HOW FEATURES OF CONTEXTUAL EVENTS ALTER THE INTERPRETATIONS OF *BEFORE* AND *AFTER*

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Abstract

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Various aspects of linguistic context affect how we interpret words within discourse. We systematically assessed the influence of contextual events on temporal prepositions (*before, after)* by asking participants to estimate the duration of events and the duration that passed between these events. In four experiments, we varied the durations of the events, the sentence structure, and the semantic relation between the events. We found that there is a strong relationship between the durations of events and the estimates of time that passed between them, corresponding to *before* and *after.* The event duration with the strongest influence on these estimates was often based on their temporal sequence, and only based on their role in the sentence in a few specific cases. This demonstrates a strong role of time in these interpretations, which is different from other influences of context on terms.

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CHAPTER 1:

INTRODUCTION

Consider the following sentences:

(1) She watched a movie after she ran the 5K.

(2) She wrote a novel after she earned her PhD.

How do we interpret *after* in these sentences? Although it means "later in time" in each sentence (Brée & Smit, 1986), the amount of time that we assume has passed between events seems different. In (1), movie watching probably occurred on the same day as the 5K. In (2), however, it seems odd to assume that writing a novel occurred on the same day as earning a PhD. The second event may actually have occurred years after the first event. In fact, informants have agreed that the sequence of events in (1) likely occurred over a much shorter time period than the sequence of events in (2). This study examined how characteristics of the events and the sentences within which they are embedded (context) influenced the interpretations of these prepositions. Specifically, in four experiments, we examined the effect of the duration of events, the sentence structure in which they were embedded, and their semantic relationship with two prepositions, *before* and *after*.

1.1 Temporal Descriptions

Temporal descriptions such as (1) and (2) are analogous in many ways to spatial descriptions such as (3).

(3) A kitten is in front of the flower stand.

For example, the objects being related in spatial descriptions serve different roles. Properties of these objects are considered when placing them in specific roles. These roles include a reference object and a located object. Reference objects are normally larger and more permanent than located objects (Talmy, 1983). In (3), the *kitten* is the located object and the *flower stand* is the reference object.

The location of the located object is being described in terms of the reference object (an object known or easily found) so that the addressee can find the located object. The located objects are new information whereas the reference objects are known or accessible information. Because we think about properties of these objects in interpreting these sentences, the mobility of the *kitten* makes it an unlikely reference object (Talmy, 1983). The interpretation of the spatial description (3') is therefore bizarre, at least in many contexts.

(3') A flower stand is in front of the kitten.

Like spatial descriptions, temporal descriptions also include a reference event and a located event (Brée & Smit, 1986). In (1), *watching a movie* is the located event and *running the 5K* is the reference event. The located event is the event in focus, similar to a located object in spatial descriptions. The located event is described as being placed in time relative to the reference event, and therefore often brings new information to the discourse (Diessel, 2008; Haviland & Clark, 1974; Talmy, 1975; Tenbrink, 2007). The

reference event is usually already known or expected (Brée & Smit, 1986; Diessel, 2008; Haviland & Clark, 1974; Tenbrink, 2007), similar to a reference object in spatial descriptions. It is used as a known event from which to place the located event in time. These objects and events in spatial and temporal descriptions are considered sentential context to the prepositions in those descriptions.

This similarity in structure between spatial and temporal descriptions likely emerges from the more general use of space to understand time. There is empirical support that demonstrates the use of space to organize time, including studies demonstrating that people arrange cards in spatial orders to organize events (Bergen & Chan Lau, 2012; Fuhrman & Boroditsky, 2010; Miles, Tan, Noble, Lumsden, & Macrae, 2011; Tversky, Kugelmass, & Winter, 1991), that spatial information can affect the way temporal information is considered (Boroditsky, 2001), that people point to specific areas in space when instructed to point to events (Fuhrman & Boroditsky, 2010; Fuhrman et al., 2011), and that people can react quickly when asked to respond with certain spatial configurations to temporal words or pictures (Boroditsky, Fuhrman & McCormick, 2011; Fuhrman & Boroditsky, 2010; Fuhrman et al., 2011; Miles et al., 2011; Torralbo, Santiago, & Lupianez, 2006; Weger & Pratt, 2008).

We will address in the general discussion the impact of this understanding of time through space, and point to places where this analogy may break down, such as whether there are defining features of the temporal events that make them good candidates for reference objects, as permanence and size do in spatial descriptions. For now though, the important point is that the objects in spatial descriptions offer a context in which the

spatial prepositions are understood. We tested here whether temporal events also offer a context in which temporal prepositions are understood.

1.2 Why Context Matters

Language is often underspecified, and therefore words are not interpreted in isolation, but in conjunction with various other sources of information both within the language and outside of it (Clark, 1996). Correct interpretation requires us to infer the more specific meaning using the other words, tone, facial expressions, gesture, and world knowledge. Other words within the sentence and their meanings are considered sentential context for any specific word.

Sentential context helps us choose between various meanings of ambiguous words (Tabossi, 1988; Tabossi & Zardon, 1993) and also helps us narrow in on important features of unambiguous words (Anderson, McGaw, & Grant, 1973; Anderson & Ortony, 1975; Barclay, Bransford, Franks, McCarrell & Nitsch, 1974; Clark, 1983; Erickson & Mattson, 1981; Tabossi, 1982). Consider the following:

(4) The man lifted the piano.

(5) The man played the piano.

These two sentences are similar but (4) invites us to note the heaviness of the piano as a piece of furniture and (5) invites us to note the musical sound of the piano as an instrument. In an analogous manner, the events being temporally related in (1) and (2) (i.e. *watching a movie*) may lead us to believe that the time passing between the two events is different.

1.2.1 Using Context - Interpreting Adjectives in Noun Phrases

We describe and discriminate among referents by using adjectives. The interpretation of an adjective depends on the noun that it modifies (Halff, Ortony, & Anderson, 1976; Miller, 1978). For example, the interpretation of "red" differs in the phrases *a red apple* and *a red sunset*. Most people do not see these two objects as sharing the exact same hue. In fact, research has shown that participants can indicate such differences by deciding which of two different objects is redder than the other (Halff et al. 1976). Researchers found that each red item encompassed an interval of possible shades within the larger interval of all possible red hues. The noun in the phrase helped participants choose a smaller interval of red hues appropriate to that object. These researchers also found individual differences in responses, and argue that interpreting these phrases relies on participants generating specific examples that are likely drawn from their own experience.

1.2.2 Using Context - Interpreting Spatial Prepositions in Spatial Descriptions

Herskovits (1985; 1986) suggests that the meanings of spatial prepositions include both an ideal meaning, based on geometric properties, and various use types, which are specific scenarios in which a given term is often used. It does not seem that these prepositions each have multiple distinct meanings, but that the use types are extensions of the ideal meaning.

The tolerance of stretching ideal meanings to use types varies with sentential context. In a description spatially relating two objects, the size of the objects influences the interpretation of distance information that is assumed in spatial relationships (Carlson & Covey, 2005; Morrow & Clark, 1988; Talmy, 1975; Talmy, 1983). For example,

Carlson and Covey (2005) asked participants to estimate the distance between two objects with sentences such as (3) and (6).

(6) A woman is in front of the department store.

They found that sentences with larger reference objects (*department store*) and with larger located objects (*woman*) elicited larger distance estimates between the two objects than sentences with smaller reference objects (*flower stand*) and with smaller located objects (*kitten*), with a stronger influence of the located objects. New information is normally more focused or prominent so these results indicate that the new information is prioritized.

Morrow and Clark (1988) also completed experiments to look at distance effects in spatial descriptions. Participants read brief descriptions including the verb *approach*. They were then asked to estimate the distance between a figure and a landmark in the description, and after a rereading of the description, to estimate the distance between an observer and a landmark. They looked for differences in estimates when changing the size of the figure, the size of the landmark, the speed of the figure, the purpose of the movement, and the distance of the observer. Distance estimates increased as the figure increased in size, as the landmark increased in size, as the figure increased in speed, and when the purpose involved interaction from afar (e.g. shooting with a rifle).

Distance information can be important even with projective spatial terms that do not explicitly describe distance information. Carlson and Van Deman (2004) tested this with spatial terms such as *above*. They used a picture/sentence verification paradigm with prime/probe trial pairs so that they could compare probes that were identical except for the preceding trial (prime). They compared response times across probes that used the

same spatial term as the primes, the same distance between items as the primes, the same term and distance between items as the primes, or neither of these the same as the primes. Participants were faster to respond when either the distance or the spatial term was kept the same across prime and probe trials. They also demonstrated that maintaining distance did not affect response times when the task was to verify whether two letters appeared in the picture or whether one letter was larger than the other. This clarifies that the distance information was only taken into account when the task was spatial, indicating a spatial component to defining distance.

The importance of distance with projective spatial terms may be due to spatial reference frames. These frames are a way of dividing up the space around us so that we can attend to different areas and communicate about them (Levelt, 1984; Levelt, 1996; Logan, 1995). Reference frames consist of four parameters: origin, orientation, direction, and scale. Origin is the center point of the frame. Orientation consists of the three axes: above/below, front/back, and left/right. Direction consists of defining the endpoints on those axes, such as left and right. Scale, also called distance, consists of the amount of space between objects within the reference frame.

People seem to create an entire reference frame to describe and interpret spatial relations. As evidence of this, Ashley and Carlson (2007) demonstrated that direction information is important even when using spatial terms such as *near* and *far*, or verbs such as *approach* or *avoid*. They used a picture/sentence verification paradigm set in prime/probe pairs. They examined differences between response times for probes that were identical except for the preceding trial (prime). The prime and probe trials could use the same spatial term in the sentence, the same direction in the pictures, both of these

could be the same, or neither could be the same. They found that participants were faster to respond when either the direction or the spatial term was kept the same on the prime and the probe trials. In a second experiment, they demonstrated that maintaining direction did not affect response times when the task was to verify whether or not two letters appeared in the picture. However, in two more experiments, they showed that direction information was also used when processing the spatial verbs, *approach* and *avoid*, in both static and motion displays.

1.2.3 Using Context - Interpreting Temporal Prepositions in Temporal Descriptions

Due to the strong relationship between space and time, reference frames may also be used to understand temporal prepositions. Temporal reference frames may also have parameters such as origin (Kolesari & Carlson, 2018), direction and orientation (Boroditsky et al., 2011; Fuhrman & Boroditsky, 2010; Fuhrman et al., 2011), and scale. We will focus on scale here but take on a more comprehensive comparison of spatial and temporal reference frames in the general discussion.

In spatial reference frames, scale corresponds to the distance between objects. Research has shown that the distances between objects are estimated to increase as the size of those objects increases (Carlson & Covey, 2005; Morrow & Clark, 1988). Although events do not have sizes, they do have durations. With respect to duration, different events used in a sentence involve different levels of granularity, or levels of detail with which they are understood (Tenbrink, 2007) based on their usual timespan. For example, the events in (1) usually take no more than a few hours, and this allows us to infer that the time between them may be relatively short. Typically, movies do not take more than 2 or 4 hours and running a 5K normally takes less than half an hour. In

contrast, the events in (2) typically last years, and this allows us to infer that the time between them may also be years.

There is evidence that scale may be an important reference frame parameter for time, as well as for space. For example, size can also be important in temporal judgments. DeLong (1981) found that participants tended to judge time as being shorter in smaller spaces. Participants were shown a scaled view of an environment and asked to pretend that a scale figure was engaging in a certain activity and tell the researcher when the figure had finished the activity. They found that participants scaled their temporal estimates so that the smaller the space, the less time activities took within that space.

There is also evidence that the temporal scale between an event that occurred in the past and the moment of speech can be affected by the event's duration. Van Jaarsveld and Schreuder (1986) created sentences with vague adverbials (e.g. *immediately*, *recently*) and events with varying durations, such as (6) and (7).

(6) The librarian has recently discovered an old manuscript.

(7) The librarian has recently deciphered an old manuscript.

