right hand of the figure represents the four possible preview combinations in the experiment: related (globe) and unrelated (hair).

Procedure. To ensure that subjects used the correct names for items, the procedure began with a training session. Each of the 192 line drawings (including the unnamed preview objects) was presented individually on the computer screen and subjects named them using bare nouns. Naming errors were corrected and subjects were asked to use the correct name for the remainder of the experiment.

Each object was displayed as a black line drawing in the center of the computer screen until the correct response was made or until the experimenter corrected the subject. It is important to note that the unnamed preview objects were subjected to the same training procedure as the target (mirror image preview) objects and therefore any lack of a preview benefit cannot be due to the fact that they had not been familiarized with the object before the experiment started.

After training, the subject put on a headset microphone and a target sticker was placed on the subject's forehead (to control for head movement when measuring eye movements). The eye tracker was calibrated using a 9-point calibration, allowing for measurement of eye location in both the x- and y-axes. On each trial, subjects saw a fixation point in the center of the screen. If the eye tracker was accurately calibrated, the experimenter pressed a button, causing the fixation point to disappear and a black box to appear in the top left quadrant of the screen (the location of the first object). Once the subject moved his or her eyes into this region, images appeared in all locations: the two objects appeared in the first- and third- to be named locations and the two gray boxes appeared in the preview locations (the second-to-be named and unnamed locations). The objects were black line drawings on a white background and arranged in four quadrants of the screen with the gray boxes so that the second and unnamed locations were equidistant from the first object location (21 degrees of visual angle, measured from midpoint to midpoint) and the third object location was the same distance (21 degrees) from the

second object location. All objects subtended approximately 5 degrees of visual angle.

The target and unnamed locations started as gray boxes and 50 ms after trial onset (fixation in the box that triggered the display to appear) previews appeared in both locations. Previews appeared for 200 ms and then reverted back to gray boxes. When the subject's eyes crossed an invisible boundary to the right of the first object, the gray box in the second location changed to the target. This occurred regardless of whether the display changes of the preview objects were complete. The display change took (on average) 15 ms to complete and occurred during a saccade (when vision is suppressed), which took approximately 50-60 ms to complete. Although some subjects were aware that display changes occurred (both the briefly presented previews and the changes to the target), they only reported being able to notice what the preview object was about 10% of the time, and most subjects were unable to notice any relationship between the previews and target. Objects remained in view until the subject named them all and the experimenter pressed a button to end the trial. The experimenter coded whether the participant named both the first and second objects correctly online. The instructions did not mention any display changes. The experiment lasted approximately 45 minutes.

Results and Discussion

Data were excluded if subjects (a) misnamed or disfluently named the first or second object (i.e., the first word in the utterance was not the target name; 2% of

the data), (b) looked at the unnamed object location, looked back from the target object to the first object, or there was track loss on the target object (31% of the data) or (c) gaze durations on the target object were more than 2.5 standard deviations from the mean, shorter than 325 ms or longer than 1325 ms (7% of the data; gaze durations outside this range would likely not reflect normal, fluent naming). After excluding these data the number of observations did not significantly differ across conditions (all $ps > .5$). Despite this, these exclusions left different numbers of missing data points across subjects, items, and conditions, so we report inferential statistics based on linear mixed-effects models (LMMs) instead of traditional ANOVAs, which are not robust to unbalanced designs. In the LMMs, preview type at each location was centered and entered as a fixed effect, and subjects and items were entered as crossed random effects (see Baayen, Davidson, & Bates, 2008). In order to fit the LMMs, the `lmer` function from the `lme4` package (Bates & Maechler, 2008) was used within the R Environment for Statistical Computing (R Development Core Team, 2009). We report regression coefficients (b) that estimate the effect size (in milliseconds) of the reported comparison, standard errors, and the t-value of the effect coefficient but not the t-value's degree of freedom⁵. For all LMMs reported, we started with a model that included all random effects, including random intercepts and random slopes for all main effects and

⁵ There is no consensus thus far in the literature as to what degree of freedom to use; but because the data set is fairly large, a t-value of 2 or greater can be taken to indicate statistical significance.

interactions. We then iteratively removed effects that did not significantly increase the model's log-likelihood and report the statistics output by this model.

Preview conditions did not significantly affect gaze durations on Object 1 (all $t_s < 2$). This is unsurprising, because as Object 1 is viewed, the target (Object 2) has not yet appeared and therefore there is not yet a relationship between the preview and target. Means and standard deviations of the gaze duration on the target are shown in Table 1. Gaze durations on the target were shorter when the preview in the second location was a mirror image compared to unrelated, but there was no difference in gaze durations when the preview in the unnamed location was a mirror image compared to unrelated.

Table 1. Gaze durations (in ms) on the target as a function of preview type in the second and unnamed locations in Experiment 1. Standard errors of the mean are in parentheses.

Second Location Preview	Unnamed Location Preview			Average Preview Benefit
	Mirror Image	Unrelated	Preview Benefit	
Mirror Image	683 (9)	688(9)	5	3
Unrelated	705 (9)	706 (9)	1	
Preview Benefit	19	25		
Average Preview Benefit	22			

The LMM revealed a significant preview benefit based on the relatedness of the preview in the second location ($b = 18.94$, $SE = 7.43$, $t = 2.55$; an average preview benefit of 22.5 ms). Subjects looked at the target for less time when the preview in that location was a mirror image of the target that ultimately appeared there than when it was unrelated. There was no effect of the relatedness of the unnamed object ($b = 10.26$, $SE = 7.43$, $t < 2$; an average preview benefit of 3 ms). Thus, information was not obtained from the preview in the unnamed location and therefore the relatedness between that preview and the target (mirror image vs. unrelated) did not affect processing of the target.

The interaction between the identities of the previews in the second and unnamed locations was not significant ($b = 7.09$, $SE = 14.84$, $t < .5$). The lack of interaction shows that the benefit observed from a mirror image versus unrelated preview at the target location was not affected by whether the simultaneous preview from the unnamed location was a mirror image or was unrelated. Thus, mirror image versus unrelated previews from the unnamed location neither directly affected target gaze durations (the absence of a main effect of the preview type at the unnamed location), nor did it modulate the significant effect observed from previews at the target location (the absence of an interaction between the preview types at both locations) – in short, the preview in the unnamed location had no effect on processing of the target at all. Note that the lack of effect of preview benefit from the unnamed location was not due to distance from fixation, as both preview objects were equidistant from the first object.

There is another possible explanation for the lack of an effect of the preview in the unnamed location observed in Experiment 1: Even though information may be processed from the unnamed location, it may be confined to that location and may not affect processing of another object (e.g., Hollingworth & Rasmussen, 2010, but see Henderson & Seifert, 2001). Indeed, this could be seen as consistent with the evidence above showing that linguistic information is activated from distractor pictures that are in the same location as the target. To test this possibility, in Experiment 2 the procedure from Experiment 1 was modified so that the previews appeared in the target and in another, to-be-named location: the location where the third object will eventually appear.

Experiment 2

If the previews from the unnamed location in Experiment 1 were ineffective because information that is activated from unnamed locations is confined to objects processed at that location, then in Experiment 2, mirror image versus unrelated preview in a to-be-named but different (i.e., the third object) location should also be ineffective, because information activated from that location should only affect processing at the third location. If, on the other hand, the effect from the unnamed location in Experiment 1 was absent because the unnamed object was not intended to be named, then in Experiment 2 when the preview in the other location is one that is also eventually to-be-named, we should see an effect of the preview in the third location on processing of the target. Indeed, data from Henderson and Siefert (2001) suggest that when subjects move their eyes to an extrafoveal pair of objects

(located side-by-side) and are required to name one of them, processing of the target is facilitated both when a preview of that target is available in the same location as where the target ultimately appears as well as when it switches its location with the other object. Furthermore, it would suggest that the lack of preview benefit from the unnamed object preview in Experiment 1 was because speakers do not activate information from objects that are irrelevant for the task at hand.

Method

Subjects. Twenty members of the University of California, San Diego community participated in the experiment with the same inclusion criteria as Experiment 1.

Design. Experiment 2 was like Experiment 1 except that previews appeared in the second and third location instead of the second and unnamed location (see Figure 2). Consequently, there were only three objects on the screen, arranged in an inverted equilateral triangle (21 degrees of visual angle apart), but a digit appeared in a fourth location upon a saccade to the third object to give the subjects a reason to leave the third object (i.e., in order to name the digit). Additionally, the object to be named in the third location did not appear until the saccade toward it, to ensure that the unrelatedness between the preview and the third object did not interfere with processing of the target. Note that when related, the preview in the third location

was related (a mirror image of) to the eventual target in the second location. As in Experiment 1, both previews were equidistant from the first object⁶.

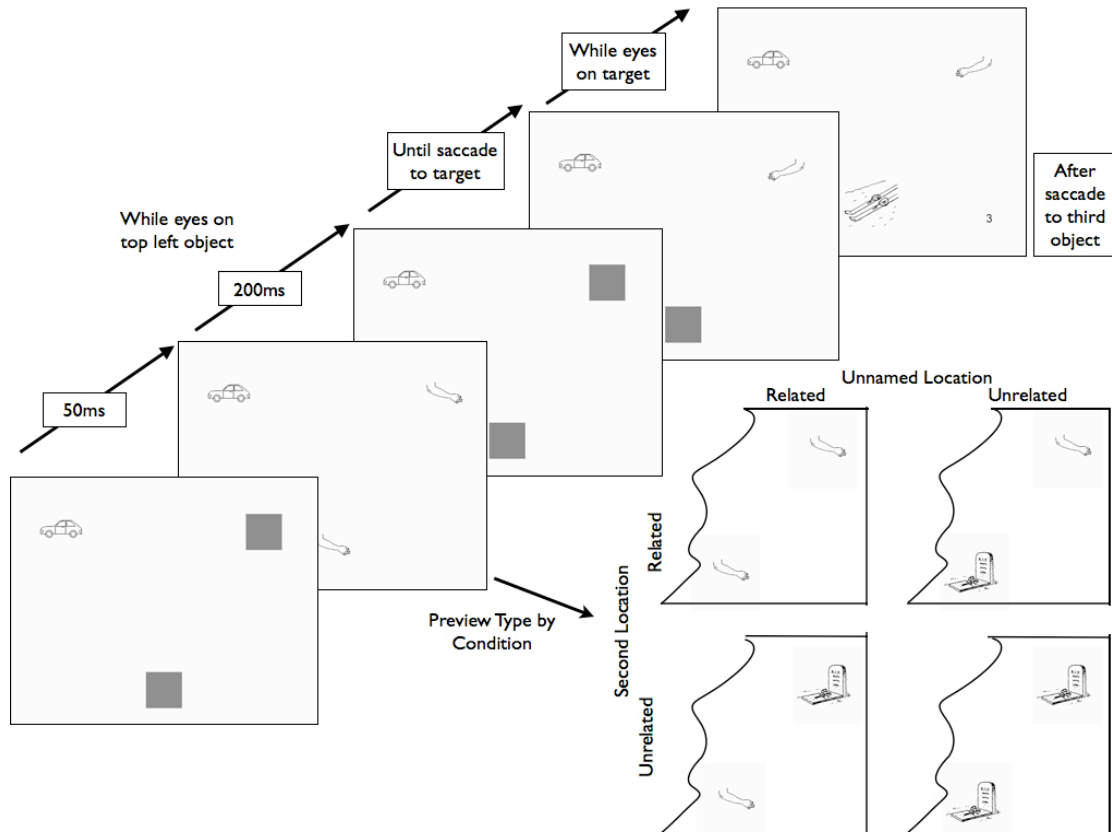


Figure 2. The display during a trial in Experiment 2. Subjects are to name the top-left object, then the top-right object, then the bottom-left object, then the digit. During fixation on the first (top left) object, previews appear in both the second and third locations. Once the subject makes a saccade to the second object the target appears there. Once the subject makes a saccade to the third location the third object appears there and a digit appears in the bottom right hand corner. On a correct trial, a subject would say “Car, arm, skis.” The bottom right hand of the figure represents the four possible preview combinations in the experiment: related (arm) and unrelated (grave).

Results and Discussion

The same data filtering process and analyses as in Experiment 1 were used.

Data were excluded if subjects (a) misnamed or disfluently named the first or

⁶ Additionally, Experiments 2 and 3 used a 20 in Sony Trinitron CRT monitor with a 1280 x 1024 pixel resolution and an 85 Hz refresh rate.

second object (3% of the data), (b) looked at the unnamed object location, looked back from the target object to the first object, or there was track loss on the target object (14% of the data), or (c) gaze durations on the target object were more than 2.5 standard deviations from the mean, shorter than 325 ms or longer than 1325 ms (8% of the data). After excluding these data the number of observations did not significantly differ across conditions (all $ps > .25$).

As in Experiment 1, preview conditions did not significantly affect gaze durations on Object 1 (all $ts < 2$). Means and standard deviations of gaze duration on the target are shown in Table 2. Gaze durations on the target were shorter when at least one of the two previews was a mirror image of the target than when both the previews were unrelated.

