University of Sunderland

Williams, Glenn P., Kukona, Anuenue and Kamide, Yuki (2019) Spatial narrative context modulates semantic (but not visual) competition during discourse processing. Journal of Memory and Language, 108. p. 104030. ISSN 0749-596X

Spatial narrative context modulates

semantic (but not visual) competition during discourse processing

Glenn P. Williams (g.williams@abertay.ac.uk)[a]*,

Anuenue Kukona (anuenue.baker-kukona@dmu.ac.uk)[b],

Yuki Kamide (y.kamide@dundee.ac.uk)[a]

[a]Division of Psychology, School of Social Sciences,

University of Dundee, Nethergate, Dundee, DD1 4HN, UK

[b]Division of Psychology, School of Applied Social Sciences,

De Montfort University, The Gateway, Leicester, LE1 9BH, UK

*Correspondence should be addressed to:

Glenn Williams

Division of Psychology

Abertay University

Dundee DD1 1HG

Scotland, UK

E-mail: g.williams@abertay.ac.uk

Abstract

Recent research highlights the influence of (e.g., task) context on conceptual retrieval. To assess whether conceptual representations are context-dependent rather than static, we investigated the influence of spatial narrative context on accessibility for lexical-semantic information by exploring competition effects. In two visual world experiments, participants listened to narratives describing semantically related (piano-trumpet; Experiment 1) or visually similar (bat-cigarette; Experiment 2) objects in the same or separate narrative locations while viewing arrays displaying these ('target' and 'competitor') objects and other distractors. Upon re-mention of the target, we analysed eye movements to the competitor. In Experiment 1, we observed semantic competition only when targets and competitors were described in the same location; in Experiment 2, we observed visual competition regardless of context. We interpret these results as consistent with context-dependent approaches, such that spatial narrative context dampens accessibility for semantic but not visual information in the visual world.

Keywords: semantic competition, visual competition, discourse processing, eye-tracking

Introduction

Although semantic memory is classically distinguished from episodic memory (e.g., Tulving, 1972), with the former reflecting knowledge divorced from experience and the latter reflecting personal experience, recent approaches argue that conceptual representations are indivisible from the contexts in which they occur (e.g., Yee & Thompson-Schill, 2016). Thus, context is hypothesised to play a central role in lexical-semantic representation and accessibility. In two experiments, we investigated the influence of spatial narrative context (i.e., participants' representations of referents in the same vs. separate locations) on accessibility for lexical-semantic information by examining so-called semantic (Experiment 1; e.g., Huettig & Altmann, 2005; Yee & Sedivy, 2006) and visual (Experiment 2; e.g., Dahan & Tanenhaus, 2005) competition effects.

The visual world paradigm (Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995), in which participants' eye movements are monitored while viewing visual stimuli and listening to linguistic auditory stimuli, provides key insights into the retrieval of lexical-semantic information during language processing. In particular, concepts sharing features have been shown to co-activate one another: for example, participants hearing 'lock' while viewing arrays depicting a lock, key, deer, and apple, fixate on the lock most, but also fixate on the semantically-related key more than the unrelated apple (Yee & Sedivy, 2006; see also Huettig & Altmann, 2005). These results suggest that rich lexical-semantic information is accessed during language processing.

However, Yee and Thompson-Schill (2016) argue that experience, including context, dictates which conceptual features are accessed from semantic memory. For example, previous research has shown that task context influences retrieval of colour features: lemon primes daffodil only when a prior task (e.g., Stroop) draws participants' attention to colour,

whereas colour-sharing concepts typically do not prime one another (Yee, Ahmed, & Thompson-Schill, 2012). Relatedly, task context influences retrieval of sensory features: Lexical decision and reading aloud is facilitated for words experienced in visual contexts, whereas only reading aloud is facilitated for words experienced in auditory contexts (Connell & Lynott, 2014). Connell and Lynott link this discrepancy to the differing modalities emphasised in these tasks (i.e., both have a visual dimension, but only reading aloud has an auditory dimension). These results suggest that task context determines accessibility for lexical-semantic features.

Experience-based approaches (e.g., Yee & Thompson-Schill, 2016) thus ground conceptual representations in specific situational contexts. In doing so, they also emphasise the relevance of a number of situational dimensions, including spatial location. Consistent with this emphasis, findings from the event cognition literature suggest that spatial context influences accessibility for items in memory, at least in the case of short-term/working memory. For example, Glenberg, Meyer, and Lindem (1987) presented participants with narratives describing a protagonist as either spatially associated with or dissociated from an object (e.g., 'John put on/took off his sweatshirt before going jogging.'), followed by anaphoric sentences referring back to the object (e.g., 'sweatshirt'). Crucially, participants' responses were facilitated when the object was spatially associated with (vs. dissociated from) the protagonist (see also Morrow, Greenspan, & Bower, 1987; Rapp, Klug, & Taylor, 2006; Rinck & Bower, 1995; Rinck & Denis, 2004). Likewise, related effects have also been observed outside narrative processing (e.g., Radvansky & Copeland, 2006; Radvansky, Krawietz, & Tamplin, 2011; Swallow et al., 2011; Swallow, Zacks, & Abrams, 2009).

Findings from the visual world paradigm also suggest that spatial narrative context influences accessibility for items in (e.g., short-term/working) memory. In Altmann and Kamide (2009), participants viewed a visual scene depicting a woman, a glass, a bottle of

wine, and a table, and they heard a narrative describing the woman as putting the glass onto the table (or not), followed by 'Then, she will … pour the wine carefully into the glass.' During 'glass', participants fixated the table more if the discourse described the glass as moving there (see also Hoover & Richardson, 2008; Kukona, Altmann, & Kamide, 2014). Collectively, these results suggest that spatial location determines accessibility for items in memory, at least in the case of short-term/working memory.

Building on the event cognition literature and related models (e.g., Radvansky, 2012; Radvansky & Zacks, 2014), the current experiments aimed to explore whether spatial narrative context influences not only accessibility for items in short-term/working memory, but also lexical-semantic information (i.e., semantic memory). Experience-based approaches (e.g., Altmann, 2017; Yee, Jones, & McRae, 2017; Yee & Thompson-Schill, 2016) hypothesise that the overlap between concepts in semantic memory is not static (e.g., Huettig & Altmann, 2005; Huettig, Quinlan, McDonald, & Altmann, 2006), but instead changes according to the context in which they are represented or accessed. In the current experiments, we manipulated the overlap between concepts via spatial narrative contexts, which described referents as either in the same or separate locations. We predicted that participants' representations of referents in the same vs. separate locations would influence how they accessed information from semantic memory, dampening accessibility (e.g., semantic competition; Huettig & Altmann, 2005; Yee & Sedivy, 2006) for concepts in separate locations. (Alternatively, these narratives may also influence the content of semantic memory, although we do not address this here.) In Experiment 1, participants viewed four objects (see Figure 1) while listening to discourses describing the locations of these objects.
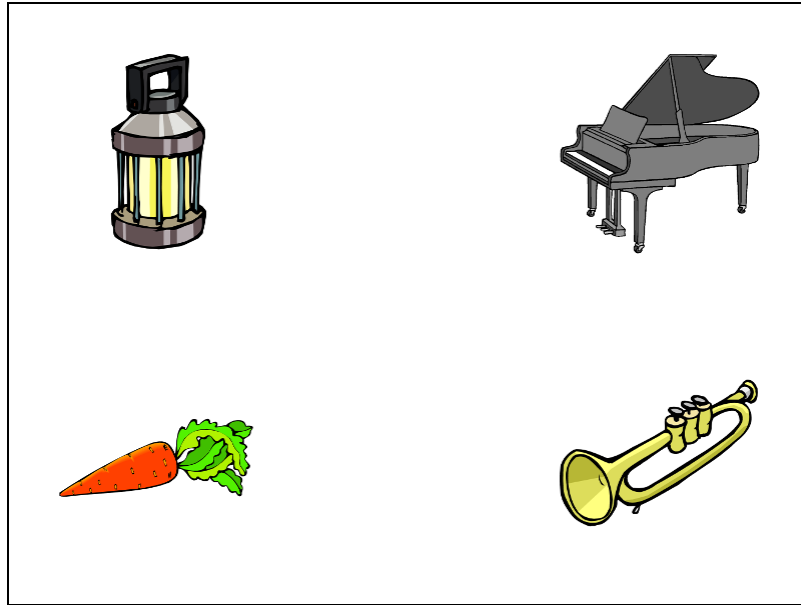
Figure 1. Example visual array paired with spoken discourses (e.g. (1) – (4)) in Experiment 1

    (1) **Together condition:** The piano and the trumpet are in the bar. The carrot and the

        lantern are in the gallery. Supposedly, the piano is exceptionally rare.

    (2) **Together condition:** The carrot and the lantern are in the bar. The piano and the

        trumpet are in the gallery. Supposedly, the piano is exceptionally rare.

    (3) **Apart condition:** The piano and the lantern are in the bar. The carrot and the trumpet

        are in the gallery. Supposedly, the piano is exceptionally rare.

    (4) **Apart condition:** The carrot and the trumpet are in the bar. The piano and the lantern

        are in the gallery. Supposedly, the piano is exceptionally rare.

In line with prior experiments (e.g. Huettig & Altmann, 2005; Yee & Sedivy, 2006), two of the objects were semantically related to one another (e.g. piano, trumpet) while the other two objects were unrelated distractors (e.g. carrot, lantern). In contrast with these studies, we manipulated the relative location of the target (e.g. piano) and its semantically related competitor (e.g. trumpet) in the discourse context, such that the target and competitor could be described in the same (e.g. (1) and (2); Together condition) or separate (e.g. (3) and (4); Apart condition) location(s). We also included conditions (1) vs. (2) and (3) vs. (4) to

control for recency of mention, as differences in the surface structure of the discourse can influence accessibility for discourse referents (Rinck, Bower, & Wolf, 1998). After establishing the locations of each object, in both conditions a final sentence re-mentioned the target object (e.g. 'Supposedly, the piano is exceptionally rare.'), allowing us to observe whether, on re-mention of the target, accessibility for the competitor was modulated by its location relative to the target.

In contrast to prior research investigating the influence of spatial narrative context on accessibility for referents in short-term/working memory (e.g., recognition of 'sweatshirt' in Glenberg et al., 1987), in the current research we aimed to explore accessibility for information in semantic memory (e.g., see Huettig & Altmann, 2005; Yee & Sedivy, 2006). In Experiment 1, we predicted that semantic competition (e.g., fixations to the competitor trumpet; see Figure 1) would be greatest when the target (e.g., piano) and competitor were described in the same (i.e., Together condition) vs. separate (i.e., Apart condition) narrative locations. In Experiment 2, we aimed to explore whether the spatial narrative context likewise modulated visual competition (e.g., bat – cigarette) in the visual world paradigm (e.g. Dahan & Tanenhaus, 2005), a task context that specifically emphasises the visual dimension (e.g., see Connell & Lynott, 2014). Thus, we also addressed whether the spatial narrative context affects competition when the information retrieved from semantic memory is compatible with the task modality (henceforth, modality compatibility).

Experiment 1

Experiment 1 aimed to explore whether competition between semantically related objects (e.g. piano and trumpet) is modulated by the spatial narrative context. To do so, participants viewed a visual scene containing two semantically related objects and two distractors while listening to discourses describing the semantically related objects in the same (i.e. Together

condition) or separate (i.e. Apart condition) narrative locations before re-mentioning one of the objects (i.e. the target). If spatial narrative context influences access for information in semantic memory, we predicted greater competition when the semantically related objects were mentioned in the same (i.e. Together condition) narrative location, rather than in different (i.e. Apart condition) narrative locations.

Method

Participants

Sixty (11 male) native speakers of English from the University of Dundee community (aged 17 – 33, $M = 20.62$, $SD = 3.66$) took part in this study for partial course credit. All participants had uncorrected vision, wore soft contact lenses, or wore spectacles, and had no known auditory, visual, or language disorders.

Materials

Thirty-two experimental visual displays such as that depicted in Figure 1 were created from commercially available ClipArt packages with a 256-colour palette using the GIMP 2.8.4 image manipulation program (Kimball, Mattis, & The GIMP Development Team, 1995), and consisted of an 800×600 pixel image, centred within a grey background of 1024×768 pixels. Visual displays were paired with pre-recorded spoken discourses, such as those outlined in (1) – (4). Discourses were recorded by a male native speaker of British English sampled at 44,100 Hz using a Sennheiser SC-60 USB-headset and the Audacity audio suite (Mazzoni & Dannenberg, 2016). The prosody of each utterance was normal and clear enunciation and pauses in speech were included to allow for ease of comprehension (e.g. Altmann, 2004). Noise was filtered from speech audio files using the Audacity audio suite

and files were spliced using the Praat software package (Boersma & Weenik, 2017). The experimental program was designed in SR Research Experiment Builder.