They found that when the events had longer durations (*deciphered*), participants' estimates of the time passing between the event and the moment of speech were longer. These influences suggest that the interpretation of *before* and *after* may depend upon the durations of the events. Accordingly, we predicted that as the durations of events increased, the durations estimated to have passed between events would increase. Across four experiments, we collected estimates of event durations and estimates of the time passing between events described in short sentences. We then ran regression analyses to

determine whether these event durations were predictive of the durations estimated to have passed between events.

1.3 Anchor and Adjustment as Possible Mechanism

If observed, such increases in durations may be due to the phenomenon of anchor and adjustment. Anchor and adjustment refers to the heuristic in which people use available information to help them estimate unavailable information (Block & Harper, 1991; Kahneman, Slovic, & Tversky, 1982). For example, researchers (Kahneman et al., 1982) asked participants to estimate the percentage of African nations in the United Nations after spinning a wheel with numbers one through one hundred on it. Their estimates were highly correlated with the numbers spun indicating a strong relationship between the number spun and available to them, and their estimate.

Information about the duration of the events may be more readily available than information about the duration between events. If someone read (1), that individual may know from experience that a typical movie takes about two hours and that running a 5K does not typically take more than 30 minutes. However, the duration passing between events is not as easily estimated from typical experience. It is less likely that someone has experienced these two events close in time and in the order being described than it is that someone has experienced one of these events alone. Any conjunction of events is by definition less likely to occur than any specific event. Therefore, I might start thinking in terms of the event durations when inferring the estimate of time between them.

The alternative possibility is that *before* and *after* are interpreted with a set time and not related to the events included in the description. Although it is possible that the

event durations would not affect estimates of the duration between events, this does not seem likely based on research with spatial descriptions. Historically, theories of spatial prepositions were put forth that were based on geometric definitions (Bennett, 1975; Clark, 1973; Coventry, Prat-Sala, & Richards, 2001; Miller & Johnson-Laird, 1976; Talmy, 1983); however, research has consistently shown that not only geometry but also various features of the objects including their function and their interaction with other objects influence how these terms are used and interpreted (Carlson & Kenny, 2006; Carlson-Radvansky, Covey, & Lattanzi, 1999; Carlson-Radvansky & Radvansky, 1996; Coventry & Garrod, 2004; Miller & Johnson-Laird, 1976). Since spatial terms are interpreted with an influence of context information about the objects, it is unlikely that temporal terms are interpreted without an influence of context information about the events.

1.4 Temporal Terms: *Before* and *After*

Temporal locative prepositions (*after, at, before, by, on*) place events relative to a reference point in time (Bennett, 1975; Haspelmath, 1997). Some of these (i.e. *at, on*) place events simultaneously with a reference event, and others (i.e. *before*, *after*) place events in sequence with a reference event. Specifically, the terms *before* and *after* are related to the spatial terms *in front of* and *behind*, which place objects in sequence spatially rather than temporally.

The terms *before* and *after* are not true converses (Anscombe, 1964; Beaver & Condoravdi, 2015; Heinamaki, 1974). *Before* has a transitive relation as shown in (8) and (9) whereas *after* does not as shown in (10) and (11).

(8) Breakfast occurs *before* lunch, and lunch occurs *before* dinner.

(9) Therefore, breakfast occurs *before* dinner.

Example (9) follows directly from (8). However, this does not work with *after* (Anscombe, 1964).

(10) The Roman Empire fell *after* the Parthenon was there, and the Parthenon was there after I was born.

(11) *Therefore, the Roman Empire fell *after* I was born.

Before is also asymmetric, but *after* is not (Anscombe, 1964). With (8), lunch cannot be said to occur *before* breakfast. However, with (10), the Parthenon can be there *after* the Roman Empire fell. Children also acquire *before* earlier than *after,* and this seems to be accounted for by a difference in their meanings (Clark, 1971).

Before has a narrow interpretation, whereas *after* is interpreted more flexibly. Saying that an event X occurred *before* event Y normally implies that event X occurred before event Y began (Anscombe, 1964; Beaver & Condoravdi, 2015; Heinamaki, 1974). *After*, on the other hand, can be interpreted in various ways. This flexibility is also related to the rules of transitivity and symmetry, described earlier. Although saying that a meeting occurred *after* lunch often implies that the meeting occurred *after* lunch was finished, this is not necessarily the case. The reference event of lunch has a number of sub events, including being seated, ordering, eating, getting dessert/coffee, paying the check, and leaving. The meeting may have occurred after the attendees were seated at lunch, or after they had eaten, or at a variety of other points, so long as it was after the first sub event included in lunch.

The biggest difference between the terms *before* and *after* is that they refer to earlier and later points in time. *Before* places an event earlier than a reference event and *after* places an event later than a reference event. As described in more detail in the next section, examining the results using both of these terms helped us to determine whether the temporal order was important for the prioritization of one event in context over another.

1.5 Dynamics of Time

One major difference between time and space is that space is static, but time is dynamic. Whereas static objects simultaneously occupy positions in space, the descriptions of their locations necessarily order them. In research on spatial memory, memories for objects are clustered not only based on their closeness in space, but also on closeness in time (e.g. McNamara, Halpin, & Hardy, 1992). Time is seen as an easy way to organize information, and people are sensitive to the order of information (Miller & Johnson-Laird, 1976; Zwaan & Radvansky, 1998).

In language, it is common for events to be said or written in the same order that they occurred, preserving the intrinsic temporal sequence (Brée & Smit, 1986; Diessel, 2008; Haiman, 1980). In fact, people have more difficulty processing sentences with events out of order than with events in the order in which they occurred (Mandler, 1986; Politzer, Ahles, Xiang & Almeida, 2017). Mandler (1986) found that participants were slower to comprehend sentences in which the events were out of order when the events were arbitrarily related in time. This may be because when people are listening or

reading, they create a situation model to help them understand what is occurring without remembering each word (Miller & Johnson-Laird, 1976; Zwaan & Radvansky, 1998).

To demonstrate this sensitivity to order information, Clark and Clark (1968) had participants read various sentences in which the temporal order and the order of mention matched or mismatched. They found that when subjects were presented with sentences in which these orders matched, they were more likely to remember the events in their proper order. When mismatched, participants often remembered the order of mention as the order in which the events occurred, even if that was not the case. Baker (1978) also found that in short stories, when the order of mention matched the event order, participants were both faster to respond and made fewer errors. This may be due to a preference for descriptions to begin with given information followed by new information.

If participants are sensitive to order, they may be tagging these events with regard to order. They could be tagging the events based on their temporal order (earlier, later) or based on their order in the sentence (1^{st} mention, 2^{nd} mention). Table 1.1 shows how each event in a sentence with *before* (center column) and with *after* (right column) can be described. The located event is the earlier event with *before,* and it is the event first mentioned. With *after*, the located event is the later event and the event first mentioned. These classifications of the located event are shown in the top row of Table 1.1. The reference event is the later event with *before,* and the second mentioned. With *after,* the reference event is the earlier event and the second mentioned event. These classifications of the reference event are shown in the bottom row of Table 1.1. Thus, examination of the prepositions *before* and *after* allow us to separate out these orders, effectively setting

up a natural 2 (order of mention: first, second) by 2 (temporal sequence: earlier, later) design.

Although we predicted that both event durations will have an influence on estimates of the time between events, we also predicted that one event will have a stronger influence than the other event. For example (1), repeated below, using anchor and adjustment, I might start thinking in terms of a two-hour movie, and estimate that one and a half hours passed between these events.

(1) She watched a movie *after* she ran a 5K.

Alternatively, I might start thinking in terms of the 5K, and estimate that 45 minutes passed between these events. If I start thinking in terms of the movie, I would be either anchoring on the located event, the event first mentioned, or the later event in time. Which event (located, 1st, later) serves as the anchor can be determined by closely comparing the influences of event durations across temporal descriptions. Consider (1) and (12).

(12) She watched a movie *before* she ran a 5K.

If estimates of the time passing between events are more similar to the duration of *watching a movie*, participants are anchoring on the located event in the sentence or the first event mentioned. If, however, estimates of the time passing between events are more similar to *running a 5K* and *watching a movie,* respectively, participants are anchoring on the earlier event in time.

If the located event serves as the anchor, this would indicate that people rely more on the information in focus when interpreting temporal terms, and would be consistent with a prioritization given to processing new and salient information (Cutler & Fodor,

1979; Hornby, 1974). This would also replicate the results found by Carlson and Covey (2005) for spatial objects and prepositions, where the located object size had a stronger influence on distance estimates with *front* and *back*. If the reference event serves as the anchor, this would indicate that people rely more on known information to interpret temporal terms, and would be consistent with a preference for processing familiar information first (Conrad & Rips, 1986).

If instead of anchoring based on the roles of the events within the descriptions, people anchor on the earlier or later event then this demonstrates that participants create situation models and reorder the events into their appropriate temporal sequence (Miller & Johnson-Laird, 1976; Zwaan & Radvansky, 1998). Alternatively, people could anchor based on the sentence order and the first or second event mentioned could be the anchor. It is unlikely that participants will choose an anchor based on sentence order because specific syntax is not normally retained, but instead a more gist like representation is normally extracted, and this representation would include the temporal order and not the sentence order (Aitcheson, 2008; Kimball, 1973). In addition, after hearing the first event mentioned, it would be difficult to immediately create an anchor because what follows is unpredictable. Experiment 1 separated out role from temporal sequence. In Experiment 2, we examined the order of mention.

TABLE 1.1

THREE POSSIBLE CLASSIFICATIONS OF EVENTS

She watched a movie before/after she ran a 5K.		
	Before	***After***
Located Event: Watched a Movie	Earlier event 1st mentioned event	Later event 1st mentioned event
Reference Event: Ran a 5K	Later event 2nd mentioned event	Earlier event 2nd mentioned event

CHAPTER 2:

EXPERIMENT 1

Experiment 1 examined how the durations of the events within a sentence influenced the interpretations of the time passing between events as referred to by *before* and *after*. Participants read sentences that related two events in time, and were asked to estimate both the durations of the events and the time that passed between these events. We predicted that the durations of the events would influence the durations between events and that one event would have the stronger influence based on role or temporal order. We did not predict an effect of sentence order because syntactic constructions are not always maintained after they have been parsed (Aitcheson, 2008; Kimball, 1973).

In the present work, *before* and *after* were chosen because they define a directional sequence in time and do not explicitly include durational information, such as *until tonight*, for example. We did not want the duration information offered by the temporal term to influence duration estimates. Other potential phrases included *earlier than* and *later than*, but these were not chosen because they cannot be used to relate different events. For example, one cannot naturalistically say,

(13) *She ate breakfast earlier than she drove to work.

This constraint would not have allowed us to change both events in the sentence independently, and we wanted to be able to examine the relative strength of each of the events.

2.1 Method

2.1.1 Participants

One hundred and twenty-eight participants were recruited on Amazon Mechanical Turk. The requirements for participants included being located in the United States, having at least a 95% approval rate indicating that the majority of their previous work on Amazon Turk has been approved by the requester, and having completed at least 100 HITs (Human Intelligence Tasks) on Amazon Mechanical Turk indicating that they were familiar with the interface. One participant was excluded due to failure to correctly answer the catch question embedded in the experiment. The average age was 34 and ages ranged from 20 to 64. All were native English speakers.

2.1.2 Materials

Experiment 1 was programmed using HTML and JavaScript and run using Amazon Mechanical Turk. Events were chosen to represent a wide variety of durations. Events with duration distributions listed in the database created by Gusev et al. (2011) were used as much as possible. This database includes events taken from news articles with duration distributions for each event. All the clauses used the simple past tense, and each event was bounded. Each temporal description described an event in which a 3RD person named individual was the agent of both actions. The events were referred to with

indefinite noun phrases. 64 total events were counterbalanced across participants so that each event appeared in each role (located and reference) equally often and appeared paired with a longer event and a shorter event equally often. This resulted in four lists of event pairs. These four lists are included in Appendix A.