Table 2. Gaze durations on the target as a function of preview type in the second and third locations in Experiment 2. Standard errors of the mean are in parentheses.

Second Location Preview	Third Location Preview			Average Preview Benefit
	Mirror Image	Unrelated	Preview Benefit	
Mirror Image	600 (8)	598 (8)	-2	11.5
Unrelated	609 (8)	634 (8)	25	
Preview Benefit	9	36		
Average Preview Benefit	22.5			

The LMM revealed a main effect of relatedness of the preview in the second location ($b = 20.34$, $SE = 10.13$, $t = 2.01$; an average preview benefit of 22.5 ms). As in Experiment 1, information obtained from the location where the target would ultimately appear facilitated processing of the target if the preview was a mirror image of the target. There was no main effect of relatedness of the preview in the third location ($b = 8.60$, $SE = 6.01$, $t < 1$; an average preview benefit of 11.5 ms), indicating no overall effect from the third location, but there was a significant interaction between the identities of the previews in the second- and third-to-be-named locations ($b = 25.19$, $SE = 12.03$, $t = 2.10$). The interaction indicates that if either preview is a mirror image of the target, processing of the target is significantly faster than if both previews are unrelated. The fact that previews from the third location facilitated gaze durations at the target location shows that subjects obtained information from both to-be-named locations and that information obtained from each can affect subsequent processing.

Thus, mirror image versus unrelated previews at the third location did affect gaze durations of objects at the second location. This shows that information is obtained from at least two objects in parallel, and that the information obtained from an object can affect processing of objects at other locations. Furthermore, this implies that the lack of preview benefit found in Experiment 1 is due to the fact that subjects never needed to name the unnamed object and could therefore exclude that object a priori. Thus, information can be obtained from multiple objects

simultaneously and can be used to benefit processing of objects in other locations, provided that that object is intended to be named.

Experiment 3

It is possible that the difference in the pattern of results found between Experiment 1 (no processing of a never-to-be-named object) and Experiment 2 (processing of a to-be-named object) was due to the difference in the number of objects on the screen. This would be so if, when there are three objects on the screen (in Experiment 2), subjects are able to extract more information from all objects in parallel, whereas when there are four objects on the screen (in Experiment 1), the additional object in view leads to less processing of those objects in parallel. To test this possibility, in Experiment 3 we presented three objects on the screen, of which subjects were only required to name two (in addition to a digit). If we found no effect of the preview in the unnamed location it would suggest that intention to name an object in a particular location is the constraining factor leading to whether or not that object is processed. If, however, we found an effect of the preview in the unnamed (third) location it would suggest that the lack of an effect of the unnamed location in Experiment 1 was due to the greater number of objects on the screen.

Method

Subjects. Twenty-four members of the University of California, San Diego community participated in the experiment with the same inclusion criteria.

Design. Experiment 3 was similar to Experiment 2 except that subjects were told they only had to name the first object, the second object, and then a digit in the lower right hand corner of the display. As in Experiment 2, previews appeared in the second and third location, but note that in this experiment, the third object is an unnamed object, similar to Experiment 1. The digit appeared upon a saccade to the second object to give the subjects a reason to leave the second object (i.e., in order to name the digit). As in the prior experiments, both previews were equidistant from the first object (21 degrees).

Results and Discussion

The same data filtering process and analyses as in Experiments 1 and 2 were used. Data were excluded if subjects (a) misnamed or disfluently named the first or second object (< 1% of the data), (b) looked at the unnamed object location, looked back from the target object to the first object, or there was track loss on the target object (19% of the data) or (c) gaze durations on the target object were more than 2.5 standard deviations from the mean, shorter than 325 ms or longer than 1325 ms (8% of the data). After excluding these data the number of observations did not significantly differ across conditions (all $ps > .15$).

As in Experiments 1 and 2, preview conditions did not significantly affect gaze durations on Object 1 (all $ts < 2$). Means and standard deviations of gaze durations on the target are shown in Table 3. Gaze durations on the target were shorter when the preview in the target location was a mirror image than when it

was unrelated to the target, but there was no difference between whether the preview in the unnamed location was a mirror image or unrelated.

Table 3. Gaze durations on the target as a function of preview type in the second and unnamed (third) locations in Experiment 3. Standard errors of the mean are in parentheses.

Second Location Preview	Unnamed (Third) Location Preview			Average Preview Benefit
	Mirror Image	Unrelated	Preview Benefit	
Mirror Image	582 (23)	586(23)	4	.5
Unrelated	597 (23)	594(25)	-3	
Preview Benefit	15	8		
Average Preview Benefit	11.5			

The LMM revealed a main effect of relatedness of the preview in the second location ($b = 11.96$, $SE = 5.52$, $t = 2.17$; an average preview benefit of 11.5 ms). As in Experiments 1 and 2, information obtained from the location where the target would ultimately be was obtained and facilitated processing of the target if the preview was related to (a mirror image of) the target.

There was no main effect of relatedness of the preview in the third (unnamed) location ($b = 1.08$, $SE = 5.52$, $t < .5$; an average preview benefit of .5 ms). As in Experiment 1, information was not obtained from an object that was not intended to be named and therefore did not affect processing of the target. Additionally, there was no interaction between the identities of the previews in the

second and third (unnamed) locations ($b = -9.61$, $SE = 11.05$, $t < 1$). The similarity between these results and those found in Experiment 1 (lack of both a main effect of the unnamed preview and the lack of an interaction between the two preview types) shows that intention to name (not number of objects on the screen) is the determining factor as to whether an object will be processed in parallel with another object.

Because the designs of Experiments 2 and 3 were essentially identical (except for the manipulation of intention to name the object in the other preview location) we performed a between-experiment analysis to test whether the pattern of results were statistically different across the two experiments. The results of the analysis reveal a significant three-way interaction between preview in the second location, preview in the third location, and experiment ($b = -32.64$, $SE = 15.17$, $t = -2.15$), demonstrating that the significant interaction in Experiment 2 is significantly different from the null interaction in Experiment 3.

General Discussion

These experiments illustrate two main points. First, preview benefits are only obtained from an object that will eventually be named. Intention to name, which we take to be an internally driven, attentional influence determines the extent to which an extrafoveal object will be processed. Second, given that an object will be named, the information obtained from that object can influence processing of an object in another location. Because both the preview objects were equidistant

from the first object in all experiments, distance from fixation cannot account for the presence or absence of preview benefit. Furthermore, Experiment 3 demonstrated that the lack of preview benefit from the unnamed location in Experiment 1 was not due to the number of objects on the screen.

These experiments confirm that speakers activate information about upcoming objects while they are fixating and processing the current object (Malpass & Meyer, 2010; Meyer et al., 2008; Morgan & Meyer, 2005; Morgan et al., 2008). This is supported by the preview benefit provided by the object in the second location in all three experiments. As mentioned above, this raises the question of how a potentially large amount of incoming information can be gated. The present experiments suggest that speakers exclude from processing objects they do not intend to name, when possible (e.g., based on location). This is supported by the lack of preview benefit based on the unnamed location in Experiments 1 and 3 compared to the preview benefit that was provided by the third object in Experiment 2. When an extrafoveal object can be excluded from processing a priori, information from it will not become activated. By this view, intention-to-name is responsible for excluding influences from many items that are available, and restricts activated information to what will be needed to support production.

These studies suggest that objects that are neither fixated nor intended to be named will not cause activation of information and those that are not currently fixated but are intended to be named will cause activation of information before they are fixated. But, given that an upcoming object is intended to be named, how do

speakers refrain from naming that object when it is different from a current target? One possibility is that information is activated less quickly from areas outside the fovea, due to acuity limitations, and therefore any information that is obtained from a foveal object (i.e., the first object) would reach threshold before the activation obtained extrafoveally (i.e., the second to-be-named object). Therefore, the representation of the extrafoveal object would not become fully activated until it is fixated and processed foveally (Morgan, van Elswijk, & Meyer, 2008). Furthermore, this priority of the first object could also be considered an attentional restriction, as working memory demands at fixation influence extrafoveal preview benefits (Malpass & Meyer, 2010). Another possibility is that only some types of information can be obtained in parallel. The present study only demonstrated mirror image preview benefits. Prior research has demonstrated that phonological preview benefits arise in the absence of visual or semantic overlap (i.e., homophones; Meyer et al., 2008; Morgan & Meyer, 2005; Pollatsek et al., 1984). The paradigm used in the present experiments could be used to test whether phonological representations of other extrafoveal objects are activated or whether the phonological preview benefits seen in these studies are due to attention shifting to the next object before the eyes (see Rayner, 1998, 2009 for reviews), during which phonological information is activated.

As mentioned in the introduction, the current study cannot determine whether the information obtained from these objects is conceptual, lexical, or phonological, because the mirror image preview and the target shared all of those

features. Future research can employ different types of previews to test what type of information is obtained from an extrafoveal object, given that it is intended to be named. Previous studies that have demonstrated semantic interference have used within-category semantic distractors (e.g., lion and tiger), which would activate separate representations that would compete for selection. The present study used previews that activate the same representation (because the preview and target represented the same object) and would therefore yield facilitation, not interference. If within-category preview-target pairs were used we might see semantic interference similar to that seen in picture-picture interference studies.

The present study does not test whether attention is allocated to objects as a consequence of the intention to name them or whether any type of task will cause the representation of an object to be activated. A simple modification to the present paradigm requiring subjects to make some other response (e.g., categorization) to the objects instead of name them would test this. Thus strictly speaking, the present studies show that “intention to process,” here as implemented by an intention to name, leads to activation of information from an object even before it is fixated.

With respect to the prior literature reporting distractor object processing, these results suggest that the reason those objects were processed (phonologically and/or semantically) was because the subjects were not able to exclude the object from being processed a priori. That is, the distractor objects were processed before the system could determine which object was the target (to-be-named) and which was a distractor (to-be-ignored). Similarly, in experiments showing phonological

facilitation from a picture when subjects are required to name the color in which it is displayed (e.g., Navarrete & Costa, 2005), it is likely because processing of the object cannot be separated from processing its color and therefore cannot be excluded a priori. The present study suggests that phonological facilitation and semantic interference would not be observed in such experiments if subjects were able to determine a priori which object they needed to process and which one they needed to ignore.

In sum, the reported experiments show that if an object is to be named, the speaker activates linguistic information about it before he or she looks at it. That activation can benefit processing not only of the object in that location, but also objects that occupy other spatial locations. Parallel activation of objects, now widely reported in multiple object naming studies (Malpass & Meyer, 2010; Meyer & Dobel, 2004; Meyer et al., 2008; Morgan & Meyer, 2005; Morgan et al., 2008; see Meyer, 2004 and Schotter, 2011 for reviews), can be restricted such that information is not activated from task-irrelevant objects that can be excluded a priori. These observations point to the strategies that mechanisms of perception and production use to manage information when we talk about what we see.

Chapter 3, in full, is a reprint of the material as it appears in Schotter, E.R., Ferreira, V.S. & Rayner, K. (2013). Parallel object activation and attentional gating of information: Evidence from eye movements in the multiple object naming paradigm. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 39, 365-374. The dissertation author was the primary investigator and author of this paper.

References

- Baayen, R., Davidson, D. & Bates, D. (2008). Mixed-effects modeling with crossed and random effects for subjects and items. *Journal of Memory and Language*, *59*, 390-412.
- Bates, E., D'Amico, S., Jacobsen, T., Szekely, A., Andonova, E., Devescovi, A., Herron, D., Lu, C. C., Pechmann, T., Pleh, C., Wicha, N., Federmeier, K., Gerdjikova, I., Gutierrez, G., Hung, D., Hsu, J., Iyer, G., Kohnert, K., Mehotcheva, T., Orozco-Figueroa, A., Tzeng, A., & Tzeng, O. (2003). Timed picture naming in seven languages. *Psychonomic Bulletin & Review*, *10*, 344-380.
- Bates, D. & Maechler, M. (2009). lme4: Linear mixed-effects models using S4 classes. R package version 0.999375-32. <http://CRAN.R-project.org/package=lme4>
- Glaser, W.R., & Glaser, M.O. (1989). Context effects on Stroop-like word and picture processing. *Journal of Experimental Psychology: General*, *118*, 13-42.
- Griffin, Z. (2001). Gaze durations during speech reflect word selection and phonological encoding. *Cognition*, *82*, B1-B14.
- Harley, T. A. (1984). A critique of top-down independent levels models of speech production: Evidence from non-plan-internal speech errors. *Cognitive Science*, *8*, 191-219.
- Henderson, J. & Siefert, A. (1999). The influence of enantiomorphic transformation on transsaccadic object integration. *Journal of Experimental Psychology: Human Perception and Performance*, *25*, 243-255.
- Henderson, J. & Siefert, A. (2001). Types and tokens in transsaccadic object identification: Effects of spatial position and left-right orientation. *Psychonomic Bulletin & Review*, *8*, 753-760.
- Hollingworth, A. & Rasmussen, I.P. (2010). Binding objects to locations: the relationship between object files and visual working memory. *Journal of Experimental Psychology: Human Perception and Performance*, *36*, 543-564.
- Humphreys, G.W., Lloyd-Jones, T.J., & Fias, W. (1995). Semantic interference effects on naming using a postcue procedure: Tapping the links between semantics and phonology with pictures and words. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *21*, 961-980.
- Jescheniak, J., Oppermann, F., Hantsch, A., Wagner, V., Madebach, A., & Schriefers, H. (2009). Do perceived context pictures automatically activate their phonological code? *Experimental Psychology*, *56*, 56 – 65.

