



Saccadic Control Networks in the Brain When Reading Paragraphs

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Why is this important?

- Reading is both a linguistic and oculomotor exercise requiring the integration of visual information with semantic knowledge to plan future action.
- Saccade amplitude and fixation duration have been used to explore linguistic theories of language processing.
- Fixations represent times when the eye is stable and visual information is gathered while saccades are ballistic movements from one target to another (Rayner, 2009).
- Previous work has identified regions associated with fixation duration (Henderson et al., 2015) however follow-up is needed.
- Little has been done to investigate saccadic planning in the brain during reading.
- Current models of reading make specific predictions about how the brain plans saccades (Reichle, 2006).

What did we do?

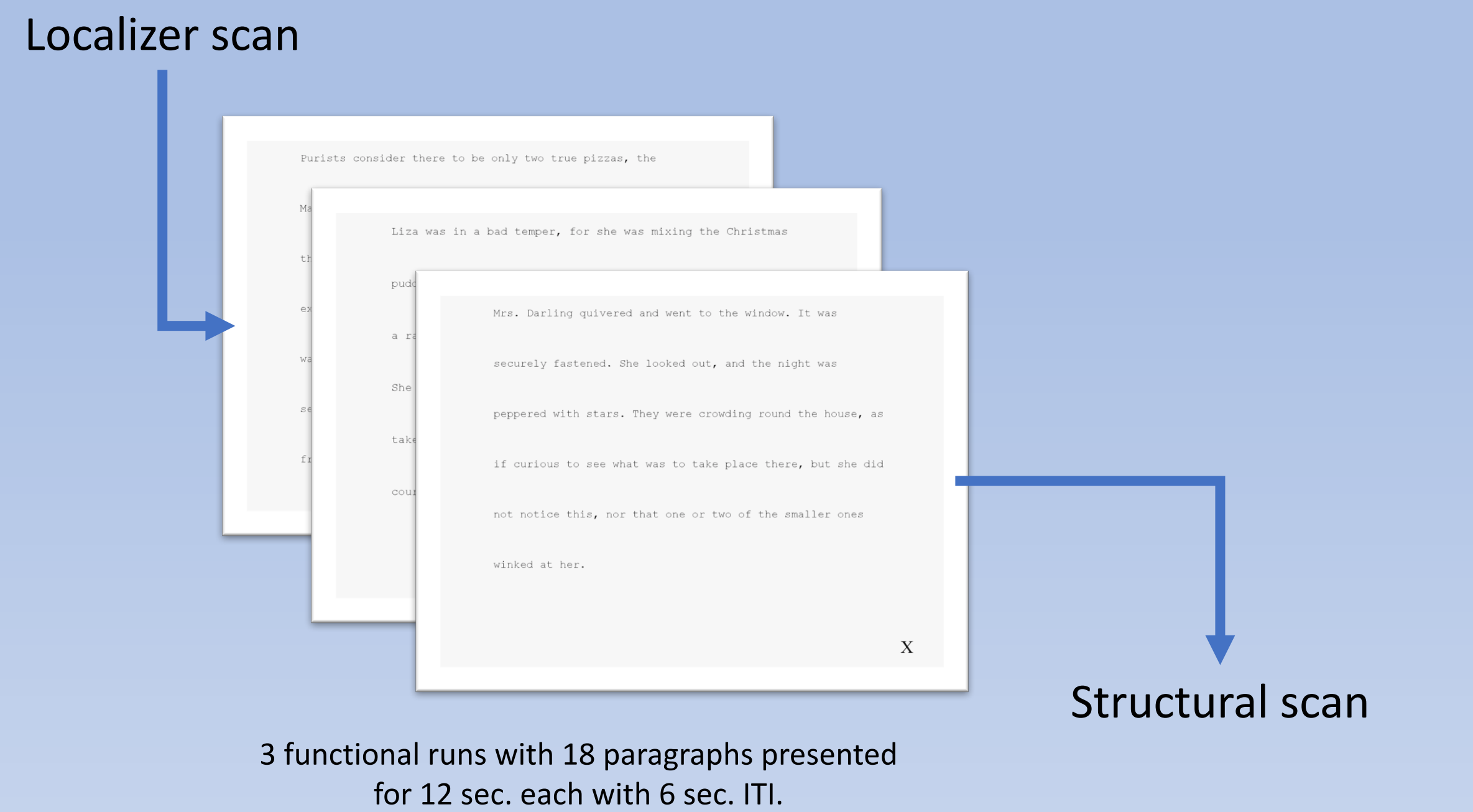
Participants: 41 BYU undergraduates with normal or corrected to normal vision with no history of neurological or learning disorders.