2.1.3 Design and Procedure

Each participant completed 32 trials. Each trial included three questions shown on three separate screens. Participants estimated the duration of each event in a counterbalanced order across subjects so that the order of questions did not always match the order of mention in the final sentence. An example trial is depicted in Figure 2.1. The instructions "Please estimate the duration of this event" were followed by one of the two events, e.g. "Aubrey watched a movie," and two drop down menus allowing participants to choose a number (1-60) and a unit (seconds, minutes, hours, days, weeks, months, years). Underneath were instructions to "click the next button when you have entered your response," and a button labeled next. After estimating the duration of both events, they estimated the duration that had passed between the events. The instructions stated, "Please estimate the time that passed between events. Some of these sentences may sound strange. Use your first instincts as much as possible." This was followed by a sentence, e.g. "Aubrey watched a movie before she ran a 5K", and the two drop down boxes with the next button. Half of participants saw the event pairs with *after*, and the other half saw the same event pairs with *before*. Once the participants had completed half of the trials, they saw a catch question. Instead of being presented with events, the instructions stated items such as, "Please select four days," to ensure that participants were reading the sentences.

2.2 Results and Discussion

We first removed any outliers from each trial across participants, defined as estimates greater than three standard deviations from each trial mean. If either an event estimate or an estimate between events was defined as an outlier, we removed all three estimates in that trial. These outliers accounted for about 7% of the total data.

Because the data were continuous, we ran a linear stepwise regression for each term to determine whether event durations predicted estimates for the durations corresponding to *before* and *after,* and if so, which event was prioritized. We ran separate regressions for *before* and *after,* because we predicted that one event would be prioritized based on time and therefore different events would be prioritized for each preposition due to the underlying semantics of the terms. We included as potential predictors located event duration estimates, reference event duration estimates, and the mean centered interaction term for located event duration estimates with reference event duration estimates. Mean centering the interaction term decreases collinearity in the model. The dependent variable was the duration estimated to have passed between events. The criterion for inclusion into the regression was that the change in F was significant at $p < .050$, and we only report variables that uniquely predicted more than 8% of the variance ($sr^2 > .08$).

The best fitting significant models included two steps for both *before*, $r^2 = 0.243$, $F\ (2, 1892) = 303$, $p < .001$, and *after*, $r^2 = 0.327$, $F\ (2, 1870) = 455$, $p < .001$. The final coefficients for each significant predictor for the *before* and *after* models are shown in Table 2.1. Figure 2.2 shows the standardized βs for each type of event for *before* and *after*. This figure invites us to compare within each model (within a term) but it is

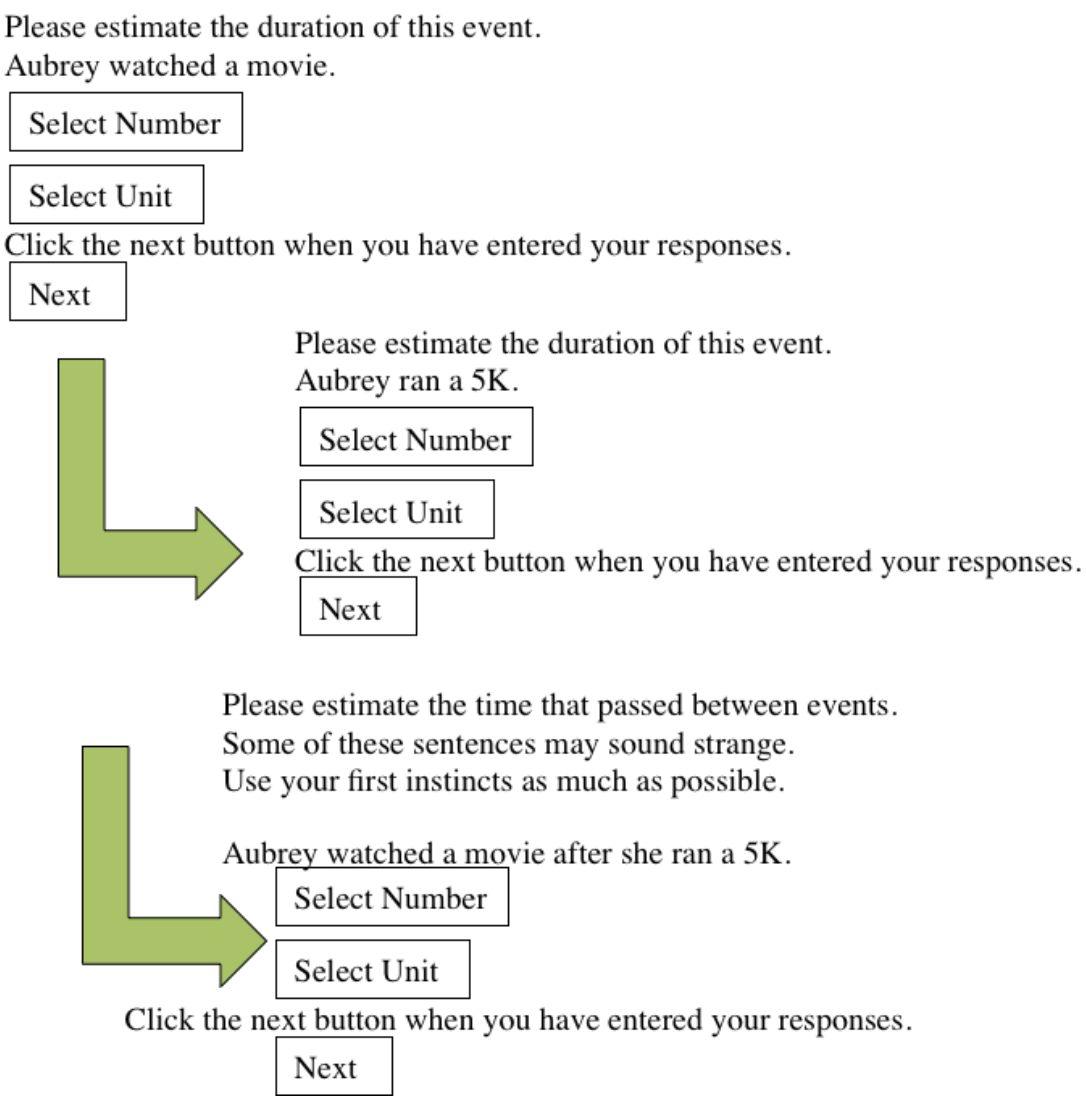

Figure 2.1 Display of a trial. Participants first estimated the duration of one of the events (top left), and then estimated the duration of the other event (middle). Finally, they estimated the time that passed between these two events (bottom right).

TABLE 2.1

SIGNIFICANT PREDICTORS IN EXPERIMENT 1

***Before* Model**	**Unstand. *B***	**SE**	**Stand. *β***	***t***	***p***	***sr*^{2}**
Located Earlier 1st Mentioned Event Durations	.512	.023	.455	22.7	< .001	.454
Reference Later 2nd Mentioned Event Durations	.311	.030	.204	10.2	< .001	.204
***After* Model**	**Unstand. *B***	**SE**	**Stand. *β***	***t***	***p***	***sr*^{2}**
Located Later 1st Mentioned Event Durations	.285	.018	.294	15.5	< .001	.293
Reference Earlier 2nd Mentioned Event Durations	.558	.021	.501	26.4	< .001	.501

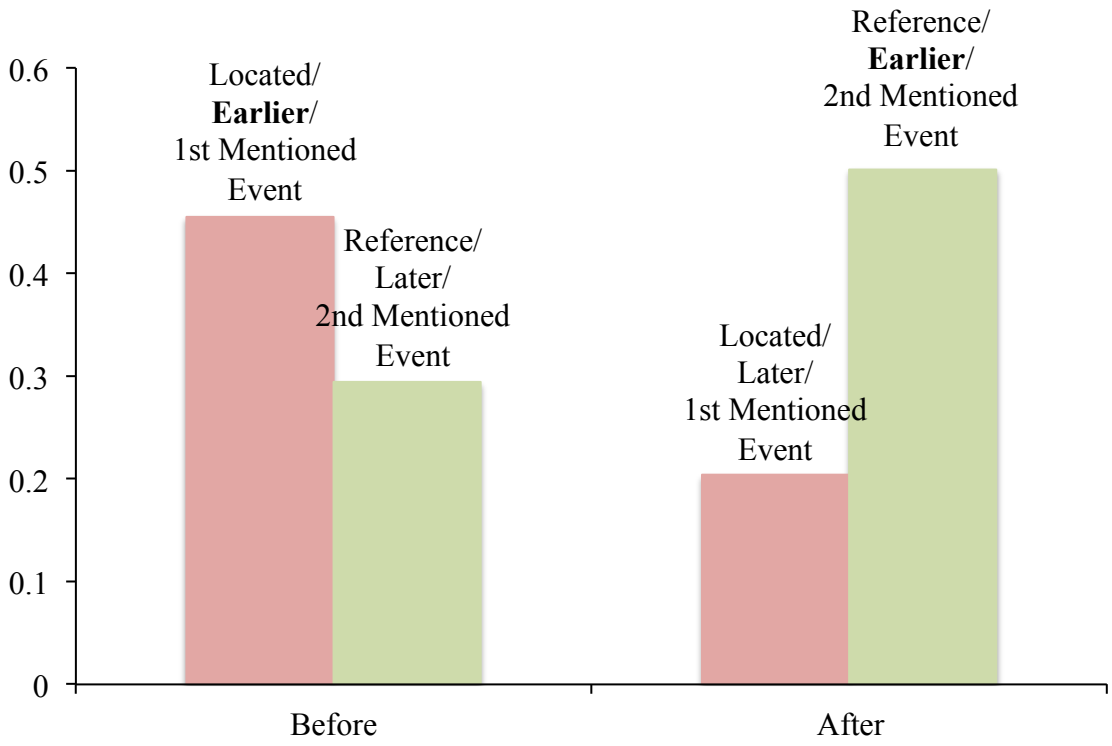

Figure 2.2. Standardized βs for Event Durations in Experiment 1.

inappropriate to compare the numerical values across models. These values have been standardized within a model and therefore are specific to that model alone. This is true for this figure, as well as all similar figures that follow.

These results indicate that participants were using the event durations to help them interpret the duration that passed between events, as reflected in the significant positive coefficients for each preposition. Within the *before* model, the located, earlier, and 1st mentioned event had the strongest influence. Within the *after* model, the reference, earlier, and 2nd mentioned event had the strongest influence. These data suggest that participants were using the earlier event with both terms, indicated in bold. These earlier events were used as an anchor to help participants interpret these prepositions appropriately.

It is possible that asking participants to estimate the durations of the events before estimating the time between them could have forced them to think of the duration between the events based on the durations of the events themselves. In order to rule out this possibility, we ran a control experiment in which some participants (N = 128) only estimated the durations between events, and other participants (N = 128) only estimated the durations of the events themselves. We ran a stepwise regression on their data with the same predictors, dependent variable, and criterion as the data above. Both of the event durations were significant predictors of the duration between events. The standardized β for located event durations was .151 and for reference event durations was .114. This indicates that even when participants were not explicitly asked to estimate the events, they still used the event durations to help them determine how much time passed between events. However, due to great variability in the specific durations of events, the r^2 for the

model was only .035. More variance was accounted for when we used participants' own estimates within the regression, so in later experiments we continue using the stronger within-subjects design.

CHAPTER 3:

EXPERIMENT 2

In Experiment 1, we could separate out the contributions of early and later events from located and reference events (see Table 1.1); however, the located event was always the event that was mentioned first in the sentence. This confound does not allow us to determine whether participants considered the role of the events or the order of mention in the sentence. To better understand this, in Experiment 2, we looked at the same events but varied the clause structure of the statements, so that the reference event came first in the sentence.

Adverbial clauses, like those that begin with *before* and *after*, can be placed before (sentence initial clauses) or after (sentence final clauses) the main clause in the sentence. The structure of the sentence may alter which event is serving as the anchor because it changes the order of mention. When the *before* and *after* clauses are final clauses, the located event is the first event mentioned in the sentence, and the sentences were structured like this in Experiment 1. We saw an effect of choosing an anchor based on temporal order, not role (located, reference) or order of mention (first, second), but all sentences used the same order of mention. Therefore, in Experiment 2, we altered the sentence presentation to examine sentences with the reference event mentioned first. Table 3.1 shows how each event in a sentence with *before* (left column) and with *after* (right column) can be classified when the clause order is shifted as in Experiment 2.