- Madebach, A., Jescheniak, J., Oppermann, F., & Schriefers, H. (2010). Ease of Processing constrains the activation flow in the conceptual–lexical system during speech planning. *Annual Meeting of the Psychonomic Society*, St. Louis, MO, USA
- Malpass, D. & Meyer, A. (2010). The time course of name retrieval during multiple-object naming: Evidence from extrafoveal-on-foveal effects. *Journal of Experimental Psychology: Learning, Memory and Cognition*, *36*, 523-537.
- Meyer, A., (2004). The use of eye tracking in studies of sentence generation. In J. M. Henderson & F. Ferreira (Eds.), *The interface of language, vision, and action: Eye movements and the visual world* (pp. 191–211). New York: Psychology Press
- Meyer, A., & Damian, M. (2007). Activation of distractor names in the picture – picture interference paradigm. *Memory and Cognition*, *35*, 494 – 503.
- Meyer A. & Dobel, C. (2003). Application of eye tracking in speech production research. In J. Hyönä , R. Radach, and H. Deubel (Eds.), *The mind's eye: Cognitive and applied aspects of eye movement research* (pp 253-272). Amsterdam: North Holland.
- Meyer, A., Ouellet, M. & Hacker, C. (2008). Parallel processing of objects in a naming task. *Journal of Experimental Psychology: Learning, Memory and Cognition*, *34*, 982-987.
- Meyer, A., Sleiderink, A. & Levelt, W. (1998). Viewing and naming objects: eye movements during noun phrase production. *Cognition*, *66*, B25-B33.
- Meyer, A. & van der Meulen, F. (2000). Phonological priming effects on speech onset latencies and viewing times in object naming. *Psychonomic Bulletin & Review*, *7*, 314-319.
- Morgan, J. & Meyer, A. (2005). Processing of extrafoveal objects during multiple-object naming. *Journal of Experimental Psychology: Learning Memory and Cognition*, *31*, 428-442.
- Morgan, J., van Elswijk, G. & Meyer, A. (2008). Extrafoveal processing of objects in a naming task: Evidence from word probe experiments. *Psychonomic Bulletin & Review*, *15*, 561-565.
- Morsella, E., & Miozzo, M. (2002). Evidence for a cascade model of lexical access in speech production. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *28*, 555 – 563.

- Navarrete, E., & Costa, A. (2005). Phonological activation of ignored pictures: Further evidence for a cascade model of lexical access. *Journal of Memory and Language*, *53*, 359 – 377.
- Oppermann, F., Jescheniak, J., & Schriefers, H. (2008). Conceptual coherence affects phonological activation of context objects during object naming. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *34*, 587 – 601.
- Oppermann, F., Jescheniak, J., Schriefers, H., & Görge, F. (2010). Semantic relatedness among objects promotes the activation of multiple phonological codes during object naming. *Quarterly Journal of Experimental Psychology*, *63*, 356-370.
- Pashler, H. (1999). *The Psychology of Attention*. Cambridge, MA: MIT Press.
- Pollatsek, A., Rayner, K. & Collins, W. (1984). Integrating pictorial information across eye movements. *Journal of Experimental Psychology: General*, *113*, 426-442.
- Pollatsek, A., Rayner, K. & Henderson, J. (1990). Role of spatial location in integration of pictorial information across saccades. *Journal of Experimental Psychology: Human Perception & Performance*, *16*, 199-210.
- Rayner, K. (1975). The perceptual span and peripheral cues in reading. *Cognitive Psychology*, *7*, 65-81.
- Schotter, E. (2011). Eye movements as an index of linguistic processing in language production. *Journal of Psychology and Behavior*, *9*, 16-23
- Strijkers, K., Holcomb, P. & Costa, A. (2011). Conscious intention to speak proactively facilitates lexical access during overt object naming. *Journal of Memory and Language*, *65*, 345-362.
- Tipper, S. The negative priming effect: Inhibitory priming by ignored objects. *Quarterly Journal of Experimental Psychology*, *37*, 571-590.
- Van der Meulen, F., Meyer, A. & Levelt, W. (2001). Eye movements during the production of nouns and pronouns. *Memory & Cognition*, *29*, 512-521.
- Zelinsky, G. & Murphy, G. (2000). Synchronizing visual and language processing: An effect of object name length on eye movements. *Psychological Science*, *11*, 125-131.

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CHAPTER 4:

SYNONYMS PROVIDE SEMANTIC PREVIEW BENEFIT BUT OTHER SEMANTIC
RELATIONSHIPS DO NOT

Abstract

While orthographic and phonological preview benefits in reading are uncontroversial (see Schotter, Angele, & Rayner, 2012 for a review), researchers have debated the existence of semantic preview benefit with positive evidence in Chinese and German, but no support in English. Two experiments, using the *gaze-contingent boundary paradigm* (Rayner, 1975), show that semantic preview benefit can be observed in English when the preview and target are synonyms (share the same or highly similar meaning, e.g., *curlers-rollers*). However, no semantic preview benefit was observed for semantic associates (e.g., *curlers-styling*). These different preview conditions represent different degrees to which the meaning of the sentence changes when the preview is replaced by the target. When this continuous predictor (determined by a norming procedure) was used as the predictor in the analyses, it was as good or better of a predictor than the condition variable in all measures (a 1-4 ms increase in reading time for every step up in meaning change, depending on the reading time measure). These data suggest that similarity in meaning between what is accessed parafoveally and what is processed foveally may be an important influence on the presence of semantic preview benefit. Why synonyms provide semantic preview benefit in reading English will be discussed in relation to (1) previous failures to find semantic preview benefit in English and (2) the fact that semantic preview benefit is observed in other languages even for non-synonymous words. Semantic preview benefit is argued to depend on several factors—attentional resources, depth of orthography, and degree of similarity between preview and target.

One of the most debated topics over the past decade in the field of eye movements during reading is whether or not semantic information can be obtained from an upcoming word while still fixating a prior word (see Rayner, 1998, 2009; Schotter, Angele, & Rayner, 2012 for reviews). Throughout this debate researchers have used various tasks and languages to examine whether readers can obtain such information. The results of these studies have come to different conclusions: some claim positive evidence while others claim negative evidence. Some studies that have been used as evidence in the debate have not investigated the task of silent reading (e.g., “reading” lists of words, Dimigen, Kliegl, & Sommer, 2012) and, because the nature of the task is different from that of silent reading, will not be considered here. The perspective in the present paper is not to provide yet another piece of evidence to weigh on one side or another, but rather to reconcile many different studies showing different results. I first discuss past studies on semantic preview benefit and develop a conceptual framework in which to reconcile them. The predictions of this framework were tested in two experiments showing that semantic preview benefit may be observed in English, but only if the preview and target are very similar in meaning—i.e., are synonyms of each other.

To test what information about upcoming words readers can access and use to while reading, researchers use the *gaze-contingent boundary paradigm* (Rayner, 1975). In this paradigm, a preview word is changed to a target word during the saccade to it (see Experiment 1 Method; Figure 1). Reading time measures on the target are compared between various related preview conditions and an unrelated

control condition. Faster processing in a related condition compared to the unrelated condition suggests *preview benefit*—that information was obtained from the preview word parafoveally and used to facilitate processing of the target. The evidence is clear that orthographically and phonologically related previews provide preview benefit, while preview benefits from other relationships (e.g., morphologically or semantically related previews) have mixed evidence and may depend on the language being considered (see Rayner, 1998, 2009; Schotter et al., 2012 for reviews). *Preview benefit* is defined as facilitated processing of a target word (e.g., *beer*) when the reader had access to a related preview word (e.g., an orthographically similar letter string, *becn*) in that location compared to an unrelated preview condition (e.g., *rope*; Rayner, Balota & Pollatsek, 1986). Rayner et al. did not find preview benefit for semantically related previews (e.g., *wine*, see below). Semantic preview benefit is one of a few effects that researchers believe distinguishes the two most prominent models of eye movement control in reading: E-Z Reader (Reichle, Pollatsek, Fisher, & Rayner, 1998; Reichle, Pollatsek, & Rayner, 2006; Reichle, Rayner, & Pollatsek, 2003; Reichle, Warren, & McConnell, 2009) and SWIFT (Engbert, Longtin, & Kliegl, 2002; Engbert, Nuthmann, Richter, & Kliegl, 2005; Schad & Engbert, 2012). Because of this, the presence of semantic preview benefit is of particular interest to the field.

Condition	Sentence
	*
Identical	Sarah tried using curlers on her stubborn straight hair before prom.
	*
Synonym	Sarah tried using rollers on her stubborn straight hair before prom.
	*
Unrelated	Sarah tried using suffice on her stubborn straight hair before prom.
	*
Target	Sarah tried using curlers on her stubborn straight hair before prom.

Figure 1. Example sentences used in Experiment 1. The asterisk represents the location of the word being fixated. The first three lines represent the sentence before the display change, during preview (while reading the sentence up until the target), while the last line represents the sentence after the display change.

Because, according to SWIFT, attention is allocated to multiple words in parallel (distributed as a gradient related to distance from fixation location) it is believed that semantic pre-activation of words naturally falls out of the model. In contrast, because attention is allocated serially in E-Z Reader, it is thought that the model is unable to account for lexical (and consequently, semantic) preprocessing of the upcoming word. However, according to the model, there is nothing barring lexical preprocessing of the upcoming word; it is just very unlikely, given that attention is only allocated to the upcoming word during a brief amount of time, after the current word has been identified but before the saccade to the upcoming word has been triggered. The robustly observed orthographic and phonological preview benefits reported throughout the literature are due to these features of words being processed parafoveally quickly during that brief attention shift. Thus, in E-Z Reader, if the preview duration is longer more time would allow for semantic pre-processing.

Semantic preview benefit likely arises because of a mechanism similar to that thought to cause semantic priming (e.g., spreading activation throughout a semantic

network; Collins & Loftus, 1975; Quillian, 1967; but see Hutchinson, 2003; Lucas, 2000; and Neely, 1991 for reviews with other accounts, as well). In essence, semantic priming is generally accepted as being due to the prime providing a head-start on processing the target (e.g., Balota, Yap, Cortese, Watson, 2008; Voss, Rothermund, Gast & Wentura, 2013). However, there are important differences between semantic priming and preview benefit (Schotter et al., 2012); most notably, the fact that target words in sentences benefit from the sentence context (putting constraints on meaning and syntactic class, etc.) and parafoveal preview (access to the visual form of the word before it is fixated). Regardless of which model of reading or semantic priming one considers, it is possible that semantic preview benefit would *not* be observed if activation from the preview has only a brief amount of time to provide a head-start on processing. Consequently, if activation does not need to spread as far in the network, semantic preview benefit might be more likely to be observed even with brief preview durations. While spreading activation is one account for semantic priming, an alternative explanation could be based on semantic features being activated (see Hutchinson, 2003; Lucas, 2000; Neely, 1991). Under this account, as well, semantic preview benefit would be more likely to be observed when the preview and target are more similar (i.e., when they share more features).

Researchers have accounted for the lack of evidence for semantic preview benefit in English (e.g., Rayner et al., 1986; see also Altarriba, Kambe, Pollatsek & Rayner, 2001) by suggesting that lexical and semantic representations are activated

after (likely as a consequence of) orthographic and phonological information and there is simply not enough time during parafoveal preview for information to feed up to semantics. Support for this idea comes from studies showing that orthographic preview benefit is larger when the pretarget word is high frequency (i.e., requires less processing to identify; Henderson & Ferreira, 1990; Kennison & Clifton, 1995), allowing for more preprocessing of the upcoming word prior to fixation.

Importantly, this should be a larger issue in a language like English than in other languages because of its deep orthography (i.e., there is an inconsistent connection between letters and sounds) and accessing phonological representations may be more effortful than in other languages. As a consequence, there may be less opportunity in English to observe semantic preview benefit, but languages with shallower orthographies may have a greater opportunity to produce semantic preview benefit (because semantic information would have a greater likelihood of being activated, either by activation spreading further in the network or by semantic features becoming more activated) even with only brief preview durations. In fact, a language (German) that does show evidence for semantic preview benefit does have a shallower orthography than English (Hohenstein & Kliegl, 2013; Hohenstein, Laubrock, & Kliegl, 2010). Relatedly, semantic preview benefit has also been reported in Chinese (Yan, Richter, Shu & Kliegl, 2009; Yang, Wang, Tong, & Rayner, 2010), which more directly represent semantics without necessarily requiring phonological mediation (Hoosain, 1991). For a more detailed account, see the General Discussion.

