This is a post-review, non-copyedited version accepted for publication in *Linguistic Landscape*. Please quote from the published version at dx.doi.org/10.1075/ll.17014.vin

Using eye tracking to investigate what bilinguals notice about linguistic landscape images: A preliminary study

Naomi Vingron[1,3], Jason W. Gullifer[1,2,3], Julia Hamill[1], Jakob Leimgruber[4], & Debra Titone[1,3]

[1] Department of Psychology, McGill University
[2] Cognitive Neuroscience Unit, Montreal Neurological Institute
[3] Centre for Research on Brain, Language and Music, McGill University
[4] English Department, University of Freiburg

Author note

Correspondence concerning this article should be addressed to Debra Titone, 2001 McGill College Avenue, Montréal, QC H3A 1G1, Canada. E-mail: dtitone@psych.mcgill.ca

Abstract

In daily life, we experience dynamic visual input referred to as the "linguistic landscape" (LL), comprised of images and text, for example, signs, and billboards (Gorter, 2013; Landry & Bourhis, 1997; Shohamy, 2010). While much is known about LLs descriptively, less is known about what people notice when viewing LLs. Building upon the bilingual eye movement reading literature (e.g., Whitford, Pivneva, & Titone, 2015) and the scene viewing literature (e.g., Henderson & Ferreira, 2004), we report a preliminary study of French-English bilinguals' eye movements as they viewed LL images from Montréal. These preliminary data suggest that eye tracking is a promising new method for investigating how people with different language backgrounds process real-world LL images.

Keywords: linguistic landscape, eye tracking, bilingualism, visual attention, Montreal

Introduction

When we move throughout our daily lives, we experience a dynamic visual input referred to as the "Linguistic Landscape" (LL) (Ben-Rafael, Shohamy, Hasan Amara & Trumper-Hecht, 2006; Gorter, 2013; Landry & Bourhis, 1997; Shohamy, Rafael & Barni, 2010). The term LL is canonically defined by Landry and Bourhis (1997) as "the language of public road signs, advertising billboards, street names, place names, commercial shop signs, and public signs on government buildings." Recently, the concept of LL has expanded to include "electronic flat-panel displays, LED neon lights, foam boards, electronic message centers, interactive touch screens, inflatable signage, and scrolling banners" (Gorter, 2013), or, put more generally, "the linguistic items found in the public space" (Ben-Rafael, et al., 2006).

For example, in the multilingual city of Montréal, whose LL has received much scholarly attention (reviewed in Backhaus, 2007; Landry & Bourhis, 1997), the LL is constrained by language policies that operate at the federal (Canadian) level to preserve official bilingualism, and the provincial (Quebec) government's policy of official monolingualism, as set out in the Charter of the French language (known as "Bill 101"). The goal of the provincial policy is to maintain vitality of French, provincial legislation stipulates that commercial signage must be in French, and if additional languages appear, French must be 'markedly predominant.' However, LL variations that deviate from legal provisions also naturally emerge from Montréal's residents (Lamarre, 2014), among whom bilingualism is widespread (Agglomération de Montréal, 2011). As a consequence, LLs provide a natural window into the "collective mind" of people residing in particular geographic locations that allows researchers to understand language- and culture-dependent social realities.

While many sociolinguistic descriptions of LL exist, less is known about what people actually *notice*, that is, psychologically attend to when they encounter LLs (for a review, see Leimgruber, Vingron & Titone, submitted). For example, would a Montréal resident, whose first language (L1) is English and second language (L2) is French, look at French words on a French–English bilingual sign (or vice versa)? Would such tendencies arise from the repeated experience of scanning LLs for familiar words; from political or cultural attitudes regarding the public use of language; or from simply being more or less proficient at reading different kinds of text? We argue that a better-suited method for addressing such questions involves an experimental tool known as *eye tracking*, which enables researchers to evaluate people's viewing behavior in real time.

Thus, in what follows, we selectively review key findings from the rich literature using eye tracking to investigate how people read multilingual text (e.g., Whitford & Titone, 2012, 2015; Whitford, et al., 2016), and encode natural scenes (Findlay & Walker, 1999; Henderson & Ferreira, 2004). We conclude with a preliminary eye tracking study that investigates how bilinguals with different language backgrounds view naturalistic multilingual LL images.

As previously mentioned, sociolinguistic research has revealed much about how multilingual LLs vary in content and form, and how they are distributed geographically within different parts of the world (Ben-Rafael, et al., 2006; Gorter, 2013; Shohamy, et al., 2010; Tufi & Blackwood, 2010). Recently, there has been discussion about the diversity and rigor of methods used in LL research, as common practices are not standardized (Gorter, 2016). LL researchers typically photograph signs within particular locations, which are chosen based on geo-demographical factors, such as average income, age and ethnicity of inhabitants (Ben-Rafael et al., 2006; Bogatto & Helot, 2010). The collected data are then analyzed with respect to a variety of factors, such as languages used, the size and originator of the sign. This allows researchers to document and discern patterns of language use within communities at particular times (Ben-Rafael et al., 2006). Accordingly, Landry and Bouhris (1997) found that, aside from schooling and social contacts, exposure to French-dominant advertisement, television, radio, and theatre were key determinants of personal identity and perceived vitality of the francophone community among French-speaking students. Lamarre (2014) extended this foundational work by investigating cross-language word play that complies with legal requirements in a manner that "winks" at minority

language speakers (e.g., naming a shoe store *Chou-Chou*). Similar examples are also found outside of Canada, in which the LL is jointly determined by legal provision and on-the-ground goals of individual people (e.g., Bogatto & Hélot, 2010).