Adverbial clauses often contain unfamiliar information and are more likely to be at the end of a sentence, following the structure in Experiment 1 (Chafe, 1984; Diessel, 2008). In a corpus analysis, Diessel (2008) found that about 82% of all *before* and *after* clauses were final clauses. Preposing the subordinate clause changes not only the order of mention, but also the prominence of the events in the description (Münte, Schiltz, & Kutas, 1998; Diessel, 2008). Consider (14) and (15) (Tenbrink, 2007).

(14) Jan lived in London after the war was over.

(15) After the war was over, Jan lived in London.

In (14), the sentence describes when Jan lived in London, and therefore it is implied that Jan only lived there at that time described (Tenbrink, 2007). In (15), the sentence describes where Jan lived after the war, and therefore leaves open the possibility that she also lived in London at other times.

In addition to a prominence shift between the sentences of Experiments 1 and 2, participants may have less experience creating situation models out of these sentences due to their less frequent occurrences. Also, Clark and Clark (1968) found that errors occur in which participants remember the events in the order they were presented in the sentence, and not in the order in which they occurred, indicating that temporal order is not always used. Lastly, participants were not asked to remember these events or their order of occurrence. We predict that in this experiment, participants will anchor based on the order of mention or the role, because temporal order is unnecessary for the task and the sentence structure is less familiar.

TABLE 3.1

THREE POSSIBLE CLASSIFICATIONS OF EVENTS IN EXPERIMENT 2

Before/After she ran a 5K, she watched a movie.		
	Before	***After***
Located Event: Watched a Movie	Earlier event 2nd mentioned event	Later event 2nd mentioned event
Reference Event: Ran a 5K	Later event 1st mentioned event	Earlier event 1st mentioned event

3.1 Methods

3.1.1 Participants

One hundred and twenty-eight participants were recruited on Amazon Mechanical Turk. They were required to have a 95% approval rate, be located in the United States, have completed 100 HITs, and not have participated in any other part of this research. One participant was excluded due to failure to correctly answer the catch questions. The average age was 35.5 and ages ranged from 21 to 68. All were native English speakers.

3.1.2 Materials

Experiment 2 was programmed using HTML and JavaScript and run using Amazon Mechanical Turk. The stimuli was the same as Experiment 1 except that the sentences were presented in the order of [temporal preposition], [reference event], and [located event]. Example sentences can be seen in Table 3.1 and the full list is in Appendix A.

3.1.3 Design and Procedure

The procedure was the same as in Experiment 1.

3.2 Results and Discussion

We first removed any outliers from each trial across participants, defined as estimates outside three standard deviations from the trial mean. These outliers accounted for about 7% of the total data. We ran two separate stepwise regressions for *before* and *after* with the same potential predictors, dependent variable, and criterion as in Experiment 1. The best fitting models included two steps for *before,* $r^2 = 0.170$, F (2,

1900) = 195, $p < .001$, and for *after*, $r^2 = 0.142$, F (2, 1854) = 153, $p < .001$. The significant predictors are shown in Table 3.2.

Even with a different, less frequent sentence structure, participants used the event durations to help them interpret the duration that passed between events, as reflected in the significant positive coefficients for each preposition. As can be seen in Figure 3.1, participants used the located event or the event mentioned second in the sentence as the anchor, indicated in bold, as this event had a stronger influence with both *before* and *after*. These results support our hypothesis that temporal order would not be used in this experiment.

TABLE 3.2

SIGNIFICANT PREDICTORS IN EXPERIMENT 2

***Before* Model**	**Unstand. *B***	**SE**	**Stand. *β***	***t***	***p***	***sr*^{2}**
Located Earlier 2nd Mentioned Event Durations	.529	.027	.408	19.5	< .001	.407
Reference Later 1st Mentioned Event Durations	.109	.028	.082	3.94	< .001	.082
***After* Model**	**Unstand. *B***	**SE**	**Stand. *β***	***t***	***p***	***sr*^{2}**
Located Later 2nd Mentioned Event Durations	.488	.029	.358	16.6	< .001	.357
Reference Earlier 1st Mentioned Event Durations	.180	.029	.134	6.21	< .001	.134

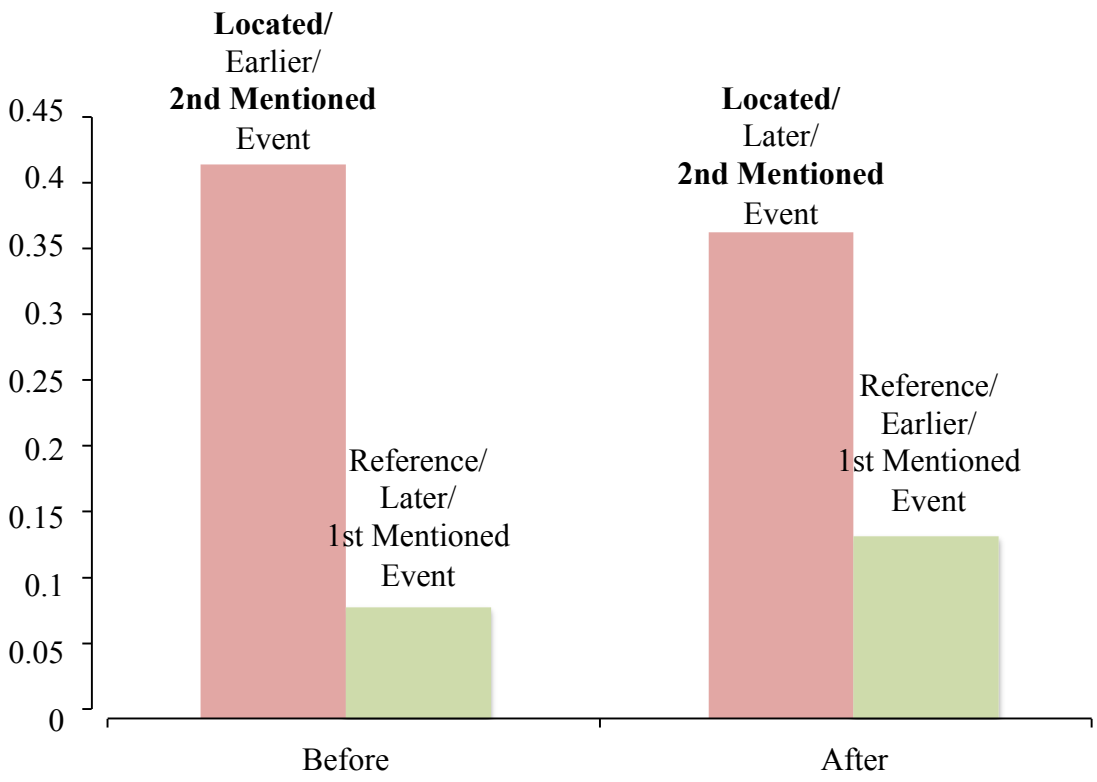

Figure 3.1. Standardized βs for Event Durations in Experiment 2.

CHAPTER 4:

EXPERIMENT 3

Some of the sentences in Experiments 1 and 2 were strange, because they connected two events that were arbitrarily related. This is an unusual use of language because it is more likely for people to pair events in sentences when the events are related (Clark, 1996; Mandler, 1986). Experiment 3 examined the effect of events on the interpretations of the terms *before* and *after* when the events were conditionally or causally related.

4.1 Event Relations

Conditional and causal relations are two of the four types of semantic relations: similarity, situating, conditional, and causal (Blühdorn, 2010). Similarity relations include any relationship between entities that is symmetrical. This type of relation cannot occur with adverbial *before* and *after* phrases because the two events occur in one order in time and therefore cannot be symmetrical. Situating relations are asymmetric but the two events are independent of each other. This is the most basic relation that can be used with *before* and *after* phrases and was used in Experiments 1 and 2.

Conditional relations occur when one event is a condition of the other occurring, called a consequence, as in (15).

(15) She cooked the steak *before* she ate it.

In (15), cooking the steak is the condition, and eating the steak is the consequence. Relations can also affect where clauses are positioned most frequently. Clauses with

implicit conditional meanings are less likely to be final clauses, as only about 40% of conditional clauses were final clauses (as in this Experiment) in a corpus analysis (Diessel, 2008). We predict that due to this less frequent sentence structure, participants will anchor on the located event as they did in Experiment 2.

Causal relations occur when one event is the cause of the other, the effect, and the effect is something that has occurred, as in (16).

(16) She fell *after* she stumbled.

In (16), falling is the effect and stumbling is the cause. Clauses with implicit causal meanings are more likely to be final clauses, as about 98% of causal clauses were final clauses (as in this Experiment) in a corpus analysis (Diessel, 2008). With causal relations, we predict that the earlier event in time (or the cause) will serve as the anchor as in Experiment 1.

An interesting difference between the terms *before* and *after* is how strongly they invite causal inferences (Anscombe, 1964). For example, consider (16). This statement invites the inference that the stumbling was the cause of the fall. The causing event (stumbling) is backgrounded and presupposed as the reference event, but the result (falling) is in focus as the located event. Consider an alternative statement such as (17).

(17) She stumbled before she fell.

In this statement, *before* prevents a strong causal inference. What would be considered the result (falling) is backgrounded and presupposed as the reference event, whereas what would be considered the cause (stumbling) is in focus as the located event, and this is not the usual organization of cause and effect statements (Diessel, 2008).

4.2 Method

4.2.1 Participants

One hundred and twenty-eight participants were recruited on Amazon Mechanical Turk. They were required to have a 95% approval rate, be located in the United States, have completed 100 HITs, and not have participated in any other part of this research. The average age was 33.3 and ages ranged from 18 to 73. All were native English speakers.

4.2.2 Materials

Different events were used from Experiments 1 and 2, but the set was consistent with previous stimuli in varying in duration. We used as many events as we could from the earlier lists, but we paired them with an event that was either conditionally or causally related. We created 32 pairs of events, 16 conditional pairs and 16 causal pairs. All the clauses used the simple past tense, and each event was bounded. Each conditional sentence described an event in which a 3^{RD} person named individual was the agent of both actions. The causal events were more varied in agents, and often required two agents. The conditional and causal trials were presented in a mixed order. These sentences are listed in Appendix A. Experiment 3 was also programmed using HTML and JavaScript and run using Amazon Mechanical Turk.

4.2.3 Design and Procedure

The procedure was the same as in earlier experiments.

4.3 Results and Discussion

We first removed any outliers from each trial across participants, defined as estimates that were outside three standard deviations from that trial mean. These outliers accounted for about 4% of the total data.

Because conditional and causal relations are different semantic relations and we had differing predictions, we separated the causal and conditional trials, and ran four (relations X terms) stepwise regressions with the same predictors, dependent variable, and criterion as in earlier experiments.

For conditional statements, the best fitting models were three step models for both *before,* $r^2 = 0.365$, $F\ (3, 971) = 186$, $p < .001$, and *after*, $r^2 = 0.681$, $F\ (3, 984) = 702$, $p < .001$. The significant predictors are shown in Table 4.1. For causal statements, the best fitting models were three step models for both *before,* $r^2 = 0.540$, $F\ (3, 981) = 384$, $p < .001$, and *after*, $r^2 = 0.496$, $F\ (3, 990) = 325$, $p < .001$. The significant predictors are shown Table 4.2. The standardized βs for the event durations can be seen in Figure 4.1.