Each visual display contained four inanimate objects that were phonologically distinct (i.e. with no rhyme or cohort overlap), two of which (i.e. the target and competitor) were semantically related to one another and were visually distinct, and two of which (i.e. the distractors) were semantically unrelated to one another, the target, and the competitor. All depicted and described objects could conceivably be contained within their described locations. For the discourses, we manipulated whether the target (e.g. piano) and competitor (e.g. trumpet) were described in the same (e.g. (1) and (2)) or separate (e.g. (3) and (4)) locations corresponding to the Together and Apart conditions respectively. Moreover, we counterbalanced whether the target was mentioned in the first (e.g. (1) and (3)) or second (e.g. (2) and (4)) sentence within items in each condition. For the analyses, we collapsed over this manipulation to control for any primacy/recency effects that might affect processing (Rinck et al., 1998).

The location for each object in the visual displays was pseudorandomised. Four lists were created for the stimuli, rotating across the 4 sentential conditions for each experimental item. Thirty-two filler items were also constructed in a similar way to the experimental items but referred back to one of the distractors in the final sentence. The order of presentation for all items was pseudo-randomised for each participant such that only two items from the same condition could be played before a different condition followed. For a full list of the experimental sentential stimuli used, see Appendix A.

Latent Semantic Analysis (LSA) (see Landauer & Dumais, 1997; Landauer, Foltz, & Laham, 1998) with restrictions of General Reading (up to 1st year college: 300 factors)[1] was used to select competitors that were strongly related to targets ($M = .54$) and distractors that were not strongly related to targets ($M = .03$) or competitors ($M = .03$). Using this method to select target – competitor pairs has been shown to accurately simulate semantic priming data (Landauer & Dumais, 1997). Additionally, LSA has been found to correlate well with fixation behaviour in eye-tracking tasks (Huettig et al., 2006).

To ensure that any semantic competition effects were driven by semantic similarity between the target and competitor and not by differences in the semantic association between the target and competitor in regards to the two locations described in each discourse (e.g. the piano in the bar vs. gallery), a one-to-many comparison using the same semantic space was carried out for the target and competitor in regards to the two mentioned locations. The average LSA cosines for the relatedness of the target and competitor to each location was similar across locations and objects (target: location 1 $M = .11$, location 2 $M = .11$; competitor: location 1 $M = .10$, location 2 $M = .10$). Thus, any effect of semantic relatedness found in this experiment is unlikely to be affected by differences in the semantic relatedness between the target and competitor in regards to the two mentioned locations. Furthermore, given that LSA captures some aspect of co-occurrence in texts, the target and competitor are controlled for plausibility of mention in each location. Therefore, fixations on the competitor when hearing the target noun are likely to be driven by competition between the target and competitor directly, and not by a spread of activation for a competitor that is highly semantically related to any location associated with the target.

---

[1] The General Reading space (up to 1st year college) was determined to be most appropriate for an undergraduate cohort of participants. While dimensionality-optimisation is useful in determining the most appropriate number of factors to include in the representational space, using 300 factors has typically been found to be effective in accurately simulating human-like responses to various language-based tasks (see Landauer & Dumais, 1997). Thus, without the means to compare LSA cosines to human judgments for the semantic similarity between the objects used in the current experiment, 300 factors were used in the representational space.

Procedure

Participants took part in a 'look and listen' task (e.g. Altmann, 2004); sitting approximately 24 inches away from a computer display (with a resolution of 1024×768 pixels and a 75 Hz refresh rate) while their eye-movements were tracked using an SR Research EyeLink 1000-plus desk-mounted eye-tracker. Eye-movements were sampled at 1000 Hz from the participants' dominant eye, but viewing was binocular. Nine-point calibration and validation was used at the start of the experiment and was repeated every 16th item.

Each visual scene remained on-screen for the duration of the trial (average of 16,090ms) so that the visual scenes and auditory stimuli were presented concurrently. Participants completed 4 practice trials at the beginning of the experiment, after which they had the opportunity to ask any questions prior to the continuation of testing. The practice trials consisted of 2 experimental-type items and 2 filler-type items. The experimental session consisted of 32 experimental and 32 filler items as outlined in the materials. For all trials, each scene was displayed for a preview of 1000ms and remained onscreen for the duration of the trial; sentences 1 and 2 were played after this preview. One thousand milliseconds after the offset of the second sentence the 3rd (critical) sentence was played. Each individual trial was automatically terminated 4000ms after the offset of the final sentence. The average durations, onsets, and offsets for each region are presented in Table 1. The full testing session lasted approximately 30 minutes.

Table 1. Mean durations (ms) of temporal regions in the experimental sentences in Experiment 1

Label	Region	Onset	Offset	Duration
Sentences 1 and 2				
	'The piano and the trumpet are in the bar. The carrot and the lantern are in the gallery.'	1060	7835	6775
Sentence 3				
verb phrase	'Supposedly,'	8835	9825	990
determiner	'the'	9825	9965	140
object noun	'piano' (target)	9965	10,425	460
verb	'is'	10,425	10,820	395
adverb	'exceptionally'	10,820	11,605	785
adjective	'rare'	11,605	12,090	485

Note: Sentences 1 and 2 varied across conditions. The region example provided above is based on one of the four conditions outlined in Sentences (1) – (4), i.e. (1).

Results

Data were prepared and analysed using R (Version 3.4.3; R Core Team, 2017) and the R-packages *tidyverse* (Version 1.2.1; Wickham, 2017) and *lme4* (Version 1.1-15; Bates, Mächler, Bolker, & Walker, 2015). We conducted our analyses during the time window spanning from the onset of the critical noun (e.g. piano) + 300ms until the offset of the critical noun + 300ms (henceforth, critical noun + 300ms). Means and standard errors for the proportion of fixations on the target (piano), competitor (trumpet), and the mean of the two distractors (carrot, lantern; henceforth 'distractor') are plotted in Figure 2 from the onset of the critical noun ('piano') until the offset of the adjective ('rare') during the final sentence. (Although we use this example item throughout, analyses included all items.) Unsurprisingly, fixations to the target were far greater than to the non-targets from the critical noun onward, which were not analysed; rather, the analyses tested for competition effects by focusing on the competitor and distractor for simplicity.
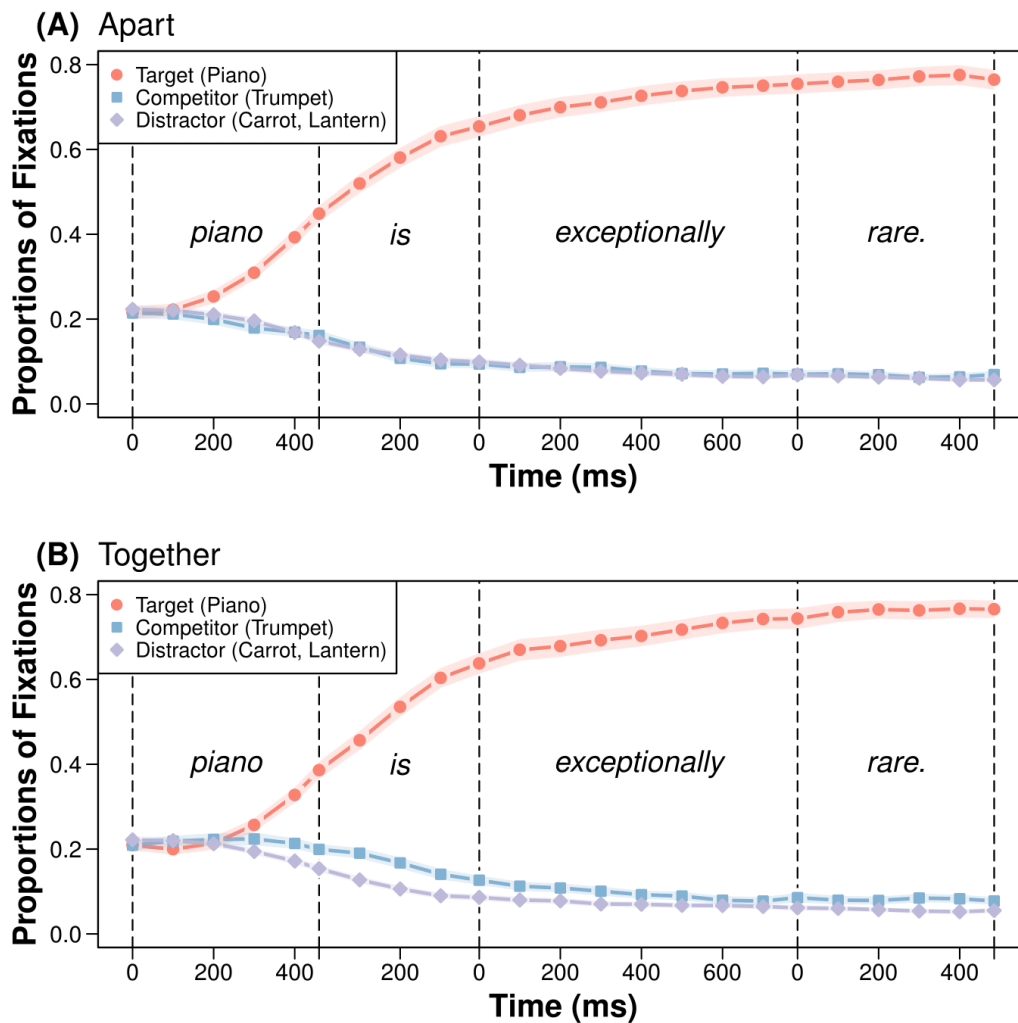
Figure 2. Mean proportion of fixations (shaded bands show ± 1 *SE* of the mean) on the target (piano), competitor (trumpet) and distractor (carrot, lantern) in the Apart (A) and Together (B) conditions in Experiment 1. Vertical broken lines indicate points at which fixations were resynchronised in the discourse.

We selected the time window of the critical noun + 300ms as previous research has shown that fixations on semantically related objects begin to diverge from those on unrelated distractors at around 200 – 300ms after the target onset, with this difference increasing and reaching a peak at around 300 – 400ms after target onset (Huettig & Altmann, 2005; Yee & Sedivy, 2006)[2]. In these experiments, approximately the same adjustment to the noun onset has been applied to the noun offset, with the time window of analysis lying between noun

---

[2] Although both studies report and found semantic competition when analyses included time-windows starting from 200ms after target onset, effects typically peaked at 300 – 400ms after target onset.

onset + 200ms until noun offset + 200ms (Huettig & Altmann, 2005) and noun onset +

200ms until asymptote (approximately noun offset + 390ms; Yee & Sedivy, 2006). As such,

the region of the critical noun + 300ms should encapsulate the earliest point with which

strong semantic competition effects can be detected and thus modulated by the spatial

discourse context during lexical access. Eye-movements launched prior to the onset of each

time-window were included in analyses to account for any anticipatory baseline effects (Barr,

Gann, & Pierce, 2011).

Prior to performing our analyses, we aggregated the data first by subjects, and then by

items, across the entire time window for fixations on the competitor and the mean of the two

distractors in each discourse condition. This aggregation was performed to account for the

autocorrelation between eye-movements, and the heavy skew towards 0% or 100% looking

on an object on individual trials within subjects and items. The mean of the two distractors

was analysed to control for any differences in fixation behaviour across the two distractors as

a measure of visual saliency (Parkhurst, Law, & Niebur, 2002). Additionally, we transformed

our dependent variable – the proportion of fixations on a given object throughout the entire

time window – into arcsine square root transformed proportions. This transformation attempts

to account for the bounded nature of the underlying binomial response for proportions. This

is necessary as variance is not homogenous across the entire range of possible outcomes; with

larger variance towards the endpoints of 0 and 1 (Mirman, 2014).

We analysed the arcsine square root transformed proportions using linear mixed

effects models. The by-subjects and by-items analyses contained fixed effects of condition

(centred) with two levels (Apart and Together conditions), object (centred) with two levels

(competitor and distractor), and the interaction between them. In both models, we used the

maximal converging random effects structure appropriate for the data (Barr, Levy, Scheepers,

& Tily, 2013), which takes the form of random intercepts by subjects/items, random

intercepts of subjects/items nested within condition, and random intercepts of subjects/items nested within object (e.g. Baayen, Davidson, & Bates, 2008). In such models, the intercept represents the average of the transformed proportion of fixations on both objects across conditions. As such, the fixed effects of object and condition represent the main effects of each factor respectively.

Where interactions between our fixed effects were present, we conducted pairwise comparisons to explore (1) the simple effect of condition on each object, and (2) the simple effect of object within each condition. In all models, *p*-values were calculated using the normal approximation, the robustness of which is discussed in Barr et al. (2013). For pairwise tests, *p*-values are reported with Bonferroni corrections. Additionally, we provide the 95% confidence intervals around parameter estimates calculated using the Wald method in *lme4*.

In cases where non-significant effects are reported across by-subjects and by-items analyses, we compare the evidence in support of the absence of an effect relative to the alternative hypothesis using approximations to Bayes factors from the Bayesian Information Criterion (BIC). To do so, we perform model comparisons between models containing the factor of interest (e.g. discourse condition) and those without the factor of interest using the method outlined in Wagenmakers (2007). Notably, these models are fitted in *lme4* using the same procedures and random effects structures used to calculate parameter estimates and *p*-values for null-hypothesis significance tests.

Interaction Model

Means (*SD*) and 95% confidence intervals for the proportion and arcsine square root transformed proportion of fixations on each object are presented in Table 2 for each condition during the critical noun region ('piano') + 300ms in Experiment 1 (as mentioned above, targets were not included in the analyses for simplicity).