While it is clear that people collectively and individually create LLs in ways that reflect their language backgrounds and attitudes (Ben-Rafael et al., 2006), an open question concerns what people *notice* when they encounter LLs, and how their backgrounds, preferences, or everyday habits impact what they see? Such questions relate to general concerns within cognitive neuroscience about how people allocate attention to specific elements within visual scenes that are more or less salient for stimulus- or goal-driven reasons (Itti & Koch, 2000). In principle, any visual element within a LL is potentially noticeable, however, people do not actively view every element in their field of view (Henderson, 2003). Thus, a methodological tool is needed that can directly measure where people look when they encounter or are immersed in visual scenes characteristic of LLs (see also Robinson, 1995, for a review of "noticing" within the context of second language acquisition).

Here, we introduce the method of eye tracking, which is commonly used in cognitive neuroscience and psycholinguistics to measure where people look within a visual display. Eye tracking has great temporal and spatial resolution for estimating which visual elements attract a viewer's interest, or which visual elements are more or less difficult to process (Findlay & Walker, 1999; Henderson & Ferreira, 2004; 2013; Rayner, 1998; 2009). This method typically uses a camera connected to a computer that emits a low-grade infrared light to the eye. This infrared light creates measurable reflections from the front and back of the cornea that enable a precise estimation of where people are looking at a fixed distance (see Figure 1).

Insert Figure 1 here

Several decades of psycholinguistic research using eye tracking have revealed much about what the eyes do when people read. For example, L1 readers generally fixate words on the first pass through a sentence for approximately 250 ms (Rayner, 1998), although fixation times can be modulated by many factors, such as word frequency, contextual predictability, or whether an upcoming word is processed peripherally (e.g., Rayner, 1998, 2009; Whitford & Titone, 2014). In addition, the time it takes for the eyes to move from one fixation to another (i.e., to make a saccade) is approximately 150 ms, during which time a corollary discharge signal from the oculomotor system suppresses visual encoding (Rayner, 2009).

Inherent in the use of eye tracking is the eye-mind assumption, which presumes a linkage between eye movement behaviors, such as fixation durations, and attention allocation (Rayner, 1998, 2009). For example, consider how the eyes might move as people read the sentence, *They liked to chat about the narcissistic politician's disregard for science*. An L1 reader would likely fixate the shorter, higher frequency words (e.g., *chat*, *about*) for short durations as they are relatively high frequent and easy to process. In contrast, the same L1 reader would likely fixate the longer, lower frequency words (e.g., *narcissistic*, *disregard*) for longer durations indicating that they are relatively more difficult to process. The same L1 English reader would likely skip function words, such as *had*, *an*, and *for*, as such words have a good chance of being encoded peripherally. Of note, while a highly proficient L2 French reader might show a globally similar pattern of eye movements, she might spend even more time fixating lower frequency words (Whitford & Titone, 2015; Whitford et al., 2016), or words that share form but not meaning across languages, such as *chat*, which refers to a human conversation in English but a furry feline in French (Libben & Titone, 2009; Titone, Pivneva, Sheikh, Webb & Whitford, 2015; Pivneva, Mercier & Titone, 2014). Thus, there are consistent differences between L1 and L2 readers in how their eyes might track the same sequence of text.

Eye movement methods have also been used to investigate real-world scene viewing. These studies involve showing pictures of real-world scenes (rather than computer generated displays) in a laboratory setting. On these images, longer or more frequent fixations indicate processing difficulty, or more attention-grabbing parts of an image (Findlay and Walker, 1999; Võ & Henderson, 2010). Accordingly, eye movements are directed toward salient parts of an image that stand out in terms of color, intensity, contrast, edge orientation, and so on (Findlay and Walker, 1999; Henderson, 2003; Itti and Koch, 2000). Eye movements may also be directed towards salient or anomalous parts of an image based on knowledge-driven expectations (e.g., Võ & Henderson, 2010). Indeed, we know from this literature that people are quite expert in rapidly discerning the overall gist of a scene in as little as 75 ms (Võ & Henderson, 2010), and can use this rapidly acquired information to later identify scene elements (e.g., Castelhano & Henderson, 2008).

In addition to basic research, a growing body of applied work uses eye movements to investigate how people view displays that combine text and images, similar to LL images. For example, web design and advertising studies have used eye tracking to optimize the placement of target text and objects in various types of displays, such as computer screens or handheld devices (Higgins, Leinenger & Rayner, 2014; Rayner, Rotello, Stewart, Keir & Duffy, 2001; Roth, Tuch, Mekler, Bargas-Avila & Opwis, 2013). Although commercial websites differ visually, people generally have enough on-line experience to actively search for common objects like a search bar, a click-to-purchase button, or a shopping basket when viewing never-before-seen retail websites (McCay-Peet, Lalmas & Navalpakkam, 2012; Roth et al., 2013). The use of eye tracking in marketing research can thus clarify the usability of newly developed web sites. Eye tracking has similarly been used to investigate viewing patterns for print advertising, which are also reminiscent of LL images. In one such study, Rayner et al. (2001) asked participants to imagine they were shopping for either a car or a skin care product. Participants tended to look at text prior to objects, and spent significantly longer time looking at ads that were relevant to the product they were instructed to buy. This work gets at underlying processes of integrating text and objects in a visual display with the goal of retrieving information, an experience not unlike that of viewing LLs.