One of the problems complicating the study of semantic preview benefit (and semantic priming, in general) is the fact that there are many possible ways in which words can be related in meaning. In fact, a review by Hutchinson (2003) identified 14 different types of relationships observed in association norm databases. Because these categories represent a whole range of types of relationships (e.g., perceptual property—*canary-yellow*, phrasal associates—*baby-boy*, supraordinate category—*dog-animal*, antonyms—*hot-cold*, etc.), it is likely that combining all (or many) of them in an experiment will obscure different and nuanced effects that vary between the different types. The seminal semantic preview benefit study (Rayner et al., 1986) did, in fact, investigate this to a small extent. Rayner et al.'s (1986) overall data showed no semantic preview benefit. In a post-hoc analysis, they compared the magnitude of the preview benefit for semantically related previews that altered the meaning of the sentence (measured by a norming procedure) compared to all sentences. They found the same pattern of data, regardless of whether the preview constituted a change in the meaning of the sentence. However, even words that were not rated to have significantly changed the meaning of the sentence may have actually changed the meaning of the sentence to enough of a degree that semantic preview benefit may have been eliminated.

For this reason, it is necessary to assess the degree to which previews that are semantically related and do *not* change the meaning of the sentence provide preview benefit. For instance, synonyms (e.g., *curlers—rollers*, which should represent the strongest meaning similarity between words) may show a different

type of preview benefit than purely related items (e.g., *curlers—styling*). Because synonyms share the same meaning, in a reading task in which the goal of the cognitive-linguistic processing system is to access word meanings, they may actually provide preview benefit even though the various semantic relationships tested in previous studies in English did not. In fact, a study by Yang et al. (2010) showed that semantic preview benefit in Chinese is only obtained when the preview is plausible given the prior sentence context. This suggests that, if the meaning of the upcoming word is anomalous in context, parafoveal information may either not be obtained from it or may be more readily discarded.

Given this, an argument could be made that *translation equivalents*—words that have the same meaning across two languages (e.g., *strong* in English and *fuerte* in Spanish) should provide substantial preview benefit to proficient bilinguals because they should not significantly alter the meaning of the sentence. However, a study by Altarriba et al. (2001) found that words such as these, which are *non-cognates* (i.e., only share meaning, and not orthography or phonology, e.g., *strong—fuerte*) did not provide any preview benefit compared to an unrelated word, but those that shared meaning, phonology and orthography (*cognates*, e.g., *cream—crema*) and those that only shared orthography and phonology but not meaning (*pseudocognates*, e.g., *grass—grasa*) did. Altarriba et al. explained this by proposing that preview benefit is based on parafoveal processing of orthographic and phonological information, but not semantic information; alternatively, as suggested above, when orthographic and phonological information changes between preview

and target any semantic information that had been obtained is discarded. However, because these words were only semantically related across languages, it is possible that Altarriba et al. failed to find a semantic preview benefit because the bilinguals may have not activated their other lexicon (e.g., Spanish) after reading words exclusively in another language (Gollan, Forster, & Frost, 1997). In fact, data by Altarriba, Kroll, Scholl, and Rayner (1996) support this explanation. They had Spanish-English bilinguals read English sentences, in a study that did not involve parafoveal preview, with either an English target word “He wanted to deposit all of his *money* at the credit union” or a Spanish translation equivalent “He wanted to deposit all of his *dinero* at the credit union.” The results of that experiment showed that subjects read Spanish target words much more slowly (by more than 100 ms) than English target words, indicating a cost of mixing languages within the text.

Given the evidence reviewed above, it is possible that when a preview and a target are dissimilar enough that information obtained from the preview parafoveally will either not have time to become activated or will be discarded and word identification on the target will start again, from scratch (see Altarriba et al., 2001; Schotter et al., 2012). However, if there is enough shared information between the preview and target to facilitate processing of the target, parafoveally obtained preview information may be retained and used to identify the target. Furthermore, prior to fixating a word, there may be some cursory check for congruity with the sentence context that, if absent, leads to preview information either not being obtained or being more readily discarded. This account makes two

specific predictions about whether preview benefit will be observed and the relative magnitude of preview benefits in different conditions. First, the more levels of representation that are shared between preview and target, the larger the preview benefit should be. Prior research demonstrates that phonological preview benefit is larger when both orthography and phonology are shared between preview and target compared to when only one representation is shared (e.g., Mielliet & Sparrow, 2004) and preview benefit is observed for bilinguals reading cognates (words that share orthographic/phonological *and* semantic representations across languages), but not non-cognate translations (words that only share semantic representations across languages; Altarriba et al., 2001). Second, and most importantly for the current experiments, the greater degree of similarity between preview and target *within* a level of representation (e.g., orthography, phonology, semantics), the larger the observed preview benefit should be. In fact, prior research has demonstrated that the degree of orthographic similarity is positively related to the magnitude of orthographic preview benefit (e.g., Mielliet & Sparrow, 2004; Pollatsek, Lesch, Morris & Rayner, 1992). Given these two predictions, one would expect that (1) synonyms should provide preview benefit while other semantic relationships should not and (2) preview benefit should be positively related to the similarity in meaning between preview and target.

To test these predictions, two experiments examined the presence and magnitude of semantic preview benefit during reading. To test for semantic preview benefit, both experiments utilized the gaze-contingent boundary paradigm (Rayner,

1975) and compared reading time measures on the target between various related preview conditions: (1) identical (e.g., *curlers—curlers*), (2) synonym (e.g., *rollers—curlers*), (3) semantically related (e.g., *styling—curlers* in Experiment 2 only), and (4) an unrelated control condition (e.g., *suffice—curlers*)¹.

Experiment 1

Method

Subjects. Thirty-six undergraduates at the University of California San Diego participated in the experiment for course credit. All subjects were native English speakers with normal or corrected-to-normal vision and were naïve to the purpose of the experiment.

Apparatus. Eye movements were recorded with an SR Research Ltd. EyeLink 1000 eye tracker (with a sampling rate of 1000 Hz) in a tower setup that restrains head movements with forehead and chin rests. Viewing was binocular, but only the movements of the right eye were recorded. Subjects were seated approximately 60 cm away from an Iiyama Vision Master Pro 454 CRT monitor with a screen resolution of 1024 x 768 pixels and a refresh rate of 150 Hz. The sentences were presented in the center of the screen with black Courier New 14-point font on a

¹ It must be noted that expectations about what word will appear next in the sentence may affect how the encountered word is processed (Roland, Yun, Koenig, & Mauner, 2012). Mainly, words that are semantically similar to the expected word are processed more easily than those that are dissimilar. However, the purpose of the present experiments is to test for semantic preview benefit—whether semantic information can be obtained from the *word itself*, in the absence of support from context. For this reason, all sentences were created to have very low cloze probabilities for all preview words so that any preview benefit observed is attributable to parafoveal preprocessing, rather than similarity between the preview and the expected word.

white background and were always presented in one line of text with 3.8 characters subtending 1 degree of visual angle. Following calibration, eye position errors were less than 0.3°. The display change was completed, on average, within 4 ms (range = 0-7 ms) of the tracker detecting a saccade crossing the boundary.

Materials and Design. Stimuli consisted of 123 target words that were paired with one synonym and one unrelated item to create the three preview conditions: identical (*curlers – curlers*), synonym (*rollers – curlers*), and unrelated (*suffice – curlers*; see Table 1, Appendix). Each target item was presented in a sentence context that was designed to be neutral and not predict either the target or either of the previews (all cloze scores < .05; see normative data section, below). The target word was always preceded and followed by a minimum of three words. The target and all previews were matched on length (number of letters), ranging from 3 to 10 letters (mean = 5.61). The synonym and unrelated previews were matched with each other on word shape (e.g., ascenders and descenders) and number of initial letters shared with the target ($M_{\text{synonym-target}} = 0.09$, $SE = .03$, $M_{\text{unrelated-target}} = 0.09$, $SE = .03$). In addition to the lexical characteristics, here, a series of norming experiments assessed the degree to which the target and previews were (1) predictable in the sentence context, (2) related in meaning, and (3) changed the meaning of the sentence. Lastly, the previews were coded for whether or not they were anomalous in the sentence context.

Table 1. Lexical characteristics of and normative data for target and preview words used in Experiment 1 (all conditions except semantically related) and Experiment 2 (all conditions). Standard errors are in parentheses.

Variable	Target		Preview Condition	
	Identical	Synonym	Semantic	Unrelated
Length	5.61 (1.46)	5.61 (1.46)	5.61 (1.46)	5.61 (1.46)
Log Frequency (HAL)	8.31 (1.86)	10.26 (1.46)	8.99 (2.11)	10.04 (1.53)
Total Letters Shared with Target	--	.72 (.09)	.81 (.10)	.55 (.07)
Initial Letters Shared with Target	--	.09 (.03)	.15 (.05)	.09 (.03)
Cloze Predictability	.02 (.05)	.05 (.12)	.00 (.02)	.00 (.01)
Word Relatedness to Target (1-9 scale)	--	7.5 (.97)	5.6 (1.5)	2.4 (.97)
Sentence Fragment Relatedness to Target (1-9 scale)	--	7.2 (1.3)	4.9 (1.8)	1.9 (.72)
Proportion of Items Anomalous in Sentence Context	.00	.00	.27	.72

Normative Data. Fifteen UCSD students, who did not participate in the reading experiment, participated in a cloze norming task to evaluate the predictability of the target and preview words. This norming task revealed that the sentences were very neutral, with (on average) the target only being produced 2% of the time, the synonym being produced 5% of the time and the unrelated word being produced 0% of the time.

A separate set of thirty UCSD students participated in a semantic relatedness judgment task to evaluate the degree to which each of the previews were similar in meaning to the target (on a 1-9 point rating scale). This norming task revealed that the target and synonym were rated as very similar in meaning ($M = 7.5$) whereas the unrelated preview was very different in meaning ($M = 2.4$).

To assess the degree to which replacing the target with a preview changed the meaning of the sentence, an additional norming task was conducted with yet

another set of thirty UCSD students. Subjects were given one sentence fragment (including the beginning of the sentences up to, and including, the target) and a second fragment where the target was replaced by one of the previews, and asked to judge how much the meaning of the sentence fragments differed. This norming task revealed results quite similar to the relatedness judgments of the isolated words. The sentence fragments that changed from target to synonym were rated as very similar ($M = 7.2$), whereas the sentence fragments with the unrelated preview were rated as very different ($M = 1.9$).

Procedure. Subjects were instructed to read the sentences for comprehension and to respond to occasional comprehension questions, pressing the left or right trigger on the response controller to answer yes or no, respectively. At the start of the experiment (and during the experiment if calibration error was greater than .3 degrees of visual angle), the eye-tracker was calibrated with a 3-point calibration scheme. At the beginning of the experiment, subjects received five practice trials, each with a comprehension question, to allow them to become comfortable with the experimental procedure.

Each trial began with a fixation point in the center of the screen, which the subject was required to fixate until the experimenter started the trial. Then a fixation box appeared on the left side of the screen, located at the start of the sentence. Once a fixation was detected in this box, it disappeared and the sentence appeared. The sentence was presented on the screen until the subject pressed a button signaling they had completed reading the sentence. The target replaced the

preview once the subject's gaze crossed an invisible boundary located before the space before the target (see Figure 1). Subjects were instructed to look at a target sticker on the right side of the monitor beside the screen when they finished reading to prevent them from looking back to a word (in particular, the target, which was often located in the center of the sentence, near the location of the fixation point that started the next trial) as they pressed the button. Comprehension questions followed 30 (41%) of the sentences, requiring a "yes" or "no" response. The experimental session lasted approximately thirty minutes.

Results and Discussion

Fixations shorter than 80 ms within one character of a previous or subsequent fixation were combined. All remaining fixations shorter than 80 ms were eliminated. Trials in which there was a blink or track loss on the target word or on an immediately adjacent word during first pass reading were excluded, as were trials in which the display change was triggered by a saccade that landed to the left of the boundary or trials in which the display change was completed late. These data exclusions left 3637 trials (82% of the original data) available for analysis. Additionally, for each measure, we excluded durations that were beyond 3 standard deviations from each subject's mean.

Data were analyzed using inferential statistics based on generalized linear mixed-effects models (LMMs) with preview entered as a fixed effect with planned contrasts (see below) and subjects and items as crossed random effects (see Baayen, Davidson, & Bates, 2008), using the maximal random effects structure (Barr, Levy,

Scheepers & Tily, 2013). There were two planned contrasts built into the model: the first tested for a difference between the identical condition and the unrelated condition (i.e., an identical preview benefit) and the second tested for a difference between the synonym and the unrelated condition (i.e., a synonym preview benefit). Using contrasts in this way allows one to compare the magnitude of preview benefit by comparing the coefficient estimates output by the LMM. In order to fit the LMMs, the `lmer` function from the `lme4` package (Bates, Maechler & Bolker, 2011) was used within the R Environment for Statistical Computing (R Development Core Team, 2012). For fixation duration measures, linear mixed-effects regressions were used, and regression coefficients (b), which estimate the effect size (in milliseconds) of the reported comparison, and the t -value of the effect coefficient are reported. For binary dependent variables (fixation probability data), logistic mixed-effects regression, and regression coefficients (b), which represent effect size in log-odds space, and the z value and p value of the effect coefficient are reported. Absolute values of the t and z statistics greater than or equal to 1.96 indicate an effect that is significant at approximately the .05 alpha level.