Table 2. Means, standard deviations (*SD*), and 95% confidence intervals (95% CI) for the proportion (Proportion) and transformed proportion (Asin) of fixations on each object (Competitor, Distractor) in each condition (Apart, Together) during the critical noun region ('piano') + 300ms in Experiment 1

		Dependent Variable			
		Proportion		Asin	
Object	Condition	Mean (*SD*)	95% CI	Mean (*SD*)	95% CI
Competitor	Apart	.150 (0.072)	[.131; .169]	0.386 (0.109)	[0.358; 0.414]
Competitor	Together	.201 (0.093)	[.177; .225]	0.451 (0.131)	[0.417; 0.485]
Distractor	Apart	.153 (0.054)	[.139; .167]	0.396 (0.078)	[0.376; 0.416]
Distractor	Together	.149 (0.055)	[.135; .163]	0.389 (0.081)	[0.368; 0.410]

Table 3 shows the fixed effects parameter estimates (*SE*), 95% confidence intervals, *t*-values, and *p*-values for the analysis during the critical noun region ('piano') + 300ms in Experiment 1.

Table 3. Parameter estimates, standard errors (*SE*), and 95% confidence intervals (95% CI) for the interaction model during the critical noun region ('piano') + 300ms in Experiment 1

Model Terms	Est. (*SE*)	95% CI	*t*	*p*
By-Subjects				
Intercept (Grand Mean)	0.406 (0.007)	[0.391; 0.420]	56.244	<.001***
Condition	0.029 (0.013)	[0.004; 0.054]	2.279	.023*
Object	0.025 (0.013)	[0.000; 0.050]	1.990	.047*
Condition × Object	0.072 (0.025)	[0.022; 0.122]	2.826	.005**
By-Items				
Intercept (Grand Mean)	0.409 (0.009)	[0.392; 0.427]	45.378	<.001***
Condition	0.030 (0.010)	[0.010; 0.049]	3.008	.003**
Object	0.029 (0.018)	[-0.006; 0.064]	1.611	.107
Condition × Object	0.073 (0.020)	[0.035; 0.112]	3.728	<.001***

*** $p <.001$; ** $p <.01$; * $p <.05$.

During the critical noun region ('piano') + 300ms, we found a significant main effect of condition (Together > Apart) by both subjects and items (both ps <.05) and a significant main effect of object (Competitor > Distractor) by subjects ($p = 0.047$) but not by items ($p = 0.107$). Crucially, we found a significant interaction between condition and object by subjects and items (both ps <.01). As such, we explored this interaction with pairwise comparisons.

Pairwise Comparisons

First, we explored the effect of condition on each object. The results of these pairwise comparisons are reported in Table 4. As in the interaction model, all models described here used the maximal converging random effects structure (Barr et al., 2013) appropriate for the data. For the simple effect of condition on each object, the treatment-coded fixed effect of condition was assessed separately for the competitor and distractor using data aggregated first by subjects and then by items. Here, the intercept represents the Apart condition, with the effect of condition evaluating the difference in the transformed proportion of fixations between the intercept (i.e. the Apart condition) and the Together condition. Similarly, for the simple effect of object within each condition, the treatment-coded fixed effect of object was assessed separately for the Apart and Together conditions using data aggregated first by subjects and then by items. Here, the intercept represents the competitor, with the effect of object evaluating the difference in the transformed proportion of fixations between the intercept (i.e. the competitor) and the distractor. In both pairwise comparisons, the random effects structure took the form of random intercepts by subjects/items.

Table 4. Parameter estimates, standard errors (*SE*), and 95% confidence intervals (95% CI) for the pairwise comparisons exploring the effect of condition within each object during the critical noun region ('piano') + 300ms in Experiment 1

Model Terms	Est. (*SE*)	95% CI	*t*	*p*
Competitor				
By-Subjects				
Intercept (Apart)	0.386 (0.016)	[0.355; 0.416]	24.830	<.001***
Condition (Together)	0.065 (0.022)	[0.022; 0.108]	2.957	.012*
By-Items				
Intercept (Apart)	0.391 (0.017)	[0.358; 0.423]	23.433	<.001***
Condition (Together)	0.066 (0.017)	[0.032; 0.100]	3.828	<.001***
Distractor				
By-Subjects				
Intercept (Apart)	0.396 (0.010)	[0.376; 0.417]	38.569	<.001***
Condition (Together)	-0.007 (0.013)	[-0.032; 0.018]	-0.552	>.999
By-Items				
Intercept (Apart)	0.398 (0.012)	[0.375; 0.422]	33.159	<.001***
Condition (Together)	-0.007 (0.009)	[-0.025; 0.011]	-0.757	>.999

*** $p < .001$; ** $p < .01$; * $p < .05$.

In both by-subjects and by-items analyses we found a significant difference between the two conditions (Together and Apart) in the transformed proportion of fixations on the competitor (both ps $< .05$), with a larger transformed proportion of fixations on the competitor in the Together condition than the Apart condition. However, we found no significant difference between the two conditions on the transformed proportion of fixations on the distractor (both ps $= 1$). Here, we evaluated evidence in support of the null hypothesis using the BIC approximations to the Bayes factors. We created an alternative model for the two conditions for fixations on the distractor using the same model specification as above (H_1) and a null model based on the same model but without the fixed effect of condition (H_0). The BIC approximations to the Bayes factors show that the data are more likely under the null than the alternative hypothesis for both by-subjects and by-items analyses (by-subjects: BIC(H_0) = -257.90, BIC(H_1) = -253.42, $BF_{01} \approx 9.39$; by-items: BIC(H_0) = -172.80, BIC(H_1) = -169.23, $BF_{01} \approx 5.97$). This suggests that fixations on the distractor are unlikely to be influenced by the discourse condition.

Next, we performed a series of pairwise comparisons to explore the effect of object within each condition. The results of these pairwise comparisons are reported in Table 5.

Table 5. Parameter estimates, standard errors (*SE*), and 95% confidence intervals (95% CI) for the pairwise comparisons exploring the effect of object within each condition during the critical noun region ('piano') + 300ms in Experiment 1

Model Terms	Est. (*SE*)	95% CI	*t*	*p*
Apart				
By-Subjects				
Intercept (Competitor)	0.386 (0.012)	[0.362; 0.410]	31.606	<.001***
Object (Distractor)	0.011 (0.017)	[-0.023; 0.044]	0.616	>.999
By-Items				
Intercept (Competitor)	0.391 (0.013)	[0.365; 0.417]	29.327	<.001***
Object (Distractor)	0.008 (0.019)	[-0.029; 0.045]	0.405	>.999
Together				
By-Subjects				
Intercept (Competitor)	0.451 (0.014)	[0.423; 0.478]	32.030	<.001***
Object (Distractor)	-0.061 (0.020)	[-0.100; -0.022]	-3.080	.008**
By-Items				
Intercept (Competitor)	0.457 (0.016)	[0.426; 0.488]	29.208	<.001***
Object (Distractor)	-0.066 (0.022)	[-0.109; -0.022]	-2.971	.012*

*** $p < .001$; ** $p < .01$; * $p < .05$.

In both by-subjects and by-items analyses we found a significant difference in the transformed proportion of fixations on the objects (Competitor and Distractor) in the Together condition (both $ps < .05$), with a larger transformed proportion of fixations on the competitor than the distractor. In the Apart condition, we found no significant difference in the transformed proportion of fixations on the competitor and distractor in both by-subjects and by-items analyses (both $ps = 1$). Again, we evaluated evidence in support of the null hypothesis using the BIC approximations to the Bayes factors. We created a model for the two objects in the Apart condition using the same model specification as above (H_1) and a null model based on the same model but without the fixed effect of object (H_0). The BIC approximations to the Bayes factors show that the data are more likely under the null than the alternative hypothesis for both by-subjects and by-items analyses (by-subjects: $BIC(H_0) = -212.84$, $BIC(H_1) = -208.436$, $BF_{01} \approx 9.035$; by-items: $BIC(H_0) = -138.69$ $BIC(H_1) = -134.7$,

$BF_{01} \approx 7.352$). This suggests that fixations on the competitor and distractor likely do not differ in the Apart condition.

Interim Discussion

These results show that during the critical noun region ('piano') + 300ms, semantic competition occurs in the Together condition but not in the Apart condition, and as a result the competitor is more accessible in the Together than the Apart condition. As the proportion of fixations allocated to the distractor does not differ across conditions, this suggests that this pattern of effects is not due to an increase in accessibility for the distractor in the Apart condition, but is likely derived from competition between the target and competitor in the Together condition.

However, the Together and Apart conditions differed not only in terms of the spatial proximity of the target and competitor within the narrative, but also in terms of the surface proximity between the target and competitor. For example, in 'The piano and the trumpet are in the bar. The carrot and the lantern are in the gallery.' (i.e. the Together condition), the target (piano) and competitor (trumpet) are mentioned together with no other objects mentioned between them. However, in 'The piano and the lantern are in the bar. The carrot and the trumpet are in the gallery.', two intervening objects are mentioned between the target and competitor. As a result, the mismatch in the surface proximity of the target and competitor could impact competition either due to mismatches in memory decay as a function of time, or due to the intervening objects interfering for access of the target (and subsequently, the competitor) in the Apart condition. To address this possibility, we report a further analysis of the Apart condition that assesses whether accessibility for the competitor decreases as the surface proximity between the target and competitor increases from 0 to 1 to 2 intervening objects (which were counterbalanced across items).

Additionally, we report a further analysis that addresses two other potential causes for the observed results. Firstly, it is possible that competition in the Together condition is driven by association of objects with the same location increasing the semantic overlap between them. Secondly, the analyses controlling for surface proximity do not also control for whether the competitor is in the same sentence as the target. Thus, simple association of objects with the same sentence might drive competition. To address these possibilities, this second additional analysis focuses on the Apart condition only, but tests whether accessibility for a single distractor, rather than the mean of the two distractors (as in the main analyses and pairwise tests), varies depending upon whether or not it is described in the same location/sentence as the target. This is necessary as in the main analyses and pairwise tests the average of the two distractors aggregates across cases where the distractor is both together with and apart from the target. Crucially, this differs from the previous analyses in that accessibility for a distractor is measured as a function of whether or not the distractor, rather than the competitor, is described in the same location as the target. If grouping of objects by the same narrative location/sentence changes the semantic overlap between unrelated objects, then we should expect the distractor to be more accessibile when described in the same narrative location/sentence as the target.

Controlling for Effects of Surface Proximity

Here we used the same data preparation techniques outlined in our main analyses: restricting our region of analysis to the critical noun (e.g. piano) + 300ms, aggregating the data separately by subjects and items, and transforming the dependent variable into arcsine square root transformed proportions of fixations. We restricted our analysis to the competitor object for items in the Apart condition only, within which items can be assigned to 1 of 3 proximity conditions pertaining to whether 0, 1, or 2 objects were mentioned between the target and competitor. For example, in our example spoken discourses, in the Apart condition

(3) has a surface proximity of 2 as the lantern and carrot are mentioned between the piano

and trumpet, while (4) has a surface proximity of 0 as no other objects are mentioned

between the piano and trumpet. Accordingly, other items had sentences with a surface

proximity of 1, where only one object was mentioned between the target and competitor.

(Conversely, in the Together condition the target and competitor were always mentioned

together, with no other objects mentioned between them. Therefore, this condition was

excluded from the analysis.) There were 16 items for each proximity condition. If the

transformed proportion of fixations on the competitor does not differ as a measure of surface

proximity then this provides compelling evidence that this factor alone cannot drive the

effects reported in our main analyses.

Means (*SD*) and 95% confidence intervals for the proportion and arcsine square root

transformed proportion of fixations on the competitor (trumpet) are presented in Table 6 as a

measure of surface proximity during the critical noun region ('piano') + 300ms in

Experiment 1.

Table 6. Means, standard deviations (*SD*), and 95% confidence intervals (95% CI) for the proportion (Proportion) and transformed proportion (Asin) of fixations on the Competitor (trumpet) as a measure of surface proximity (by the number of other objects mentioned between the target and competitor) during the critical noun region ('piano') + 300ms in Experiment 1

	Dependent Variable			
	Proportion		Asin	
Proximity	Mean (*SD*)	95% CI	Mean (*SD*)	95% CI
0	.140 (0.131)	[.106; .174]	0.319 (0.232)	[0.259; 0.379]
1	.155 (0.096)	[.130; .180]	0.381 (0.153)	[0.341; 0.420]
2	.149 (0.143)	[.112; .186]	0.333 (0.240)	[0.271; 0.395]

Note. Examples of each proximity type (all in the Apart condition): (i) Proximity 0 – *The lantern and the piano (Target) are in the bar. The trumpet (Competitor) and the carrot are in the gallery*; (ii) Proximity 1 – *The piano (T) and the lantern are in the bar. The trumpet (C) and the carrot are in the gallery. Or, The lantern and the piano (T) are in the bar. The carrot and the trumpet (C) are in the gallery*; (iii) Proximity 2 – *The piano (T) and the lantern are in the bar. The carrot and the trumpet (C) are in the gallery;* Half of the items had the target first (as in the examples above), and the other half had the competitor first.