To our knowledge, only one prior study has used eye tracking in the context of a LL study. In a Masters thesis, Seifi (2015) investigated how 31 native and 13 non-native speakers of Dutch viewed movies and images of multilingual LLs, with a specific focus on determining which types of signs attracted viewers' attention. Seifi reported that people preferred certain types of signs over others, for example, advertisements in shop windows, traffic signs, or stone inscriptions as opposed to graffiti or hanging banners. People were also more likely to view signs containing either the official language, Dutch, or the unofficial language, English. In contrast, signs containing both English and Dutch, or signs containing minority languages were viewed less frequently. These results are thus consistent with the idea that people selectively attend to different elements of LL images, however, many open questions remain. For example, how would differences among people in language background modulate viewing patterns for the same set of LL images? It is this specific question towards which the preliminary study reported below is directed.

A Preliminary Eye Tracking Study of how Bilinguals View LL Images

Building upon the literatures reviewed above, we conducted a preliminary eye tracking study of mutlilingual LL viewing. Our preliminary results suggest that while there are many commonalities in viewing patterns between people for whom English is an L1 or for whom French is an L1, individual differences in language background modulate the manner in which the eyes move when encoding LL images.

Methods

Participants. In this preliminary study, we tested six university-aged bilinguals recruited from an English-speaking university in Montreal. All participants reported being fluent in both English and French and using the two languages in their daily lives. Three or the participants were L1 French speakers, and three were L1 English speakers. Participants did not report fluency in any

languages beside French and English. All participants had been living in Canada for a mean of 11.2 years (SD = 9.7)[1]. On a questionnaire that asked participants to estimate what percentage of the time they spoke English in daily interactions, they reported speaking it for a mean of 80% of the time (SD = 4.5). L1 French speakers reported mixing the two languages more (M = 5, SD = 1, on a 1 – 7, low to high scale) than L1 English speakers (M = 3.3, SD = 0.58).

Materials. Stimuli consisted of 60 experimental LL images, 5 practice LL images, and 12 filler images. The 60 LL images were distributed over five sign types, with 12 images per condition. Two of the five sign types were English-only or French-only semi-matched billboard advertisements from across Canada, which had matched English and French versions (e.g., Tim Horton's billboards in English vs. French, see Figures 2a and 2b). In this condition participants saw two photographs of billboards advertising the same product but one of the billboards was in French and the other in English. The three remaining sign types consisted of naturalistic images collected in Montréal, that were either English-only, French-only, or English and French mixed. All of these signs in these three conditions were unique and included a wide variety of advertisements, store signs and street signs. On mixed language signs, French text always appeared on top and was more salient than the English text. These images were collected during fieldwork as part of a larger-scale project (Leimgruber, under review, see Figures 3a, b and c).

Insert Figures 2a and b & 3a, b and c here

Procedure. Two counterbalanced blocks manipulated viewing instructions, and images were repeated across these two blocks. In one block, participants viewed 77 images (60 experimental, 12 filler, 5 practice) for 8 seconds each while their eye movements were monitored. In order to ensure participants remained visually and cognitively engaged during the task, they rated the *informativeness* after seeing each image using a 7-point scale. In the other block, participants viewed the same images but rated how *aesthetically pleasing* they found each image. In what follows, we collapsed across the two blocks to maximize the number of data points per image type.

Eye movements were recorded using a SR-Research Eyelink at 1000 Hz. Then, we used DataViewer (SR-Research) to preprocess and analyze the data. First, we created interest areas around French text, English text, and non-text objects for each experimental image to calculate the proportion of fixations over time within each interest area. Second, we down-sampled the data to 250 Hz, and created a sample report that provided information about which interest areas were fixated for each time sample. Finally, we calculated fixation proportions over time for each interest area over the entire 8000 ms trial. To illustrate, a participant may have made a total of 100 fixations on the breakfast advertisement in Figures 2a or b over the 8 second trial. Assuming that 57 of those fixations were on the text, 30 on the object, and the remaining on other parts of the image (i.e., the background), the proportion of fixations on text would be 57/100 (or 57%), and the proportions of fixations on the object would be 30/100 (or 30%).

Results. To estimate how fixations changed over time, we divided each 8000 ms trial into three time bins as a matter of convenience: The initial time bin was 0-2666 ms; the middle time bin was 2667-5333 ms; and the final time bin was 5334-8000 ms. We then separated participants into English L1 and French L1 groups; averaged all fixations over time for each picture for each group; and tested for significant differences in the proportion of fixations allocated to text over the three time bins using paired samples t-tests.

[1] The L1 French participants in this study had immigrated from Europe to Canada. All participants resided in Montreal for the full duration of their studies and were therefore considered to have sufficient exposure to the local LL to participate in this study.

Question 1: How do bilinguals differentially view L1 text, L2 text, and objects when viewing unilingual, semi-matched LL images? Figures 4 and 5 presents the mean proportion of fixations over time on text vs. objects for English signs (left panel), and French signs (right panel). Figure 4 depicts English L1 bilinguals; Figure 5 depicts French L1 bilinguals.

English L1 Bilinguals. As seen in the left panel of Figure 4, English L1 bilinguals fixated English L1 text more during the initial portion of the trial ($M = 0.85$, $SD = 0.15$), compared to the middle ($M = 0.71$, $SD = 0.21$, $t(5) = 2.91$, $p < 0.05$, Cohen's d = 0.77), and compared to the final portion of the trial, but note that this effect is only marginally significant according to our t-test ($M = 0.66$, $SD = 0.26$, $t(5) = 2.36$, $p = 0.065$, Cohen's d = 0.9). Fixation proportions between the middle and final portions of the trial did not differ.