Materials: 54 paragraphs of connected text with previously determined predictability values computed via cloze procedure from Luke & Christiansen, 2016.

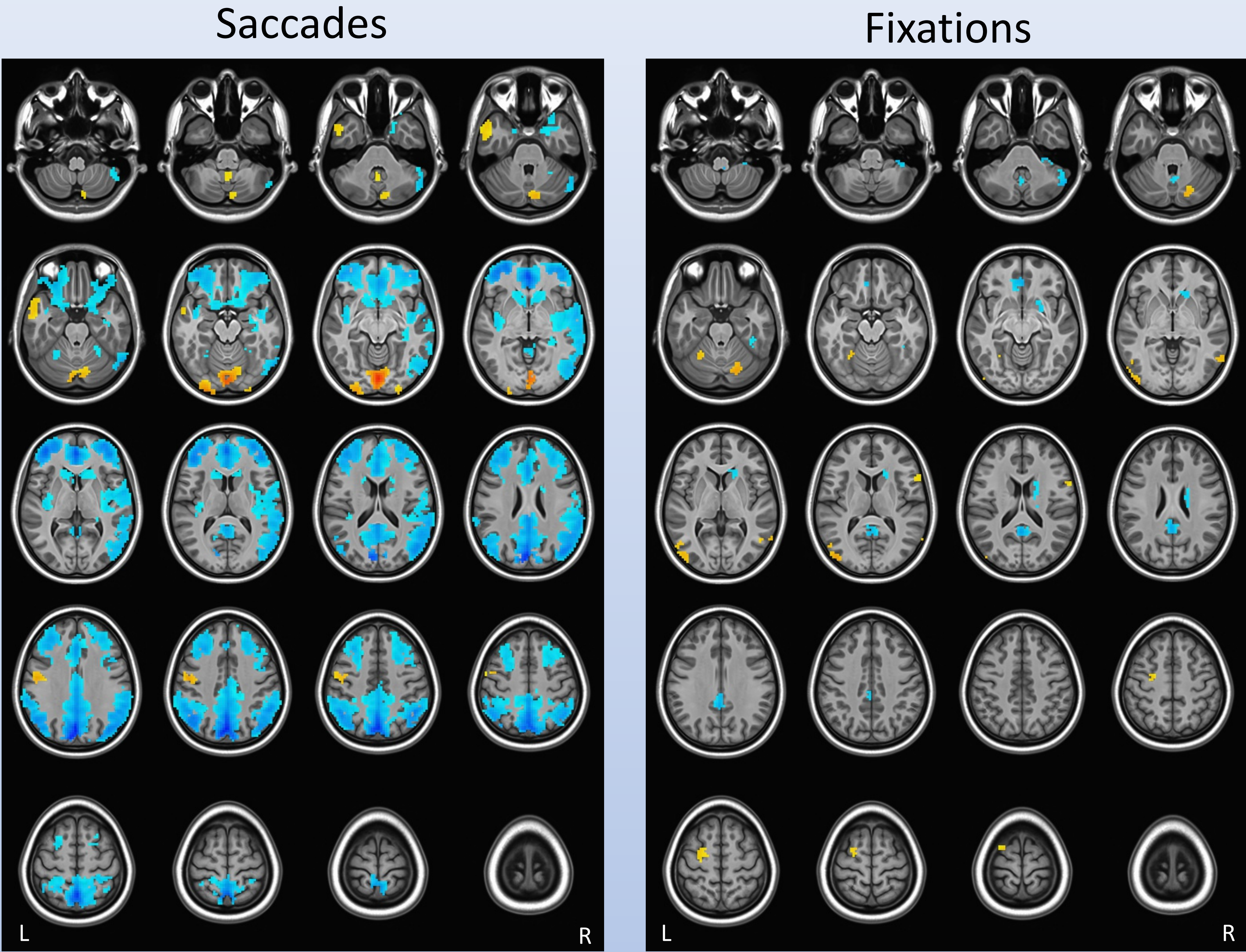
Equipment: Right eye movements were recorded via Eyelink 1000 plus long-range MRI eye tracker at 1000Hz. Text was displayed using a Cambridge Systems MRI-safe LCD monitor at a resolution of 1600x1200 pixels. Text was displayed in Courier New font, subtended to 4 letters per degree of visual angle. Imaging was performed using a Siemens 3T Tim Trio with a 12-channel receive-only head coil.