We analysed the data using linear mixed effects models. The by-subjects and by-items analyses contained fixed effects of the treatment-coded proximity condition. Here, the random effects structure took the form of random intercepts by subjects/items. As the proximity condition has 3 levels (i.e. 0, 1, or 2 items mentioned between the target and competitor) we first fitted the full model to our data prior to conducting pairwise comparisons (with Bonferroni corrections) using the *glht* function from the *multcomp* package in R (Version 1.4.8; Hothorn, Bretz, & Westfall, 2008). These comparisons explored differences in the transformed proportion of fixations on the competitor at each level of proximity. The results of these pairwise comparisons are reported in Table 7.

Table 7. Parameter estimates, standard errors (*SE*), and 95% confidence intervals (95% CI) for the pairwise comparisons exploring the effect of surface proximity between the target and competitor on the transformed proportion of fixations on the competitor during the critical noun region ('piano') + 300ms in Experiment 1

Model Terms	Est. (*SE*)	95% CI	t	p
By-Subjects				
0 vs. 1	0.062 (0.038)	[-0.028; 0.152]	1.612	.321
0 vs. 2	0.014 (0.038)	[-0.076; 0.104]	0.359	>.999
2 vs. 3	-0.048 (0.038)	[-0.138; 0.042]	-1.253	.631
By-Items				
0 vs. 1	0.026 (0.042)	[-0.073; 0.126]	0.618	>.999
0 vs. 2	-0.002 (0.042)	[-0.101; 0.098]	-0.038	>.999
2 vs. 3	-0.028 (0.042)	[-0.127; 0.072]	-0.656	>.999

*** $p <.001$; ** $p <.01$; * $p <.05$.

We found no significant differences between each level of proximity in both the by-subjects and by-items models. Therefore, as in our main analyses comparisons, we assessed the evidence in support of the null hypothesis for these comparisons using the BIC approximations to the Bayes factors (Wagenmakers, 2007). While the by-subjects data contains one observation of each condition for each subject, the by-items data contains one observation for between one and two conditions for each item. Thus, the models for the by-subjects data are fitted as a linear mixed effects model (as above), with random intercepts by subjects. However, the by-items models are instead fitted with a general linear model given

that no random intercept can be estimated for each level of proximity within each item. In

each case, the BIC approximations to the Bayes factors are calculated in the same way as in

our main analyses. The results of these analyses are reported in Table 8.

Table 8. BIC and BIC approximations to the Bayes factors in support of the null hypothesis
for each model for the effect of proximity during the critical noun region ('piano') + 300ms
in Experiment 1

Model	BIC (H_0)	BIC (H_1)	Approximate BF_{01}
By-Subjects			
0 vs. 1	-28.100	-21.400	27.960
0 vs. 2	12.500	21.600	96.480
2 vs. 3	-26.200	-18.500	46.030
By-Items			
0 vs. 1	-54.800	-52.000	4.080
0 vs. 2	-32.500	-29.100	5.650
2 vs. 3	-36.000	-32.900	4.620

Together, the approximations to the Bayes factors for all comparisons show evidence

in support of the null hypothesis (all $BF_{01} \gtrsim 3$). Thus, the proximity of mention between the

target and competitor is unlikely to play a role in the accessibility for the competitor. Instead,

the spatial narrative location is still a likely candidate for the effects reported in our main

analyses.

Spatial Context Effects on Semantically Unrelated Objects

Having shown that the spatial narrative context likely drives the effects reported in

our main analyses, we further explored the mechanism with which spatial narrative context

modulates semantic competition. This analysis addresses the possibility that the spatial

narrative context changes semantic representations of the objects themselves, rather than

changing event representations (and thus accessibility for objects/overlapping features

between objects). If spatial association alone is enough to modulate semantic representations,

then distractors should be more accessible when described in the same narrative location as

the target (vs. a separate narrative location). Specifically, this account predicts that grouping of objects by spatial narrative location increases the conceptual overlap between the items maintained in the same location, even if those items are semantically unrelated to one another. Alternatively, if spatial association has no impact on accessibility for the distractor, this implies that changes to the spatial narrative context do not directly modulate overlap between objects in the same/different location(s), but instead modulates accessibility for otherwise competitive sources of information (e.g. for semantically-related objects). Additionally, this analysis directly tests whether simply mentioning two objects in the same sentence could drive semantic competition. Similarly, this account predicts that even unrelated objects mentioned in the same sentence will compete with one another. However, if the sentence structure plays no role in competition then the distractor should be equally accessible regardless of whether it is described in the same or separate sentence as the target.

We again restrict our analyses to the Apart condition only, which is the only condition that varies whether or not the distractors are mentioned in the same or a separate location to the target. As such, here our condition labels of Together and Apart refer to whether the target and *distractor* are described in the same (Together) or separate (Apart) location(s) as the target, and not whether the target and *competitor* are described in the same or separate location(s). Means (*SD*) and 95% confidence intervals for the proportion and arcsine square root transformed proportion of fixations on the distractor (e.g. carrot, lantern) are presented in **Error! Reference source not found.** as a measure of whether the target and distractor are mentioned in the same (Together) or separate (Apart) narrative locations during the critical noun region ('piano') + 300ms in Experiment 1.

Table 9. Means, standard deviations (*SD*), and 95% confidence intervals (95% CI) for the proportion (Proportion) and transformed proportion (Asin) of fixations on a single distractor (e.g. carrot, lantern) as a measure of whether the target and distractor are mentioned in the same (Together) or separate (Apart) narrative locations during the critical noun region ('piano') + 300ms in Experiment 1

	Dependent Variable			
	Proportion		Asin	
Target-Distractor Grouping	Mean (*SD*)	95% CI	Mean (*SD*)	95% CI
Apart	.146 (.077)	[.127; .166]	0.379 (0.114)	[0.350; 0.409]
Together	.160 (.083)	[.139; .182]	0.396 (0.127)	[0.363; 0.429]

Note. Examples of the new 'Apart' and 'Together' conditions based on the Target and Distractor grouping (all in the original Apart condition): (i) Together – *The piano (Target) and the carrot (Distractor) are in the bar. The trumpet (Competitor) and the lantern are in the gallery*; (ii) Apart – *The piano (T) and lantern are in the bar. The trumpet (C) and the carrot (D) are in the gallery*; For the other distractor ('the lantern'), the condition labels were swapped.

We analysed the data using linear mixed effects models. The by-subjects and by-items analyses contained fixed effects of the treatment-coded grouping condition. Here, the random effects structure took the form of random intercepts by subjects/items. In both models, the intercept represents the transformed proportion of fixations on the distractor in the Apart condition, with the effect of grouping evaluating the difference in the transformed proportion of fixations on the distractor between the Apart condition and the Together conditions. The results of these analyses are presented in Table 10.

Table 10. Parameter estimates, standard errors (*SE*), and 95% confidence intervals (95% CI) for the models exploring the effect of grouping for the target and a single distractor in the same (Together) or separate (Apart) narrative locations on the transformed proportion of fixations on the distractor (carrot, lantern) during the critical noun region ('piano') + 300ms in Experiment 1

Model Terms	Est. (*SE*)	95% CI	*t*	*p*
By-Subjects				
Intercept (Apart)	0.379 (0.016)	[0.349; 0.410]	24.289	<.001
Grouping (Together)	0.017 (0.022)	[-0.027; 0.060]	0.748	.454
By-Items				
Intercept (Apart)	0.382 (0.018)	[0.346; 0.417]	21.022	<.001
Grouping (Together)	0.022 (0.026)	[-0.028; 0.073]	0.874	.382

*** *p* <.001; ** *p* <.01; * *p* <.05.

We found no significant differences in the transformed proportion of fixations on the distractor regardless of whether the target and distractor were described in the same or separate narrative location(s) to the target. We further assessed the evidence in support of the null hypothesis for these comparisons using the BIC approximations to Bayes factors (Wagenmakers, 2007), using a similar method to that described above. Here, models took the same form as that described for the null hypothesis significance tests, with the reduced model excluding the factor of interest (i.e. grouping). The BIC approximations to the Bayes factors show that the data are more likely under the null than the alternative hypothesis for both by-subjects and by-items analyses (by-subjects: $BIC(H_0) = -146.347$, $BIC(H_1) = -136.33$, $BF_{01} \approx 149.655$; by-items: $BIC(H_0) = -91.54$, $BIC(H_1) = -82.659$, $BF_{01} \approx 84.807$). This suggests that there is no difference in the transformed proportion of fixations on the distractor regardless of whether it is described in the same or a separate narrative location to the target.

Together, these findings suggest that the association of objects with the same narrative location/sentence as the target is not enough to modulate semantic overlap between the target and distractor, and thus influence accessibility for the distractor on mention for the target. Thus, we conclude that the narrative location, rather than the sentence structure, modulates semantic competition on access for the target. This effect is likely due to changing the accessibility of the competitor in the representation of the narrative events (and thus the accessibility of overlapping features in semantic memory), rather than changing the overall semantic overlap between the target and competitor in semantic memory.

Summary of Results

These results show that during the critical noun region ('piano') + 300ms, the competitor is more accessible in the Together than the Apart condition, resulting in semantic competition in the Together condition only. Additionally, in the Apart condition the

competitor was equally accessible regardless of differences in the surface proximity between the target and competitor, suggesting that such differences are unlikely to modulate the semantic competition effects between the Together and Apart conditions. Finally, association of the distractor with the same (vs. a separate) narrative location/sentence as the target did not make the distractor more accessible, suggesting that the spatial narrative context modulates semantic competition between the target and competitor due to differences in accessibility for objects in certain event representations, rather than by changing the semantic overlap between objects in the same/separate location(s). This experiment thus provides compelling evidence that the spatial narrative context influences accessibility not only for items held in working memory, but also for items held in semantic memory.

Discussion

An open question raised by these results concerns the interface between spatial narrative context and modality compatibility (specifically, language processing in the visual world paradigm), as addressed in prior research (e.g., Connell & Lynott, 2014; Yee et al., 2012). We conclude from Experiment 1 that the spatial narrative context modulates semantic competition by making certain objects less accessible (i.e. those in a different location to the target). When the competitor is in a different spatial narrative context to the target, the competitor is thus less accessible on mention for the target, making the competitor less likely to compete with the target. However, it is possible that the spatial narrative context can only modulate competition for features that are not highly relevant to the ongoing task, i.e. of processing visual and linguistic stimuli in the visual world paradigm, which does not explicitly focus attention on the semantic overlap between objects. However, as an experimental procedure, the visual world paradigm specifically emphasises the visual dimension, thus making visual features highly salient during processing. Therefore, might

very different results be observed for visual competition (e.g., Dahan & Tanenhaus, 2005), which likewise focuses on visual similarity?

In Experiment 2, we chose to focus on visual competition rather than other types of competition primarily because the visual world paradigm is a procedure that draws attention to the visual modality. As Connell and Lynott (2014) found enhanced priming for words associated with or experienced in visual contexts during tasks with a visual component, we predicted that visual features would be highly salient (and thus highly accessible) in the visual world paradigm. Thus, visual competition, which relies on the visual aspects of a word, may not be subject to spatiotemporal discourse context effects in the same way as other competition effects (i.e. that do not draw on the visual aspects of a word, as in Experiment 1) in the context of the visual world paradigm. To test whether non-visual information, i.e. discourse context, can modulate competition for visual features in the visual world paradigm, in Experiment 2 we used a similar methodology to that employed in Experiment 1, but we replaced the semantic competitors with visual competitors (see Figure 3).

Experiment 2

Experiment 2 aimed to explore whether the discourse context can modulate competition for features that are highly salient due to compatibility with the modality of perceptual attention and the information to be retrieved (e.g. visual features in the visual world paradigm), thereby influencing competition for visually similar objects (e.g. bat and cigarette). To do so, participants viewed a visual scene containing two visually similar objects and two distractors while listening to discourse describing the visually similar objects in the same (i.e. Together condition) or separate (i.e. Apart condition) narrative locations before re-mentioning one of the objects (i.e. the target). This experiment allowed us to test for two main predictions (amongst others): If accessibility for visual information can be modulated by the spatial

narrative context, then the same pattern of results found in Experiment 1 should be found here. Specifically, visual competition should be greatest when the visually similar objects are described in the same (i.e. Together condition) narrative location rather than in different narrative locations (i.e. the Apart condition). Alternatively, if the modality compatibility biases attention towards visual features, which the visual world paradigm presumably does, then we should find visual competition regardless of the discourse context (i.e. a main effect of object only).

Method

Participants

A separate cohort of 60 (16 male) participants to those that took part in Experiment 1 was tested here. All participants were native speakers of English from the University of Dundee community (aged 18 – 42, $M = 19.85$, $SD = 3.51$) and took part in this study for partial course credit. All participants had uncorrected vision, wore soft contact lenses, or wore spectacles, and had no known auditory, visual, or language disorders.