Insert Figures 4 & 5 here

Further, as seen in the right panel of Figure 4, English L1 bilinguals fixated French L2 text more during the initial portion of the trial ($M = 0.87$, $SD = 0.12$), compared to the middle ($M = 0.69$, $SD = 0.24$, $t(5) = 3.09$, $p < 0.05$, Cohen's d = 0.95), and compared to the final portion of the trial ($M = 0.76$, $SD = 0.2$, $t(5) = 2.72$, $p < 0.05$, Cohen's d = 1.28). However, unlike the English L1 signs, English L1 bilinguals made significantly more fixations on French L2 text during the final portion of the trial compared to the middle portion of the trial ($t(5) = 2.77$, $p < 0.05$, Cohen's d = 0.32), indicating that they regressed to L2 text at the end of the trial.

French L1 Bilinguals. In contrast with English L1 bilinguals, French L1 bilinguals (left panel of Figure 5) fixated English L2 text more during the initial portion of the trial ($M = 0.77$, $SD = 0.2$), compared to the middle ($M = 0.56$, $SD = 0.26$, $t(5) = -4.04$, $p < 0.01$, Cohen's d = 0.9), and compared to the final portion of the trial ($M = 0.57$, $SD = 0.26$, $t(5) = -2.74$, $p < 0.05$, Cohen's d = 0.86). Fixation proportions between the middle and final portions of the trial were not significantly different from one another. Nevertheless, the visualization of the data (left panel of Figure 5) does appear to suggest that French L1 bilinguals regressed to English L2 text.

Finally, French L1 bilinguals fixated French L1 text (right panel of Figure 5) more during the initial portion of the trial ($M = 0.81$, $SD = 0.17$), compared to the middle ($M = 0.62$, $SD = 0.18$, $t(5) = 2.8$, $p < 0.05$, Cohen's d = 1.09), and compared to the final portion of the trial ($M = 0.63$, $SD = 0.25$, $t(5) = 3.41$, $p < 0.05$, Cohen's d = 0.84). Fixation proportions between the middle and final portions of the trial did not differ, suggesting that French L1 bilinguals did not regress to French L1 text.

Fixations on Objects vs. Text. With respect to fixations on objects, there were three main findings. First, all bilinguals fixated objects to a lesser degree than text across all LL images (all relevant t-test comparisons, $p < 0.05$). Second, this avoidance of objects was greatest during the initial portion of the trial, across all signs, suggesting that bilinguals were more attentive to text when they first viewed each image (all relevant t-test comparisons, $p < 0.05$). Finally, there was one condition where the avoidance of objects and preference for text differed compared to the other conditions. Specifically, when French L1 bilinguals viewed English L2 signs, the overall difference between text and objects was reduced (text: $M = 0.64$, $SD = 0.48$; object: $M = 0.3$, $SD = 0.45$, $t(44100) = 79.44$, $p < 0.01$).

Thus, to answer Question 1, "How do bilinguals differentially view L1 text, L2 text, and objects when viewing unilingual, semi-matched LL images", there were three key findings. First, bilinguals viewing L1 signs (left panel of Figure 4, and right panel of Figure 5), looked more at text than objects irrespective of their L1, especially during the beginning portions of the trial. In contrast, bilinguals viewing L2 signs (right panel of Figure 4, and left panel of Figure 5), showed a different pattern. When English L1 bilinguals viewed French L2 signs, they regressed more to text at the end of the trial. When French L1 bilinguals viewed English L2 signs, regression to text at the end of the trial was less pronounced, however, they did look somewhat more at objects throughout the trial, suggesting that viewing the objects may have been useful to reinforce their textual interpretations. Thus, eye movement patterns revealed differences across bilinguals in both L1 and L2 LL viewing, and indicated that individual differences in language background modulated how people viewed the LL images.

Question 2: How do bilinguals differentially view L1 text, L2 text, and objects when viewing mixed language (i.e., multilingual) LL images? Figures 6 and 7 presents the mean proportion of fixations over time on text vs. objects for English signs (left panel), French signs (middle panel), and mixed language signs (right panel). Figure 6 depicts English L1 bilinguals; Figure 7 depicts French L1 bilinguals.

Insert Figures 6 & 7 here

As seen in the left and middle panels Figures 6 and 7, which present the data for unilingual, unique signs, the overall pattern is similar to that reported above for semi-matched unilingual signs in that people overwhelmingly fixated text compared to objects, particularly at the beginning of the trial. If anything, this effect was even more pronounced here, in that there tended to be fewer objects overall on these signs. Further, there are hints in these data of what we reported above for the L2 LL viewing conditions, however, these effects were not significant here likely due to the more varied nature of the stimuli and the small sample size. Thus, we emphasize below the findings for the mixed language condition, where there were robust eye movement effects that met statistical significance.

English L1 Bilinguals. First, when viewing mixed language LL images that displayed English and French text simultaneously, English L1 bilinguals first fixated the French text, but this changed over the course of the trial. As shown in the right panel of Figure 6, English L1 bilinguals fixated French L2 text more during the initial portion of the trial ($M = 0.62$, $SD = 0.24$), compared to the middle, although only marginally significant according to our t-test ($M = 0.5$, $SD = 0.23$, $t(11) = 1.88$, $p = 0.09$, Cohen's d = 0.51), and compared to the final portion of the trial ($M = 0.49$, $SD = 0.2$; $t(11) = 2.47$, $p < 0.05$, Cohen's d = 0.59). Fixation proportions between the middle and final portions of the trial did not differ. Conversely, English L1 bilinguals fixated English L1 text less during the initial portion of the trial ($M = 0.29$, $SD = 0.18$), compared to the middle, although only marginally significant according to our t-test ($M = 0.42$, $SD = 0.18$, $t(11) = -2.04$, $p = 0.06$, Cohen's d = 0.72), and compared to the final portion of the trial ($M = 0.43$, $SD = 0.14$, $t(11) = -2.96$, $p < 0.05$, Cohen's d = 0.87). Thus, English L1 bilinguals fixated French more than English text during the initial but not by the end of the trial.

