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Do Event Boundaries Influence Processing Of Concurrently Presented Information?

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by

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Abstract

During our everyday experiences, working memory representations of the current situation are updated at event boundaries, where meaningful perceptual or conceptual changes occur. These event boundaries lead to increases in perceptual processing, attention, activation of semantics and event schemas to generate a more accurate representation of what is currently happening. Previous literature has demonstrated that information embedded within an elapsing experience that is presented at event boundaries receives a processing advantage that leads to better memory for that information compared to information presented at non-boundary locations. However, it is not clear whether information presented concurrently but outside of the elapsing event structure also benefits from being presented at event boundaries. We presented participants with a list of words while watching movies of actors engaged in everyday activities. Words were either conceptually related or unrelated to the event structure and were presented either at previously identified event boundaries or non-boundary points in the movies. At the end of each movie, participants had to recall the list of words they learned. Memory performance was better for related than unrelated words, but there was no difference in memory for words presented at boundaries versus non-boundaries. These results suggest that the event model is limited in the amount of information incorporated from the overall experience during working memory updating. Additionally, perceiving a transpiring experience may provide semantic support for words conceptually related to the experience. However, information not contained within the event structure does not appear to receive a specific encoding boost from the updating that occurs at event boundaries.

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Introduction

As we carry out everyday tasks, we continuously receive an overwhelming amount of information from different sensory systems. Understanding how people select, process, and encode subsets of that information from short-term memory into long-term memory will help us understand how this information is later organized and represented in long-term memory. *Event segmentation theory* (Zacks, Speer, Swallow, Braver, & Reynolds, 2007; EST) provides an explanation for this phenomenon. EST proposes that people automatically segment information into meaningful spatiotemporal units, or events (Speer, Swallow, & Zacks, 2003; Zacks et al., 2001). For example, a Friday night dinner can be segmented into discrete events such as being seated by a host, ordering food, eating, and finally paying. These units, or events, contain both conceptual and perceptual information. Segmentation occurs at *event boundaries,* where meaningful changes in the stream of information occur (i.e., when one event ends, and another one begins). Information about the current event is actively maintained and accessible through a working memory representation known as an *event model*. The way in which we remember past events depends on the organization of event models in long-term memory. Previous research has demonstrated that event boundaries also influence our memory for information directly contained within a transpiring experience (Swallow, Zacks, & Abrams, 2009). That is, information presented at event boundaries tends to be more readily accessible than information presented within an event. However, it is unclear how event boundaries may influence long-term memory for information not contained in the transpiring event structure. For example, it is not unusual to overhear side conversations while watching a movie at a movie theater. How does the structure of the unfolding movie affect our long-term memory for information contained in the side conversation?

Classic Memory Theories

Several classic memory theories have tried to conceptualize how information is organized and encoded into long-term memory. For example, Squire and colleagues (1980) proposed a taxonomy of long-term memory by categorizing long-term memory into declarative and non-declarative memory (Cohen & Squire, 1980; Squire, 1992). Declarative memory refers to information that can be verbalized and accessed via conscious retrieval (e.g., memory of events or facts). On the other hand, non-declarative memory represents information that is more difficult to verbalize such as motor skills or procedural skills such as riding a bike. The *monohierarchical multimemory systems* model (Tulving, 1985) extends the system model proposed by Squire and colleagues by dividing declarative memory into two different, yet interacting systems, semantic memory, and episodic memory. Semantic memory is general knowledge that we have acquired, such as meanings and facts that are independent of the temporal context in which they were acquired. Episodic memory contains information about personal experiences of a particular time and place. Overall, these memory systems assume that information is stored into these systems through learning and provide an initial explanation about memory organization. However, an explanation regarding the specific processes engaged during learning is usually not provided.

Unlike system theories, process theories divide memory into several cognitive processes, providing an explanation as to how information is encoded. For example, the *multi-store* model provides an account of both how information is segregated into several stores of information and how information reaches those stores (Atkinson & Shiffrin, 1968). The model states that memory consists of three stores: sensory memory, short-term memory, and long-term memory and that the likelihood of encoding information into long-term memory depends on the amount of time

information is actively maintained in short-term memory. Information is held in sensory memory for a small relative time. The length of time varies on the modality, with iconic memory lasting no more than one second and echoic memory lasting three to five seconds (Dickt, 1974; Lu & Sperling, 2011). Information that we attend to reaches short-term memory and is available for approximately thirty seconds. It is then by rehearsal that information reaches long-term memory. However, later research demonstrated that factors other than time spent rehearsing predict successful long-term memory encoding. For example, Craik and Lockhart (1972) determined that the level at which information is initially processed during encoding influences encoding success (Craik & Lockhart, 1972). Specifically, deep processing (i.e., semantic processing) compared to shallow (i.e., structural processing, and phonetic processing) was associated with higher performance in subsequent memory tests. These results lead to the development of the *levels of processing* model that, unlike the *multi-store* model, is a non-linear framework that focuses on the depth of processing. Further work demonstrated that self-referential encoding might lead to better memory performance than semantic encoding (Rogers, Kuiper, & Kirker, 1977). When participants were asked to judge whether target words were self-descriptive versus processing semantic or structural information about words at encoding, self-referential encoding produced better recall than structural or semantic encoding of the same information. Note that this is not an exhaustive list of memory theories. However, the purpose of this review is to illustrate what previous memory theories have to say regarding how information is encoded an organized in long-term memory. However, everyday experience tends to be more complex and dynamic than some of the stimuli used in previous studies of memory (Zacks et al., 2007). Furthermore, these classic models of memory mainly focus on semantic memory while providing little explanation for episodic memory (Atkinson & Shiffrin, 1968; Craik & Lockhart, 1972).

Thus, models of memory that focus on processing of information into episodic memory are necessary.

Event Segmentation Theory (EST)

EST provides an explanation as to how people make sense of their everyday experience and make predictions about what might happen next. EST states that current sensory information is processed and transformed into working memory representations known as event models with rich perceptual content such as color, shapes, spatial location, and motion trajectories, and semantic content such as object identity, and the identities and attitudes of other people. Event models are not to be confused with *schemas*, long-term memory represntations of how a type of event unfolds (Hard, Tversky, & Lang, 2006). Event schemas are conceptual in nature and include information regarding goals or sub-goals an individual might engage in during an event. For example, an event schema can be the general knowledge of how a Friday night dinner unfolds (i.e., being seated, ordering, eating, and paying). On the other hand, event models are complex mental models built from previous experience, event schemas, and current perceptual and conceptual information that provide a representation of what is happening at the current moment. For example, we create event models of a Friday night dinner by activating previous experience (e.g., what you like and dislike from the menu), as well as activating event schemas (e.g., how a Friday night dinner typically unfolds), processing current perceptual features (e.g., light, color, smell, and sounds) and conceptual features (e.g., what you plan to order from the menu). See Zacks and colleagues (2007) for an illustration of the model.

EST and Future Predictions

Event models allow an individual to anticipate or make predictions about upcoming

actions or future circumstances (Zacks, Kurby, Eisenberg, & Haroutunian, 2011). These future predictions are constantly compared to the current state of the event model, providing an assessment of perceptual processing. When perceptual processing is erroneous, prediction errors transiently increase. The prediction error is automatically broadcasted across the brain to reset and rebuild the event model with current perceptual and sensory information from multiple modalities (Zacks et al., 2001, 2007). Perceptual information is integrated and processed in a bottom-up fashion. Once integrated into the event model, the information is processed and matched to semantic information through event schemas and previous experience (i.e., top-down). After the event model is rebuilt, prediction errors decrease and the cycle repeats (Kurby & Zacks, 2008; Radvansky & Zacks, 2011). Through this system, event segmentation allocates attention resources when needed. During periods of low prediction errors, fewer attentional resources are allocated to sensory information. However, as prediction errors increase, more attentional resources are allocated to sensory information to update the event model with current information (Zacks et al., 2007). These increases in prediction errors are indicative of event boundaries. Event boundaries are experienced in narrative text, films, and action-based changes like moving across rooms. They are cued by changes in perceptual features such as color, shape, and location, as well as conceptual changes such as goal-directed behavior (Zacks, Speer & Reynolds, 2009).

When an event boundary is encountered, the ill-fitting event model is updated with current sensory, perceptual and conceptual information to improve processing of information and future predictions. Zacks and colleagues (2011) demonstrated that participants were better at making future predictions while watching a movie if an event boundary did not occur within the next 2.5 seconds than if an event boundary did occur within the next 2.5 seconds. These results

demonstrate that when an event model fits the current situation, future predictions are accurate and reliable. Once prediction errors increase, the event model must be updated to fit the current situation. Thus, event boundaries influence the online maintenance of working memory representations and the processing and encoding of perceptual and conceptual information.