When the events had a stronger semantic relationship, participants used the event durations to help them interpret the duration that passed between events, as reflected in the significant positive coefficients for each term. In each of these models, the interactions between located and reference event durations were also significant. This indicates that the slope of one event estimate on the between estimates varied based on the other event estimate, although all slopes indicated some positive linear relationship. The unstandardized B for the interaction is quite small because the product of the two event estimates is so much larger than the estimates of time passing between events. We do not depict the interaction coefficients in Figure 4.1 because these would not help to

demonstrate the prioritization of the events. As can be seen in Figure 4.1, with conditional relations, participants used the located event or the event mentioned first in the sentence as the anchor, indicated in bold, as this event had a stronger influence with both *before* and *after,* and these results replicate Experiment 2. Although participants could have used the second mentioned event in Experiment 2, and the first mentioned event with conditional relations, the simpler explanation is that participants used the located event in both cases. Also, theoretically we did not expect participants to anchor on the simple syntactic order, whereas the role was predicted to be important. With causal relations, participants used the earlier event in time as the anchor, indicated in bold, as this event has a stronger influence with both *before* and *after*, and these results replicate Experiment 1.

TABLE 4.1

SIGNIFICANT PREDICTORS IN EXPERIMENT 3 CONDITIONAL TRIALS

Conditional - *Before*	**Unstand. *B***	**SE**	**Stand. *β***	***t***	***p***	***sr*^{2}**
Located Earlier 1st Mentioned Event Durations	.594	.053	.501	11.2	< .001	.287
Reference Later 2nd Mentioned Event Durations	.166	.015	.362	11.2	< .001	.286
Located Event Durations* Reference Event Durations	-.000000124	< .001	-.178	-3.6	< .001	-.092
Conditional - *After*	**Unstand. *B***	**SE**	**Stand. *β***	***t***	***p***	***sr*^{2}**
Located Later 1st Mentioned Event Durations	.433	.025	.470	17.0	< .001	.306
Reference Earlier 2nd Mentioned Event Durations	.331	.073	.119	4.5	< .001	.082
Located Event Durations* Reference Event Durations	.000000603	< .001	.319	9.4	< .001	.170

TABLE 4.2

SIGNIFICANT PREDICTORS IN EXPERIMENT 3 CAUSAL TRIALS

Causal - *Before*	**Unstand. *B***	**SE**	**Stand. *β***	***t***	***p***	***sr*^{2}**
Located Earlier 1st Mentioned Event Durations	.734	.034	.662	21.5	< .001	.466
Reference Later 2nd Mentioned Event Durations	.609	.026	.603	23.7	< .001	.513
Located Event Durations* Reference Event Durations	-.000000131	< .001	-.572	-17.1	< .001	-.371
Causal - *After*	**Unstand. *B***	**SE**	**Stand. *β***	***t***	***p***	***sr*^{2}**
Located Later 1st Mentioned Event Durations	.645	.039	.503	16.4	< .001	.370
Reference Earlier 2nd Mentioned Event Durations	.662	.043	.530	15.2	< .001	.344
Located Event Durations* Reference Event Durations	-.0000000676	< .001	-.251	-6.2	< .001	-.140

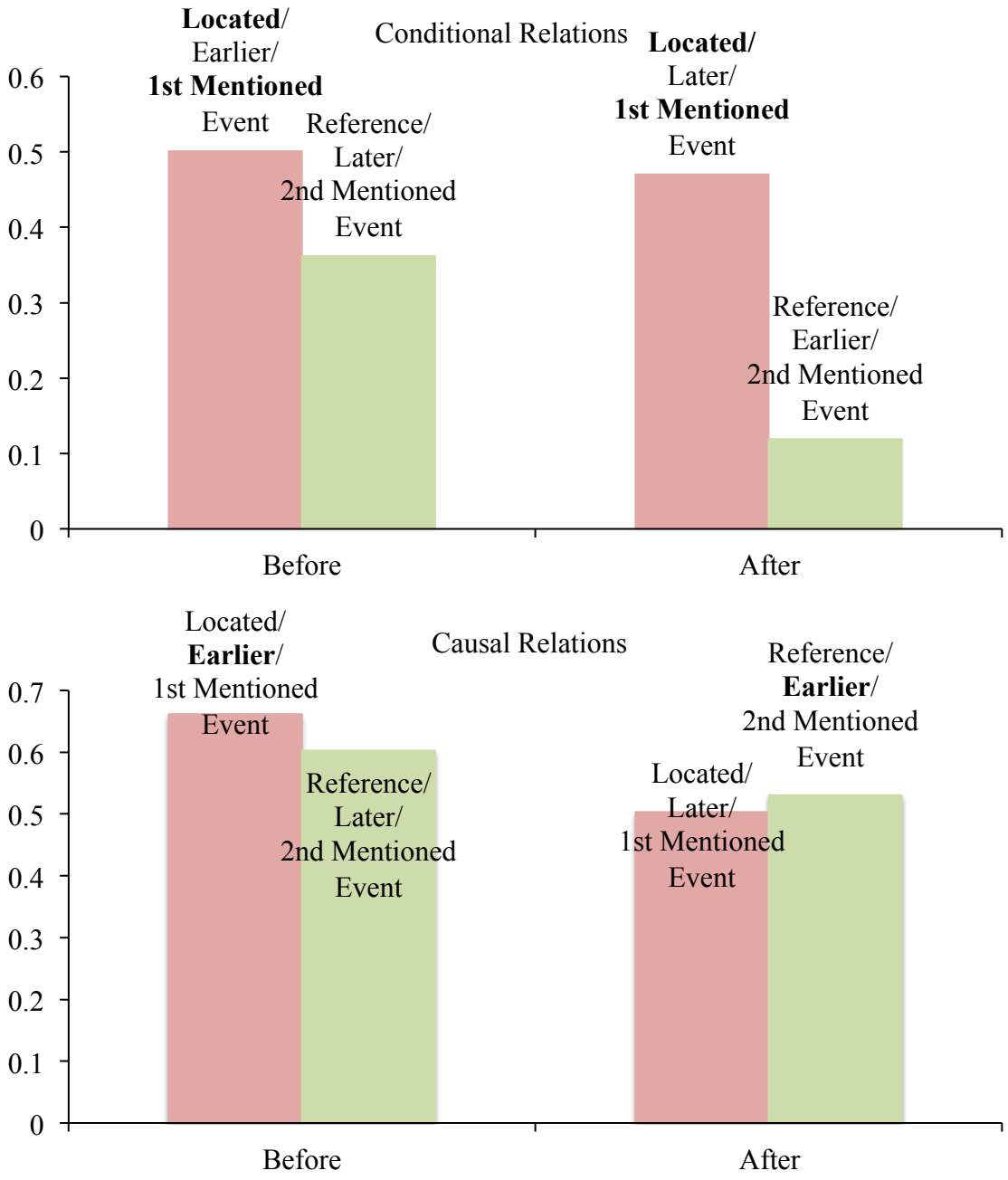

Figure 4.1. Standardized βs for Event Durations in Experiment 3.

CHAPTER 5:

EXPERIMENT 4

In Experiment 4, we looked at the same events as in Experiment 3 but used the sentence structure from Experiment 2. This allowed us to examine sentences in which the reference event was mentioned first, and compare sentence order with role when the events had conditional or causal relations. Given the results of Experiments 2 and 3, we predicted that preposing the temporal adverbial clauses would lead participants to anchor on the earlier event with conditional relations and to anchor on the located event with causal relations. Clauses with implicit conditional meanings are more likely to be initial clauses, as about 60% of conditional clauses were placed as initial clauses (as in this Experiment) in a corpus analysis (Diessel, 2008). As in Experiment 1, sentences with a more common sentence structure may lead participants to anchor on the sequence of events in time. Clauses with implicit causal meanings are less likely to be initial clauses, as only about 2% of causal clauses were placed as initial clauses (as in this Experiment) in a corpus analysis (Diessel, 2008). As in Experiment 2, participants may anchor on the located event.

5.1 Methods

5.1.1 Participants

One hundred and twenty eight participants were recruited on Amazon Mechanical Turk. They were required to have a 95% approval rate, be located in the United States, have completed 100 HITs, and not have participated in any other part of this research. Three participants were excluded due to failure to correctly answer the catch question. The average age was 37 and ages ranged from 19 to 63. All were native English speakers.

5.1.2 Materials

Experiment 4 was programmed using HTML and JavaScript and run using Amazon Mechanical Turk. We used the same event pairs as in Experiment 3 but presented the sentences as [preposition] [reference event], [located event].

5.1.3 Design and Procedure

The procedure was the same as in earlier experiments.

5.2 Results and Discussion

We first removed any outliers from each trial across participants, defined as estimates that were outside three standard deviations from that trial mean. These outliers accounted for about 3% of the total data.

Following Experiment 3, we separated the causal and conditional trials, and ran four (relations X terms) stepwise regressions with the same predictors, dependent variable, and criterion as in earlier experiments.

For conditional statements, the best fitting models were two step models for both *before,* $r^2 = 0.459$, $F\ (2, 998) = 423$, $p < .001$, and *after,* $r^2 = 0.551$, $F\ (2, 973) = 597$, $p < .001$. The significant predictors are shown in Table 5.1. For causal statements, the best fitting models were two step models for both *before,* $r^2 = 0.797$, $F\ (2, 994) = 1{,}949$, $p < .001$, and *after,* $r^2 = 0.607$, $F\ (2, 974) = 752$, $p < .001$. The significant predictors are shown in Table 5.2.

With this sentence structure, participants used the event durations to help them interpret the duration that passed between events, as reflected in significant positive coefficients in each case. As can be seen in Figure 5.1, with conditional relations, participants used the later event in time as the anchor, indicated in bold, as this event has a stronger influence with both *before* and *after.* Although the specific anchor is different with these relations, participants were still anchoring based on order in time as in Experiment 1. With causal relations, participants used the earlier event in time as the anchor, indicated in bold, as this event has a stronger influence with both *before* and *after.* We predicted that participants would anchor on the located event for these sentences due to their low frequency. However, causally related events can only occur in one order, and this may make anchoring on time easier than it is with situationally related events, which can occur in any order.

TABLE 5.1

SIGNIFICANT PREDICTORS IN EXPERIMENT 4 CONDITIONAL TRIALS

Conditional - *Before*	**Unstand. *B***	**SE**	**Stand. *β***	***t***	***p***	***sr*^{2}**
Located Earlier 2nd Mentioned Event Durations	.608	.051	.317	12.0	< .001	.280
Reference Later 1st Mentioned Event Durations	.329	.019	.467	17.7	< .001	.411
Conditional - *After*	**Unstand. *B***	**SE**	**Stand. *β***	***t***	***p***	***sr*^{2}**
Located Later 2nd Mentioned Event Durations	.499	.019	.640	26.3	< .001	.566
Reference Earlier 1st Mentioned Event Durations	.349	.047	.182	7.5	< .001	.161

TABLE 5.2

SIGNIFICANT PREDICTORS IN EXPERIMENT 4 CAUSAL TRIALS

Causal - *Before*	**Unstand. *B***	**SE**	**Stand. *β***	***t***	***p***	***sr*^{2}**
Located Earlier 2nd Mentioned Event Durations	.786	.018	.761	44.6	< .001	.637
Reference Later 1st Mentioned Event Durations	.263	.021	.209	12.2	< .001	.175
Causal - *After*	**Unstand. *B***	**SE**	**Stand. *β***	***t***	***p***	***sr*^{2}**
Located Later 2nd Mentioned Event Durations	.638	.043	.313	14.8	< .001	.297
Reference Earlier 1st Mentioned Event Durations	.928	.032	.622	29.4	< .001	.590