French L1 Bilinguals A somewhat similar pattern emerged for mixed LL images for French L1 bilinguals. Here again, participants initially fixated French more than English, and these fixation patterns changed over time. As shown in the right panel of Figure 7, French L1 bilinguals fixated

English L2 text significantly less during the initial part of the trial (M = 0.3, SD = 0.16) compared to the middle (M = 0.49, SD = 0.16, $t(11) = -4.37$, $p < 0.01$, Cohen's d = 1.19), and compared to the final portion of the trial (M= 0.5, SD= 0.2, $t(11) = -3.03$, $p < 0.05$, Cohen's d = 1.1). Fixation proportions between the middle and final portions of the trial did not differ statistically, although an upward trend in the final portion of the trial can be seen in the left panel of Figure 7. Conversely, French L1 bilinguals fixated French L1 text more during the initial portion of the trial (M = 0.59, SD = 0.22), compared to the middle (M = 0.4, SD = 0.2, $t(11) = -4.47$, $p < 0.01$, Cohen's d = 0.9), and compared to the final portion of the trial (M = 0.4, SD = 0.23, $t(11) = -2.67$, $p < 0.05$, Cohen's d = 0.84). Thus, French L1 bilinguals fixated French more than English text during the initial portion of the trial but not by the end of the trial.

Thus, to answer Question 2, "How do bilinguals differentially view L1 text, L2 text, and objects when viewing mixed language (i.e., multilingual) LL images", there were again three key findings. First, when bilinguals viewed the unilingual English-only or French-only signs, their viewing patterns were very similar to that reported above, although individual difference effects were less apparent, likely due to the fact that the English and French signs were not semi-matched, and also the small sample size. Second, when we focus exclusively on mixed language signs, we see that all bilinguals first viewed the text that was most prominent on the sign (i.e., French), especially at the beginning of the trial, and irrespective of language background. Finally, and again focusing on the mixed language signs, we see that individual differences in language background modulated eye movement patterns, especially towards the end of the trial. When English L1 bilinguals viewed mixed language signs, they regressed to the English L1 text towards the end of the trial, such that they were fixating with equal proportion English L1 and French L2 text. When French L1 bilinguals viewed mixed language signs they regressed to English L2 text at the end of the trial to a much greater degree compared to French L1 text. Taken together, these data suggest again that eye movement measures of LL processing are sensitive to individual differences in bilingual language knowledge.

General Discussion

The goal of this paper was to enrich the growing LL literature by beginning to investigate the question of what people actually notice and look at when they encode LLs using a novel method within this literature, eye tracking (see also, Leimgruber, Vingron & Titone, submitted). Specifically, we reported a preliminary study that assessed how English L1 and French L1 bilinguals' eye movement patterns differed when viewing real-world LL images containing L1 or L2 text exclusively, or combined L1 and L2 text. We hoped to have demonstrated, both by the literature review presented above and these very preliminary data, that the eye movement method holds promise for expanding upon the kinds of questions sociolinguistic and psycholinguistic researchers can ask of LLs.

With respect to the preliminary data reported, although all participants were highly proficient in their L2, both groups showed different viewing patterns for L1 and L2 text during LL viewing. Specifically, when English L1 bilinguals viewed French L2 signs, they regressed more to text at the end of the trial, similar to what might be found during normal sentence reading. These viewing patterns may be a cause or consequence of comprehension challenges that arise from reading L2 text (e.g., Whitford et et al., 2015). Eye movement regressions to L2 text may have occurred because our bilingual viewers needed more time to process L2 text, which may have been functionally less frequent for them, or may have triggered cross-language activation of competing meanings that would slow reading.

In contrast, when French L1 bilinguals viewed English L2 unilingual signs, they did not regress more to English L2 text at the end of the trial, however, they did look somewhat more at objects throughout the trial, suggesting that viewing these non-linguistic visual elements may have

been useful to reinforce their linguistic interpretations (e.g., a picture of a cat on a cat food advertisement), similar to what has been found previously for eye movement studies of print advertisement (Luna & Peracchio, 2001). This effect leads to new questions about the differential impact of semantically related vs. unrelated images and their impact on LL processing, which may be an important future direction for research. Such findings also have potential relevance to the design of real world LL images given specific legal considerations (e.g., Bill 101 in Quebec).

Perhaps more interesting were the eye movement patterns observed for mixed language signs where, irrespective of language background, bilinguals first viewed text that was most prominent (French), particularly at the beginning of the trial. This finding suggests provisions within the Charter of the French language (Bill 101) that commercial signage (advertising, billboards, store names, even signage indoors) must have French as 'markedly predominant' are likely to be highly effective in increasing people's active noticing of French. However, bilinguals still view English text, particularly towards the end of the trial, although individual differences in L1 modulated the degree to which bilinguals viewed English more than French. Specifically, when English L1 bilinguals viewed mixed language signs, fixated English L1 and French L2 text with equal proportion by the end of the trial. However, French L1 bilinguals viewed English L2 text more than French L1 text by the end of the trial. Such findings are again compatible with prior eye movement studies of sentence reading (e.g., Pivneva et al., 2014; Whitford & Titone, 2016).