Scan Types: Participants read while eye movements were tracked across 3 runs of interleaved T₂*-weighted echo-planar imaging. T₁ weighted imaging was also performed.

fMRI–Procedure



What was found?



Peak Activations of Significant Clusters

Volume (μl)	Max z	MNI coordinates			Anatomical landmark
		x	y	z	
426006	-2.8659	-1	-76	37	L. precuneus
11880	2.6982	1	-85	-10	R. lingual gyrus
5427	0.8983	-55	10	-25	L. anterior middle temporal gyrus
3429	1.4074	-52	-13	34	L. precentral gyrus
2808	1.6125	-25	-100	-16	L. occipital lobe
1350	-0.5478	49	-49	-52	R. cerebellum
1026	0.5518	1	-52	-43	R. cerebellum
918	0.8708	28	-100	-16	R. occipital lobe
864	-0.3731	28	-52	-28	R. cerebellum
864	-0.5312	-25	-55	-19	L. cerebellum

A voxel-wise threshold of $p < 0.001$, and a cluster threshold of 27 was used to yield an overall alpha < 0.05 . Cluster thresholds were determined via a nonparametric approach (Cox, 2017).

Volume (μl)	Max z	MNI coordinates			Anatomical landmark
		x	y	z	
5319	-0.0135	-2	-52	16	L. posterior cingulate
3213	0.0138	-43	-85	10	L. occipital lobe
2403	0.0092	-28	-7	58	L. superior frontal sulcus
2295	0.0156	13	-79	-25	R. cerebellum
2106	-0.0083	19	22	-4	R. head of caudate
1728	-0.0119	1	37	-7	R. anterior cingulate
1107	-0.008	19	-7	22	R. caudate
1026	-0.0112	55	-61	-37	R. cerebellum
999	0.0107	58	-61	1	R. fusiform gyrus
945	-0.0256	1	-46	-55	R. inferior cerebellar peduncle
918	0.0099	-24	-52	-16	L. fusiform gyrus
918	0.0092	55	10	16	R. inferior frontal gyrus
891	-0.0096	31	-34	-43	R. cerebellum
864	-0.006	46	-43	-25	R. fusiform gyrus
783	-0.0071	2	-55	-34	R. cerebellum

What does this mean?

- This study replicates some but not all of the previous findings of other studies on fixation duration.
 - **L. superior frontal sulcus (FEF)** has appeared in other studies of eye movement control and is involved in the initiation of saccades.
 - **R. inferior frontal gyrus** exerts attentional control (Hampshire et al., 2010; Sebastian et al., 2016) and may be acting to prolong fixation.
 - **Anterior and posterior cingulate** activity is probably related to monitoring the rate of incoming stimuli (Raichle et al., 2001; Yarkoni et al., 2008). They do respond emotional conceptualization and semantic processing of text but this exercise was not limited to stimuli with overt emotional value.
 - **R. caudate** has appeared in previous studies of eye movement control.
 - **R/L fusiform gyri** are known to respond to features such as faces (FFA) and words (VWFA). A positive association with fixation duration is probably due to word recognition.
 - **Cerebellum** activity is interesting as it is consistently right sided in both the fixation and saccade paradigm.
- Saccade amplitude was previously unstudied.
 - The **negative association** of the frontal lobes, right temporal lobe, anterior and posterior cingulate, cuneus and precuneus with saccadic amplitude are theoretically interesting. Behaviorally, short saccades indicate increased effort of reading and understanding text. This indicates greater cognitive control of gaze as text becomes more difficult.
 - **Left temporal pole** has been shown to respond to both semantic (Binder et al., 2009; Price, 2012) and syntactic features of text (Brennan et al., 2012; Henderson et al., 2016). Therefore as saccadic planning relies more on these features as saccades become longer.
 - **Left precentral gyrus** has appeared in other studies of saccade control and is probably related to the motor component of rightward eye movement (Henderson et al., 2016).
 - **Occipital lobe** activity was positively associated with saccade amplitude. This may be due to increased visual input, as long saccades are generally indicative of increased reading speed.

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