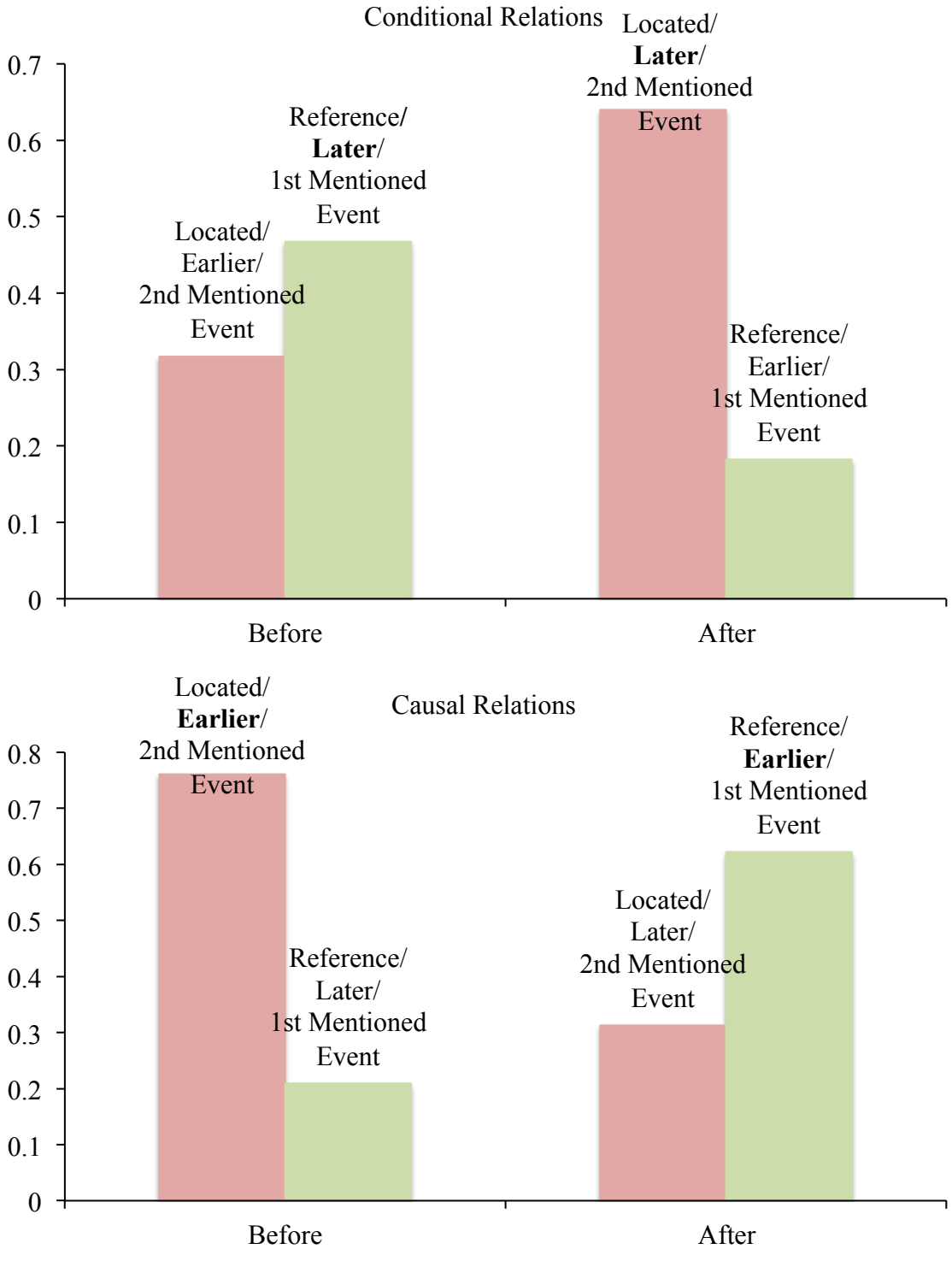

Figure 5.1. Standardized βs for Event Durations in Experiment 4.

CHAPTER 6:
GENERAL DISCUSSION

6.1 Summary of Results

Across four experiments, we found that durations of events in sentences influenced duration estimates for *before* and *after.* As durations of events increased, durations that passed between events increased, similar to how sizes of objects influence the interpretations of spatial prepositions. However, we also found that which event was prioritized varied across sentence structure and relation, and was often determined with regard to temporal sequence as well as role in the sentence. In contrast, with spatial descriptions, which object is prioritized is often determined by only its role in the sentence. Temporal descriptions are more complex, as they describe a sequence in time that has an inherent order, and because language is also sequential, it allows for a matching sequence that is not possible with space.

In Experiment 1, we examined sentences with *before* and *after* adverbial clauses following the main clauses that included events with situational relations. We found that with both *before* and *after* clauses, the earlier event duration had a stronger predictive relationship with the duration estimated between events. The events that were prioritized in each experiment are shown in Table 6.1. The top left cells labeled early represent Experiment 1, and these are printed in bold because this sentence structure is more frequent with situational relations.

In Experiment 2, we examined sentences with *before* and *after* adverbial clauses preceding the main clauses that included events with situational relations. We found that

with both *before* and *after* clauses, the located event duration had a stronger predictive relationship with the duration estimates between events. The top right cells in Table 6.1 represent Experiment 2.

In Experiment 3, we examined sentences with *before* and *after* adverbial clauses following the main clauses that included events with both conditional and causal relations. For conditional sentences, we found that with both *before* and *after* clauses, the located event duration had a stronger predictive relationship with the duration estimates between events. For causal sentences, we found that with both *before* and *after* clauses, the earlier event duration had a stronger predictive relationship with the duration estimates between events. The bottom left cells in Table 6.1 represent Experiment 3. In the bottom row, early is printed in bold because this sentence structure is more frequent with causal relations.

In Experiment 4, we examined sentences with *before* and *after* adverbial clauses preceding the main clauses that included events with both conditional and causal relations. For conditional sentences, we found that with both *before* and *after* clauses, the later event duration had a stronger predictive relationship with the duration estimates between events. For causal sentences, we found that with both *before* and *after* clauses, the earlier event duration had a stronger predictive relationship with the duration estimates between events. Even with less common sentence structures for causal relations, the earlier event is still being used as the anchor. Research has shown that people have less difficulty processing and remembering events with causal relations regardless of presentation in the sentence (Clark & Clark, 1968; Mandler, 1986). Causal events can only occur in one order, for example, one cannot fall before one trips. Because

TABLE 6.1

STRONGER PREDICTIVE EVENT ACROSS EXPERIMENTS

Relations	She watched movie before/after she ran a 5K.		Before/After she watched a movie, she ran a 5K.	
	Before	*After*	*Before*	*After*
Situational (Movie, 5K)	**Early** (Exp. 1)	**Early** (Exp. 1)	Located/ 2nd Mention (Exp. 2)	Located/ 2nd Mention (Exp. 2)
Conditional (Cook, Eat)	Located/ 1st Mention (Exp. 3)	Located/ 1st Mention (Exp. 3)	**Later** (Exp. 4)	**Later** (Exp. 4)
Causal (Stumble, Fell)	**Early** (Exp. 3)	**Early** (Exp. 3)	Early (Exp. 4)	Early (Exp. 4)

the events can be reordered with respect to world knowledge, only the events themselves need to be processed. The earlier event may be prioritized without regard to sentence presentation or preposition, but simply due to it being the cause. The bottom right cells in Table 6.1 represent Experiment 4. In the middle row, later is printed in bold because this sentence structure is more frequent with conditional relations.

To summarize, by manipulating sentence structure and relationships between events, we asked about both commonly used sentence types and less common sentence types. With more familiar sentence structures, we found that the more predictive event was based on temporal order. The located event served as the anchor with some less common sentence structures, which replicates spatial preposition findings by Carlson and Covey (2005) in which the located object had a stronger influence. In the remainder of the general discussion we focus on broader implications of the work, including methodology, linguistic factors, reference frames, and the more general space time relationship. In each section, we note predictions for future work.

6.2 Methodology

The methodology used in the current study is based on methodologies previously used to answer analogous questions in space. In the development of this project, we considered methodologies that require spatial placement responses as well as numerical estimates.

One approach to studying spatial prepositions is a placement task. Logan and Sadler (1996) asked participants to draw an X in a given spatial relation to a box on a page. The X's drawn corresponded to the terms *above, below, over, under, left of* and

right of and were at varying distances, but mostly fell along one of the central axes bisecting the box. In another spatial placement study, Carlson (2009) asked participants to indicate the location of the best use of the term *front* with a dollhouse cabinet as the reference object. They were then asked to indicate the farthest location from the cabinet where the term *front* would still apply, and whether at this far location, an alternative term would be preferred. If an alternative term was preferred, they were asked to indicate the location where *front* would become preferred over the alternative. Carlson (2009) also looked at the effects of the size of objects by asking participants to place various objects (Barbie, her dog) *in front of* the dollhouse cabinet. She found the predicted size effects where smaller objects were placed closer to the cabinet than larger objects, likely due to changes in participants' interpretations of objects' regions of interaction.

Because placement is well established for spatial prepositions, we piloted a possible version of the current study, in which participants placed events on a spatial timeline. We found that the data collected (x-coordinates) was not fine-grained enough to answer our questions. It was also difficult to ask participants to determine the size (duration) of the events, as well as the space between them on the timeline, when the length of the timeline needed to be fixed. We also found that labeling the endpoints of the timeline introduced a scale to be used, but without labels, participants' interpretations were unclear.

Placement tasks, as well as numerical estimation tasks, put participants in the role of comprehenders. They read terms or sentences, and respond with an interpretation of the meanings as an indirect measure of comprehension. It would be interesting to explore more direct measures of comprehension in the future. For example, participants might

read a story with these terms and then answer comprehension questions including inference questions about implied durations. Alternatively, production of these terms could be explored by providing participants with non-linguistic scenarios in time, and asking them to describe them linguistically. These investigations would lead to a better understanding of how these terms are interpreted with more available context and how they are chosen within descriptions.

6.3 Linguistic Factors Related to Interpreting Temporal Prepositions

6.3.1 Tense

In this study, we only looked at simple past tense statements. When time is discussed in discourse, it is centered on the present moment (Benveniste, 1965; Tenbrink, 2007). This implies that in order to talk about time, an origin is placed at the present moment. The past and the future tense are only interpretable when compared to the moment in time of the discourse. Consider the future tense in (16).

(16) She will watch a movie after she runs a 5K.

With the future tense, the planned order of events can be changed. Temporal order would likely be less important with the future tense because the temporal order is changeable, at least with situationally related events. Participants would then anchor on the located event in the sentence instead of based on temporal order. With the future tense, the located event is likely the event that is currently being planned, and this may make it more salient. Consider the present tense in (17).

(17) She watches a movie after she runs a 5K.

With the present tense, a habitual or repetitive interpretation is implied. This repetition would likely make the temporal sequence more important. Not only has this order of events been repeated, but also there is likely an intention to continue having these events in this order. The earlier event in time would likely serve as the anchor in this scenario.

Tense is often discussed with boundedness. An event is bounded if it is represented as having a clear endpoint, such as *watching a movie,* or *running a 5K* (Declerck, 1979; Depraetere, 1995). Since these events have clear endings beyond which they cannot continue, they may have a stronger effect on the estimates between events than unbounded events. An event is unbounded if it does not have a clear endpoint and occurs for an indefinite period of time, such as *watching TV,* or *running.* Since these stevents do not have clear endpoints or clear durations, they may not have as strong of an effect on the estimates between events.

6.3.2 Temporal Prepositions

There is a large overlap between terms that are used to describe space and terms that are used to describe time (Tenbrink, 2011). For example, locative prepositions (*at, in, on*) place objects or events at specific points either in space or in time (Bennett, 1975; Haspelmath, 1997; Radden, 2004; Traugott, 1975). These terms may be influenced by context based on role similar to other spatial prepositions. Alternatively, they could be influenced by context based on temporal order similar to other temporal prepositions. If they show a spatial interpretation even in temporal contexts, this may indicate that these terms are primarily spatial in meaning. It is possible that temporal order would still be important for semantically related events that can only occur in one invariant order.

Other interesting sequential temporal prepositions are the terms *earlier* and *later,* and these can be used relatively. They lead to less focus on the time between events and their sequence, and more focus on comparing the times of similar events. Consider (18).

(18) Spring came later this year.

This statement does not invite the reader to determine how much time passed between spring last year and spring this year. Instead, it invites the comparison between the time of spring this year and the time of spring last year. Instead of relating two events in time like *before* and *after,* it compares the timing of similar instances.

There are also terms that can place events in time either sequentially or simultaneously. For example, the term *when* is interpreted as placing events simultaneously or sequentially based on context.

(19) When we were in London, it rained.

(20) When he broke his leg, he ordered crutches.