To conclude, we hoped to have offered some convincing arguments and experimental evidence that eye tracking may be useful for investigating LLs, in addition to the wide variety of other measures currently used by sociolinguistic researchers. While the approach we took here is very limited in scope, future efforts could potentially use eye movement measures to more precisely investigate LL processing, especially when combined with more tightly controlled experimental protocols and greater numbers of participants. To this end, our group is now conducting a more comprehensive eye movement investigation of LL processing that explicitly manipulates the kinds of LL images people see in a manner that tightly controls text content, placement and size as well as salience of text vis a vis objects by creating our own materials. Each individual's language history uniquely influences the way they extract information from the LL. Patterns of attention, including which texts are read, whether objects are examined to aid comprehension or whether a regression to text takes place make eye tracking is a well-suited way to investigate both conscious and unconscious attitudes. Thus, using this paradigm, we hope to examine a wider range of individual difference variables, including language background as well as linguistic and cultural attitudes, in a much larger sample. We also plan to conduct more naturalistic eye movement studies similar in spirit to Seifi (2015) to investigate the extent to which individual differences in language background and attitudes influence the kinds of signs bilinguals view when naturally traversing different streets in Montréal.

Thus, there are many possible questions that arise for us when thinking about LL processing in the context of eye movement research. Eye tracking cannot replace other long-standing sociolinguistic methods that have been crucial for advancing the field (e.g., detailed field work, language policy research). However, we believe that this approach, in combination with these other methods, may help to both generate and answer many important new questions about language perception within the public space, thereby enriching continued interdisciplinary study of LLs.

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APPENDIX

Figure 1. A desk-mounted eye tracker

Figures 2a and 2b. Examples of semi-matched advertisements, in English (left) and French (right)

Figures 3a, 3b and 3c. Examples of English (left), French (center), and multilingual (right) signage used in the task

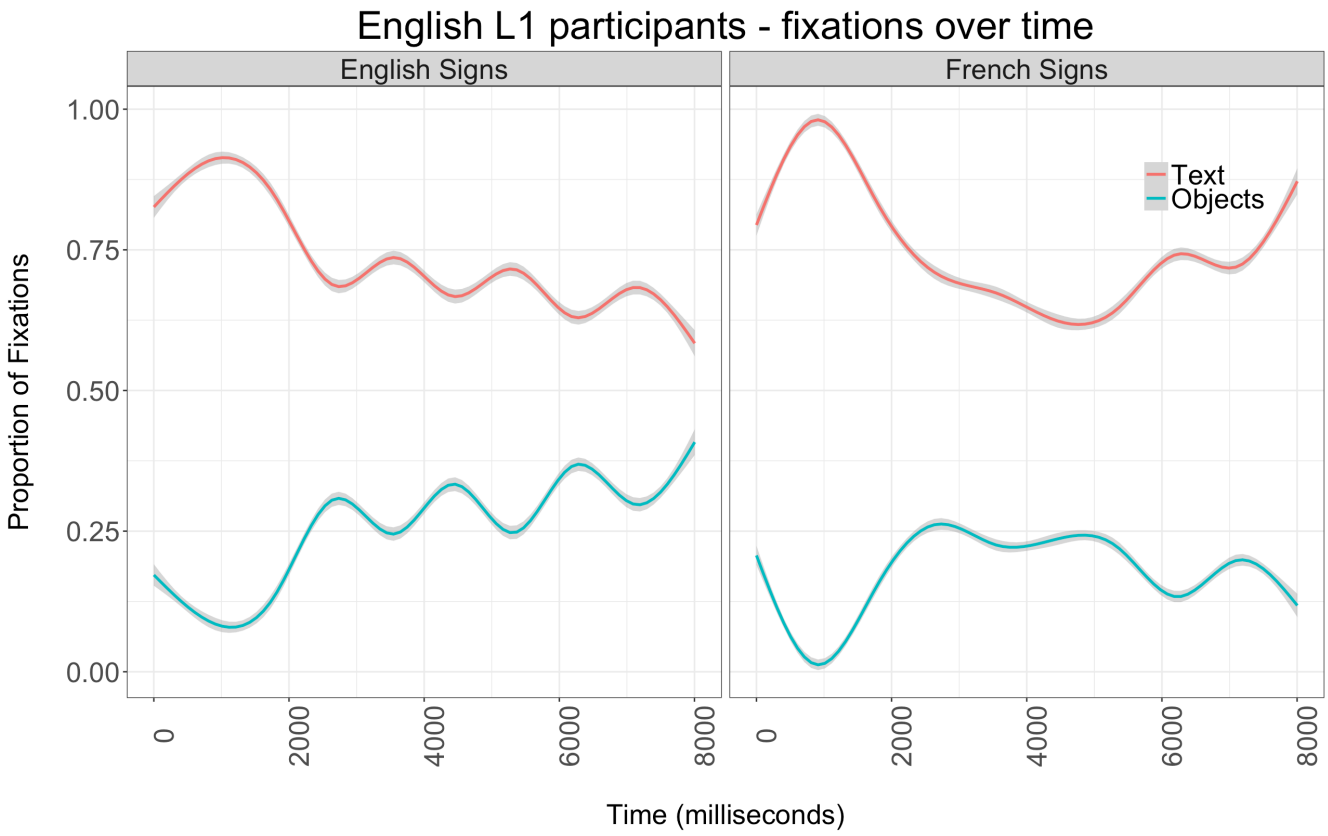

Figure 4. English L1 Subjects viewing semi-matched signs (collapsed over question conditions)