Materials

All items were created using similar methods to those used in Experiment 1. However, for this experiment all images were presented in greyscale to eliminate any overlap in colour between items such that visual similarity would primarily be determined by visual shape. Thus, we created 32 experimental visual displays such as that depicted in Figure 3.
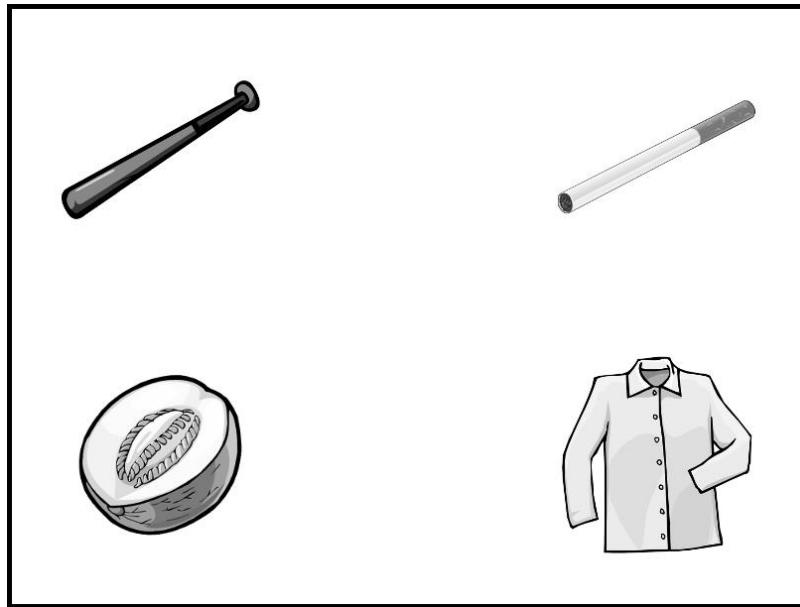
Figure 3. Example visual array paired with spoken discourses (e.g. (5) – (8)) in Experiment 2

Visual displays were paired with pre-recorded spoken discourses, such as those

outlined in (5) – (8) below.

> (5) **Together condition:** The bat and the cigarette are in the cafeteria. The melon and the shirt are in the parlour. It seems that the bat is beautifully made.

> (6) **Together condition:** The melon and the shirt are in the cafeteria. The bat and the cigarette are in the parlour. It seems that the bat is beautifully made.

> (7) **Apart condition:** The bat and the shirt are in the cafeteria. The melon and the cigarette are in the parlour. It seems that the bat is beautifully made.

> (8) **Apart condition:** The melon and the cigarette are in the cafeteria. The bat and the shirt are in the parlour. It seems that the bat is beautifully made.

Each visual display contained 4 (greyscale) inanimate objects that were

phonologically distinct (i.e. with no rhyme or cohort names), two of which (i.e. the target and

competitor) were visually similar to one another. Two distractors were also included, which

were visually distinct to one another, the target, and the competitor. The target, competitor,

and distractors were selected as appropriate visual competitors or distractors by experimenter

judgment. Furthermore, all objects could conceivably be contained within their described

locations. The order for the locations of each object in each visual scene was pseudo-

randomised using similar methods to that outlined in Experiment 1. Each visual array was

paired with one of 4 spoken discourses, which varied the described locations of each object in a narrative; see (5) - (8). Similarly to Experiment 1, the target (e.g. bat) and competitor (e.g. cigarette) could be described in the same (e.g. (5) and (6)) or separate (e.g. (7) and (8)) locations; corresponding to the Together and Apart conditions respectively. Again, we counterbalanced the order of mention of the target in each sentence within items and conditions, such that the target could be mentioned in the first sentence (e.g. (5) and (7)) or second sentence (e.g. (6) and (8)) respectively. As in Experiment 1, our analyses collapsed across both cases to control for any primacy/recency of mention effects for the target and competitor (Rinck et al., 1998). Thirty-two filler items were also constructed in a similar way to the experimental items but referred back to one of the distractors in the final sentence. For a full list of the experimental sentential stimuli used, see Appendix B.

LSA was used to control for any differences in the semantic relatedness between targets and competitors ($M = .08$), targets and distractors ($M = .07$), and competitors and distractors ($M = .05$). Additionally, the target and competitor were equally related to both locations within items ($M = .07$). This analysis was performed in the same way as in Experiment 1. Thus, it is unlikely that, on mention for the target, any difference between conditions in the proportion of fixations on the competitor and distractor will be driven by an imbalance in semantic similarity between the objects and locations mentioned in the discourse.

Procedure

A similar procedure to that used in Experiment 1 was used here. The two experiments differed only in their items used; with visual competitors replacing semantic competitors in this experiment, and with all images displayed in greyscale. Each visual scene remained on-screen for the duration of the trial (average of 19, 280ms) so that the visual scenes and

auditory stimuli were presented concurrently. Similarly to Experiment 1, 4 practice trials consisting of 2 experimental-type and 2 filler-type items were included at the beginning of testing, with participants having the opportunity to ask any questions prior to the continuation of testing. The experimental session consisted of 32 experimental and 32 filler items as outlined in the materials. For all trials, each scene was displayed for a preview of 1000ms and remained onscreen for the duration of the trial; sentences 1 and 2 were played after this preview. One thousand milliseconds after the offset of the second sentence, the 3rd (critical) sentence was played. Each individual trial was automatically terminated 4000ms after the offset of the final sentence. The average durations, onsets, and offsets for each region are presented in Table 11. The full testing session lasted approximately 30 minutes.

Table 11. Mean durations (ms) of temporal regions in the experimental sentences in Experiment 2

Label	Region	Onset	Offset	Duration
Sentences 1 and 2				
	'The bat and the cigarette are in the cafeteria. The melon and the shirt are in the parlour.'	1060	10,490	9430
Sentence 3				
verb phrase	'It seems that'	11,490	12,725	1235
determiner	'the'	12,725	13,070	345
object noun	'bat' (target)	13,070	13,585	515
verb	'is'	13,585	13,995	410
adverb	'beautifully'	13,995	14,700	705
adjective	'made'	14,700	15,280	580

Note: Sentences 1 and 2 varied across conditions. The region example provided above is based on one of the four conditions outlined in Sentences (5) – (8), i.e. (5).

Results

Similar analyses to those carried out in Experiment 1 were used here, using the same programs and packages. In line with Experiment 1, we conducted our analyses during the earliest point with which visual competition effects have previously been shown in order to detect visual competition effects during lexical access. As prior research suggests that fixations on visual competitors can diverge from those on unrelated distractors around 200 –

300ms after target onset and continue until around 1200ms after target onset (Dahan & Tanenhaus, 2005), we selected the window spanning from the onset of the critical noun (e.g. bat) + 200ms until the offset of the critical noun + 200ms (henceforth, critical noun + 200ms). This region presumably reflects lexical processing and the earliest point with which visual competition can occur.

We also conducted a further analysis during a later region spanning from the onset of the critical noun + 400ms until the offset of the critical noun + 400ms. This region was selected as previous research has shown that, given a long preview of the visual display prior to the onset of the critical noun, visual competition effects occur 100ms later than semantic competition effects when the target is absent from the display. Additionally, this research has also shown that fixations on the target diverge from those on distractors starting from 400 – 500ms after the critical noun onset when the target is present in the display (de Groot, Huettig, and Olivers, 2016). Given that our main focus is on modulating visual competition, and not on detecting the earliest point with which competition can occur, and that participants viewed the visual display for an average of 13,070ms prior to the target onset – during which the target was already mentioned – we selected the region of the critical noun + 400ms. This region presumably reflects post-lexical processing and the point at which visual competition is strongest, and thus most susceptible to modulation by the discourse context.

Means and standard errors for the proportion of fixations on the target (piano), competitor (trumpet), and the mean of the two distractors (carrot, lantern; henceforth 'distractor') are plotted in Figure 4 from the onset of the critical noun ('bat') until the offset of the adjective ('made') during the final sentence. (Although we use this example item throughout, analyses included all items).
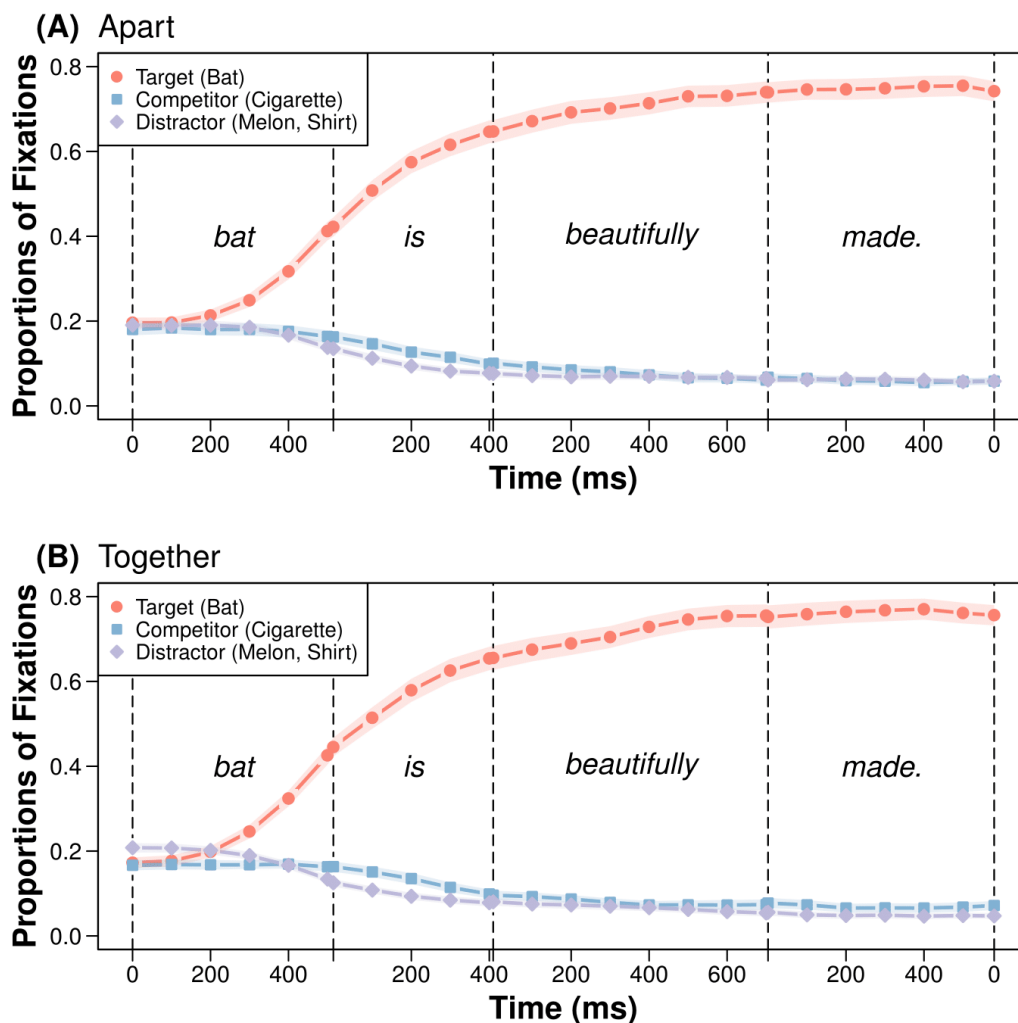
Figure 4. Mean proportion of fixations (shaded bands show ± 1 *SE* of the mean) on the target (bat), competitor (cigarette) and distractor (melon, shirt) in the Apart (A) and Together (B) conditions in Experiment 2. Vertical broken lines indicate points at which fixations were resynchronised in the discourse.

During the critical noun region ('bat') + 200ms

Means (*SD*) and 95% confidence intervals for the proportion and arcsine square root transformed proportion of fixations on each object are presented in Table 12 for each condition during the critical noun region ('bat') + 200 ms in Experiment 2.

Table 12. Means, standard deviations (*SD*), and 95% confidence intervals (95% CI) for the proportion of fixations (Proportion) and the transformed proportion of fixations (Asin) on each object (competitor, distractor) in each condition (Apart, Together) during the critical noun region ('bat') + 200ms in Experiment 2

Object	Condition	Proportion Mean (*SD*)	Proportion 95% CI	Asin Mean (*SD*)	Asin 95% CI
Competitor	Apart	.167 (.099)	[.142; .193]	0.404 (0.138)	[0.368; 0.440]
Competitor	Together	.164 (.071)	[.145; .182]	0.408 (0.098)	[0.382; 0.433]
Distractor	Apart	.157 (.069)	[.140; .175]	0.399 (0.098)	[0.374; 0.424]
Distractor	Together	.159 (.062)	[.143; .175]	0.403 (0.089)	[0.380; 0.426]

For Experiment 2, we used the same methods of analyses outlined in Experiment 1. Table 13 shows the fixed effects parameter estimates (and standard errors), 95% confidence intervals, *t*-values, and *p*-values (calculated using the normal approximation) for the analysis during the critical noun region ('bat') + 200ms in Experiment 2.