In (19), *when* is interpreted as placing the two events simultaneously. This requires that the reference event (being in London) is at least as long as the located event (raining). These event requirements may lead participants to anchor on the known and longer reference event in these sentences. In (20), the simultaneous interpretation does not make sense, so the located event is interpreted to have occurred immediately after the reference event. This immediacy likely leads to smaller durations estimated to have passed between the events regardless of the duration of the events themselves.

Other terms place events simultaneously with different requirements. With the term *while*, the reference event must be temporary and if in past tense, not currently occurring. The events also need to be of similar duration.

(21) Sarah lived in London while they were married.

In (21), there is an implicature that Sarah is no longer married. The two events are interpreted as being of the same duration. Because the events are the same duration, the located event (new, salient information) may serve as the anchor to estimate the reference event duration in a sentence like (21).

6.3.3 Pragmatic Factors

Language is often used to communicate more than just the words being stated. One way to accomplish this is by violating a maxim that is normally followed during language use. Grice (1975) describes a list of maxims that are usually followed in order to ensure successful communication. One of these is to "be orderly." Since it is easier to process and remember events when they are mentioned in the order that they occurred, there must be a reason why events are not always described in this order. Consider (14) and (15) reprinted below.

(14) Jan lived in London after the war was over.

(15) After the war was over, Jan lived in London.

In (14), the events are not mentioned in the order in which they occurred. As discussed in the introduction to Experiment 2, the reason for this may be to communicate that Jan only lived there after the war and not at any other time. Although (15) mentions the events in the order in which they occurred, it leaves open the possibility that Jan also lived there at other times. These maxims can be flouted for pragmatic reasons and the resulting shifts may impact the estimates of durations associated with these events.

6.3.4 Semantics and Acquisition of Temporal Terms

In this study, we tested adult participants. However, Clark (1973) explains that children must understand space before they can learn spatial terms, and that this understanding of spatial terms is then applied to time. He cites evidence that children learn spatial meanings of these terms first, and often answer temporal questions with spatial answers. With terms that can be used for both space and time, children will likely interpret these terms similar to other spatial terms if this spatial meaning is understood first. If these are interpreted similar to other spatial terms at a young age, there must be a demonstrable shift between these spatial interpretations and the prioritization of temporal sequence for temporal terms.

The use of the terms *before* and *after* increases over the years from age 3 to age 5, but often emerges quite early (Grant & Suddendorf, 2010). Prior to children understanding *before* and *after*, they often use the order of mention to sequence events (Clark, 1971). Three year olds use order of mention; however, they are able to sequence events with an invariant order (i.e. causally related events) using temporal order, even if it differs from the order of mention (Carni & French 1984). Four year olds can sequence events using temporal order with events of both invariant and arbitrary relations. As children learn to understand temporal sequence, they may shift to using this factor to prioritize certain events in context.

6.4 Space/Time Analogy and Reference Frames

Following, we compare spatial and temporal findings and ideas to determine where the analogy is clear, and where the analogy may break down. We begin with

reference frame parameters, which show good symmetry. We then discuss characteristics of referents, prioritization of regions, types of reference frames, and how terms can influence the type of frame used.

6.4.1 Parameters of Reference Frames

In a spatial reference frame, the origin defines where the frame is placed (Levelt, 1984; Levelt, 1996; Logan, 1995). Depending on the type of frame, discussed below, the origin can be placed at the self or on an object. In a temporal reference frame, the origin is placed on the self for a left to right timeline of events (Kolesari & Carlson, 2018). In a spatial reference frame, the orientation refers to the axis (e.g. horizontal) and the direction refers to the endpoints (e.g. left/right). In a temporal reference frame, the orientation refers to the axis of the timeline (e.g. horizontal) and the direction refers to the endpoints representing the past (or earlier point in time) and the future (or later point in time). For English speakers, the timeline often runs from the past (or earlier times) on the left to the future (or later times) on the right (Boroditsky et al., 2011; Fuhrman & Boroditsky, 2010; Fuhrman et al., 2011). In a spatial reference frame, the scale is based on the size of the objects and the distances between objects. In a temporal reference frame, as demonstrated in this study, the scale is based on the durations of the events and the durations between them. Spatial and temporal reference frames, therefore, have good symmetry, which increases our confidence in the space-time analogy.

6.4.2 Choosing Reference Events

For spatial descriptions, reference objects are often chosen based not only on whether they are known to the addressee, but also based on factors intrinsic to these objects, such as their size and permanence (Talmy, 1983). These factors make the cat a questionable reference object in (3'), repeated below.

(3') A flower stand is in front of the kitten.

For temporal descriptions, it is less clear whether there are factors intrinsic to events that make a good reference event. Factors that make a good reference event can be based on relation; the cause is normally the reference event in a causal temporal description. Duration can be also be important for some terms. For the terms *while* or *during,* the reference event is usually longer than the located event.

However, with the terms *before* and *after,* there are no clear intrinsic factors that lead to one event being chosen as a reference event. Within a conversational setting, reference events can be chosen based on whether they are known to the addressee, or assumed to be in common ground, similar to spatial reference objects. Consider the following sentences.

(22) I will eat dinner after the big game.

(23) The big game is on after I plan to eat dinner.

In (22), the big game makes a likely reference event because it is assumed to be known by the addressee. In (23), eating dinner is an unlikely reference event because the addressee likely does not know exactly when I plan to eat dinner. Although the referents in both cases are usually in common ground, at least with *before* and *after,* it does not seem to be the case that reference events have certain intrinsic qualities like reference

objects. This is a limitation to the space-time analogy with respect to referents used in descriptions.

6.4.3 Prioritization of Certain Regions

The space in front of individuals seems to be an especially important region. Franklin, Henkel, and Zangas (1995) had participants point to the boundaries of the *front, back, left,* and *right* regions around them in a circular room created by a hanging curtain. They found that the *front* region was the largest, followed by *back*, followed by *left* and *right*, which were about equal. In a second experiment, participants were shown a peg for five seconds at a location in the circular room, moved around, and then asked to point to where the peg had been relative to them. They found that when objects had been in front of the participants, responses were more accurate than in any other region, showing that objects in front space may be given priority over other objects.

To further investigate the term *front*, Carlson (2009) asked participants to choose the best use of the term *front* with a dollhouse cabinet as the reference object. They were also asked how far away one could move and still use the term *front*. They were then asked if an alternative term would be preferred at the farthest distance where *front* was still acceptable, and if so, to choose the location where *front* was preferred over the chosen alternative term. Using this paradigm, they also looked at functional effects by varying which way the door of the cabinet opened, to the right or the left, and they found smaller regions of acceptability for the side on which the cabinet opened than for the other side with the term *front* but not the term *back*.

There may also be prioritization in time. De la Fuente, Santiago, Román, Dumitrache and Casasanto (2014) put forth the temporal focus hypothesis, which claims

that people place the past or future in front of them depending on which they (or their culture) focus more on. They found that Moroccan Arabic speakers put the past in front of the individual in a nonlinguistic task, even though their linguistic metaphors place the past behind them. They followed up this anomaly by administering a temporal focus questionnaire to both Spaniards and Moroccans and found significant differences in past and future focus between the groups. They also found that elderly Spaniards were more likely to put the past in front than young Spaniards, but not as likely as Moroccans. In a last experiment, they asked Spaniards to write about either the past or the future, and found that this affected whether participants placed the past or the future in front, demonstrating effects of temporal focus experimentally. A prioritization of regions in time seems to be based on the prioritization of the front in space, demonstrating clear symmetry in the space-time analogy.

6.4.4 Types of Reference Frames for Space and Time

For space, three types of spatial reference frames are usually distinguished (Levinson, 1996a; Levinson, 1996b; Levinson, 2003). One is the **absolute** reference frame, also called allocentric or environment-based, which uses consistent cues from the environment such as cardinal directions. Another is the **intrinsic** reference frame, also called allocentric or object-based, which uses the axes inherent in the reference object. The last frame of reference is the **relative** frame, also called egocentric, which uses the axes inherent in the observer and therefore needs an observer to be present with a known location. The relative frame can be placed on an object in three ways creating three subtypes: rotation, translation, or reflection. In **rotation**, the axes are rotated 180 degrees so that the front of an object is facing the person's front, and the object's left is the

person's right. In **translation**, the axes are simply pushed forward so that the person is looking at the object's back and their left and right remain the same. In **reflection**, the axes are reflected back as in a mirror so that the participant is looking at the object's front, but their left and right sides are still the same. Lastly, a **basic** frame is sometimes included (Danziger, 2010). This frame uses the observer as the reference object and is used for deictic statements such as *here.*

For time, Bender, Beller, and Bennardo (2010) believe four different spatial reference frames are used for time. The **absolute** frame of reference in time is based on time itself, so the front of time is always the future. The **intrinsic** frame of reference in time is based on the reference event and therefore front is the beginning of this event or facing pastwards. The **reflection** type of the **relative** frame of reference requires a viewer to be situated at the present moment. In this type of frame, front is considered to be closer to the viewer so for past events, front is the future, but for future events, front is the past. The **translation** type of the **relative** frame of reference requires a viewer as well. In this type of frame, front is considered to be farther from the viewer so for past events, front is farther into the past, and for future events, front is farther into the future. The **translation** type is not commonly used in space, but has been shown with a Tongan population (Bennardo, 2000), as well as Hausa (Hill, 1982). These frames all refer to the future and the past, which links them to the A-series theory of time. The A-series theory describes time as constantly changing (or moving) events, which are in the future, and then in the present, and then in the past (Zinken, 2015).

Similar to the A-series theory of time, the time-moving view posits that time moves towards individuals and then passes them while the individuals remain stationary.

Alternatively, the ego-moving view posits that individuals are moving forward through time while time remains stationary. These metaphors can both be seen in common English phrases (Alverson, 1994; Lakoff & Johnson, 1980). For example, *we are approaching spring* indicates an ego-moving view, while *spring is approaching us* indicates a time-moving view. In both of these views, the events change from future to present to past.

To test the cognitive consequences of these two views, McGlone and Harding (1998) gave participants a fictional event date and then presented them with sentences using either the ego-moving or time-moving metaphor for time. Participants were asked to judge whether the sentences were true or false with respect to the fictional event date given. They were presented with the fictional date, followed by four context sentences one at a time that each used the same metaphor and had the same grammatical subject. Following this, they were presented with a test sentence that could match the metaphor, match the grammatical subject, match both, or not match either. They found that when the grammatical subject matched the context sentences, response times were faster. More importantly, participants also responded faster when the metaphor remained the same. In another experiment, they found that when context sentences depicted moving-ego or moving-time metaphors, responses to an ambiguous temporal question were affected. Questions such as *next Wednesday's meeting has been moved forward two days, when is the meeting now taking place?* normally elicit mixed responses. Moving-ego context sentences led participants to match the metaphor and choose Friday whereas moving-time context sentences led participants to match the metaphor and choose Monday.

To further investigate the priming of temporal metaphors, Boroditsky and Ramscar (2002) replicated the effect that spatial prime questions (ego-moving, time-moving) influenced responses to the ambiguous temporal question (next Wednesday's meeting). Spatial position in a lunch line also influenced answers, with those further along in line more likely to adopt an ego-moving view. They also asked this question at the airport, and found that those who had just flown in were the most likely to adopt an ego-moving view, followed by those who were about to fly (slightly more likely to adopt ego-moving), and those just picking someone up were equally likely to adopt either perspective. When they asked this question on a train, they found that those who just got on and those who were about to get off were both more likely to adopt an ego-moving perspective, but those in the middle of the journey were only slightly more likely to adopt an ego-moving perspective.

Not all cultures use a relative reference frame to create timelines. Boroditsky and Gaby (2010) have found that Pormpuraawans think of time as going from East to West in an absolute frame of reference. Participants completed the card arrangement task facing multiple directions and their arrangement patterns indicate an underlying East to West timeline. This absolute frame of reference may be related to the B-series theory of time which claims that events are ordered in a specific way which does not change and the ordered relations between events makes up time (Zinken, 2015).