Eye movement measures. To assess the degree to which semantic information was obtained from the target words parafoveally, standard *local reading time measures* (see Rayner, 1998, 2009; Schotter et al., 2012) on the target word across conditions were compared: *first fixation duration* (the duration of the first fixation on the word, regardless of how many fixations are made), *single fixation duration* (the duration of a fixation on a word when it is the only fixation on

that word in first pass reading), *gaze duration* (the sum of all fixations on a word prior to leaving it, in any direction), *total viewing time* (the sum of all fixations on a word, including regressions) and *go past time* (the sum of all fixations on a word and any words to the left of it before going past it to the right). The fixation probability measures reported are *fixation probability* (the probability of making a fixation on the target during first pass reading), *regressions out of the target* (probability of making a regression out of the target, to a word to the left of it) and *regressions into the target* (probability of making a regression into the target from one of the words to its right). Note that, because of the display change, readers never fixated the preview (i.e., the target was present upon fixation in all conditions) and the only access they had to the preview was parafoveally. Thus, any differences across conditions are due to the information readers had obtained from the preview prior to fixating it and the facilitation that information provided to processing the target during fixation on it. Means and standard errors (aggregated by subject) for local reading time measures are reported in Table 2.

Table 2. Means and standard errors (aggregated by subjects) for reading measures on the target across condition in Experiment 1.

Measure	Preview		
	Identical	Synonym	Unrelated
Fixation Duration Measures			
First Fixation Duration	223 (4.3)	220 (4.3)	234 (5.4)
Single Fixation Duration	227 (4.7)	227 (5.1)	244 (6.4)
Gaze Duration	247 (5.6)	251 (6.7)	267 (7.0)
Total Viewing Time	286 (9.4)	294 (8.1)	320 (12.0)
Go Past Time	277 (9.0)	281 (8.6)	308 (13.0)
Fixation Probability Measures			
Fixation Probability	.81 (.03)	.83 (.02)	.85 (.02)
Regressions into the Target	.14 (.02)	.18 (.02)	.19 (.02)
Regressions out of the Target	.09 (.02)	.09 (.01)	.13 (.02)

Fixation duration measures. Results of the LMMs for fixation duration measures are reported in Table 3. Across all measures there was a significant preview benefit in the identical condition; reading times were significantly shorter on the target when the preview was identical, than when it was unrelated (FFD: $b = 12.51$, $t = 3.05$; SFD: $b = 18.23$, $t = 3.72$; GZD: $b = 21.75$, $t = 4.22$; TVT: $b = 39.90$, $t = 5.32$, Go-Past: $b = 31.50$, $t = 3.84$). Similarly, there was a significant preview benefit in the synonym condition: reading times were significantly shorter on the target when the preview was a synonym of the target than when it was unrelated (FFD: $b = 14.84$, $t = 3.61$; SFD: $b = 17.81$, $t = 3.63$; GZD: $b = 16.63$, $t = 3.10$; TVT: $b = 27.19$, $t = 3.14$, Go-Past: $b = 29.54$, $t = 3.28$). Importantly, the estimated effect sizes (the b values) in each measure are of similar magnitudes for the identical preview benefit and the synonym preview benefit, suggesting that not only did the synonym provide

a significant facilitation to processing the target compared to the unrelated preview, the benefit was approximately as good as having a preview of the target word itself (although all coefficients are larger for the identical preview benefit than the synonym benefit, except in first fixation duration). These results suggest that semantic information can be extracted from the parafovea and used to facilitate processing of the target, once it is fixated (see General Discussion).

Table 3. Results of the linear mixed effects models for reading time measures on the target across condition in Experiment 1. Preview benefit refers to the difference in processing between the unrelated condition and either the identical or synonym, separately. Significant effects are indicated by boldface.

Measure	Preview Benefit Comparison	b	SE	t
First Fixation Duration	Identical	12.51	4.10	3.05
	Synonym	14.84	4.11	3.61
Single Fixation Duration	Identical	18.23	4.90	3.72
	Synonym	17.81	4.91	3.63
Gaze Duration	Identical	21.75	5.16	4.22
	Synonym	16.63	6.01	3.10
Total Time	Identical	39.90	7.50	5.32
	Synonym	27.19	8.66	3.14
Go-Past Time	Identical	31.50	8.20	3.84
	Synonym	29.54	9.00	3.28

Fixation probability measures. Results of the LMMs on fixation probability measures are reported in Table 4. There was no effect of preview condition on the probability of fixating the target: both the difference between the identical and unrelated conditions and the difference between the synonym and unrelated

conditions were not significant (both $ps > .65$). For regressions, the difference between the identical and unrelated conditions was significant for both regressions into the target ($z = 4.16, p < .001$) and regressions out of the target ($z = 4.14, p < .001$) whereas the difference between the synonym and unrelated conditions was not significant for regressions into the target ($z < 1$) but was marginally significant for regressions out of the target ($z = 1.71, p = .09$).

Table 4. Results of the linear mixed effects regression model for fixation probability measures on the target across condition in Experiment 1. Preview benefit refers to the difference in processing between the unrelated condition and either the identical or synonym, separately. Significant effects are indicated by boldface.

Measure	Preview Benefit Comparison	b	z	p
Fixation Probability	Identical	.08	0.44	.66
	Synonym	-.05	0.26	.79
Regressions into the Target	Identical	.83	4.16	< .001
	Synonym	.14	.98	.33
Regressions out of the Target	Identical	.89	4.14	< .001
	Synonym	.35	1.71	.09

Taken together, these results suggest that semantic information can be obtained from an upcoming word during silent reading and, if that semantic information is similar enough to that of the target (i.e., if preview and target are synonyms) the information will be used to facilitate processing of the target. Note that the orthographic similarity between the synonym preview and target and the unrelated preview and target was well-matched and very low (on average almost no similar letters) so that a perceptually-based account of these data is unlikely.

Experiment 2

To further test the predictions laid out in the introduction, a second experiment was conducted using the boundary paradigm to test for semantic preview benefit. This experiment contained the same sentences and conditions as Experiment 1, but also included a semantically related (but not synonymous) condition (e.g., *styling—curlers*). This experiment is important to (1) replicate the finding of preview benefit provided by synonyms from Experiment 1 and (2) replicate the finding of a lack of preview benefit for semantically related, but not synonymous words (Rayner et al., 1986). This experiment directly tests whether the reason why semantic preview benefit was observed in Experiment 1, here, but not by Rayner et al. (1986) is due to the degree of semantic similarity between preview and target. That is, many of their semantically related previews changed the meaning of the sentence (as do many of the semantically related previews in Experiment 2) while synonyms do not. Thus, we should not see preview benefit from the semantically related previews in Experiment 2, but we should still see preview benefit from the synonym previews.

Method

The method was identical to that of Experiment 1 with the following exceptions.

Subjects. Forty undergraduates at the University of California San Diego participated in the experiment for course credit. None of the subjects participated in

any of the other experiments and were chosen using the same inclusion criteria as Experiment 1.

Materials and Design. Stimuli were identical to those used in Experiment 1, except for the inclusion of an additional condition—semantically related but not synonymous words—which were matched in length to the target (see Table 1 and Appendix). In the cloze norming task (see Experiment 1 Method), the semantically related word was never produced (cloze probability = 0%). In the relatedness norming procedure to test for similarity in meaning between the preview and target, the semantically related words were rated as related to the target ($M = 5.6$ on a 9 point scale), but not as related as the synonyms were ($M = 7.5$). Additionally, in the norming procedure to test for similarity in meaning of the sentence when the preview was replaced by the target, these items were somewhat similar in meaning to the fragment with the target ($M = 4.9$), but not as similar as the fragment with the synonym ($M = 7.2$).

Results and Discussion

The same data processing procedure used in Experiment 1 was used in Experiment 2. These data exclusions left 4048 trials (82% of the original data) available for analysis. The same analysis procedure used in Experiment 1 was used in Experiment 2, with an additional planned contrast (semantically related vs. unrelated) entered into the models. Means and standard errors (aggregated by subject) of local reading measures are presented in Table 5.

Table 5. Means and standard errors (aggregated by subjects) for reading measures on the target across condition in Experiment 2.

Measure	Preview			
	Identical	Synonym	Semantic	Unrelated
Fixation Duration Measures				
First Fixation Duration	225 (5.2)	230 (5.7)	241 (6.7)	236 (5.9)
Single Fixation Duration	232 (5.2)	239 (6.1)	252 (7.5)	246 (6.4)
Gaze Duration	253 (6.3)	261 (7.4)	273 (8.1)	270 (8.0)
Total Viewing Time	326 (13)	345 (13)	354 (14)	351 (12)
Go Past Time	294 (9)	302 (11)	317 (12)	323 (11)
Fixation Probability Measures				
Fixation Probability	.88 (.02)	.86 (.02)	.88 (.02)	.89 (.02)
Regressions into the Target	.17 (.02)	.24 (.02)	.23 (.02)	.24 (.02)
Regressions out of the Target	.12 (.01)	.12 (.02)	.13 (.02)	.15 (.02)

Fixation duration measures. Results of the LMMs on fixation duration measures are reported in Table 6. Across all measures there was a significant preview benefit in the identical condition; reading times were significantly shorter on the target when the preview was identical, than when it was unrelated (FFD: $b = 11.15$, $t = 3.07$; SFD: $b = 14.93$, $t = 3.46$; GZD: $b = 16.35$, $t = 3.03$; TVT: $b = 24.36$, $t = 2.77$, Go-Past: $b = 27.66$, $t = 3.51$). There was a significant preview benefit in the synonym condition: reading times were significantly shorter on the target when the preview was a synonym of the target than when it was unrelated in all measures (SFD: $b = 9.78$, $t = 2.61$; GZD: $b = 9.46$, $t = 2.06$; Go-Past: $b = 21.23$, $t = 2.44$) except first fixation duration, where it was marginal ($b = 6.18$, $t = 1.89$) and total viewing time ($b = 5.66$, $t < 1$). Importantly, none of the measures showed a significant preview benefit in the semantically related condition (all $ts < 1.4$).

Table 6. Results of the linear mixed effects models for reading time measures on the target across condition in Experiment 2. Preview benefit refers to the difference in processing between the unrelated condition and either the identical, synonym, or semantically related, separately. Significant effects are indicated by boldface.

Measure	Preview Benefit Comparison	b	SE	t
First Fixation Duration	Identical	11.15	3.63	3.07
	Synonym	6.18	3.27	1.89
	Semantic	-4.98	3.59	1.39
Single Fixation Duration	Identical	14.93	4.32	3.46
	Synonym	9.78	3.74	2.61
	Semantic	-4.47	3.91	1.14
Gaze Duration	Identical	16.35	5.39	3.03
	Synonym	9.46	4.60	2.06
	Semantic	-3.41	4.65	.73
Total Time	Identical	24.36	8.78	2.77
	Synonym	5.66	8.03	.71
	Semantic	-4.11	7.54	.54
Go-Past Time	Identical	27.66	7.88	3.51
	Synonym	21.23	8.70	2.44
	Semantic	5.77	7.33	.79

Fixation probability measures. Results of the LMMs on fixation probability measures are reported in Table 7. Only the synonym preview condition significantly differed from the unrelated condition in terms of probability of fixating the target ($z = 3.27, p < .005$), neither the identical nor the semantically related condition were significantly different from the unrelated condition (both $ps > .23$). For the probability of making regressions into the target, the difference between the identical and unrelated conditions was significant ($z = 4.22, p < .001$) but neither the difference between the synonym nor the semantically related conditions and

unrelated conditions were significant (both $ps > .78$). For regressions out of the target, all three preview contrast were significant, indicating that subjects were more likely to make a regression from the target to prior words in the text when the preview was identical to ($z = 1.99, p < .05$), a synonym of ($z = 2.17, p < .05$) or semantically related to the target ($z = 2.61, p < .01$) than when it was unrelated.

Table 7. Results of the linear mixed effects regression model for fixation probability measures on the target across condition in Experiment 2. Preview benefit refers to the difference in processing between the unrelated condition and either the identical, synonym or semantically related, separately. Significant effects are indicated by boldface.

Measure	Preview Benefit Comparison	b	z	p
Fixation Probability	Identical	.19	1.18	.24
	Synonym	.56	3.27	< .005
	Semantic	.12	.69	.49
Regressions into the Target	Identical	.54	4.22	< .001
	Synonym	-.03	.27	.79
	Semantic	.01	.12	.91
Regressions out of the Target	Identical	.31	1.99	< .05
	Synonym	.31	2.17	< .05
	Semantic	.38	2.61	< .01

Taken together these data replicate the lack of semantic preview benefit reported by Rayner et al. (1986) using semantically related items that do not share the same meaning with the target. Importantly, these data contrast with the finding (replicated across two experiments in this study) that synonyms do provide semantic preview benefit. These results suggest that semantic information can be extracted from the parafovea and used to facilitate processing of the target, once it is

fixated, but only if the meaning of the word does not change between preview and target.