Table 13. Parameter estimates, standard errors (*SE*), and 95% confidence intervals (95% CI) during the critical noun region ('bat') + 200ms in Experiment 2

Model Terms	Est. (*SE*)	95% CI	*t*	*p*
By-Subjects				
Intercept (Grand Mean)	0.403 (0.010)	[0.384; 0.423]	40.321	<.001***
Condition	0.004 (0.010)	[-0.017; 0.024]	0.353	.724
Object	0.005 (0.013)	[-0.019; 0.030]	0.417	.677
Condition × Object	0.000 (0.021)	[-0.041; 0.041]	-0.003	.997
By-Items				
Intercept (Grand Mean)	0.409 (0.008)	[0.394; 0.424]	54.204	<.001***
Condition	0.000 (0.011)	[-0.022; 0.021]	-0.012	.991
Object	0.008 (0.015)	[-0.022; 0.037]	0.505	.613
Condition × Object	-0.006 (0.022)	[-0.049; 0.036]	-0.291	.771

*** *p* <.001; ** *p* <.01; * *p* <.05.

During the critical noun region ('bat') + 200ms we found no main effect of condition or object, and no significant interaction between condition and object across the by-subjects and by-items analyses (all *p*s > .05). Here, we evaluated evidence in support of the null hypothesis using the BIC approximations to the Bayes factors. We created an alternative model evaluating the main effects and interactions for object and condition using the same model specification as above (H$_1$), and other alternatives with the same model specification

but without the fixed effect of condition (H_2), or without the fixed effect of object (H_3), or without the interaction of object and condition (H_4). The BIC for all models is displayed in Table 14, along with the BIC approximation to the Bayes factor for each model in relation to the maximal model used to fit the data (i.e. H_1). The approximations to the Bayes factors compare evidence against the maximal model in relation to models containing all other factors except the one of interest.

Table 14. BIC and BIC approximation to the Bayes factor for each model during the critical noun region ('bat') + 200ms in Experiment 2

Model	BIC	Approximate Bayes Factor comparison	Approximate Bayes Factor
By-Subjects			
H1: Maximal model (with all terms)	-387.703	–	–
H2: H1 without Condition	-393.057	BF_{21}	14.541
H3: H1 without Object	-393.007	BF_{31}	14.185
H4: H1 without Condition × Object	-393.184	BF_{41}	15.492
By-Items			
H1: Maximal model (with all terms)	-273.269	–	–
H2: H1 without Condition	-278.121	BF_{21}	11.313
H3: H1 without Object	-277.858	BF_{31}	9.919
H4: H1 without Condition × Object	-278.034	BF_{41}	10.831

The BIC approximations to the Bayes factors show that the data are more likely under the null than the alternative hypothesis for both by-subjects and by-items analyses for all model comparisons. This suggests that it is unlikely that object, condition, or their interaction plays a role in guiding fixations during the critical noun region + 200ms. Next, we analysed the data using the same methods above during the critical noun region + 400ms.

During the critical noun region ('bat') + 400ms

Means (*SD*) and 95% confidence intervals for the proportion and arcsine square root transformed proportion of fixations on each object are presented in Table 15 for each condition during the critical noun region ('bat') + 400 ms in Experiment 2.

Table 15. Means, standard deviations (*SD*), and 95% confidence intervals (95% CI) for the proportion of fixations (Proportion) and the transformed proportion of fixations (Asin) on each object (competitor, distractor) in each condition (Apart, Together) during the critical noun region ('bat') + 400ms in Experiment 2

Object	Condition	Proportion		Asin	
		Mean (*SD*)	95% CI	Mean (*SD*)	95% CI
Competitor	Apart	.145 (.093)	[.121; .169]	0.372 (0.136)	[0.337; 0.407]
Competitor	Together	.145 (.077)	[.125; .165]	0.375 (0.120)	[0.344; 0.406]
Distractor	Apart	.118 (.067)	[.101; .136]	0.338 (0.105)	[0.311; 0.365]
Distractor	Together	.117 (.061)	[.101; .133]	0.337 (0.100)	[0.312; 0.363]

Table 16 shows the fixed effects parameter estimates (and standard errors), 95% confidence intervals, *t*-values, and *p*-values (calculated using the normal approximation) for the analysis during the critical noun region ('bat') + 400ms in Experiment 2.

Table 16. Parameter estimates, standard errors (*SE*), and 95% confidence intervals (95% CI) during the critical noun region ('bat') + 400ms in Experiment 2

Model Terms	Est. (*SE*)	95% CI	t	p
By-Subjects				
Intercept (Grand Mean)	0.356 (0.011)	[0.334; 0.377]	32.804	<.001***
Condition	0.001 (0.011)	[-0.020; 0.022]	0.107	.915
Object	0.036 (0.014)	[0.009; 0.063]	2.593	.010*
Condition × Object	0.004 (0.022)	[-0.039; 0.047]	0.182	.856
By-Items				
Intercept (Grand Mean)	0.364 (0.009)	[0.347; 0.381]	42.106	<.001***
Condition	-0.002 (0.011)	[-0.024; 0.020]	-0.170	.865
Object	0.041 (0.017)	[0.007; 0.075]	2.363	.018*
Condition × Object	0.002 (0.022)	[-0.042; 0.045]	0.084	.933

*** p <.001; ** p <.01; * p <.05.

During the critical noun region ('bat') + 400ms we found a significant main effect of object in both by-subjects and by-items analyses (both ps < .05). Here, we found a larger transformed proportion of fixations on the competitor than the distractor across both conditions. However, we found no significant main effect of, or interaction of object with, the discourse condition (all ps > .05). We evaluated evidence in support of the main effect only model (H_1) in comparison to a main effects and interactions model (H_2) using the BIC approximations to the Bayes factors. Both models took the same form as that described

above, with the only difference being that the H_1 model did not contain the interaction

between the fixed effects. The BIC approximations to the Bayes factors show that the data are

more likely under the model of main effects only (with no interaction) than under the model

including the interaction term for both by-subjects and by-items analyses (by-subjects:

$BIC(H_1) = -360.00$, $BIC(H_2) = -354.55$, $BF_{12} \approx 15.23$; by-items: $BIC(H_1) = -258.73$, $BIC(H_2)$

$= -253.88$, $BF_{12} \approx 11.27$). This suggests that during the critical noun region ('bat') + 400ms in

Experiment 2, there is no interaction between object and discourse condition.

Discussion

In Experiment 2, during the critical noun region ('bat') + 200ms, we found no evidence of

visual competition. However, analyses during the critical noun region + 400ms revealed that

the competitor was more accessible than the distractor, but there was no difference in the

transformed proportion of fixations allocated to each object as a measure of condition. This

suggests that, during the critical noun region + 400ms in Experiment 2, visual competition

occurs regardless of any manipulation to discourse context. We interpret these results in light

of those from Experiment 1 in the General Discussion.

General Discussion

In two experiments, comprehenders viewed visual scenes depicting a target,

competitor, and two distractors while they listened to narratives describing the target and

competitor (as well as two distractors) in the same or separate narrative locations. In

Experiment 1, the target and competitor were semantically (throughout, we use this term to

refer to gross semantic-relatedness, as captured by LSA: e.g., piano – trumpet) but not

visually similar to one another, whereas in Experiment 2, the target and competitor were

visually but not semantically similar to one another (e.g., bat – cigarette). We aimed to

explore whether manipulations to the discourse context, specifically the described locations

of the objects in the narrative, influenced accessibility for related objects, and hence accessibility for the rich lexical-semantic information associated with the target and competitor. Thus, in both experiments, we used the transformed proportion of fixations on the competitor and distractor as a means to explore competition on access for the target.

In Experiment 1, we predicted that semantic competition on access for the target would be modulated by whether or not the target and competitor were previously described in the same or separate narrative locations. Specifically, we predicted that semantic competition would be greatest if the target and competitor were described in the same location (vs. separate locations) due to this association increasing accessibility for objects (and specifically the competitor) in the same location as the target (Glenberg et al., 1987), and thus accessibility for their overlapping features.

During the critical noun region + 300ms we found semantic competition (i.e. a larger proportion of fixations on the competitor than the mean of the two distractors) when the target and competitor were described in the same location, and no competition at all (rather than reduced competition as per our predictions) when the target and competitor were described in separate narrative locations. Further analyses showed that this effect depends on manipulations to the spatial narrative context rather than differences in surface proximity between the two conditions. Crucially, these findings innovate on prior research, revealing that spatial narrative context influences accessibility for information in semantic memory in a similar way to task context (e.g., Connell & Lynott, 2014; Yee et al., 2012).

We hypothesise that this effect is the result of the target and competitor being considered in relation to their spatial locations in the narrative: following models of event representation (e.g. Radvansky, 2012; Radvansky & Zacks, 2014), when the target is accessed, information maintained in the same event representation (i.e. spatial narrative

location) is highly accessible, and information maintained in different event representations is less accessible (Glenberg et al., 1987). Given that competition on access for the target is driven by access for the overlapping conceptual features between the target and competitor (Dahan & Tanenhaus, 2005; Huettig & Altmann, 2007; Huettig & McQueen, 2007; Yee & Sedivy, 2006) it is likely that when the target and competitor share the same narrative location, competition occurs because the competitor – and its features that overlap with the target – are highly accessible. However, when the target and competitor do not share the same narrative location, the competitor and its features that overlap with the target are thus less accessible, therefore reducing (or blocking) competition.

While these findings can be explained under an account of differences in event representations, they could also be explained by changes in semantic overlap between the target and competitor in semantic memory. Given that spatiotemporal information is crucial for autobiographical memory (Tulving, 1972), which in turn is required for abstraction and forming semantic associations between concepts (Altmann, 2017), when the target and competitor share the same narrative location, this could increase the semantic overlap between them, thus resulting in competition on access for the target. Conversely, when the target and competitor do not share the same narrative location, this could reduce semantic overlap between them, resulting in little (or no) competition on access for the target. Thus, the narrative context may directly modulate the semantic overlap between the two objects described in the discourse. However, while this may represent how long-term semantic representations form and develop, it is unlikely that simply one instance of association through the spatial narrative context can change long-term semantic representations. Still, a weaker account may argue that the associations between particular instantiations of these concepts (i.e. the objects described in the discourse, not their concepts) may be more susceptible to such immediate changes in the narrative context. Yet, if spatial association can

act to increase the semantic overlap between two objects, then the distractor should become a competitor for the target when the two objects share the same location. However, further analyses showed that the distractor is equally accessible regardless of its narrative location relative to the target, rendering such an account unsatisfactory. Such results, however, can be reconciled with an event representation account: while the distractor may well be more accessible when located in the same location as the target (vs. a different location), it is still unrelated (and irrelevant) to the target, and thus should not compete on access for the target.

Furthermore, it is possible that rather than the structure of events dictating accessibility for objects, listeners instead activate context-dependent properties of objects tied to the locations in which they are mentioned (e.g. highlighting bar-related aspects of a piano and gallery-related aspects of a trumpet on hearing the description of the piano in the bar and the trumpet in the gallery), which in turn dictates whether or not objects might compete with one another on access (Barsalou, 1982; Tabossi, Colombo, & Job, 1987). Yet, such an account relies on listeners having long-term associations between objects and locations that do not overlap across locations. While in some instances (e.g. the piano in the bar/gallery) this is plausible, for others (e.g. the jar in the reception/library; see Appendix A) it is less so. Thus, it is more likely that listeners rely on their immediate representations of events, which dictates accessibility for objects, and thus accessibility for overlapping features between objects.

To explore whether discourse context effects can influence accessibility for information stored in semantic memory when there is a high degree of modality compatibility (i.e. between attentional focus and the information to be retrieved), in Experiment 2 we used a similar paradigm to Experiment 1 but (amongst other changes) replaced the two semantically related objects in the visual scenes with visually similar objects. Here, we explored whether the spatial narrative context could modulate visual competition: a

dimension that is highly salient in the visual-world paradigm, and therefore potentially less susceptible to discourse-based modulation of competition. In this experiment, visual competition occurred during a later region (i.e. the critical noun + 400ms) while manipulations to the spatial narrative context did not modulate visual competition effects. Our findings for Experiment 2 suggest that, at least in the current paradigm, visual competition is independent and unaffected by the spatial narrative context. Crucially, the findings of Experiments 1 and 2 collectively innovate on prior research by suggesting that the discourse context differentially influences accessibility for information in semantic memory depending upon the compatibility between the modality of perceptual attention and semantic information to be retrieved (e.g., see Connell & Lynott, 2014; Yee et al., 2012).

The lack of any spatial narrative context effects on competition in Experiment 2 is consistent with previous research exploring visual competition in situations where the discourse context was related to the to-be-mentioned target (Huettig & Altmann, 2007); e.g. hearing about zookeepers in the presence of a snake and visually similar cable. Here, the discourse context established the snake as the likely target in the unfolding narrative. In such contexts, fixations on the snake occurred prior to the onset of 'snake', but fixations on the rope only increased after the onset of 'snake'. Thus, the discourse context did not modulate accessibility for the competitor. In our Experiment 2, the narrative did not allow for prediction of the target, but we instead tested whether the spatial narrative context could influence accessibility for the competitor during lexical access. Here, we similarly found that visual competition occurred independently of the discourse context.