In experimental settings, to measure people's perception of event structure, participants are asked to attend to a stream of information (i.e., a movie or narrative text), and indicate, by pressing a button, when one event ends, and another event begins (Newtson, 1973). Neuroimaging data has provided support for the automaticity of event segmentation by asking participants to passively view a movie then segment the same movie, all while fMRI data was being collected (Zacks et al., 2001). The results demonstrated high correlation of brain activity between passive viewing and active segmentation. Furthermore, segmentation is hierarchical; people segment fine-grained events within coarse-grained events. For example, within the context of preparing lunch for work, making a sandwich could be considered a coarse-grained event, while the steps required to prepare the sandwich (i.e., taking out the bread, getting utensils, getting the meats and condiments from the fridge) can be considered fine-grained events. Coarse-grained segmentation tends to be marked by changes in character goals, while fine-grained segmentation is typically characterized by changes in character sub-goals such as movements and object interactions (Zacks, 2004). When instructed, participants can segment the movies either at a fine-grained level or coarse-grained level. In the fine segmentation task, the participants are instructed to identify the smallest units of activity that appear natural and meaningful to them. In the coarse segmentation task, participants are asked to identify the largest units of activity that appear natural and meaningful to them. Participants tend to show high agreement in their perceived location of event boundaries (Zacks & Swallow, 2007). These

findings have been replicated in studies involving identification of events within text passages (Zwaan, Magliano, & Graesser, 1995; Zwaan & Radvansky, 1998). Furthermore, segmentation patterns are reliable (Speer et al., 2003); when participants were asked to segment twice, with a one year interval between segmentations, they demonstrated the same pattern of segmentation.

Event Segmentation and Memory

Event segmentation has been shown to guide memory and learning. Research suggests that segmentation ability is associated with subsequent memory. For example, if event boundary presentation is disturbed, memory for the depicted activity is weaker (Schwan & Garsoffky, 2004). By asking participants to recall the content from edited films (i.e., inserting a 1 second blank screen) at boundary and non-boundary points, Schwan and Garsoffky (2004) demonstrated that participants' memory was weaker for boundary edited films than non-boundary edited films. Thus perceiving and encoding boundary structures is necessary for memory organization. Similar findings were obtained when participants were asked to recognize information from a film that had commercial breaks following either boundary points or non-boundary points (Boltz, 1992). Presenting films with commercial breaks after boundary points were experienced lead to better recall and recognition of the content of the films than films with commercial breaks at non-boundary points. These data suggest that event boundaries influence how information is organized in long-term memory. This boundary influence on long-term memory organization has also been demonstrated when participants were asked to read narrative text and then had to recall the next sentence that followed a cued sentence (Ezzyat & Davachi, 2011). The results demonstrated that participants had more difficulty recalling information if the cued sentence preceded an event boundary than when the cued sentence did not precede an event boundary. Thus, participants were better at recalling information if the information was contained within

the same event than across events.

Furthermore, people who are better at segmenting an activity can remember more of the activity later (Zacks, Speer, Vettel, & Jacoby, 2006). For example, Zacks and colleagues (2006) asked participants to discriminate between pictures taken from a movie they had recently segmented and foil pictures. People who segmented more similarly to the rest of the participants had better recognition memory performance than people who segmented out of the norm. Thus, having a good event structure representation aids memory. Another study demonstrated that people were better at recalling an activity depicted by a movie if their fine-grained segmentation was hierarchically organized within their coarse grain segmentation (Sargent et al., 2013). Additionally, a study conducted by Flores and colleagues (2017) demonstrated that participants had better memory performance when they were instructed to actively segment a movie rather than simply passively view it (Flores, Bailey, Eisenberg, & Zacks, 2017). These benefits were reliable in delays ranging from 10 minutes up to a month between presentation and test phase. Overall, these studies demonstrate that event segmentation has an influence on long-term memory encoding. Specifically, good segmentation ability and highlighting boundary locations benefits long-term memory encoding.

Boundary Benefits

In addition, information presented at event boundaries tends to be better recognized than information presented within an event (Newtson & Engquist, 1976; Swallow et al., 2011, 2009). In the study conducted by Newtson and colleagues (1976), participants performed a picture discrimination task after watching a movie. The pictures were extracted from event boundaries or non-boundary points of the movie, and from foil movies. The results demonstrated that accuracy was higher for pictures taken from event boundaries. Similar findings were obtained by Swallow

and colleagues (2009) by presenting participants with eventful movies while periodically pausing and probing the participants' memory for recently presented objects. The objects were presented either at event boundaries or within an event. The results demonstrated that boundary objects were better recognized than non-boundary objects. As well, participants' conceptual and perceptual memories for recently presented objects were probed to determine what type of information is affected by event boundaries. To test conceptual memory, participants chose between a picture of an object that was conceptually the same-type of object as the one being tested (e.g., a different pot) and a picture of an object that was a different-type of object (e.g., a spatula). To test for perceptual memory, participants chose between a picture of the object from the movie (e.g., a pot) and a picture of the same type of object with different perceptual characteristics (e.g., a different pot). The results demonstrated that boundary benefits were higher for conceptual memory but still present for perceptual memory.

Similar boundary benefits have been seen for visual attention when participants were asked to detect a target presentation as quickly as possible (Swallow & Jiang, 2010). In this study, participants were instructed to press the spacebar whenever they saw a white square (target) in the center of the screen and to make no response whenever a black square (distractor) appeared. During this task, scenes were presented in the background and participants were instructed to remember the scenes for a later recognition task. Participants had better recognition for background scenes that were presented along with a target than for scenes presented along with a distractor. This was also the case when participants monitored auditory tones for a target while being presented with background scenes. Thus, it seems like changes in events can result in higher perceptual processing for concurrent information presented in both the same and across

different modalities. Therefore, information presented at event boundaries is more likely to be encoded into long-term memory due to increases in perceptual processing and attention.

According to EST, the perception of event boundaries triggers an increase in processing, resulting in event model updating. This idea is further supported by a recent study that collected segmentation data and eye tracking data during passive viewing of eventful movies (Eisenberg & Zacks, 2016). The study demonstrated that participants engaged in exploratory visual processing, indicated by shorter fixations and a lower amplitude of saccades at event boundaries. Similar physiological responses have been seen when participants are asked to read a narrative text (Swets & Kurby, 2015). When faced with an event boundary participants' reading speed decreased and regressive saccades were more likely to occur than at non-boundary points.

In contrast, there is evidence that retrieving information after an event boundary can result in lower accuracy or prolonged retrieval (Radvansky & Copeland, 2006; Radvansky, Krawietz, & Tamplin, 2011; Radvansky, Pettijohn, & Kim, 2015; Radvansky, Tamplin, & Krawietz, 2010a). In these studies, participants were asked to move objects through virtual or real rooms. After setting the object down new objects were handled and the process was repeated. Objects were placed inside a box so that the object was no longer visually available to the participant while being carried. During this process, participants' memory for the objects was probed by having participants recognize if a presented color and name of a shape matched either the object they were carrying or the object they previously had set down. Participants made more errors when there was an event shift than when there was no event shift. That is, when moving from one room to another, participants' memory for the objects was less available, even if the probed object was currently being carried. Thus, after experiencing an event boundary, working memory is updated, leading to difficulty in memory retrieval of prior information. These results

demonstrate that information about a previous event is less accessible than information being manipulated by the current event model.

Event Segmentation and Concurrent Information

Although EST provides an explanation for how event boundaries might improve long-term memory, it is still not clear whether these benefits generalize to broader information that may not fit well within the currently transpiring event structure. Most prior studies addressed memory performance by probing memory for objects presented as part of the transpiring activity (Radvansky & Copeland, 2006; Radvansky et al., 2015, 2010a; Radvansky, Tamplin, & Krawietz, 2010b; Swallow et al., 2011, 2009). It is unclear whether event boundaries also influence how information presented simultaneously with a transpiring activity, but which is not inherently part of that activity gets incorporated into the event model. Based on EST and evidence provided by previous research (Swallow et al., 2011, 2009; Zacks et al., 2007), information presented at event boundaries should receive additional attentional, perceptual and conceptual processing which should result in better memory performance than for information presented within an event. Furthermore, if event models are working memory representations built from current perceptual and conceptual information that guides our perception by making future predictions, it is feasible that information conceptually related to, but not part of the transpiring activity receives a greater benefit from updating at event boundaries than unrelated information. This is due to the fact that working memory capacity is limited and thus, only relevant information to the current event structure may be incorporated into the event model.