Does similarity in meaning drive semantic preview benefit in English?

The planned contrasts between conditions suggest that synonyms provide semantic preview benefit but other semantic relationships do not. The results of the norming procedure reveal that the previews in these conditions lead to different degrees of similarity to the meaning of the sentence when replaced by the target (7.2, 4.9, and 1.9 for the synonym, semantically related and unrelated previews on a 9-point scale, respectively). Thus, to more directly test this hypothesis, follow-up analyses were conducted using the normative data results as a continuous predictor in the LMMs (see Table 8). Because the identical condition represents a case in which the preview and target are the same, relatedness norming data were not collected and reading time data for this condition was not used. Thus, the following analyses were only conducted on the synonym, semantically related and unrelated preview conditions and the estimated effects are likely to be smaller than they would be if the identical condition were included.

Table 8. Results of the linear mixed effects models for reading time measures on the target as a function of degree to which the meaning of the sentence fragment changes between preview and target in Experiment 2 (excluding items from the identical condition). Significant effects are indicated by boldface.

Measure	b	SE	t
First Fixation Duration	1.32	0.58	2.29
Single Fixation Duration	1.91	0.68	2.82
Gaze Duration	1.64	0.83	1.98
Total Time	0.81	1.19	0.68
Go-Past Time	3.95	1.10	3.58

These analyses reveal that the degree to which the meaning *changes* (10 minus the mean rating from the norming procedure in which subjects rated how *similar* the meaning is) between preview and target is positively related to all fixation duration measures (FFD: $b = 1.32$, $t = 2.29$; SFD: $b = 1.91$, $t = 2.82$; GZD: $b = 1.64$, $t = 1.98$; Go-Past: $b = 3.95$, $t = 3.58$) except total time ($t < 1$). There were also significant effects on the probability of fixating the target ($z = 2.34$, $p < .05$), and the probability of making a regression out of the target ($z = 3.53$, $p < .005$), but not the probability of making a regression into the target ($p = .59$; see Table 9). These data suggest that the difference between synonyms providing preview benefit and semantically related but not synonymous words not providing benefit may be due to the fact that synonyms preserve the meaning of the sentence while other semantically related words do not (see Figure 2).

Table 9. Results of the linear mixed effects regression model for fixation probability measures on the target as a function of degree to which the meaning of the sentence fragment changes between preview and target in Experiment 2. Significant effects are indicated by boldface.

Measure	b	z	p
Fixation Probability	.06	2.34	< .05
Regressions into the Target	.01	0.54	.59
Regressions out of the Target	.08	3.53	< .001

Obviously, because the different preview conditions represent different points along the continuous predictor, the analysis in which only the continuous predictor is entered may capture variance in reading times that actually represents differences across condition. Because of collinearity, when both predictors (the continuous predictor and the coded contrasts used in the previous analyses) are entered into a model, the model cannot decide to which it should attribute the effect, and thus neither yield significant effects (and the model with both predictors does not significantly improve the model's fit to the data above either the model with just the continuous predictor or the condition contrasts). However, one of the advantages of the LMMs used for these analyses is the ability to compare the models' fit to the data (taking into account the number of parameters) using the AIC (Akaike Information Criterion) and the BIC (Bayesian Information Criterion). Both of these criteria indicate that a model with only the continuous predictor is a better model, suggesting that the degree to which changing the preview to the target changes the meaning of the sentence may be a better account of the differences observed across conditions.

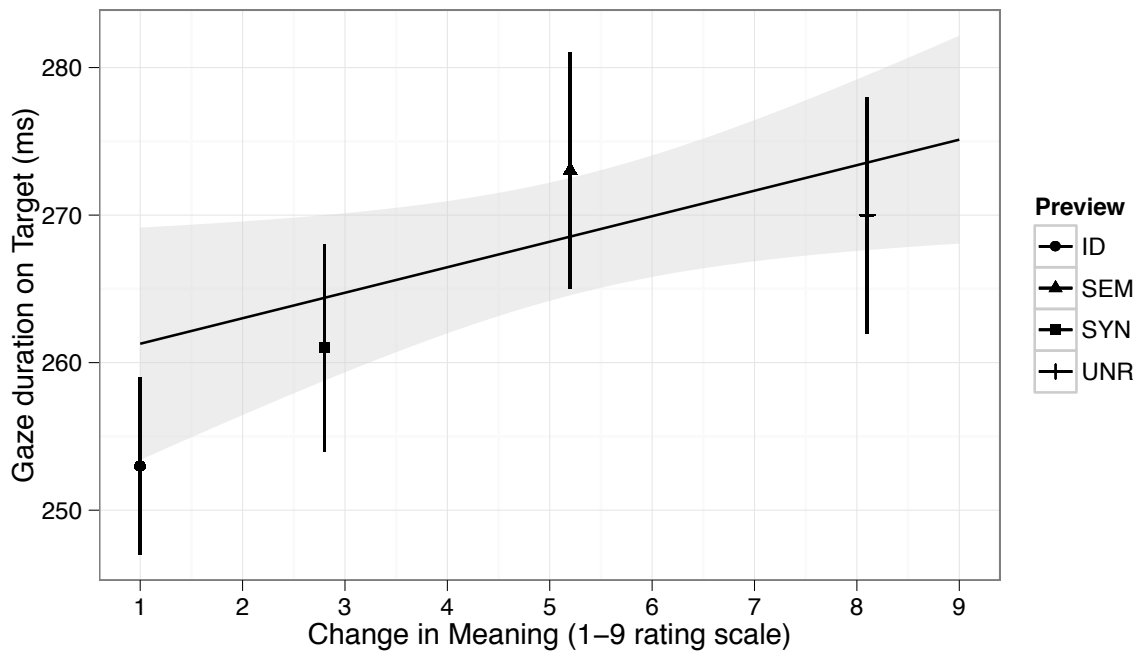


Figure 2. Linear trend for the relationship between the degree to which the sentence changes meaning when the preview is replaced by the target (results of a norming study) and gaze duration on the target in Experiment 2. Linear fit was calculated without the identical condition. Data points and error bars represent the means and standard errors for each preview condition (mean gaze duration and mean norming score) and are plotted for reference (i.e., were not used in fitting the LMM or the regression line in the figure).

Additionally, it is possible that the inflated reading times on the target in the semantically related and unrelated conditions were due to items that were anomalous, given the preceding sentence context. To test this, the items in these conditions were coded for whether or not they were anomalous (a binary predictor) and this was used as the predictor variable in LMMs for each of the reading measures. This predictor did not significantly affect reading times on the target except for in go-past time ($b = 18.25, t = 2.42$) and the probability of making a regression out of the target ($z = 2.30, p < .05$), no other effects were significant (fixation duration measures: all t s < 1.11 ; fixation probability measures: both p s

> .12). Because the only measures to demonstrate this effect (go-past time and regressions out) are generally assumed to reflect later, integrative processing, it is unlikely that anomalousness is driving the semantic preview benefit seen in first pass measures, which reflect word identification, rather than integration (Rayner, 1998, 2009; Schotter et al., 2012).

General Discussion

In two experiments using the gaze-contingent boundary paradigm, preview benefit was observed for previews that were synonymous with the target (Experiments 1 and 2) but not for previews that were semantically related to the target, but not synonymous (Experiment 2; see also Rayner, et al., 1986). Further analyses revealed that reading times on the target were influenced by the degree to which the preview significantly changed the meaning of the sentence; previews that were similar in meaning produced faster reading on the target than previews that were different. Considering the coefficient estimates from the LMMs that used degree of meaning change as a continuous predictor, it seems as if every step up in meaning change constitutes a 1-4 ms increase in reading time (depending on the reading measure considered). Returning to the prior literature on semantic preview benefit discussed in the introduction, it becomes apparent that semantic preview benefit is possible, but is not ubiquitous, and may depend on the right conditions to support it. I discuss each of these influences, in turn.

First, it is clear that attentional resources must be available for preview benefit to be robust. Henderson and Ferreira (1990; Kennison & Clifton, 1995) demonstrated that preview benefit is modulated by foveal load—preview benefit is larger when the pre-target word is easier to process (e.g., high frequency) than when it is more difficult. This finding is not controversial and can be accounted for by both models of eye movements during reading. SWIFT accounts for this effect by modulating the breadth of the *zoom lens of attention* such that more difficult words narrow the distribution of attention to focus on few words (or even just the fixated word) and easier words allow attention to be distributed over more words (Schad & Engbert, 2012). E-Z Reader accounts for this effect in that more difficult words are identified more slowly, leading to less time between the completion of word identification (completion of L_2) and the execution of the saccade (completion of M_2), which constitutes the duration of preview benefit (White, Rayner, & Liversedge, 2005). The influence of foveal processing on preview benefit of the upcoming word is clear. But are there properties of the upcoming word that might make semantic preview benefit more or less possible?

Prior research has revealed that phonological preview benefit is modulated by the orthographic similarity between the preview and target: phonological preview benefit is larger when orthography is more similar (e.g., beach-beech) than when it is less similar (e.g., shoot-chute; Mielliet & Sparrow, 2004; Pollatsek, et al., 1992). Thus it may be reasonable to assume that orthographic properties of words would have an effect on semantic preview benefit, as well. Comparisons between

existing studies across different languages (with different orthographic properties) help to demonstrate this point. Prior to the present study, semantic preview benefit has been observed for German (Hohenstein & Kliegl, 2013; Hohenstein, Laubrock, & Kliegl, 2010), a shallower orthography than English, which may lead to faster foveal word identification and consequently more parafoveal preview benefit.

Furthermore studies using Chinese have also observed semantic preview benefit (Yan et al., 2009; Yang et al., 2010). Semantic preview benefit might be more likely in Chinese because of the density of the script—there are no spaces between words and words are generally one or two characters long, leading to a higher probability that the upcoming word lies within the fovea and can be processed with higher acuity than target words in English studies. Additionally, rather than the orthography representing phonology (as in alphabetic languages), Chinese more directly represents semantics (via semantic radicals), potentially leading to a higher likelihood of semantic access, which would explain the semantic preview benefit. These orthographic influences on semantic preview benefit are not yet accounted for by either SWIFT or E-Z Reader and pose interesting avenues for future research.

The above account suggests that semantic preview benefit should not be (or is very unlikely to be) observed in English. However, the present study demonstrates that semantic preview can be observed in English when the preview and target are synonyms, and the degree to which the preview facilitates target processing may be related to how much the meaning changes between the two versions of the sentence. Taken together, these data and data from the prior

literature suggest that preview benefit in English is a sensitive effect. If the preview represents a meaning that is identical or close to the target, this speeds processing of the target once it is fixated. Once meaning is sufficiently different, semantic preview benefit is not observed. However, the studies demonstrating semantic preview benefit in German and Chinese did not use exclusively synonyms, suggesting that this is not a necessary condition. Rather, it may be that the orthographic properties of these languages, mentioned above, make word processing efficient enough that there is more time for semantic information to spread throughout the network (or semantic features to become more activated), leading to semantic preview benefit for even non-synonymous previews. In English, however, orthographic and phonological processing may be sufficiently slow that there is not enough time for spreading activation in a semantic network to activate semantic associates. Synonyms may either be stored together or have stronger connections to the target than other semantic relationships in the network and thus provide semantic preview benefit.

In summary, the present experiments and the prior literature suggest that semantic preview benefit is possible—readers may be able to obtain meaning-based information from upcoming words before they move their eyes to it. However, there are certain circumstances (e.g., when foveal load is high, depth of orthography interferes with rapid preprocessing of the upcoming word, the preview is anomalous, or when the meaning changes too drastically between preview and

target) that work against preview benefit, making semantic information either not accessible or causing semantic information to be discarded.

The results reported here suggest that, in English, semantic information can be obtained from the upcoming word before it is fixated, but such information only facilitates target processing if the preview and target are synonyms. Whether these effects are better accounted for by failure to activate semantic information parafoveally or by parafoveally obtained information being discarded after the target is encountered is still an open question. Furthermore, the sentences used in the present study were created to not constrain the meaning of the target or preview (cloze probabilities for the target and preview words were 0-5%). This design feature was chosen so that any preview benefit observed could be attributed to parafoveal preprocessing, rather than facilitated processing from semantic similarity between the expected word and the encountered word (see Roland et al., 2012). It will be interesting to see whether the effects observed in the present study change when the sentence constrains the meaning and the target word (and consequently synonym) is more expected.

Chapter 4, in full, has been submitted for publication of the material as it appears in 2013, Schotter, E.R. Synonyms provide semantic preview benefit in English but other semantic relationships do not. The dissertation author was the sole investigator and author of this paper.

Appendix. Stimuli used in the experiments. Target words (identical previews) are presented in boldface (not in boldface in the experiments). Columns to the right represent the synonym, semantically related and unrelated previews.