What drives the discrepancy between the results of Experiments 1 and 2? In Experiment 1, the semantic similarity between the target and competitor is derived from shared category labels and statistical regularities abstracted across various contexts (Yee et al., 2017) that may be more or less relevant in a given context. Thus, when the target and

competitor are described in the same narrative location, the objects (and their similar

features) are highly accessible (e.g. Glenberg et al., 1987), resulting in competition. However,

when the target and competitor are described in different narrative locations, the overlapping

features are less accessible, resulting in no competition. In Experiment 2, the visual similarity

between the target and competitor is an inherent property of the visual depiction of the

objects in the experimental paradigm. While access for certain visual features, such as colour,

can be modulated by context (e.g. Huettig & Altmann, 2011; Yee et al., 2012), it is likely that

because the visual-world paradigm presents participants with visual information, attention is

biased towards the visual modality (Yee et al., 2012). Thus, the visual information associated

with the objects in the display is highly salient, which might make detecting any modulating

effects of the spatial narrative context particularly difficult. One prediction that comes from

this line of reasoning is that competition for other forms of similarity, such as conceptual

visual shape similarity (e.g. Dahan & Tanenhaus, 2005), may be manipulated by the spatial

narrative context if the experimental paradigm does not bias towards activation of these

features.

Another possible factor that contributed to the different outcomes in the experiments

is concerned with the relationship between the type of competition (semantic vs. visual) and

the type of discourse (spatial). It could be argued that spatial discourse constraints have much

more in common with visual features (in Experiment 2) than semantic features (in

Experiment 1), and that the commonality prevented the spatial discourse from having effects

on the former, but not the latter. The first type of commonality is the modality that the

information relies on. Both object shape and object location can be easily visualised and are

often associated with the visual modality, whereas semantic features (especially functions) of

objects are not often related with the visual modality. The second type of commonality

between visual features and spatial discourse is the type of memory in which the information

is stored. In our experiments, the spatial discourse constraints were given specifically for the particular discourse in the experiment (e.g., the piano being in the bar), which does not require listeners' long-term, experience-based memory. The visual properties of objects we used as the common feature between the targets and competitors in Experiment 2 (e.g., both a bat and a cigarette are long) were compatible with listeners' long-term memory, yet the features were also visually available during the experiment, which did not necessitate activation of long-term memory representations. However, the semantic features used in Experiment 1 (e.g. object functions; both a key and a lock are used to lock a door) needed to be retrieved from listeners' long-term memory. In sum, the two types of constraints – visual features (object shape) and spatial discourse (object location) – in Experiment 2 seem to have commonalities in a few domains (i.e. visual modality, memory space). Thus, the shared properties might have prevented one from modulating the other. In contrast, the semantic features (e.g. object functions, amongst others) studied in Experiment 1 seem to have much less in common with spatial discourse, and the independence of the two types of constraints might have afforded the discourse effects.

A further question for the differences between Experiment 1 and 2 is why the time course of competition differs between the two experiments. Huettig and Altmann (2007) argue that when the name of an object is mentioned, visual attention is directed towards those objects that match the conceptual and perceptual features of the named object. Yet, there is some discrepancy in the time course with which conceptual and perceptual features can guide visual attention. For example, when given a 200ms preview of a display of objects, visual attention is guided to visually similar objects prior to semantically (and even phonologically) similar objects to the target (Huettig & McQueen, 2007). However, when participants have a longer preview, semantic competition effects emerge earlier than visual competition effects by around 100ms (de Groot et al., 2016). In both experiments reported here, participants had

a long preview of the visual display (i.e. 1000ms), and the critical noun played 9965ms and 13,070ms after the display onset in Experiments 1 and 2 respectively. That we detected semantic competition during the critical noun + 300ms in Experiment 1, and visual competition during the critical noun + 400ms in Experiment 2 fits with these findings.

Conclusions

The two experiments reported here aimed to explore the role of discourse context on competition during lexical access. Using the visual-world paradigm (e.g. Tanenhaus et al., 1995), we manipulated whether discourse contexts described a to-be-mentioned target and semantic (Experiment 1) or visual (Experiment 2) competitor in the same or separate narrative location(s). In Experiment 1, we predicted that competition would be greatest when the target and competitor are described in the same (vs. separate) narrative location(s) due to an increase in accessibility for the competitor and its features that overlap with the target. Here, we found stronger effects than expected, with competition (during the critical noun region + 300ms) only occurring if the target and competitor were described in the same narrative location. Further analyses revealed no difference in accessibility for the distractor when the target and the distractor were described in the same (vs. separate) narrative location(s). This suggests that associating two objects with the same narrative location is not enough to modulate semantic overlap in the short-term, suggesting that the modulating effects of the spatial narrative context can be attributed to differences in the event representations across conditions. In Experiment 2, as in prior research (e.g. Connell & Lynott, 2014; Yee et al., 2012), we tested whether modality compatibility can determine accessibility for information stored in semantic memory during lexical access, exploring whether competition effects could be modulated for visual features that are highly salient in the visual world paradigm. Here, we found competition during a later region (i.e. the critical noun region + 400ms), with no effect of the discourse context.

Innovating on prior research, we have shown that, like task context, the spatial narrative context can modulate accessibility for information in semantic memory in addition to information from working memory. However, the modulating effect of the spatial narrative context is dependent on the compatibility between the modality of perceptual attention and the type of information to be retrieved. When perceptual attention does not bias towards activation of the type of information to be retrieved (e.g. the visual world paradigm does not bias towards activation of gross semantic categories), the spatial narrative context can influence accessibility for this information by increasing/decreasing accessibility for discourse referents and their overlapping semantic features. However, when perceptual attention biases towards activation of the type of information to be retrieved (e.g. the visual world paradigm biases towards activation of visual features), the spatial narrative context is unlikely to influence competition. Thus, we show compelling evidence that the ongoing task and narrative contexts are important factors in determining competition during lexical access. As such, these findings show direct support for recent theories of semantic memory (e.g. Altmann, 2017; Yee et al., 2017; Yee & Thompson-Schill, 2016), which argue that activation of individual features or properties associated with concepts is relatively fluid and is largely context-dependent. Additionally, these findings extend the substantial body of work in event cognition (Glenberg et al., 1987; Morrow et al., 1987; Radvansky & Copeland, 2006; Radvansky et al., 2011; Rinck & Bower, 1995), showing that the spatiotemporal makeup of narrative events plays a role in determining accessibility for information stored in long-term semantic memory in addition to its influences on working memory.

References

Altmann, G. T. M. (2004). Language-mediated eye movements in the absence of a visual

world: The "blank screen paradigm". *Cognition*, *93*(2), 79–87.

https://doi.org/10.1016/j.cognition.2004.02.005

Altmann, G. T. M. (2017). Abstraction and generalization in statistical learning: implications

for the relationship between semantic types and episodic tokens. *Philosophical*

Transactions of the Royal Society of London. Series B, Biological Sciences, *372*, 1–9.

https://doi.org/http://dx.doi.org/10.1098/rstb.2016.0060

Altmann, G. T. M., & Kamide, Y. (2009). Discourse-mediation of the mapping between

language and the visual world: Eye movements and mental representation. *Cognition*,

111(1), 55–71. https://doi.org/10.1016/j.cognition.2008.12.005

Baayen, R. H., Davidson, D. J., & Bates, D. M. (2008). Mixed-effects modeling with crossed

random effects for subjects and items. *Journal of Memory and Language*, *59*(4), 390–

412. https://doi.org/10.1016/j.jml.2007.12.005

Barr, D. J., Gann, T. M., & Pierce, R. S. (2011). Anticipatory baseline effects and

information integration in visual world studies. *Acta Psychologica*, *137*(2), 201–207.

https://doi.org/10.1016/j.actpsy.2010.09.011

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(3), 255–278. https://doi.org/10.1016/j.jml.2012.11.001

Barsalou, L. W. (1982). Context-independent and context-dependent information in concepts.

Memory & Cognition, *10*(1), 82–93.

Bates, D., Mächler, M., Bolker, B. M., & Walker, S. C. (2015). Fitting Linear Mixed-Effects Models using lme4. *Journal of Statistical Software*, *67*(1), 1–48. https://doi.org/10.18637/jss.v067.i01

Boersma, P., & Weenik, D. (2017). Praat: Doing Phonetics by Computer. Retrieved from http://praat.org/

Connell, L., & Lynott, D. (2014). I see/hear what you mean: Semantic activation in visual word recognition depends on perceptual attention. *Journal of Experimental Psychology: General*, *143*(2), 527–533. https://doi.org/10.1037/a0034626

Dahan, D., & Tanenhaus, M. K. (2005). Looking at the rope when looking for the snake: Conceptually mediated eye movements during spoken-word recognition. *Psychonomic Bulletin & Review*, *12*(3), 453–459. https://doi.org/10.3758/BF03193787

de Groot, F., Huettig, F., & Olivers, C. N. L. (2016). When meaning matters: The temporal dynamics of semantic influences on visual attention. *Journal of Experimental Psychology: Human Perception and Performance*, *42*(2), 180–196. https://doi.org/10.1037/xhp0000102

Glenberg, A. M., Meyer, M., & Lindem, K. (1987). Mental models contribute to foregrounding during text comprehension. *Journal of Memory and Language*, *26*(1), 69–83. https://doi.org/10.1016/0749-596X(87)90063-5

Hoover, M. A., & Richardson, D. C. (2008). When facts go down the rabbit hole: Contrasting features and objecthood as indexes to memory. *Cognition*, *108*(2), 533–542. https://doi.org/10.1016/j.cognition.2008.02.011

Hothorn, T., Bretz, F., & Westfall, P. (2008). Simultaneous inference in general parametric models. *Biometrical Journal*, *50*(3), 346–363. https://doi.org/10.1002/bimj.200810425

Huettig, F., & Altmann, G. T. M. (2005). Word meaning and the control of eye fixation: Semantic competitor effects and the visual world paradigm. *Cognition*, *96*(1), B23-32. https://doi.org/10.1016/j.cognition.2004.10.003

Huettig, F., & Altmann, G. T. M. (2007). Visual-shape competition during language-mediated attention is based on lexical input and not modulated by contextual appropriateness. *Visual Cognition*, *15*(8), 37–41. https://doi.org/10.1080/13506280601130875

Huettig, F., & Altmann, G. T. M. (2011). Looking at anything that is green when hearing "frog": How object surface colour and stored object colour knowledge influence language-mediated overt attention. *Quarterly Journal of Experimental Psychology*, *64*(1), 122–145. https://doi.org/10.1080/17470218.2010.481474

Huettig, F., & McQueen, J. M. (2007). The tug of war between phonological, semantic and shape information in language-mediated visual search. *Journal of Memory and Language*, *57*(4), 460–482. https://doi.org/10.1016/j.jml.2007.02.001

Huettig, F., Quinlan, P. T., McDonald, S. A., & Altmann, G. T. M. (2006). Models of high-dimensional semantic space predict language-mediated eye movements in the visual world. *Acta Psychologica*, *121*(1), 65–80. https://doi.org/10.1016/j.actpsy.2005.06.002

Kimball, S., Mattis, P., & The GIMP Development Team. (1995). GNU Image Manipulation Program. Retrieved from https://www.gimp.org/

Kukona, A., Altmann, G. T. M., & Kamide, Y. (2014). Knowing what, where, and when: Event comprehension in language processing. *Cognition*, *133*(1), 25–31. https://doi.org/10.1016/j.cognition.2014.05.011

Landauer, T. K., & Dumais, S. T. (1997). A solution to Plato's problem: The latent semantic

analysis theory of acquisition, induction, and representation of knowledge. *Psychological Review*, *104*(2), 211–240. https://doi.org/10.1037//0033-295X.104.2.211

Landauer, T. K., Foltz, P. W., & Laham, D. (1998). An introduction to latent semantic analysis. *Discourse Processes*, *25*(2–3), 259–284. https://doi.org/10.1080/01638539809545028

Mazzoni, D., & Dannenberg, R. (2016). Audacity. Retrieved from http://audacityteam.org/

Mirman, D. (2014). *Growth Curve Analysis and Visualization Using R*. Boca Ranton, FL.: Chapman and Hall/CRC Press.

Morrow, D. G., Greenspan, S. L., & Bower, G. H. (1987). Accessibility and situation models in narrative comprehension. *Journal of Memory and Language*, *26*(2), 165–187.

Parkhurst, D., Law, K., & Niebur, E. (2002). Modelling the role of salience in the allocation of visual selective attention. *Vision Research*, *42*(1), 107–123.

R Core Team. (2017). R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. Retrieved from http://www.r-project.org/

Radvansky, G. A. (2012). Across the event horizon. *Current Directions in Psychological Science*, *21*(4), 269–272. https://doi.org/10.1177/0963721412451274

Radvansky, G. A., & Copeland, D. E. (2006). Walking through doorways causes forgetting: Situation models and experienced space. *Memory & Cognition*, *34*(5), 1150–1156. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/17128613

Radvansky, G. A., Krawietz, S. A., & Tamplin, A. K. (2011). Walking through doorways causes forgetting: Further explorations. *Quarterly Journal of Experimental Psychology*,

64(8), 1632–1645. https://doi.org/10.1080/17470218.2011.571267

Radvansky, G. A., & Zacks, J. M. (2014). *Event Cognition*. New York, NY: Oxford

University Press.

Rapp, D. N., Klug, J. L., & Taylor, H. A. (2006). Character movement and the representation

of space during narrative comprehension. *Memory & Cognition*, *34*(6), 1206–1220.

Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/17225503

Rinck, M., & Bower, G. H. (1995). Anaphora resolution and the focus of attention in

situation models. *Journal of Memory and Language*, *1*(34), 110–131.