The Present Study

The purpose of the current study was to investigate how long-term memory updating at event boundaries influences memory for information that is presented in conjunction with but not

contained within the transpiring activity that contains the relevant boundary structure. This study will further explore how boundary structure influences memory for this concurrent information when it is related (i.e., conceptually similar) or unrelated (i.e., conceptually dissimilar) to the transpiring activity. More specifically, we investigate the following questions: (1) whether the memory benefits produced by event boundaries generalize to memory for information outside the transpiring event and (2) whether the benefits produced by event boundaries depend on whether the concurrent information is conceptually related to the transpiring activity. This will help extend our knowledge of how event boundaries influence memory and determine whether the influence of boundaries on memory extends beyond information wholly contained within the transpiring activity. To the best of our knowledge, this is the first study to assess how event boundaries and event model updating influence long-term encoding of concurrent information.

In order to test the benefits of event boundaries on concurrent information two experiments were conducted. Experiment 1 consisted of a norming study to develop a set of stimulus words that were related to the event models represented in a set of movies showing actors engaged in everyday activities. This stimulus set was then used for Experiment 2. In Experiment 2, participants watched a set of movies and concurrently heard a list of words. The words were either related or unrelated to the experience depicted in the movie. Words were presented at either event boundaries (i.e., between the end and beginning of a new event) or non-boundaries (i.e., within an event) in the movies. After each movie, participants were tested on their memory for the content of the movie using a recognition task; their memory for the words presented was assessed using a free recall task. We predicted better recall for concurrently presented information at event boundaries due to the additional processing occurring at event boundaries, and with greater boundary benefits for information related (i.e., relevant) versus

unrelated (i.e., irrelevant) to the transpiring activity.

Experiment 1

The purpose of Experiment 1 was to develop a stimulus set of words related to the everyday movies we planned to use in Experiment 2.

Method

Participants

Forty undergraduate students (*M* = 19.98, *SD* = 3.14; 18 males) were recruited from the University of Texas at El Paso (UTEP) psychology department subject pool. All students were proficient in English, and had normal or corrected to normal vision and hearing. See Table 1 for language characteristics. Participants were granted course credit for their participation. The experiment was approved by the UTEP Institutional Review Board (IRB).

Materials & Design

Movies

Twelve movies (1 practice 11 experimental) of actors engaged in everyday activities were used. See Table 2 for movie descriptions. Movie order was randomized across participants. All movies had been used in previous event segmentation studies (Bailey et al., 2013; Bailey, Kurby, Giovannetti, & Zacks, 2013; Zacks et al., 2011).

Language Background Questionnaire

The *ESPADA* (English-Spanish Proficiency and Dominance Assessment, Francis & Strobach, 2013) language background questionnaire was used to assess English and Spanish language proficiency. This questionnaire is a multiple-item untimed, self-report questionnaire that assesses multiple dimensions of a participant's language background. The items include information on the age of language acquisition, information regarding where the participant has lived (US, Mexico, or other Spanish-speaking country), family language usage, social language

usage, educational language usage, self-rated proficiency levels on reading, writing, and speaking in each language and other general language background information.

Procedure

Participants provided consent and demographic information at the beginning of the session. All participants completed the ESPADA language background questionnaire to gather information about their English language and Spanish language proficiencies. Participants were told they would watch portions of movies of actors engaged in everyday activities and would have to generate nouns related to the movies. Participants completed a practice movie to get familiarized with the task. The first minute of the practice movie was shown to the participants to allow them to generate a sense of the overall purpose and content of the movie without exposing them to excessive visual details. This procedure provided enough conceptual information for participants to generate words not present during the movie but conceptually related to the event structure. After watching the first minute of the practice movie, participants were instructed to type forty nouns that they believed were highly related to the movie into an excel sheet. If the participants ran out of ideas, they were instructed to come up with words related to the words they had already generated. The experimenter provided examples of related nouns, if needed, during the practice movie only. The experimenter answered any questions the participant had after the participant completed the 40 nouns for the practice movie. Participants were given the same instructions and procedure for the remaining 11 movies but were not provided any assistance with generating nouns. However, if the experimenter noted that a participant generated any words that were not nouns, the participant was asked to try to come up with replacement words that were nouns. The participants were debriefed at the end of the session.

Data Analysis

Several guidelines were established to control for word variation. See Table 3 for a list of guidelines and examples. Also, we coded for the visual presentation of the generated nouns. For example, if a participant generated the word "cabinet" and a cabinet(s) was visually available during the movie, then the noun was coded as present, otherwise, the noun was coded as absent. Words that were not visually present during the movie and were generated by at least 15% of participants were selected for Experiment 2.

Results

In total 812 words were generated by at least 15% of participants, Table 4 provides the total number of absent and present nouns generated for each movie and the overall average of the proportion value of words generated by at least 15% of participants. See Appendix A for a list of absent words generated during each movie by at least 15% of participants.

Experiment 2

The purpose of Experiment 2 was to determine whether information outside the transpiring event receives long-term memory benefits from being presented at event boundaries. EST predicts that when prediction error increases people update their event models based on currently available sensory, perceptual and conceptual information. If event models can integrate conceptual information that is not part of the transpiring activity, then we expect to see better recall for information presented at event boundaries than information presented during an event. Furthermore, it is unclear whether updating selectively applies to information related to the transpiring activity. If event models facilitate encoding for any information that is presented during a transpiring event, then both related and unrelated information may benefit from the additional processing at event boundaries. On the other hand, if updating only benefits information that is conceptually meaningful to the transpiring event, then we would expect to see boundary benefits only for related words.

Method

Participants

The required sample size for each group in our experiment ($N = 48$) was calculated using G*Power 3 software (Faul, Erdfelder, Lang, & Buchner, 2007) assuming a medium effect size ($\eta_p^2 = .25$) with a power of .90. One hundred seventeen undergraduate students were recruited from the UTEP psychology department subject pool. Seventeen participants were replaced due to low reported English language proficiency (< 7 on a 10-point scale; $n = 7$), incomplete data ($n = 4$), poor performance on the picture discrimination task (< .70; $n = 3$), or computer errors ($n = 3$). All remaining 100 participants (Age = 20.76 ± SD = 4.63 years; 37 males) were proficient in English (see Table 5 for language characteristics) and had normal or corrected to normal vision

and hearing. Participants were granted course credit for their participation or received gift cards totaling $20. The experiment was approved by the UTEP Institutional Review Board (IRB).

Materials

Movies

The experiment was programmed using E-prime 2.0 experimental software. Six movies from Experiment 1 were used for Experiment 2. See Table 2 for movie descriptions. Movie selection was based on fine-grained segmentation data from previous studies. In these studies, participants were asked to watch a movie and indicate, by pressing a button, when a meaningful change occurred in the movie. Segmentation data was aggregated across participants and analyzed using Gaussian kernel density estimation (3s bandwidth). A 5-sec window was then drawn around each local maximum and minimum to compute the proportion of participants that segmented the movie within this window. This procedure is outlined in detail in Zacks and Kurby (2011). Maxima values where used for boundary points, while minima values were used as non-boundary points. The range in agreement for boundary points was 25% to 80% with an overall average of 55%. Non-boundary time point agreement ranged between 0% and 17% with an overall average of 2%. We selected a total of six boundary points and six non-boundary points for each movie. The first two time points at the beginning of each movie and the last two time points at the end of each movie were partially counterbalanced to reduce any primacy or recency effects. For example, if one participant received two boundary points at the beginning of a movie and two non-boundary points at the end of the same movie, then another participant received two non-boundary points and two boundary point at the beginning and end of the movie, respectively. Movie selection was also based on the total number of words generated by at least

15% of participants from Experiment 1. Thus, movies with a low number of potential boundary time points and few words that fit the 15% criterion were not selected for Experiment 2.