Sentence	Synonym	Semantic	Unrelated
My friends have the same favorite movie that they watch every week.	video	audio	water
Dave admired his well kept turf while driving home.	lawn	yard	lava
Samantha was very prudent about not making a mistake in her drawing.	careful	precise	invited
Some students cannot comprehend the topics covered in lecture.	understand	assimilate	individual
The company did not realize the harsh impact their products had on the environment.	effect	result	attack
Jenna loved how her necklace would sparkle on sunny days.	glitter	flicker	platter
In kindergarten the kids would loudly notify the teacher when someone cut in line.	inform	update	actors
The teacher thought most of the reports were too brief and needed more content.	short	empty	stand
The well trained scout led the group along the cliff.	guide	guard	quote
We had to read many surveys in our psychology class.	reviews	breadth	measure
Rain makes it difficult to properly steer the vehicle safely.	drive	wheel	times
Last week, Alexander totaled his car on his way to school.	wrecked	skidded	awaited
Elizabeth goes to the store nearly every weekend to buy groceries.	almost	always	street
The soccer ball hit the shelf and made the vase smash into many pieces.	break	clean	heart
Boris needed a loyal sponsor to begin his campaign trail.	support	advisor	suggest
Gary thought if he put on a costume he could excite the children in the class.	thrill	arouse	thrift
Next week, we must propose a new financial plan to the executive board.	suggest	present	support
I have always wanted to attend academy meetings down the hall.	society	seminar	variety
Kenny told his longtime rival to meet him outside for a fight after school.	enemy	fists	array
The committee said the plan should be approved contrary to the president's advice.	opposite	rejected	appendix
Peter was asked to point out on the large globe where Antarctica was.	world	earth	small
The teacher tried to plan artful activities for the children.	crafty	pretty	verily
The little girl complained about her upset tummy and asked to skip soccer practice.	belly	torso	daddy
I always stay at the same cabin in Tahoe for vacation.	house	shack	known
The student was very astute because she answered the tricky question.	clever	brains	cheese
Brad thought his project idea was incredibly ingenious	brilliant	inventive	fortified

and wanted to tell everyone.

The salesman said the car would hold its original worth for many years.	value	price	sites
Many people are extremely committed to recycling their waste.	dedicated	betrothed	liberated
Jill goes for a long jog in the morning.	run	leg	own
In ancient times, the pharaoh needed warriors to defend his kingdom.	soldiers	strength	millions
After witnessing the theft, many guards chased the thief.	police	cadets	palace
Although having a car may seem essential there are many other ways to commute.	necessary	requisite	remaining
Chris is always told that he should relax after playing a soccer game.	sleep	chill	cheap
Dan needed to have his molar replaced after many years of eating candy.	tooth	crown	tenth
George was afraid of a possibly lethal bite while handling the snake at the zoo.	deadly	mortal	kindly
The surgeon promised an extremely rapid to start bubbling.	quick	brisk	giant
The road signs inform drivers when hazardous terrain is approaching.	dangerous	turbulent	diagnosis
Dave wore his favorite hat to the baseball game.	cap	bag	cry
His father is a proud physics teacher in my school district.	science	biology	various
The man was a notorious murderer responsible for many deaths.	assassin	killings	enormous
After the party the couch felt grimy from all the guests sitting on it.	dirty	filth	lucky
Every year the children wish for new toys.	hope	pray	days
The response Tom received was not a very fair representation of his effort.	just	good	post
Sally forgot the specific tune she would always sing in the shower.	song	note	warp
Steven made a mean quip about his sister's hair.	joke	jest	gate
At the zoo I saw the giant adult panda eating bamboo leaves.	older	aging	album
The teacher always posted a relevant topic to start a discussion.	issue	theme	music
The dishes are stored below the sink in the kitchen.	under	handy	order
Tommy decided he would fling the stone into the pond later that day.	throw	chuck	floor
Jack saw more unusual sightings in the woods last week.	strange	startle	storage
Max had to have the teacher clarify when the homework assignment was due.	explain	discuss	captain
Jen thought it was a terrible omen that she had a nightmare before the exam.	sign	mark	nope
The sons were quite lousy at doing their chores before dinner.	awful	great	rated
James agreed to meet in the front foyer of the hotel before dinner.	lobby	doors	fifty

Fred and Will ordered nine super burritos after the little league game.	great	ample	point
Laura had strong ache in her tooth after eating too much candy.	pain	ouch	join
The sisters could not name all their favorite movies because there were too many.	list	cite	best
The students must save all their homework until the quarter is over.	keep	mass	long
Everyone was pleased that the talented chef prepared such a wonderful meal.	cook	food	acid
Last night my dreams were very lucid so I wrote about them in my journal.	clear	stark	class
The church received a beautiful piano from an anonymous donor.	organ	flute	argue
Felix likes to wear clean boots to his line dancing party.	shoes	socks	chess
I noticed that there was a small stone spire on top of the tower.	tower	point	horse
The Johnson family fell in love with the beautiful vast backyard at their new home.	huge	open	dogs
The children must mow the lawn every Friday.	cut	dig	net
The noise caused Tim to suddenly fall to his knees and cover his ears.	drop	down	king
The police were alert on patrol when they got a call from dispatch.	ready	vigil	early
My dog can always select the correct bowl with the treat inside.	choose	reject	chance
The decorator loved the detailed lip of the new vase.	rim	top	zoo
It appeared that the symphony lacked the true emotion the guests were expecting.	missed	showed	animal
Tammy noticed many items were left blank when grading the exam.	empty	clear	imply
Children are often very obdurate when it comes to cleaning up.	stubborn	outburst	stitches
After dinner Wendy always rinsed the dishes before putting them in the dishwasher.	washed	soaked	socket
Some animals eat from very tall trees in the zoo.	high	long	kept
Steph noticed a torn bill in her wallet and looked for the other half.	note	card	side
The team captain tried to establish concord between the rivals.	harmony	rapport	forming
After working out, Shelley felt a sudden acute pain in her calves.	sharp	quick	strip
Shelia would never utter a word about what happened.	speak	vocal	equal
The notorious gang defaced the statue in front of city hall.	damaged	wrecked	foreign
Ian auctioned an antique clock to raise money for a charity.	watch	timer	match
Howard was extremely envious of my new game boy.	jealous	zealous	gardens
The dog would always sniff the grass in front of the house.	smell	whiff	vault
Rita had a very strong feeling about the political candidates.	opinion	thought	species

Callie and her coworker must evade the office because their boss is mad at them.	avoid	greet	round
Her perfume was very aromatic and caught the attention of many men.	fragrant	distinct	linguist
The ring had a beautiful jewel in the center.	stone	pearl	clean
Although the apartments decor was very drab the owners felt it suited their needs.	dull	grey	hulk
I got a really cool gadget for my seventeenth birthday.	device	iphone	drives
I received a very important prize for my hard work at the company.	award	stars	weird
Tim wanted to be more than buddies with Stacey, but she had a boyfriend.	friends	hugging	towards
After a week the messy family started to create a heaping rubbish pile in their yard.	garbage	rummage	postage
The losing team's rebuttal was so legendary that it went viral on YouTube.	response	reaction	congress
The horse race will begin in a couple minutes.	start	ready	check
Cops need to be aware of a possible ambush while on the job.	attack	battle	effort
Betty enjoys going to the nearby town to go shopping on the weekends.	city	area	only
Carter is always bothering Lisa in class when she tries to take notes.	harassing	involving	burrowing
Joel made a rapid halt when the light turned red.	stop	skid	ship
After a while Kim noticed a weird scent coming from the trash can.	smell	noses	vault
Will keeps a large knife in his backpack to protect himself.	blade	rifle	flute
Carla had a pleasant chat with her friend at the salon.	talk	rant	half
Despite living at the beach, George seldom goes surfing.	rarely	cannot	nically
The weatherman predicted that a dangerous tornado might hit the town this week.	twister	cyclone	booster
Sarah tried using curlers on her stubborn straight hair before prom.	rollers	styling	suffice
Some people think a heavy brick could break a window.	stone	block	clean
My old nanny made me a bracelet with string for my fifth birthday.	thread	strand	threat
The crowd could only see the very rear of the stage from the discounted seats.	back	side	find
The class complained about the long exam to the professor.	test	quiz	kind
The loving couple looked at the peaceful shore while on vacation.	beach	ocean	trust
My roommate will continuously scrub the dishes until they are clean.	clean	bathe	alone
My neighbor took out his vintage satan costume for Halloween.	devil	demon	trend
The community thought of Amy with the highest esteem after her work at the shelter.	regard	praise	expand
Some people thought the parrot was mute but it just did not want to talk.	dumb	talk	loud

Erin fell asleep for a mere moment while driving on the highway.	second	period	around
I wrote down the incorrect avenue and got lost on my way to the restaurant.	street	suburb	client
My neighbor made a majestic portrait of my family as a Christmas present.	painting	panorama	pounding
Nadine goes to the gym because she wants to look lean in a swimsuit at the beach.	thin	slim	kiss
The chemist did not realize the reaction could arise without a spark.	occur	start	seven
Sheldon could not hear their answers over the loud music.	replies	opinion	replace
Julie watched the birds flock together in the sky.	group	bunch	going
Frank always sits in the exact middle of the classroom.	center	corner	member
In the morning Jessica tallied up all of the sales from last weekend.	counted	rounded	existed
Andrew enjoyed the interesting tome he borrowed from the library.	book	read	fact
In the pond a frog leaped across a lily pad and landed on a log.	jumped	hopped	gospel

References

- Altarriba, J., Kambe, G., Pollatsek, A., & Rayner, K. (2001). Semantic codes are not used in integrating information across eye fixations in reading: evidence from fluent Spanish-English bilinguals. *Perception & Psychophysics*, *63*, 875-890.
- Altarriba, J., Kroll, J.F., Scholl, A., & Rayner, K. (1996). The influence of lexical and conceptual constraints on reading mixed-language sentences: Evidence from eye fixations and naming times. *Memory & Cognition*, *24*, 477-492.
- Baayen, R. H., Davidson, D. H., & Bates, D. M. (2008). Mixed-effects modeling with crossed random effects for subjects and items. *Journal of Memory and Language*, *390*-412.
- Balota, D. A., Yap, M. J., Cortese, M. J., & Watson, J. M. (2008). Beyond mean response latency: Response time distributional analyses of semantic priming. *Journal of Memory and Language*, *59*(4), 495-523.
- Barr, D.J., Levy, R., Scheepers, C., & Tily, H.J. (2013). Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of Memory and Language*, *68*, 255-278.
- Bates, D. M., Maechler, M., & Bolker, B. (2011). Lme4: Linear mixed-effects models using S4classes. R package version 0.999375-42. <http://CRAN.R-project.org/package=lme4>.
- Collins, A.M. & Loftus, E.F. (1975). A spreading-activation theory of semantic processing. *Psychological Review*, *82*, 407-428.
- Dimigen, O., Kliegl, R., & Sommer, W. (2012). Trans-saccadic parafoveal preview benefits in fluent reading: A study with fixation-related brain potentials. *NeuroImage*, *62*, 381-393.
- Engbert, R., Longtin, A., & Kliegl, R. (2002). A dynamical model of saccade generation in reading based on spatially distributed lexical processing. *Vision Research*, *42*, 621-636.
- Engbert, R., Nuthmann, A., Richter, E. M., & Kliegl, R. (2005). SWIFT: A dynamical model of saccade generation during reading. *Psychological Review*, *112*, 777-813.
- Gollan, T.H., Forster, K.I., & Frost, R. (1997). Translation priming with different scripts: Masked priming with cognates and noncognates in Hebrew-English

bilinguals. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 23, 1122-1139.

Henderson, J. M., & Ferreira, F. (1990). Effects of foveal processing difficulty on the perceptual span in reading: Implications for attention and eye movement control. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 16, 417-429.

Hohenstein, S., & Kliegl, R. (2013). Semantic preview benefit during reading. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, in press.

Hohenstein, S., Laubrock, J., & Kliegl, R. (2010). Semantic preview benefit in eye movements during reading: a parafoveal fast-priming study. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 36, 1150-1170.

Hoosain, R. (1991). Psycholinguistic implications for linguistic relativity: A case study of Chinese. Hillsdale, NJ: Lawrence Erlbaum Associates.

Hutchinson, K.A. (2003). Is semantic priming due to association strength or feature overlap? A microanalytic review. *Psychonomic Bulletin & Review*, 10, 785-813.

Kennison, S. M., & Clifton, C. (1995). Determinants of parafoveal preview benefit in high and low working memory capacity readers: Implications for eye movement control. *Journal of Experimental Psychology: Learning, Memory & Cognition*, 21, 68-81.

Lucas, M. (2000). Semantic priming without association: A meta-analytic review. *Psychonomic Bulletin & Review*, 7, 618-630.

Miellet, S., & Sparrow, L. (2004). Phonological codes are assembled before word fixation: Evidence from boundary paradigm in sentence reading. *Brain and language*, 90, 299-310.

Neely, J. H. (1991). Semantic priming effects in visual word recognition: A selective review of current findings and theories. *Basic processes in reading: Visual word recognition*, 11.