Rinck, M., Bower, G. H., & Wolf, K. (1998). Distance effects in surface structures and

situation models. *Scientific Studies of Reading*, *2*(3), 221–246.

https://doi.org/10.1207/s1532799xssr0203

Rinck, M., & Denis, M. (2004). The metrics of spatial distance traversed during mental

imagery. *Journal of Experimental Psychology: Learning, Memory, and Cognition*,

30(6), 1211–1218. https://doi.org/10.1037/0278-7393.30.6.1211

Swallow, K. M., Barch, D. M., Head, D., Maley, C. J., Holder, D., & Zacks, J. M. (2011).

Changes in events alter how people remember recent information. *Journal of Cognitive

Neuroscience*, *23*(5), 1052–1064. https://doi.org/10.1162/jocn.2010.21524

Swallow, K. M., Zacks, J. M., & Abrams, R. A. (2009). Event boundaries in perception affect

memory encoding and updating. *Journal of Experimental Psychology: General*, *138*(2),

236–257. https://doi.org/10.1037/a0015631

Tabossi, P., Colombo, L., & Job, R. (1987). Accessing lexical ambiguity: Effects of context

and dominance. *Psychological Research*, *49*(2–3), 161–167.

https://doi.org/10.1007/BF00308682

Tanenhaus, M. K., Spivey-Knowlton, M. J., Eberhard, K. M., & Sedivy, J. C. (1995). Integration of visual and linguistic information in spoken language comprehension. *Science*, *268*, 1632–1634.

Tulving, E. (1972). Episodic and semantic memory. In E. Tulving & W. Donaldson (Eds.), *Organization of memory* (pp. 381–403). New York: Academic Press.

Wagenmakers, E.-J. (2007). A practical solution to the pervasive problems of p values. *Psychonomic Bulletin & Review*, *14*(5), 779–804. https://doi.org/10.3758/BF03194105

Wickham, H. (2017). Tidyverse: Easily install and load the "tidyverse". Retrieved from https://cran.r-project.org/package=tidyverse

Yee, E., Ahmed, S. Z., & Thompson-Schill, S. L. (2012). Colorless green ideas (can) prime furiously. *Psychological Science*, *23*(4), 364–369. https://doi.org/10.1177/0956797611430691

Yee, E., Jones, M. N., & McRae, K. (2017). Semantic memory. In J. T. W. & S. Thompson-Schill (Ed.), *The Stevens' handbook of experimental psychology and cognitive neuroscience* (4th ed., pp. 1–23). New York: Wiley.

Yee, E., & Sedivy, J. C. (2006). Eye movements to pictures reveal transient semantic activation during spoken word recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *32*(1), 1–14. https://doi.org/10.1037/0278-7393.32.1.1

Yee, E., & Thompson-Schill, S. L. (2016). Putting concepts into context. *Psychonomic Bulletin & Review*, *23*, 1015–1027. https://doi.org/10.3758/s13423-015-0948-7

 Appendices

Appendix A. Sentential items used in Experiment 1.

For all items, there were four versions of sentences. Half of the items (16) had the Target before the Competitor in the two Together conditions and one Apart condition (as in the Example: Items 1-16), and the other half (16) had them in the opposite order (Items 17-32). For half of each group of 16 items, the order of the Competitor and Distractor were swapped in the Apart condition to create variations in the proximity between the Target and Competitor across items (i.e. such that in the Apart condition the Target and Competitor could be mentioned with 0, 1, or 2 intervening objects). Distractors 1 and 2 were assigned randomly in each item.

In the subsequent item list, only the Together 1 condition is shown for each item. (T – Target; C – Competitor; D1 – Distractor 1; D2 – Distractor 2):

Example:

[Together 1] The piano (T) and the trumpet (C) are in the bar. The carrot (D1) and the lantern (D2) are in the gallery. Supposedly, the piano (T) is exceptionally rare.

[Together 2] The carrot (D1) and the lantern (D2) are in the bar. The piano (T) and the trumpet (C) are in the gallery. Supposedly, the piano (T) is exceptionally rare.

[Apart 1] The piano (T) and the lantern (D2) are in the bar. The carrot (D1) and the trumpet (C) are in the gallery. Supposedly, the piano (T) is exceptionally rare.

[Apart 2] The carrot (D1) and the trumpet (C) are in the bar. The piano (T) and the lantern (D2) are in the gallery. Supposedly, the piano (T) is exceptionally rare.

Note that American English spellings were used for all items for compatibility with

LSA.

Experimental Sentences

1i. The lock and the key are in the cafeteria. The ball and the melon are in the parlour.
1ii. It seems that the lock is very old.

2i. The bat and the racket are in the park. The cigarette and the pear are in the dunes.
2ii. It appears that the bat is quite heavy.

3i. The battery and the plug are in the lounge. The necklace and the map are in the high-street.
3ii. Apparently, the battery is strikingly powerful.

4i. The skateboard and the bike are in the playroom. The coin and the porridge are in the student's union.
4ii. Seemingly, the skateboard is relatively small.

5i. The wine and the grapes are in the base. The paint and the bagpipes are in the field.
5ii. It is thought that the wine is expertly crafted.

6i. The coat and the boot are in the office. The egg and the guitar are in the lighthouse.
6ii. It is said that the coat is highly expensive.

7i. The muffin and the cake are in the street. The glove and the accordion are in the kitchen.
7ii. Allegedly, the muffin is exceedingly tasty.

8i. The piano and the trumpet are in the bar. The carrot and the lantern are in the gallery.
8ii. Supposedly, the piano is exceptionally rare.

9i. The chair and the table are in the farm. The dumbbell and the poncho are in the yard.
9ii. It seems that the chair is incredibly dated.

10i. The banana and the coconut are in the hallway. The rug and the lighter are in the ticket office.
10ii. It appears that the banana is perfectly ripe.

11i. The stapler and the glue are in the front room. The dart and the card are in the workshop.
11ii. Apparently, the stapler is always broken.

12i. The sausage and the bacon are in the hairdressers. The calculator and the doorstop are in the recording studio.
12ii. Seemingly, the sausage is extremely appetising.

13i. The hammer and the nail are in the warehouse. The snorkel and the couch are in the spa.
13ii. It is thought that the hammer is considerably worn.

14i. The sandwich and the butter are in the restaurant. The medicine and the cork are in the arcade.
14ii. Allegedly, the sandwich is absolutely delicious.

15i. The shirt and the trousers are in the nursery. The computer and the flower are in the lodge.
15ii. It is said that the shirt is beautifully made.

16i. The potato and the celery are in the club house. The lipstick and the notepad are in the garden.
16ii. Supposedly, the potato is especially flavourful.

17i. The jar and the bottle are in the reception. The typewriter and the acorn are in the library.
17ii. It appears that the bottle is really big.

18i. The screw and the drill are in the garage. The crayon and the mustard are in the shed.
18ii. Apparently, the drill is normally missing.

19i. The jam and the toast are in the train station. The microphone and the chalk are in the club.
19ii. It seems that the toast is mostly stale.

20i. The cutters and the hacksaw are in the pharmacy. The umbrella and the jelly are in the campus.
20ii. Seemingly, the hacksaw is awfully sharp.

21i. The money and the wallet are in the resort. The burger and the goggles are in the porch.
21ii. It is thought that the wallet is astonishingly pricey.

22i. The milk and the cheese are in the foyer. The sock and the torch are in the teacher's lounge.
22ii. It is said that the cheese is uncommonly strong.

23i. The spoon and the cup are in the rugby club. The plant and the book are in the airport.
23ii. It is thought that the cup is notably fragile.

24i. The drum and the violin are in the meadow. The sandal and the pumpkin are in the grounds.
244ii. Supposedly, the violin is massively extravagant.

25i. The pan and the kettle are in the hotel. The speaker and the compass are in the pub.
25ii. It seems that the kettle is almost brand-new.

26i. The ink and the pencil are in the mine. The spade and the feather are in the carpark.
26ii. Supposedly, the pencil is too blunt.

27i. The brick and the trowel are in the toilets. The strawberry and the radio are in the staff room.
27ii. Apparently, the trowel is surprisingly tiny.

28i. The tomato and the lettuce are in the craft room. The rope and the phone are in the greenhouse.
28ii. Seemingly, the lettuce is altogether crisp.

29i. The letter and the envelope are in the bistro. The cap and the pancake are in the shop.
29ii. It appears that the envelope is securely sealed.

30i. The orange and the apple are in the retail park. The ticket and the calendar are in the villa.
30ii. It is said that the apple is remarkably sweet.

31i. The trophy and the medal are in the stock room. The sushi and the pipe are in the gymnasium.
31ii. Allegedly, the medal is curiously light.

32i. The jacket and the tie are in the barber's shop. The ruler and the keyboard are in the car dealership.
32ii. Allegedly, the tie is decidedly thick.

Appendix B. Sentential items used in Experiment 2

The same ordering rules used for the stimuli in Experiment 1 were used here.

Experimental Sentences

1i. The bat and the cigarette are in the cafeteria. The melon and the shirt are in the parlour.
1ii. It seems that the bat is beautifully made.

2i. The carrot and the cigar are in the park. The football and the blackboard are in the dunes.
2ii. It appears that the carrot is very old.

3i. The lipstick and the pen are in the lounge. The salad and the gramophone are in the high street.
3ii. Apparently, the lipstick is remarkably scented.

4i. The apple and the balloon are in the playroom. The rucksack and the computer are in the student's union.
4ii. Seemingly, the apple is perfectly ripe.

5i. The soap and the butter are in the base. The vice and the headphones are in the field.
5ii. It is thought that the soap is highly expensive.

6i. The mustard and the glue are in the office. The cocktail and the accordion are in the lighthouse.
6ii. It is said that the mustard is uncommonly strong.

7i. The dart and the pencil are in the street. The map and the steak are in the kitchen.
7ii. Allegedly, the dart is awfully sharp.

8i. The razor and the mallet are in the bar. The underwear and the pan are in the gallery.
8ii. Supposedly, the razor is too blunt.

9i. The doughnut and the wheel are in the farm. The mouse and the piano are in the yard.
9ii. It seems that the doughnut is remarkably sweet.

10i. The quiche and the doorstop are in the hallway. The newspaper and the leaf are in the ticket office.
10ii. It appears that the quiche is extremely appetising.

11i. The toothpaste and the paint are in the workshop. The honey and the cup are in the front room.
11ii. Apparently, the toothpaste is very dry.

12i. The wand and the mace are in the hairdresser's. The acorn and the teapot are in the recording studio.
12ii. Seemingly, the wand is strikingly powerful.

13i. The earring and the handcuff are in the warehouse. The couch and the grapes are in the spa.
13ii. It is thought that the earring is expertly crafted.

14i. The coin and the biscuit are in the restaurant. The helmet and the lamp are in the arcade.
14ii. Allegedly, the coin is incredibly dated.

15i. The boomerang and the scissors are in the nursery. The porridge and the jacket are in the lodge.
15ii. It is said that the boomerang is exceptionally rare.

16i. The record and the tart are in the club house. The sock and the wheat are in the garden.
16ii. Supposedly, the record is normally missing.

17i. The potato and the cork are in the reception. The jar and the shorts are in the library.
17ii. It appears that the cork is quite thin.

18i. The clarinet and the bolt are in the garage. The dinghy and the flower are in the shed.
18ii. Apparently, the bolt is utterly worthless.

19i. The celery and the paintbrush are in the train station. The money and the boat are in the club.
19ii. It seems that the paintbrush is incredibly tough.

20i. The battery and the sushi are in the pharmacy. The guitar and the jeans are in the campus.
20ii. Seemingly, the sushi is absolutely delicious.

21i. The compass and the pizza are in the resort. The medal and the umbrella are in the porch.
21ii. It is thought that the pizza is astonishingly pricey.

22i. The monocle and the pipe are in the foyer. The kettle and the trophy are in the teacher's lounge.
22ii. It is said that the pipe is notably fragile.

23i. The drill and the gun are in the rugby club. The monitor and the pineapple are in the airport.
23ii. It is thought that the gun is securely stored.

24i. The film and the bullet are in the meadow. The cactus and the motorcycle are in the grounds.
24ii. Supposedly, the bullet is surprisingly hefty.

25i. The pillow and the stamp are in the pub. The car and the chips are in the hotel.
25ii. It seems that the stamp is highly collectable.

26i. The spoon and the trowel are in the car park. The magazine and the painting are in the mine.
26ii. Supposedly, the trowel is quite heavy.

27i. The jam and the ink are in the toilets. The hacksaw and the tie are in the staff room.
27ii. Apparently, the ink is exceptionally bright.

28i. The ticket and the envelope are in the greenhouse. The pie and the campfire are in the craft room.
28ii. Seemingly, the envelope is massively extravagant.

29i. The screwdriver and the javelin are in the shop. The vest and the mayonnaise are in the bistro.
29ii. It appears that the javelin is strikingly weighty.

30i. The bacon and the ruler are in the retail park. The armour and the plug are in the villa.
30ii. It is said that the ruler is totally new.

31i. The notepad and the calendar are in the stock room. The racket and the jelly are in the gymnasium.
31ii. Allegedly, the calendar is almost brand-new.

32i. The purse and the lock are in the car dealership. The beanbag and the scales are in the barber's shop.
32ii. Allegedly, the lock is surprisingly tiny.