Word Stimuli

Sixty nouns related to the experimental movies were used for the related condition in Experiment 2. In this condition, 12 nouns conceptually related to the movie were presented during each movie. All related nouns were produced by at least 15% of participants in Experiment 1 and represented items that were not directly presented in the movies. The length of the words, number of syllables, part of speech, and Hyperspace Analogue to Language (HAL) log word frequency were obtained from the English Lexicon Project (ELP) database (Balota et al., 2007). The part of speech data was used to confirm all words were nouns. The HAL word frequency was obtained from 131 million words gathered across 3,000 Usenet newsgroups (Burgess & Livesay, 1998); the log of the word frequency was used as our measure of word frequency in the current study. Sixty unrelated nouns, 12 per movie, were also identified using the ELP. For each movie, 12 unrelated nouns were matched to the related nouns on average word length, number of syllables and the average HAL log word frequency. This allowed us to create a list of 60 words unrelated to the movies that were matched to the words in the related word list on the above characteristics. For both related and unrelated word lists word location was counterbalanced. If a word was presented as a boundary word in one list, in the second list it was presented as a non-boundary word. Table 6 provides the average of the word attributes for each movie. See Appendix B for the full list of related and unrelated words and their attributes. All words for Experiment 2 were recorded using Audacity 2.1.2 by a male voice with American Standard English dialect. The duration of all the sound files were matched to the duration of the longest sound file (i.e., 1,200 milliseconds) by adding equal interval of silence to the beginning

and end of the sound file. For example, if a sound file was 600 milliseconds long, 300 milliseconds of silence were added to the beginning and end of the sound file. During the movie, sound file onset occurred 600 milliseconds before the calculated boundary time point. This procedure allowed us to present the event boundary directly in the center of the sound file.

Language Background Questionnaire

The ESPADA language questionnaire was again administered to participants in Experiment 2.

Design

This experiment employed a 2 (relatedness) x 2 (word location) design. Relatedness was treated as a between-subject variable; participants were either presented with a list of related or unrelated words. Word location was treated as a within-subject variable; all participants were presented with words either at event boundaries or non-boundary points in the movies. Three minutes after movie presentation, participants completed a recall task for the words were accuracy was measured.

Procedure

Participants provided consent, demographics, and language proficiency information at the beginning of the testing session. Participants were told that they would be presented with movies of actors engaged in everyday activities and that periodically throughout the movies, they would be presented with auditory words. Participants were instructed to try their best to remember the content of the movie and the words because they were going to be tested on both. Half of the participants were assigned to the related condition where they heard nouns related to the movies and the other half were assigned to the unrelated condition where they heard unrelated nouns.

After each movie, the participants completed a picture discrimination task to assess their memory regarding the content of the movie. For the picture discrimination task, participants were presented with two different pictures, one from the movie and one foil picture from a similar but different movie. Participants were asked to judge which picture was contained in the movie and respond using "Q" for the left-side picture or "P" for the right-side picture. Picture location was randomized so that the correct picture was not always located on the left or right side of the screen. Trial order was also randomized so that participants received the set of pictures in a different order.

Once participants completed the picture discrimination task, participants completed a random number generation task. Participants were asked to generate numbers between ten and ninety-nine, and to avoid repetitions, sequential orders, and patterns (e.g., increments of two, five, etc.). The required duration of the random number generation task for a participant was calculated based on the length of time it took the participant to complete the picture discrimination task. The total combined duration of the two tasks was three minutes. This timing ensured that during the word recall task, we assessed long-term memory for the words presented during the movie.

During the free recall task, participants were instructed to type any words they remembered from the movie as quickly and as accurately as possible into an E-prime response window. Although participants were only presented with twelve words, they were given the opportunity to type up to sixteen words to assess any intrusion errors that might arise. Participants were given as much time as needed to recall as many words as they could. The recall task ended once the participants reported not being able to recall more words. After completing all the movies, participants were asked to fill out an exit questionnaire to assess any strategies

they used to try to remember the words (i.e., recited the words, organized the words, etc.) and any additional comments they had about the movies or the words. After the exit questionnaire, participants were compensated and debriefed.

Results

Language Proficiency

Participants who scored themselves as having a proficiency of 7 or less out of 10 in any English skill (i.e., reading, writing, speaking and speech comprehension) were replaced. The remaining participants had an overall English reading, writing, speaking and speech comprehension average of 9.57 (*SD* = .72), 9.49 (*SD* = .77), 9.62 (*SD* = .72), and 9.79 (*SD* = .55), respectively. Table 6 provides the average self-reported English skill ratings for monolinguals, English-Spanish bilinguals, and Spanish-English bilinguals.

Picture Discrimination

Participants who had a proportion less than .70 in accuracy on this task were replaced because such poor performance suggested they were not attending well to the content of the movies. The remaining participants had an average accuracy of .86 (*SD* = .05) and an average reaction time of 2,955 milliseconds (*SD* = 804.74) across trials. On average, the picture discrimination task lasted a total of 81.81 seconds (*SD* = 29.91).

Random Number Generation

On average, participants generated 29.65 numbers (*SD* = 12.69). The random number generation task lasted an average of 95.18 seconds (*SD* = 15.67).

Word Accuracy

A mixed ANOVA was used to analyze word recall accuracy data. There was no interaction between the relatedness of the words and the word location, as well as no main effect

of location, all *ps* > .20. Namely, participants recalled boundary words with the same level of accuracy as non-boundary words. There was a main effect of relatedness, $F(1, 98) = 14.77$, $MSE = .05$, $p < .001$, $\eta_p^2 = .13$; participants in the related condition ($M = .63$) recalled more words than participants in the unrelated condition ($M = .51$). Figure 2 illustrates the results from this task.

Word Intrusions

A word intrusion analysis was completed post-hoc to evaluate whether any meaningful patterns in intrusion errors occurred across conditions. Word intrusions were coded into 10 categories: related, unrelated, synonym, across movies, root word, repeat, incomplete, phonological, orthographical, and phonological & orthographical. Table 7 provides examples for each type of condition and the total number of intrusions by condition. Intrusion data was analyzed only if the error was committed at least 40 times across participants and trials. The final data analyses included the related, repeated, and phonological intrusions. Related word intrusions were submitted to a Welch's t-test. There was a significant difference in related intrusions between the related and unrelated condition, $t(53.52) = 4.53$, $p < .05$. Participants in the related condition committed more related intrusions ($M = 2.66$, $SD = 3.57$), than participants in the unrelated condition ($M = .32$, $SD = .77$). Repeated and phonological word intrusions were submitted to a 2 (relatedness) X 2 (error location) mixed ANOVA to assess any boundary and non-boundary word error differences. There was a main effect of relatedness for phonological intrusions, $F(1, 98) = 21.87$, $MSE = 29.04$, $p < .001$, $\eta_p^2 = .182$; participants in the unrelated condition ($M = .50$, $SD = 1.67$) recalled words that were phonologically similar to words actually presented during the movie more often than participants in the related condition ($M = .14$, $SD = .37$). There was no main effect of relatedness, error location or interaction for the repeated intrusions all *ps* > .08.

Types of Strategy

The type of strategies employed by the participants to recall the words was analyzed post-hoc using a Welch's t-test. Types of strategies were coded as either rehearsal, elaborative rehearsal (e.g., repeating the words in a rhythm, using fingers to count), self-referencing (i.e., relating the words to one's self), visualizing the words, recalling the actors' actions, and creating a story. Some participants reported more than more strategy and therefore contributed more than one observation. There was a significant difference in the reported use of rehearsal between the related and unrelated condition, $t(97.47) = 2.91$, $p <.05$. That is, participants in the related condition reported rehearsing the words more frequently than participants in the unrelated condition. A significant difference in the use of self-referencing between the related and unrelated condition was also evident, $t(64.54) = -2.25$, $p < .05$. Participants in the unrelated condition reported self-referencing the words more often than those in the related condition. We also found a significant difference in the number of times participants reported remembering the actors' actions between the related and unrelated condition, $t(49) = 2.58$, $p < .05$. Participants in the related condition recalled the actors' actions more frequently than those in the unrelated condition. Finally, there was a significant difference in creating a story for the related and unrelated condition, $t(86.61) = -2.11$, $p < .05$. Participants in the unrelated condition reported creating a story more frequently vs. participants in the related condition. Use of all other types of strategies did not differ significantly across related and unrelated conditions *ps* > .30. Table 8 provides the descriptive statistics for the types of strategies engaged by participants.

Discussion

In the current study, we explored the benefits of event boundaries on long-term recall of concurrently presented information by asking participants to memorize lists of words while watching movies of everyday activities. The words were related or unrelated to the transpiring activity depicted by the movie and were presented either at event boundaries or non-boundary points in each movie. Participants who encoded related words during the task showed better recall than participants who encoded unrelated words. Contrary to predictions from EST, we found no benefit for words presented at event boundaries versus non-boundaries. This absence of a boundary effect was found for both the related and the unrelated word conditions.