Pollatsek, A., Lesch, M., Morris, R. K., & Rayner, K. (1992). Phonological codes are used in integrating information across saccades in word identification and reading. *Journal of Experimental Psychology: Human Perception and Performance*, 18, 148-162.

Quillian, M. R. (1967). Word concepts: A theory and simulation of some basic semantic capabilities. *Behavioral science*, 12, 410-430.

- R Development Core Team. (2012). R: A language and environment for statistical computing [Computer software]. Vienna, Austria: R Foundation for Statistical Computing.
- Rayner, K. (1975). The perceptual span and peripheral cues in reading. *Cognitive Psychology*, 7, 65-81.
- Rayner, K. (1998). Eye movements in reading and information processing: 20 years of research. *Psychological bulletin*, 124, 372-422.
- Rayner, K. (2009). The Thirty-fifth Sir Frederick Bartlett Lecture: Eye movements and attention in reading, scene perception, and visual search. *The Quarterly Journal of Experimental Psychology*, 62, 1457-1506.
- Rayner, K., Balota, D. A., & Pollatsek, A. (1986). Against parafoveal semantic preprocessing during eye fixations in reading. *Canadian Journal of Psychology*, 40, 473-483.
- Reichle, E. D., Pollatsek, A., Fisher, D. L., & Rayner, K. (1998). Toward a model of eye movement control in reading. *Psychological Review*, 105, 125-157.
- Reichle, E. D., Pollatsek, A., & Rayner, K. (2006). EZ Reader: A cognitive-control, serial-attention model of eye-movement behavior during reading. *Cognitive Systems Research*, 7(1), 4-22.
- Reichle, E. D., Rayner, K., & Pollatsek, A. (2003). The E-Z Reader model of eye movement control in reading: Comparisons to other models. *Behavioral and Brain Sciences*, 26, 445-476.
- Reichle, E. D., Warren, T., & McConnell, K. (2009). Using E-Z Reader to model the effects of higher-level language processing on eye movements during reading. *Psychonomic Bulletin & Review*, 16, 1-20.
- Roland, D., Yun, H., Koenig, J.-P., & Mauener, G. (2012). Semantic similarity, predictability, and models of sentence processing. *Cognition*, 122, 267-279.
- Schad, D.J. & Engbert, R. (2012). The zoom lens of attention: Simulated shuffled versus normal text reading using the SWIFT model. *Visual Cognition*, 20, 391-421.
- Schotter, E. R., Angele, B., & Rayner, K. (2012). Parafoveal processing in reading. *Attention, Perception, & Psychophysics*, 74, 5-35.

- Voss, A., Rothermund, K., Gast, A., & Wentura, D. (2013). Cognitive processes in associative and categorical priming: A diffusion model analysis. *Journal of Experimental Psychology: General*, *142*, 536-599.
- White, S.J., Rayner, K., & Liversedge, S.P. (2005). Eye movements and the modulation of parafoveal processing by foveal processing difficulty: A reexamination. *Psychonomic Bulletin & Review*, *12*, 891-896.
- Yan, M., Richter, E. M., Shu, H., & Kliegl, R. (2009). Readers of Chinese extract semantic information from parafoveal words. *Psychonomic bulletin & review*, *16*, 561.
- Yang, J., Wang, S., Tong, X., & Rayner, K. (2010). Semantic and plausibility effects on preview benefit during eye fixations in Chinese reading. *Reading and Writing*, *25*, 1031-1052.

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CHAPTER 5:
GENERAL DISCUSSION

Together, the studies in this dissertation suggest that perception and linguistic processing interface in very sophisticated ways to support efficient speaking and reading. For the tasks involved in these studies, the perceptual system accesses information from the environment in a way that is appropriate for the task (broadly and continuously accessing information from relevant objects, but not from irrelevant objects). The linguistic system then uses that information to access the appropriate representation (phonology for speaking and semantics for reading).

In Study 1, I addressed whether access of information from upcoming objects was discrete (i.e., only occurred briefly) or opportunistic (i.e., occurred continuously during prior object processing). Preview benefit was not modulated by SOA (i.e., there was no preview type by SOA interaction), suggesting that speakers had accessed the semantic information of the object, regardless of when it appeared. Further analyses revealed that the magnitude of preview benefit was also unaffected by the latency between preview offset and saccade to the target, further providing evidence that speakers continuously pre-activate information from upcoming objects. Lastly, the results of Study 1 showed that the magnitude of preview benefit was unaffected by whether the subject was able to identify the preview, suggesting that preview benefit is not attributable to the spontaneous onset of the preview drawing attention and causing it to be processed. The results suggest that speakers access information about upcoming objects opportunistically—the perceptual system takes advantage of any information provided by the environment, regardless of when it appears.

In Study 2, I addressed whether this opportunistic access of information was indiscriminate (i.e., occurs on all visually available objects) or selective (i.e., occurs on only task-relevant objects). In Experiment 1, preview benefit was observed from a preview that appeared in the target location but not for a preview that appeared in the to-be-ignored location. In Experiment 2, preview benefit was observed from both previews that appeared in the target and third-to-be-named locations, suggesting that intention to process (in this case, intention to name) an object is what determines whether it will be pre-processed. Experiment 3 showed that this effect was not driven by the complexity of the display. The results of Study 2 suggest that one way speakers manage incoming information is by excluding from processing those objects that are irrelevant.

Critically, the findings from Studies 1 and 2 suggest that successful speaking is achieved by using perceptual processing to access information from all necessary objects as soon as they are available (Study 1) and using the attentional system as an executive control mechanism that attenuates or blocks perceptual information obtained from irrelevant objects (Study 2). As mentioned in Chapter 1, the ability to perceive objects outside the fovea allows for preprocessing that facilitates rapid speech. The ability to restrict irrelevant information from entering the cognitive-linguistic processing system facilitates accurate speech. This information is fed to the cognitive-linguistic processing system, which is tasked with activating the concept that the visual form of the object represents, selecting the appropriate

lexical representation and coordinating articulation of the sounds that comprise its spoken form.

In Study 3, I addressed how the linguistic system constrains readers' use of perceptually obtained information, in an attempt to address a long-standing debate over the presence of semantic preview benefit in reading. Most critically, the experiments in Study 3 demonstrated semantic preview benefit in English when preview and target were synonyms (Experiments 1 and 2), but not when they shared associative semantic relationships (Experiment 2, see also Rayner et al., 1986). This finding contrasts with studies in German (Hohenstein & Kliegl, 2013; Hohenstein, Laubrock, & Kliegl, 2010) and Chinese (Yan, Richter, Shu & Kliegl, 2009; Yang, Wang, Tong, & Rayner, 2010) that find semantic preview benefit even when the preview is *not* a synonym of the target. To account for differences across languages, I argued that English is less likely than German or Chinese to show semantic preview benefit because of its deep orthography. The consequence of a deep orthography is that more attention needs to be allocated to decoding the parafoveal word phonologically, delaying semantic access. If the preview is semantically activated later, then, there is less time for that activation to spread to semantically related words (but synonyms may still show the effect because they are so close in meaning and less time would be necessary for activation from the preview to affect processing of the target). Those languages that show semantic preview benefit for non-synonymous words may do so because semantics can be accessed sooner (either through a shallow orthography as in German or through

semantic radicals that directly connect orthography to semantics, rather than using phonology as a mediating representation) and activation may have more time to spread to related words. Thus, we now see that, even if perceptual information is obtained from upcoming objects, the complexity of the linguistic processing that succeeds imposes constraints on how influential that information is (i.e., whether that information affects ongoing processing).

The role of context in vision-language interaction.

As mentioned above, speakers may distribute attention broadly across multiple objects because they are simultaneously exploring and apprehending the scene, as well as describing it (Griffin & Bock, 2000). Critically, though, the displays used in these experiments (in Study 1 and 2) were quite sparse (containing only the objects and no background). Speakers in this task may have taken advantage of the sparseness of the display and been able to process the individual objects more efficiently than they would have if they were integrated into a more complex scene. It would be interesting to determine whether the way speakers allocate attention to objects within scenes changes based on the complexity of the scene (and thus the speakers' opportunity for clearer perceptual processing). Note that a similar issue exists for speech comprehension because the task used to study this with eye movements (the visual world paradigm; see Huettig, Rommer & Meyer, 2011 for a review) typically uses sparse scenes.

Scene complexity is a perceptual example of how context could affect the coordination of vision and linguistic processing. Sentence context has an immense influence on the efficiency of reading (e.g., Balota, Pollatsek & Rayner, 1985; Ehrlich & Rayner, 1981; Kliegl, Grabner, Rolfs & Engbert, 2004; Morton, 1964; Rayner & Well, 1996; Slattery, 2009; Zola, 1984; see Rayner, 1998, 2009; Schotter et al., 2012 for reviews) and is an example of a linguistic constraint on vision-language coordination. The experiments in Study 3 used extremely low cloze probability words, but readers may activate different sets of candidate words, based on the prior context (Roland, Yun, Koenig, & Mauener, 2012). Therefore, it is possible that the sentence context could change the relationships between nodes in a semantic network before any bottom-up input is received and increase or diminish semantic preview benefit.

Summary

Two impressive human capabilities are the ability to make sense of visual or linguistic input. These abilities are so complex that researchers in artificial intelligence have still not yet created artificial systems that are as capable as humans at achieving either one of these tasks (e.g., identifying and categorizing novel objects in complex scenes or carrying on spontaneous and meaningful conversations). But what is even more extraordinary about human cognition is our ability to not only perform, but also coordinate and synchronize these two, independently complex skills. The studies in this dissertation only scratch the surface of the interface of vision and linguistic processing, but they give us a sense of

how sophisticated it is. From Study 1, we know that speakers obtain information from objects other than the one they are currently attempting to name, to get a head-start on later processing. From Study 2, we know that speakers are selective in how they access this perceptual information, only doing so when needed. From Study 3, we know that visual information feeds the linguistic system that carries its own processing demands and organizational structure. This work constitutes a small but important step forward toward understanding the complexity underlying human cognition.

References

- Balota, D. A., Pollatsek, A., & Rayner, K. (1985). The interaction of contextual constraints and parafoveal visual information in reading. *Cognitive Psychology*, *17*, 364–390.
- Ehrlich, S. F., & Rayner, K. (1981). Contextual effects on word perception and eye movements during reading. *Journal of Verbal Learning and Verbal Behavior*, *20*, 641–655.
- Griffin Z. & Bock J.K. (2000). What they eyes say about speaking. *Psychological Science*, *11*, 274–279.
- Hohenstein, S., & Kliegl, R. (2013). Semantic preview benefit during reading. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, in press.
- Hohenstein, S., Laubrock, J., & Kliegl, R. (2010). Semantic preview benefit in eye movements during reading: a parafoveal fast-priming study. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *36*, 1150-1170.
- Huetting, F., Rommers, J., & Meyer, A.S. (2011). Using the visual world paradigm to study language processing: A review and critical evaluation. *Acta Psychologica*, *137*, 151-171.
- Kliegl, R., Grabner, E., Rolfs, M., & Engbert, R. (2004). Length, frequency, and predictability effects of words on eye movements in reading. *European Journal of Cognitive Psychology*, *16*, 262–284.
- Morton, J. (1964). The effects of context on the visual duration threshold for words. *British Journal of Psychology*, *55*, 165-180.
- Rayner, K. (1998). Eye movements in reading and information processing: 20 years of research. *Psychological Bulletin*, *124*, 372–422.
- Rayner, K. (2009). The Thirty-fifth Sir Frederick Bartlett Lecture: Eye movements and attention in reading, scene perception, and visual search. *The Quarterly Journal of Experimental Psychology*, *62*, 1457–1506.
- Rayner, K., Balota, D. A., & Pollatsek, A. (1986). Against parafoveal semantic preprocessing during eye fixations in reading. *Canadian Journal of Psychology*, *40*, 473–483.
- Rayner, K. & Well, A.D. (1996). Effects of contextual constraint on eye movements in reading: A further examination. *Psychonomic Bulletin & Review*, *3*, 504-509.
- Roland, D., Yun, H., Koenig, J.-P., & Mauener, G. (2012). Semantic similarity, predictability, and models of sentence processing. *Cognition*, *122*, 267-279.

- Schotter, E. R., Angele, B., & Rayner, K. (2012). Parafoveal processing in reading. *Attention, Perception, & Psychophysics*, 74, 5–35.
- Slattery, T. J. (2009). Word misperception, the neighbor frequency effect, and the role of sentence context: Evidence from eye movements. *Journal of Experimental Psychology: Human Perception and Performance*, 35, 1969–1975.
- Yan, M., Richter, E.M., Shu, H., & Kliegl, R. (2009). Readers of Chinese extract semantic information from parafoveal words. *Psychonomic bulletin & review*, 16, 561.
- Yang, J., Wang, S., Tong, X., & Rayner, K. (2010). Semantic and plausibility effects on preview benefit during eye fixations in Chinese reading. *Reading and Writing*, 25, 1031-1052.
- Zola, D. (1984). Redundancy and word perception during reading. *Perception & Psychophysics*, 36, 277–284.