Even one English speaker may have multiple ways of mapping time. In a review written by Bender and Beller (2014), it is pointed out that English speakers make use primarily of the front/back axis for time, with past mapped to the back and future mapped to the front. However, the reverse direction is also possible and is demonstrated by mixed

responses to the Wednesday's meeting question. Only half of the participants move the meeting to Friday (move forward to the future) and the other half move the meeting to Monday (move forward to the past). For English speakers, gestures occur on both the front/back and the left/right axis, with a preference for the left/right, especially when describing non-deictic sequences. English speakers have also been shown to use the left/right axis with spatial layouts and congruency priming tasks. Different temporal reference frames may lead to different prioritization patterns of contextual events.

6.4.5 Different Terms Use Different Frames

Some spatial terms may give priority to certain reference frames. Carlson-Radvansky and Irwin (1993) found that *above* was rated more acceptable when it was correct with reference to an absolute frame of reference than to an intrinsic frame. In multiple experiments, they tested this using an acceptability rating task and a production task. The pictures used had various reference objects and a fly as the located object, which could be *above* with respect to an absolute frame, an intrinsic frame, both, or neither. Participants rated the acceptability of the term *above*, and in the production task, they drew the fly *above* the reference object. The absolute frame was both rated as more acceptable, and more likely to be used for drawing. However, the intrinsic frame was rated as more acceptable than when neither frame allowed the term *above*, and a small percentage of participants drew using this frame. In another experiment, participants completed a production task where they were asked to describe the location of the fly verbally while either sitting up or lying on their side to dissociate the absolute and relative frames. They found that participants used the term *above* most often with respect to an absolute frame with little influence of the relative frame.

There are also interesting differences in the priority vertical and horizontal terms are given. Hayward and Tarr (1995) asked participants to describe the relationship between two objects shown. They found that vertical prepositions (*above, below)* were more common to describe every location except those directly along the horizontal axis, where horizontal prepositions were more common.

The terms *before* and *after* are used to sequence specific instances in order. It is therefore likely that these terms are used primarily with an absolute reference frame. These terms are also more compatible with the B-series of time, as they order events in an unchanging way without regard to tense. The terms *earlier* and *later* are used to compare the timing of two similar events, and not necessarily order them in time. It is therefore likely that these terms are used primarily with a relative reference frame, compatible with the A-series theory of time.

6.5 Conclusion

In conclusion, the durations of events influence the interpretations of the durations of the temporal prepositions, *before* and *after.* People choose an anchor based on temporal order most often, but sometimes choose an anchor based on its role in the sentence. The methodology used was inspired by spatial distance estimation tasks, but has been converted to be used for temporal duration estimation tasks. This methodology can be used to better understand the effects of duration on temporal preposition interpretations. This study also demonstrated support for the space-time analogy in reference frames, as we have demonstrated how scale may be set in temporal

descriptions. Scale is set with unique characteristics based on the dynamics of time, however, making it not completely symmetrical with spatial scale.

APPENDIX A:

STIMULI

A.1 Four Lists for Experiments 1 & 2

A.1.1 List One

Aaliyah mowed a lawn before/after she drove home

Adam ate lunch before/after he held a meeting.

Angela installed new software before/after she baked cookies.

Arianna lost a game before/after she opened an account.

Austin parked a car before/after he passed a test.

Ayden changed a tire before/after he placed an order

Mark cooked a meal before/after he presented an award

Matthew purchased a ticket before/after he put out a fire

Caleb read an article before/after he dug a tunnel

Camilla received an award before/after put together a jigsaw puzzle

Caroline caught a fish before/after she compiled a database

Chloe returned a call before/after she filmed a documentary

Christian saved a life before/after he filmed a movie

Colton packed a suitcase before/after he filmed a scene

Cora climbed a ladder before/after she found a job

David smoked a cigarette before/after he graduated college

Belle performed a surgery before/after she submitted an application

Britney published a magazine before/after she climbed a tree

Caitlin quit smoking before/after she wrote a letter

Cameron read a novel before/after he shoveled a driveway

Carson designed a building before/after he took a shower

Carter recorded a song before/after he went grocery shopping

Chase repaired a car before/after he paid a bill

Claire built a house before/after she played a game of chess

Andrea completed an internship before/after she hosted a tournament

Antonio launched a campaign before/after he attended a conference

Asher negotiated a contract before/after he painted a picture

Audrey painted a house before/after she appointed a new director

Clara sent a letter before/after she shot a scene

Daniel climbed a mountain before/after he underwent surgery

Elijah wrote an article before/after he bought a house

Charles released an album before/after he watched a game

A.1.2 List Two

Abigail drove home before/after she mowed a lawn

Andrew held a meeting before/after he ate lunch.

Anthony baked cookies before/after he installed new software

Ashley opened an account before/after she lost a game

John passed a test before/after he parked a car.

Benjamin placed an order before/after he changed a tire

Brandon presented an award before/after he cooked a meal

Caden put out a fire before/after he purchased a ticket

Dylan submitted an application before/after he performed a surgery

Elias climbed a tree before/after he published a magazine

Ella wrote a letter before/after she quit smoking

Emily shoveled a driveway before/after she read a novel

Emma took a shower before/after she designed a building

Eric went grocery shopping before/after he recorded a song

Ava paid a bill before/after she repaired a car

Brian played a game of chess before/after he built a house

Aaron dug a tunnel before/after he read an article

Adalyn put together a jigsaw puzzle before/after she received an award

Adeline compiled a database before/after she caught a fish

Aiden filmed a documentary before/after he returned a call

Alex filmed a movie before/after he saved a life

Alexa filmed a scene before/after she packed a suitcase

Alexander found a job before/after he climbed a ladder

Alice graduated college before/after she smoked a cigarette

Angel hosted a tournament before/after he completed an internship

Aria attended a conference before/after she launched a campaign

Aurora painted a picture before/after she negotiated a contract

Aubrey appointed a new director before/after she painted a house

Connor shot a scene before/after he sent a letter

Elena underwent surgery before/after she climbed a mountain

Elizabeth bought a house before/after she wrote an article

Eli watched a game before/after he released an album

A.1.3 List Three

Caleb read an article before/after he received an award.

Caroline caught a fish before/after she returned a call

Christian saved a life before/after he packed a suitcase

Cora climbed a ladder before/after she smoked a cigarette

Dylan submitted an application before/after he climbed a tree

Ella wrote a letter before/after she shoveled a driveway

Emma took a shower before/after she went grocery shopping

Ava paid a bill before/after she played a game of chess

Aaliyah mowed a lawn before/after she completed an internship

Abigail drove home before/after she hosted a tournament

Adam ate lunch before/after he launched a campaign

Andrew held a meeting before/after he attended a conference

Angela installed new software before/after she negotiated a contract

Anthony baked cookies before/after he appointed a new director

Arianna lost a game before/after she painted a house

Ashley opened an account before/after she painted a picture

Clara sent a letter before/after she parked a car

Connor shot a scene before/after he passed a test

Daniel climbed a mountain before/after he changed a tire

Elena underwent surgery before/after she placed an order

Elijah wrote an article before/after he cooked a meal

Elizabeth bought a house before/after she presented an award

Charles released an album before/after he purchased a ticket

Eli watched a game before/after he put out a fire

Aaron dug a tunnel before/after he put together a jigsaw puzzle

Adeline compiled a database before/after she filmed a documentary

Alex filmed a movie before/after he found a job

Alexa filmed a scene before/after she graduated college

Belle performed a surgery before/after she published a magazine

Caitlin quit smoking before/after she read a novel

Carson designed a building before/after he recorded a song

Chase repaired a car before/after he built a house

A.1.4 List Four

Camilla received an award before/after she read an article

Chloe returned a call before/after she caught a fish

Colton packed a suitcase before/after he saved a life

David smoked a cigarette before/after he climbed a ladder

Elias climbed a tree before/after he submitted an application

Emily shoveled a driveway before/after she wrote a letter

Eric went grocery shopping before/after he took a shower.

Brian played a game of chess before/after he paid a bill

Austin parked a car before/after he sent a letter

John passed a test before/after he shot a scene

Ayden changed a tire before/after he climbed a mountain

Benjamin placed an order before/after he underwent surgery

Mark cooked a meal before/after he wrote an article

Brandon presented an award before/after he bought a house

Matthew purchased a ticket before/after he released an album

Caden put out a fire before/after he watched a game

Andrea completed an internship before/after she mowed a lawn

Angel hosted a tournament before/after he drove home

Antonio launched a campaign before/after he ate lunch

Aria attended a conference before/after she held a meeting

Asher negotiated a contract before/after he installed new software

Aubrey appointed a new director before/after she baked cookies.

Audrey painted a house before/after she lost a game

Aurora painted a picture before/after she opened an account

Adalyn put together a jigsaw puzzle before/after she dug a tunnel

Aiden filmed a documentary before/after he compiled a database

Alexander found a job before/after he filmed a movie

Alice graduated college before/after she filmed a scene

Britney published a magazine before/after she performed a surgery

Cameron read a novel before/after he quit smoking

Carter recorded a song before/after he designed a building

Claire built a house before/after she repaired a car

A.2 Stimuli for Experiments 3 & 4

A.2.1 Conditional Stimuli

Camilla packed her suitcase before she drove to the airport with it.

Camilla drove to the airport with her suitcase after she packed it.

Chloe wrote the essay before she submitted her application with it.

Chloe submitted her application with the essay after she wrote it.

Colton went grocery shopping before he cooked dinner.

Colton cooked dinner after he went grocery shopping.

David found a job before he negotiated his contract.

David negotiated his contract after he found a job.

Elias recorded the songs before he released the album.

Elias released the album after he recorded the songs.

Emily charged her phone before she returned a call with it.

Emily returned a call with her phone after she charged it.

Eric completed the necessary internship before he graduated college.

Eric graduated college after he completed the necessary internship.

Brian read the article before he led a discussion on it.

Brian led a discussion on the article after he read it.

Austin bought the house before he painted it.

Austin painted the house after he bought it.

John purchased the ticket before he went to the game.

John went to the game after he purchased the ticket.

Ayden preheated her oven before she baked cookies.

Ayden baked cookies after she preheated her oven.

Benjamin drove home before he ate lunch.

Benjamin ate lunch after he drove home.

Mark turned on the light before he had a midnight snack.

Mark had a midnight snack after he turned on the light.

Brandon memorized the song before he performed it.

Brandon performed the song after he memorized it.

Matthew filled his car up with gas before he drove it across town.

Matthew drove his car across town after he filled it up with gas.

Caden filled up the air mattress before he took a nap on it.

Caden took a nap on the air mattress after he filled it up.

A.2.2 Causal Stimuli

Andrea won the contest before she received the award.

Andrea received the award after she won the contest.

Antonio broke his arm before the doctor put it in a cast.

The doctor put Antonio's arm in a cast after he broke it.

Paul spilled his juice before he mopped it up.

Paul mopped up his juice after he spilled it.

Asher drove too fast before he got a speeding ticket.

Asher got a speeding ticket after he drove too fast.

Aubrey pulled the cat's tail before it hissed.

The cat hissed after Aubrey pulled its tail.

Aurora lifted weights before she took a shower.

Aurora took a shower after she lifted weights.

The pine tree was hit by lightning before it fell over.

The pine tree fell over after it was hit by lightning.

The boat hit a rock before it sank.

The boat sank after it hit a rock.

Alexander studied for the exam before he performed well on it.

Alexander performed well on the exam after he studied for it.

The lion chased the gazelle before he caught it.

The lion caught the gazelle after he chased it.

The jury found Alice guilty before she went to prison.

Alice went to prison after the jury found her guilty.

The nurse administered a sedative to Britney before she fell asleep.

Britney fell asleep after the nurse administered a sedative to her.

Claire received three stitches after the dog bit her.

The dog bit Claire before she received three stitches.

Timothy worked with asbestos before he developed a disease.

Timothy developed a disease after he worked with asbestos.

Charles found a job before he moved to a new state.

Charles moved to a new state after he found a job.

Harry complained to the landlord before the landlord refurbished the rooms.

The landlord refurbished the rooms after Harry complained.

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