These findings suggest that information concurrently presented with a transpiring activity does not benefit from the increases in attention, perceptual and conceptual processing thought to occur at event boundaries, regardless of whether the information is related or unrelated to the activity. From an EST perspective, event models are a working memory representation of the current situation that assists in perceptual processing by predicting the near future. The amount of information incorporated into the event model is therefore confined to the limits of working memory. Thus, only information relevant to the current event structure may be processed into the event model to improve future predictions and processing of information. It is possible that during updating, only information contained in the transpiring activity receives additional attentional resources devoted to perceptual, and conceptual processing. At the current state, EST assumes that any information presented during updating receives additional processing. Therefore, revising the model should be taken into consideration based on the findings of the current study. Perhaps, a revision to the model migth require an addition of a filter at the level of perceptual processing. It is possible that concurrent information is not integrated into the event

model due to filtering mechanisms that filter out information during perceptual processing that is irrelevant for future predictions. This filtering mechanism allows event models to fuction adequately within the limits of working memory. Nonetheless, more work is warranted to fully understand how concurrent information is processed during a transpiring activity.

Although the current study did not find boundary benefits for concurrent information, we did find a higher recall for related versus unrelated information. It is possible that perceiving an event structure activates conceptual information that provides semantic support for concurrently presented related information. This semantic support could be a result of tonic event schema activation, which is rich in conceptual information regarding how an experience typically unfolds. Thus, it is possible that as words were being perceived during a particular movie in the current study, the conceptual information present in the relevant schema facilitated the conceptual activation of the concurrent information without necessarily being integrated into the event model. Nonetheless, these initial findings require further exploration; it is possible that the related findings are due solely to the semantic relationship between the words within individual lists. This relationship could have activated a category scheme within the lexicon that facilitated retrieval between the words, regardless of the movie content. This occurrence has previously been demonstrated in studies that look at the overall lexical organization of nouns and verbs (Huttenlocher & Lui, 1979; Langacker, 1987). Higher recall for related nouns could be an end result of the hierarchical semantic organization in the mental lexicon, which is thought to spread activation when a single word is retrieved. As a result, retrieval is facilitated for related nouns. This idea is further supported by previous studies where related intrusions occurred more frequently when participants were asked to recall a list of related words than unrelated words (Roediger & McDermott, 1995; Stadler, Roediger III, & McDermott, 1999). Similarly, the

current study found more related intrusions for the related word condition than the unrelated word condition. Therefore, future studies should focus on assessing whether the results seen in the current study are due to the semantic relationship between the words or the semantic support provided by the related event structure. This could be accomplished by presenting a list of words which are related to one another along with a related or unrelated movie and assessing any differences in word recall.

Previous research has demonstrated that proper segmentation of a stream of information is related to subsequent memory performance (Flores et al., 2017; Sargent et al., 2013; Swallow et al., 2011, 2009). Furthermore, memory performance is higher for boundary presented information than non-boundary information (Swallow et al., 2009). The current study attempted to address the influence of event boundary benefits in long-term memory encoding. Items were probed three minutes after the completed of each movie. Consequently, it is likely that the event models were no longer active or easily accessible. On the other hand, many prior studies that have demonstrated boundary benefits have probed memory for items a few seconds after the item is presented, when the event model is likely easily accessible (Swallow et al., 2009). Future studies could employ a task where concurrent information is probed a few seconds after presentation. It is possible that probing memory a few seconds after the information is presented results in higher boundary benefits than when the information is probed a few minutes later.

Many prior studies have employed a recognition task where the items being used to probe memory are rich in perceptual detail (Swallow et al., 2011, 2009; Swallow & Jiang, 2010). Perhaps boundary benefits are only revealed when cues rich in perceptual detail are provided. The present study employed a recall task where no cue was provided to the participant. One possible future direction is to have participants recall the word presented at a specific time point

in the movie (i.e., boundary versus non-boundary locations) after presenting the participant a cue involving a screenshot of the time point being probed. It is possible that the boundary effect is too small to be observed in the current recall task. Thus, it is possible that a recognition task may be more sensitive to boundary effects.

Another possible way to evaluate boundary benefits is through assessing how information is retrieved from long-term memory. If a boundary benefit exist, it is possible that boundary information is retrieved more easily from long-term memory and thus, is recalled prior to non-boundary information. However, it is also likely that if participants rehearsed the words throughout the movie, then item recall would be primarily serial in nature.

Another relevant issue is controlling for any type of rehearsal. In the current study, participants were not provided any specific instructions as to how to memorize the words. As a result, rehearsal was employed by more than half of the participants. Rehearsing the words possibly overshadowed any boundary effects by repeatedly reactivating the word multiple times throughout the movie. Therefore, the words were likely reexperienced at multiple boundary and nonboundary points in the movie. Future studies should employ a task where rehearsal opportunities are more difficult to engage in, for example, by asking participants to perform an articulatory suppression task as words are being presented to them. This would control experiencing the words more than one time throughout the movie.

Conclusion

Previous research has demonstrated that information within an event structure receives additional processing when meaningful changes occur. However, it has been unclear how changes in an event structure influence processing of concurrently available information. In this study, we demonstrated that not all the information presented at an event boundary receives

additional processing as suggested by previous literature and the assumptions of EST. Thus, during updating, only information relevant to the current situation may be integrated into the event model to provide a stable representation of the current event structure. However, it is possible that the conceptual information activated by the event structure provides some form of semantic support for the concurrent information. Further work is required to untangle the findings in the current study and to assess whether EST requires revision regarding the type of information processed and encoded by the event models.

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Table 1: Language Self-Assessed Proficiency Ratings for Experiment 1

		Age of acquisition (years)			
		English		Spanish	
Type of Bilingual	N	Mean	SD	Mean	SD
Spanish Dominant	2	8.00	3.00	1.5	1.5
English Dominant	19	3.32	2.51	3.21	3.30
English Monolingual	19	1.53	1.50	—	—

		Self-assessed ratings[a]			
		English		Spanish	
Type of Bilingual	Skill	Mean	SD	Mean	SD
Spanish-English	Reading	7.5	2.5	8.0	2.0
English-Spanish		9.26	1.25	5.58	2.21
Monolingual		9.79	.52	2.26	1.41
Spanish-English	Writing	7.5	2.5	7.5	2.5
English-Spanish		9.32	1.26	4.68	2.05
Monolingual		9.74	.55	1.84	1.14
Spanish-English	Speaking	8	2	8.5	1.5
English-Spanish		9.47	1.23	6.89	1.77
Monolingual		9.79	.69	2.63	1.42
Spanish-English	Listening	9.5	.5	9.5	.5
English-Spanish		9.21	1.70	7.79	2.07
Monolingual		9.79	.69	3.16	1.84

[a] Based on a scale of 1-10

Table 2: Movie Descriptions for Experiment 1 and 2

Movie Name	Movie Description
Carwash	Female actor washing a car
Breakfast	Female actor cooking breakfast
Flower Box[b]	Male actor planting a flower box
Grill	Female actor setting up a patio table and grilling hot dogs
Journalist	Female actor reviewing mail and news articles
Laundry[b]	Female actor doing laundry
Library[b]	Female actor searching for and checking out a book
Megablocks	Male actor building a boat out of megablocks
Packing	Male actor packing luggage
Party[b]	Male actor decorating for a party
Sandwich[ab]	Female actor making a sandwich
Tent[b]	Female actor setting up a tent

[a] Practice movie for Experiment 1 and 2.
[b] Movies used in Experiment 2.

Table 3: Guidelines to Control for Word Variation

Guideline	Example
Change plural nouns to singular nouns [a]	Shoes → Shoe
Change all abbreviations or shortened word forms to their full word	Fridge → Refrigerator
Delete any adjectives	Red Block → Block
Change synonyms to the noun that was generated most frequently across all participants	Male > Man = Male
Change brand names to their generic noun	Coca-Cola → Soda

[a] Except for cases where the plural noun describes a different object than the singular noun or when the plural noun is the common form of the noun (e.g., handcuffs, vs. handcuff).

Table 4: Total Number of Words Generated by At Least 15% of Participants in Experiment 1

Movie	Absent		Present	
	Number of words	Average Proportion	Number of words	Average Proportion
Carwash	26	0.27	36	0.44
Breakfast	26	0.27	53	0.39
Flower Box	27	0.26	38	0.41
Grill	24	0.24	43	0.45
Journalist	26	0.32	48	0.36
Laundry	27	0.33	34	0.42
Library	14	0.23	40	0.32
Megablocks	24	0.25	40	0.39
Packing	15	0.21	53	0.39
Party	30	0.32	43	0.39
Sandwich	39	0.31	34	0.45
Tent	46	0.25	26	0.43

Note: Number of words = total number of words generated by at least 15% of participants. Average proportion = the overall average of the proportion value of words generated by at least 15% of participants.