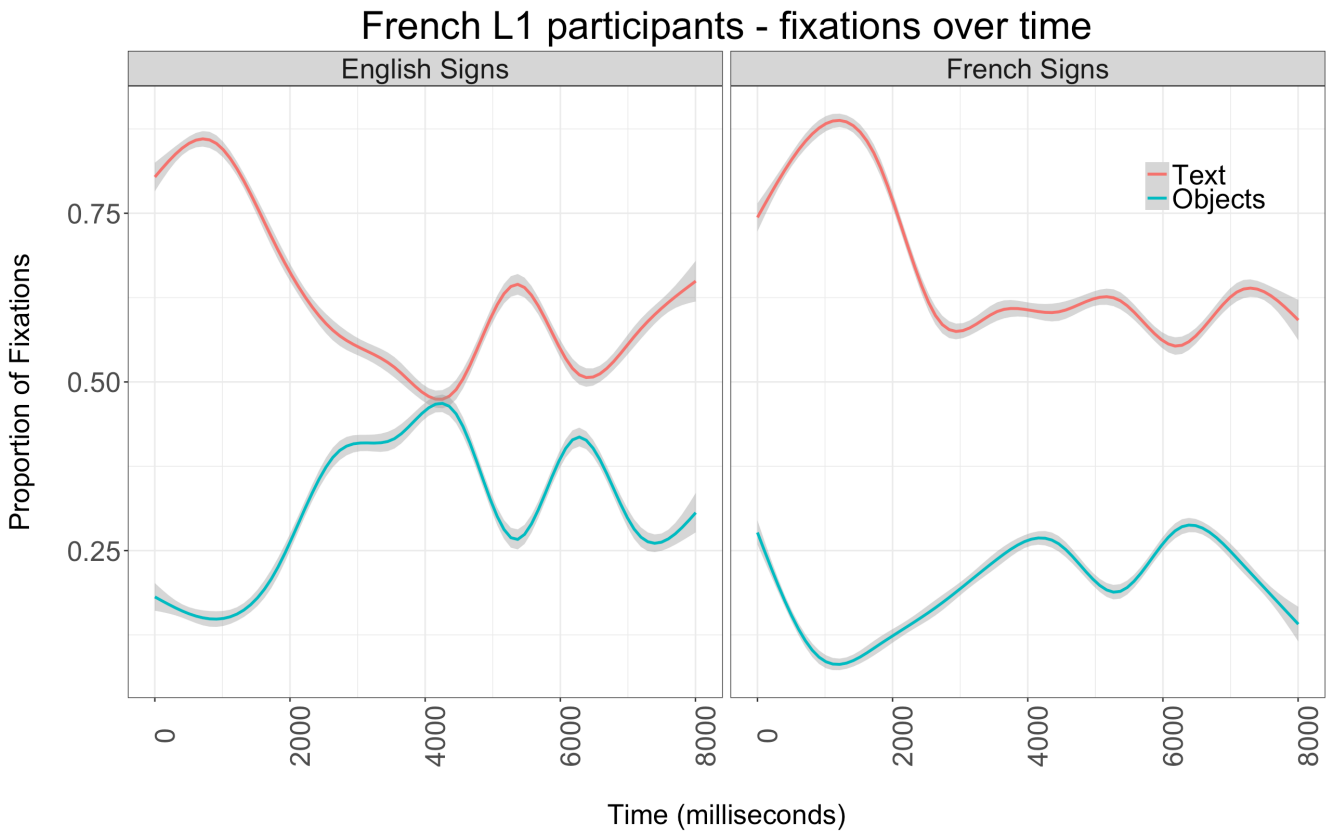

Figure 5. French L1 Subjects viewing semi-matched signs (collapsed over question conditions)