Table 5: Language Self-Assessed Proficiency Ratings for Experiment 2

				Age of acquisition (years)			
				English		Spanish	
Type of Bilingual	Related	Unrelated	Total N	Mean	SD	Mean	SD
Spanish Dominant	8	7	15	7.93	2.95	1	0.63
English Dominant	24	27	51	4.0	2.54	2.76	3.33
English Monolingual	19	15	34	1.79	1.37	—	—

		Self-assessed ratings[a]			
		English		Spanish	
Type of Bilingual	Skill	Mean	SD	Mean	SD
Spanish-English	Reading	8.80	.83	9.27	.93
English-Spanish		9.63	.68	7.31	1.92
Monolingual		9.82	.45	2.21	1.47
Spanish-English	Writing	8.67	.79	9.27	.93
English-Spanish		9.57	.72	6.49	2.27
Monolingual		9.74	.56	1.71	1.07
Spanish-English	Speaking	8.73	.85	9.00	.97
English-Spanish		9.69	.67	7.71	2.19
Monolingual		9.91	.28	2.47	1.44
Spanish-English	Listening	9.27	.93	9.67	.70
English-Spanish		9.82	.47	8.57	1.72
Monolingual		9.97	.17	2.53	1.80

[a] Based on a scale of 1-10

Table 6: Average of Word Attributes for Individual Movies

	Related				Unrelated		
Movie	Length	LFH	NSyll	Proportion	Length	LFH	NSyll
Flower Box	5.17	8.71	1.58	0.28	5.33	8.88	1.75
Laundry	7	8.35	2.17	0.35	6.92	8.33	2.17
Library	6.50	9.92	1.92	0.23	6.42	9.92	2.08
Party	5.25	9.89	1.67	0.34	5.33	9.86	1.67
Tent	6.83	8.57	2.00	0.23	6.75	8.49	2.08
Sandwich	5.60	8.84	1.80	0.51	5.60	8.86	1.60

Note: LFH = The HAL frequency of a word transformed by the natural logarithm. NSyll = Number of Syllables. Proportion = Proportion of participants who generated the word in Experiment 1.

Table 7: Word Recall Intrusions

Type of Error Intrusion	Description	Related			Unrelated		
		Boundary	Non-Boundary	Total	Boundary	Non-boundary	Total
Related	Words related to the event structure	-	-	139*	-	-	14
Unrelated	Words unrelated to the event structure	-	-	28	-	-	6
Synonym	Synonyms of words presented during the movie	8	8	16	8	7	15
Across Movies	Words recalled from a previous movie	1	1	2	12	15	27
Root Word	Root word of a word presented during a movie (e.g., library → librarian)	19	16	35	0	4	4
Repeat	Words repeated within same recall list	24	24	48	20	24	44
Incomplete	Incomplete words (e.g., bu → bug)	6	5	11	2	7	9
Phonological	Similar pronunciation, different meaning/spelling (e.g., patrolling → petroleum)	5	10	15	28	22	50 *
Orthographical	Similar orthography, different meaning/pronunciation (e.g., boil → oil)	2	1	3	0	2	2
Phonological/orthographical	(e.g., test → pest)	5	2	7	0	5	5

Note. * = Statistically significant difference between related and unrelated condition.

Table 8: Descriptive Statistics of Type of Strategies

Type of Strategy	Example	Related		Unrelated	
		Mean	SD	Mean	SD
Rehearsal	Repeating the words	.70	.46	.42	.50*
Elaborate Rehearsal	Repeating the words in a rhythm	.38	.49	.34	.47
Self-referencing	Relating the word to one's self	.02	.14	.14	.35*
Visualizing	Visualizing the word	.02	.14	.06	.23
Remembering actor’s actions	Recalling actor’s actions during word presentation	.12	.32	0	0*
Creating a story	Creating a story with the words	.10	.30	.26	.44*

Note. * = Statistically significant difference between related and unrelated condition.

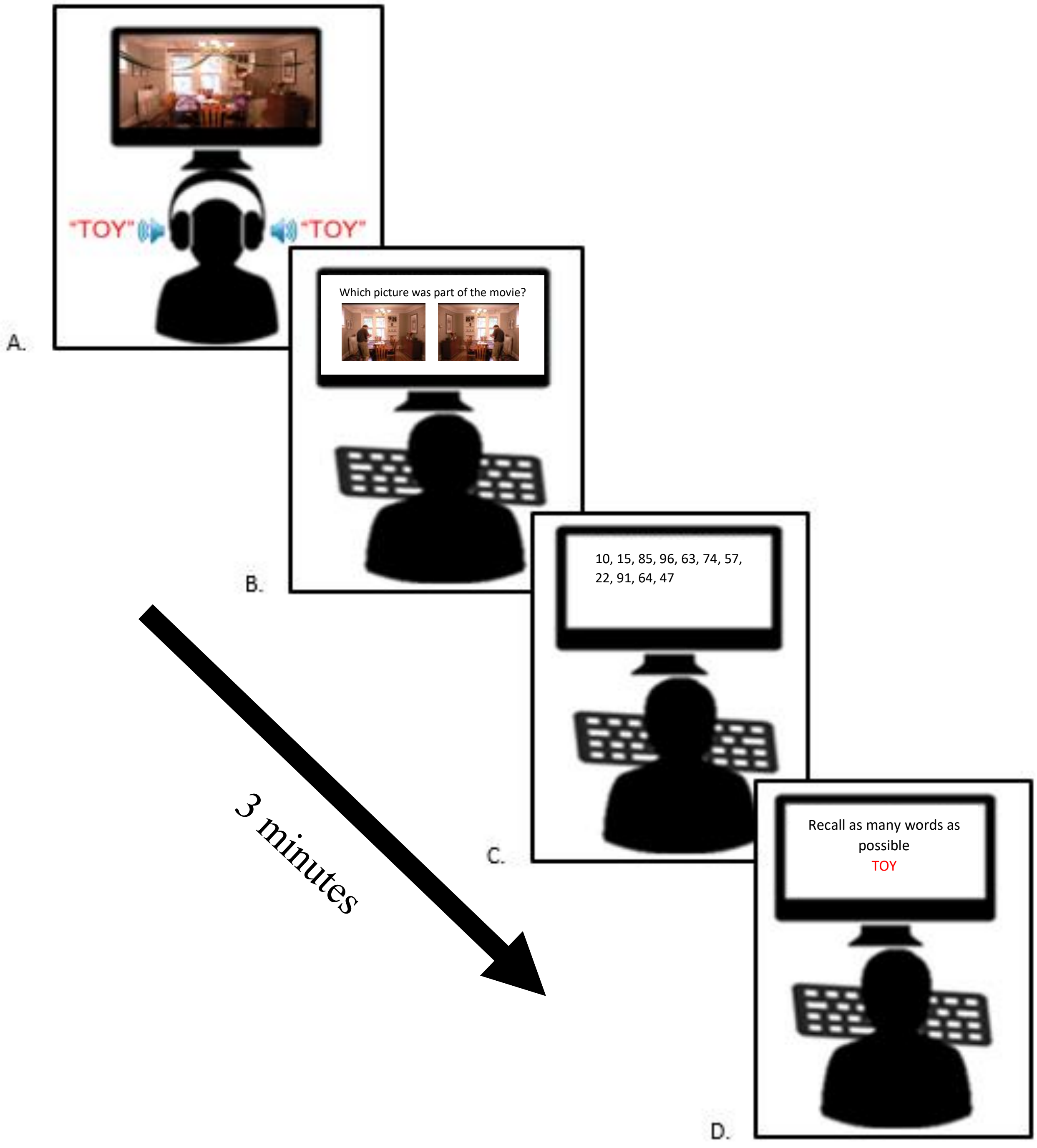

Figure 1. A schematic of a movie block of the movie of a man decorating for a party. (A) Movie viewing and word presentation. (B) Picture discrimination task. (C) Random number generation task. (D) Word Recall.

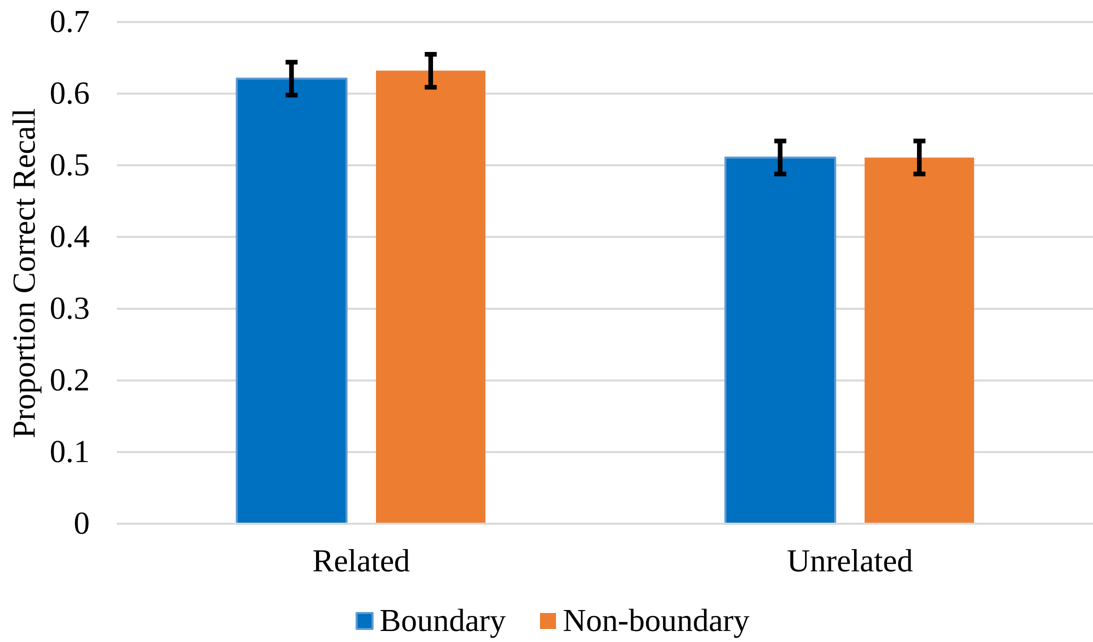

Figure 2. Comparison of proportion word recall for Experiment 2. Error bars represent ± one standard error of the mean.

Appendix A

Word Generation for Experiment 1

Table A1: absent and present Word Generation for Experiment 1

Movie	Word	Proportions
Breakfast	Milk	0.70
	Water	0.60
	Coffee	0.50
	Microwave	0.48
	Soap	0.40
	Picture	0.35
	Ham	0.28
	Oil	0.28
	Cheese	0.23
	House	0.23
	Napkin	0.23
	Table	0.23
	Tea	0.23
	Bacon	0.20
	Chicken	0.20
	Salt	0.20
	Flower	0.18
	Freezer	0.18
	Ice	0.18
	Teapot	0.18
	Yogurt	0.18
	Apple	0.15
	Chair	0.15
	Cookie	0.15

	Waffle	0.15
	Watch	0.15
Carwash	Basketball	0.73
	Sun	0.53
	Bird	0.48
	Towel	0.45
	Seat	0.43
	Engine	0.40
	Sponge	0.35
	Brake	0.28
	Cloud	0.28
	Dirt	0.28
	Steering wheel	0.25
	Kid	0.23
	Radio	0.23
	Ball	0.20
	Park	0.20
	Dog	0.18
	Gas	0.18
	Glass	0.18
	Neighborhood	0.18
	Oil	0.18
	Wiper	0.18
	Glasses	0.15
	Summer	0.15
	Sunglasses	0.15
	Wax	0.15
	Wood	0.15
Flower Box	Water	0.68
	Bird	0.55
	Sun	0.50

	Wood	0.35
	Fertilizer	0.33
	Hose	0.33
	Worm	0.30
	Bee	0.25
	Cloud	0.25
	Seed	0.25
	Ant	0.23
	Insect	0.23
	Sock	0.23
	Bug	0.20
	Car	0.20
	Dog	0.20
	Door	0.20
	Fruit	0.20
	Rake	0.20
	Hat	0.18
	Squirrel	0.18
	Vegetable	0.18
	Root	0.15
	Sky	0.15
	Spider	0.15
	Stair	0.15
	Table	0.15
Grill	Bird	0.43
	Cup	0.43
	Dinner	0.38
	Fire	0.35
	Steak	0.33
	Meat	0.30
	Propane	0.30

	Sun	0.30
	Grass	0.28
	Man	0.23
	Chicken	0.20
	Dog	0.20
	Lighter	0.20
	Napkin	0.20
	Date	0.18
	Forest	0.18
	Ice	0.18
	Pants	0.18
	Soda	0.18
	Bug	0.15
	Charcoal	0.15
	Cloud	0.15
	Insect	0.15
	Party	0.15
Journalist	Milk	0.80
	Water	0.65
	Plate	0.63
	Fork	0.50
	Spoon	0.48
	Table	0.48
	Egg	0.35
	Creamer	0.33
	Sugar	0.33
	Bowl	0.28
	Juice	0.28
	Morning	0.28
	Pan	0.28
	Soap	0.28

	Apple	0.25
	Breakfast	0.25
	Pot	0.25
	Cheese	0.23
	Fruit	0.23
	Potato	0.23
	Freezer	0.20
	Vegetable	0.20
	Ice	0.18
	Avocado	0.15
	Blender	0.15
	Salt	0.15
Laundry	Dryer	0.93
	Sock	0.80
	Soda	0.75
	Water	0.73
	Underwear	0.65
	Quarter	0.43
	Dollar	0.33
	Towel	0.33
	Trash	0.33
	Brassiere	0.28
	Dryer sheet	0.28
	Apartment	0.25
	Sheet	0.25
	Softener	0.25
	Basement	0.23
	Drink	0.23
	Jacket	0.23
	Blanket	0.20
	Shorts	0.20

	Can	0.18
	Electricity	0.18
	Bag	0.15
	Child	0.15
	Closet	0.15
	Dirt	0.15
	House	0.15
	Stain	0.15
Library	Pencil	0.43
	Pen	0.35
	Laptop	0.30
	Librarian	0.30
	Glasses	0.23
	Printer	0.23
	Map	0.20
	School	0.20
	Student	0.20
	Magazine	0.18
	Card	0.15
	Coffee	0.15
	Notebook	0.15
	Scanner	0.15
Megablocks	Child	0.63
	House	0.58
	Window	0.50
	Light	0.33
	Water	0.33
	Belt	0.30
	Building	0.25
	Sock	0.23
	Car	0.20

	Carpet	0.20
	Drawer	0.20
	Food	0.20
	Picture	0.20
	Bulb	0.18
	Dinner	0.18
	Fan	0.18
	Game	0.18
	Glass	0.18
	Castle	0.15
	Frame	0.15
	Kitchen	0.15
	Living room	0.15
	Plate	0.15
	Tree	0.15
Packing	Window	0.40
	Water	0.30
	Light	0.28
	Book	0.25
	Toilet	0.25
	Sock	0.20
	Curtain	0.18
	Fan	0.18
	Movie	0.18
	Sink	0.18
	Bathtub	0.15
	Cable	0.15
	Glass	0.15
	Mouse	0.15
	Show	0.15
Party	Cake	0.78

	Food	0.58
	Spoon	0.55
	Knife	0.48
	Candy	0.45
	Ice cream	0.43
	Child	0.40
	Music	0.40
	Soda	0.40
	Family	0.35
	Game	0.35
	Hat	0.35
	Gift	0.33
	Friend	0.30
	Candle	0.28
	Door	0.28
	Drink	0.28
	Water	0.25
	Chip	0.23
	Flower	0.23
	Juice	0.23
	Light bulb	0.23
	Toy	0.23
	Clown	0.20
	Piñata	0.20
	Grass	0.18
	Hotdog	0.18
	Pizza	0.18
	Confetti	0.15
	Invitation	0.15
sandwich	Milk	0.70
	Juice	0.65

Cheese	0.63
Fork	0.60
Spoon	0.60
Egg	0.58
Water	0.58
Cup	0.45
Lettuce	0.45
Tomato	0.40
Pan	0.38
Sink	0.38
Table	0.35
Napkin	0.33
Ketchup	0.28
Orange	0.28
Pot	0.28
Apple	0.25
Ice	0.25
Soap	0.25
Chips	0.23
Grape	0.23
Pickle	0.23
Toaster	0.23
Banana	0.20
Bowl	0.20
Cereal	0.20
Chair	0.20
Vegetable	0.20
Cookie	0.18
Freezer	0.18
Fruit	0.18
Lunch	0.18

	Onion	0.18
	Turkey	0.18
	Butter	0.15
	Chicken	0.15
	Pepper	0.15
	Salt	0.15
Tent	Sleeping bag	0.53
	Bird	0.48
	Sun	0.48
	Water	0.48
	Rock	0.45
	Cloud	0.40
	House	0.35
	Ant	0.33
	Bear	0.33
	Girl	0.33
	Watch	0.33
	Animal	0.30
	Bug	0.30
	Dog	0.30
	Fire	0.30
	Repellent	0.28
	Sock	0.28
	Stick	0.28
	Flower	0.25
	Pillow	0.25
	Pole	0.25
	Blanket	0.23
	Fish	0.23
	Insect	0.23
	Car	0.20