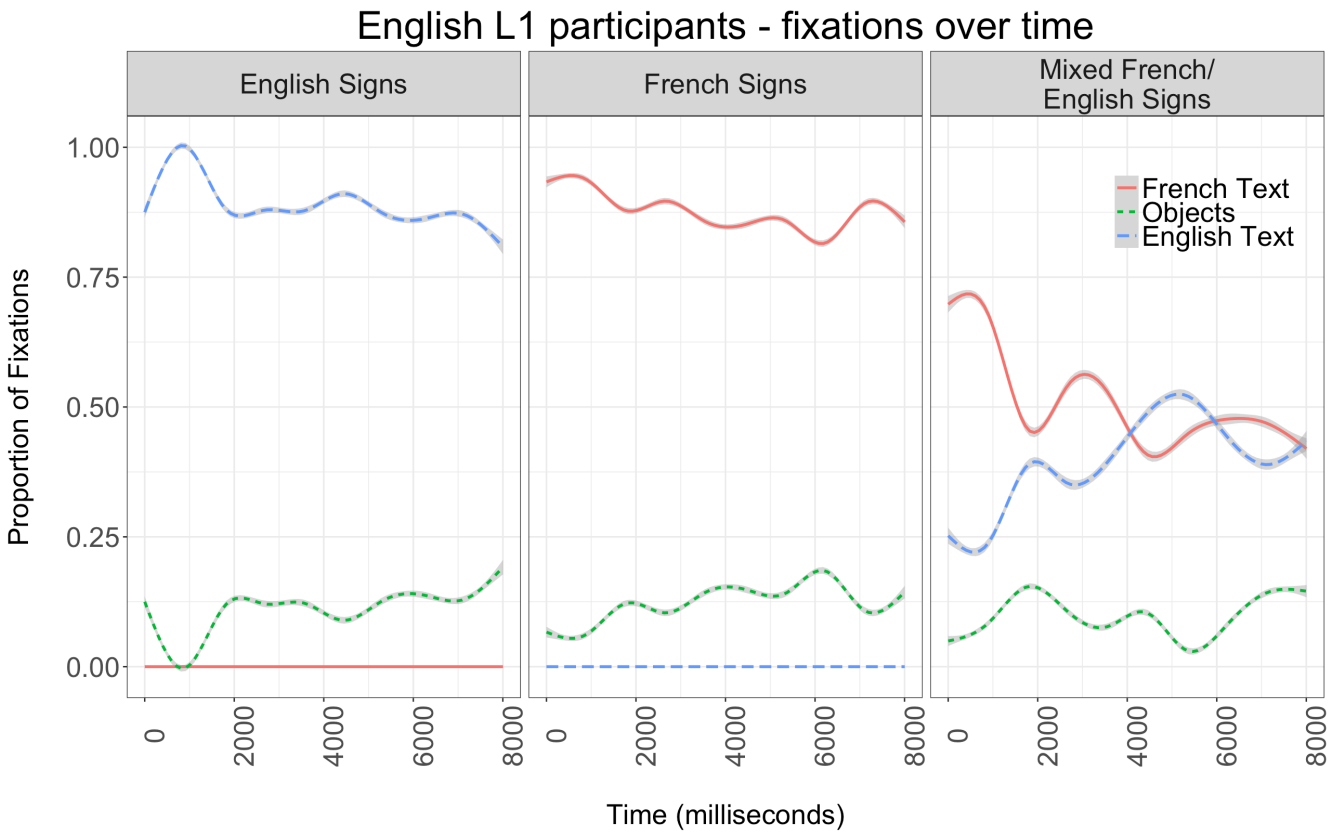

Figure 6. English L1 Subjects viewing English, French and mixed signs (collapsed over question conditions)

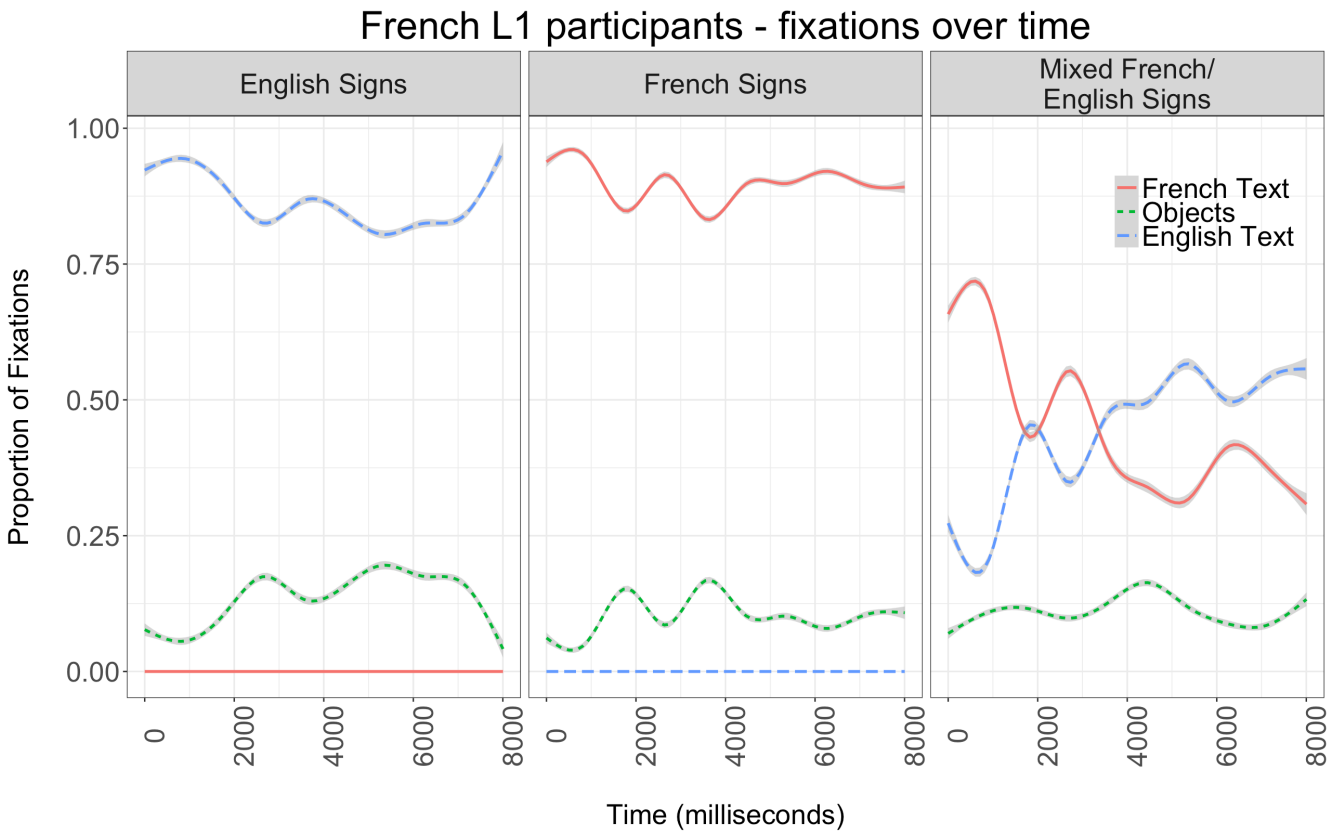

Figure 7. French L1 Subjects viewing English, French and mixed signs (collapsed over question conditions)