Marshmallow	0.20
Metal	0.20
Mosquito	0.20
Spider	0.20
Campfire	0.18
Flashlight	0.18
Forest	0.18
Moon	0.18
Mountain	0.18
Ball	0.15
Bottle	0.15
Chocolate	0.15
Dessert	0.15
Family	0.15
Food	0.15
Rain	0.15
Snake	0.15
Squirrel	0.15
Star	0.15
Sunscreen	0.15
Tool	0.15

Note. Proportion = Proportion of participants who generated the word in Experiment 1

Appendix B

Word Selection for Experiment 2

Table B1: Word Attributes for the Related Condition

Movie	Word	Length	LFH	NSyll	POS	Proportions
Flower Box	Wood	4	10.087	1	NN	0.35
	Water	5	11.571	2	NN|VB	0.675
	Fertilizer	10	7.116	4	NN	0.325
	Seed	4	9.014	1	NN|VB	0.25
	Root	4	10.218	1	NN|VB	0.15
	Rake	4	6.823	1	VB|NN	0.2
	Vegetable	9	8.101	3	NN	0.175
	Squirrel	8	7.595	2	NN|VB	0.175
	Hat	3	9.371	1	NN	0.175
	Bee	3	8.098	1	NN	0.25
	Worm	4	8.321	1	NN|VB	0.3
	Hose	4	8.262	1	NN	0.325
Laundry	Underwear	9	8.13	3	NN	0.65
	Apartment	9	9.1	3	NN	0.25
	Basement	8	8.45	2	NN	0.225
	Sheet	5	9.74	1	NN	0.525
	Jacket	6	9.23	2	NN	0.225
	Electricity	11	8.52	5	NN	0.175
	Towel	5	8.13	1	NN|VB	0.325
	Sock	4	7.04	1	NN|VB	0.8
	Shorts	6	8.62	1	NN|VB	0.2
	Dollar	6	10.08	2	NN	0.325
	Softener	8	4.96	3	NN	0.25
	Blanket	7	8.25	2	NN	0.2
Library	Printer	7	10.61	2	NN|JJ	0.225
	Card	4	12.31	1	NN	0.15

	Glasses	7	9.05	2	NN	0.225
	Librarian	9	8.34	3	NN	0.3
	Magazine	8	11.01	3	NN	0.175
	Scanner	7	9.28	2	NN	0.15
	Student	7	10.94	2	NN	0.2
	School	6	11.69	1	NN|VB	0.2
	Pencil	6	8.01	2	NN|VB	0.425
	Tablet	6	8.925	2	NN	0.33
	Notebook	8	8.73	2	NN	0.15
	Map	3	10.16	1	NN|VB	0.2
Party	Friend	6	11.3	1	NN	0.3
	Toy	3	10.13	1	NN|VB	0.225
	Food	4	11	1	NN	0.575
	Knife	5	8.87	1	NN|VB	0.475
	Family	6	11.39	3	NN	0.35
	Invitation	10	8.28	4	NN	0.15
	Game	4	12.19	1	NN|VB	0.35
	Candle	6	7.91	2	NN	0.275
	Gift	4	9.37	1	NN	0.325
	Music	5	11.81	2	NN	0.4
	Clown	5	7.92	1	NN	0.2
	Candy	5	8.49	2	NN	0.45
Tent	Bug	3	10.38	1	NN|VB	0.3
	Mountain	8	10.46	2	NN	0.175
	Marshmallow	11	5.65	3	NN	0.2
	Forest	6	9.75	2	NN	0.175
	Flashlight	10	6.74	2	NN	0.175
	Repellent	9	5.51	3	JJ	0.275
	Animal	6	10.12	3	NN	0.3
	Stick	5	10.25	1	NN|VB	0.275
	Fish	4	10.33	1	NN|VB	0.225

	Bottle	6	9.833	2	NN|VB	0.25
	Campfire	8	6.2	2	NN	0.175
	Pillow	6	7.65	2	NN	0.25
Sandwich	Cheese	6	9.07	1	NN	0.625
	Lettuce	7	6.88	2	NN	0.45
	Tomato	6	7.67	3	NN	0.4
	Table	5	10.93	2	NN|VB	0.35
	Milk	4	9.63	1	NN|VB	0.7

Note: LFH = The HAL frequency of a word transformed by the natural logarithm. NSyll = Number of Syllables. POS = Part of Speech (NN= Noun, VB= Verb). Proportion = Proportion of participants who generated the word in Experiment 1.

Table B2: Word Attributes for the Unrelated Condition

Movie	Word	Length	LFH	NSyll	POS
Flower Box	Beer	4	10.115	1	NN
	Class	5	11.454	1	NN|VB
	Typewriter	10	7.013	3	NN
	Robot	5	9.295	2	NN
	Bell	4	10.12	1	NN
	Zebra	5	6.82	2	NN
	Television	10	10.024	4	NN
	Pamphlet	8	7.657	2	NN
	Jet	3	9.417	1	NN
	Cab	3	8.128	1	NN
	Oven	4	8.266	2	NN
	Fin	3	8.21	1	NN
Laundry	Petroleum	9	8.093	3	NN
	Scientist	9	9.11	2	NN
	Neighbor	8	8.45	2	NN
	Sword	5	9.73	1	NN
	Walker	6	9.107	2	NN
	Accelerator	11	8.547	5	NN
	Trunk	5	8.093	1	NN
	Pest	4	6.98	1	NN
	Jungle	6	8.61	2	NN
	Guitar	6	10.12	2	NN
	Villager	8	4.956	3	NN
	Walnut	6	8.137	2	NN
Library	Degree	6	10.65	2	NN
	Money	5	12.25	2	NN
	Stadium	7	9.06	2	NN
	Physician	9	8.34	3	NN
	Document	8	10.96	3	NN

	Leather	7	9.35	2	NN
	Manager	7	10.999	3	NN
	House	5	11.554	1	NN
	Dancer	6	8	2	NN
	Tunnel	6	8.916	2	NN
	Sinkhole	8	8.659	2	NN
	Bed	3	10.35	1	NN|VB
Party	Package	7	11.047	2	NN
	Deck	4	10.267	1	NN|VB
	Dog	3	10.974	1	NN|VB
	Yeast	5	8.838	1	NN
	Driver	6	11.14	2	NN
	Journalist	10	8.305	3	NN
	Case	4	12.2	1	NN|VB
	Paddle	6	7.9	2	NN
	Bush	4	9.3	1	NN
	Server	6	12.004	2	NN
	Lava	4	7.92	2	NN
	Venom	5	8.425	2	NN
Tent	Bar	3	10.36	1	NN|VB
	Director	8	10.508	3	NN
	Stockholder	11	5.58	3	NN
	Diamond	7	9.814	2	NN
	Mouthpiece	10	6.724	2	NN
	Periscope	9	5.442	3	NN
	Poster	6	10.12	2	NN
	Menu	4	10.26	2	NN
	Oil	3	10.457	1	NN
	Helmet	6	8.657	2	NN
	Trapdoor	8	6.21	2	NN
	Trophy	6	7.693	2	NN

Sandwich	Singer	6	9.149	2	NN
	Bathtub	7	6.9	2	NN
	Barber	6	7.659	2	NN
	Brain	5	10.9	1	NN
	Boat	4	9.671	1	NN

Note: LFH = The HAL frequency of a word transformed by the natural logarithm. NSyll = Number of Syllables. POS = Part of Speech (NN= Noun, VB= Verb).

Curriculum Vitae

Omar Carrasco was born in El Paso, Texas. Mr. Carrasco became involved in research during his undergraduate degree at the University of Texas at El Paso, under the supervision of Dr. Ashley Bangert. His primary areas of interest were time perception and event perception. Specifically, he investigated the influence of event boundaries on time perception. In the spring of 2013, Mr. Carrasco graduated with a B.S. in Psychology. Mr. Carrasco is currently in his 3rd years of study in the Social Cognitive Neuroscience Program at the University of Texas at El Paso. He has presented his research at multiple conferences and was awarded the distinguished poster award in October of 2017 at the 25th Annual ARMADILLO Southwest Regional Conference. In the fall of 2017, he will graduate with an M.A. in Experimental Psychology. Mr. Carrasco currently serves as a graduate student representative in the Information Technology committee of the Faculty Senate at the University of Texas at El Paso. Outside of academics, Mr. Carrasco has gained valuable experience by serving the community of El Paso, Texas as a caseworker, therapist, and teacher.

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