Time-dependent transformation of episodic memories

by

Kyra McKelvey

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Graduate Department of Psychology
University of Toronto

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Abstract

Although there has been over a century of research on memory and consolidation, there remains no consensus with respect to the nature of episodic memories over time. This study tests two prominent theories (Standard Consolidation Theory and Trace Transformation Hypothesis), which make opposing predictions as to the quality of remote episodic memory, by investigating memories for film clips. Using true/false questions to test recall immediately, 3 days, and 7 days after encoding, these experiments demonstrate that details (both perceptual and story-line details) are lost, while the gist of memories is maintained over time. These data also suggest that gist and detail may be maintained independently in the brain. These results broaden our understanding of recent and remote memory, and provide support for the transformation view of consolidation. In the future, the transfer of this paradigm to neuroimaging will allow us to investigate the neural basis of episodic memory over time.
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1 Introduction

1.1 Consolidation

Consolidation, a term first adopted in 1900 to refer to the process of memory stabilization (Muller & Pilzecker, 1900), has been a major topic of memory research for over a century. The suggestion that memories may be reorganized over time dates back even further, to Ribot (1882) who observed that recent memories seemed to be more affected by brain damage than remote ones. The study of memory and consolidation took another leap forward mid-way through the 20th century when Scoville and Milner (1957) and Penfield and Milner (1958) published their seminal work attributing the retrograde and anterograde amnesia of patient HM to medial temporal lobe (MTL) lesions. Critically, this work identified the first neural correlate of consolidation, indicating the hippocampus’s importance to declarative memory.

Although many theories of consolidation have emerged over the years, the mechanisms underlying this process and the nature of memory changes over time remain unclear. One major debate within the literature is the quality and hippocampal dependence of recent and remote episodic memory. This study sheds light on the first issue by identifying what type of information is lost (details) and retained (gist), as episodic memories become more remote. Furthermore, the paradigm developed in this study, when moved to a functional magnetic resonance imaging (fMRI) scanner, will help resolve the second issue by elucidating the neural basis of this mnemonic transformation.

1.2 Episodic and Semantic Memory

The research mentioned above is focused on episodic and semantic memory which are components of declarative memory. Episodic memory is defined as a system that is concerned with information about temporal-spatial relations of events (i.e. sensory, perceptual, affective information) that are tied to a specific context and linked to the self, enabling re-experiencing of the event in rich detail (Tulving, 1972, 1983; Brewer, 1996; Anderson & Conway, 1993). Semantic memory, on the other hand, involves memory for facts, concepts, schemata, and scripts that are not associated with a specific context or accompanying perceptual details (Tulving, 1983).
Although it is generally accepted that memories are organized and stabilized over time through a process of consolidation, the roles of the hippocampus and neocortex in this process remain the focus of many conflicting theories. The traditional view on consolidation is captured by Standard Consolidation Theory (SCT), which posits that all declarative memories are acquired hippocampally but, with time, consolidated and maintained in extra-hippocampal neocortical structures (Squire & Alvarez, 1995; Squire & Wixted, 2011). In SCT there is no distinction between the neural bases for the consolidation of semantic and episodic memories, and remote neocortical memories are proposed to retain the features of the original hippocampal traces (Squire & Alvarez 1995). Other researchers, however, have proposed that the episodic system is particularly susceptible to a loss of information and that memories shift from episodic to semantic form through this loss of information (Conway, Gardiner, Perfect, Anderson, & Cohen, 1997; Tulving, 1972). This loss of information could arise from forgetting of details, from abstraction of statistical regularities common to episodes, or from assimilation of episodes to schemas (Conway et al., 1997; van Kesteren, Ruiter, Fernández, & Henson, 2012). This view is consistent with the Trace Transformation Hypothesis (TTH), which proposes that the hippocampus is critical for the consolidation of episodic memories, but that a shift in representation from hippocampal to extra-hippocampal structures entails a transformation of memory from its initial detailed form to a more generalized, gist-like representation (Winocur, Moscovitch, & Bontempi, 2010; Winocur, Moscovitch, & Sekeres, 2007). Critically, TTH maintains that the hippocampus continues to be required for episodic memories as long as they exist in their detailed/context-bound form (Winocur et al., 2007).

These conflicting theories of consolidation emerged from a long history of neuropsychological research on amnesia. Initially, MTL damage was reported to consistently result in temporally-graded retrograde amnesia, suggesting that all recent memories are hippocampus-dependent, while all remote memories are not (presumably because they have been consolidated extra-hippocampally) (Squire & Alvarez, 1995). However, with time, amnesia without a temporal gradient began to be reported (Nadel & Moscovitch, 1997), a trend that has been confirmed over the years, since at least as many cases of ungraded amnesia have now been identified as amnesia with a temporal gradient (Winocur et al., 2010). Furthermore, hippocampal damage seems to preferentially impair episodic autobiographical memory across the lifespan, with gradients emerging mostly when semantic information is being tested, suggesting that different types of
memory are maintained independently in the brain and are differentially sensitive to hippocampal damage (Winocur et al., 2010). Critically, some still maintain that MTL damage always results in temporally graded amnesia, even for autobiographical memory, attributing loss of remote memory to extensive damage outside the MTL (Kirwan et al. 2008). These conflicting results indicate the need for further cognitive/behavioural research to differentiate clearly between memories that are truly episodic and those that are more semantic or gist-like, before one can proceed to determine the extent to which each is dependent on the hippocampus.

Although there is much evidence from neuropsychological, neuroimaging, and animal studies consistent with TTH (see Winocur et al., 2010), the quality of memory throughout this transformation remains to be elucidated. In order to help resolve this issue, it is crucial to determine how the nature of episodic memory changes over time and the patterns of neural activation associated with such transformations. Thus, this study seeks to characterize the nature of recent and remote episodic memories by objectively measuring the levels of different types of information (focusing on detail and gist) over the week following encoding of specific laboratory memories. Subsequent studies will focus on the neural representation of these memories.

1.3 Narrative Memory and Transformation

Broadly, episodic memories concern events in our lives, which are strung together to create a coherent narrative of our life, containing a mix of both general and specific information (Anderson & Conway, 1993). Thus, it is useful to consider narrative memory more widely, due to the wealth of research in this area. Over the past 50 years, much evidence has emerged suggesting that memory for narratives is composed of multiple levels of information, where the highest level is the general story-line, while the lower levels are composed of details (Rumelhart & Ortony, 1977). Craik (1979) suggests that memory depends on representation of a story in general terms. Specific detail information about an episode is then proposed to fit into this general macrostructure, supporting recall of peripheral elements such as perceptual, affective, and contextual details (Kintsch et al., 1977). Reflecting this mix of central and peripheral information, episodic and semantic memory are described as existing on a continuum from highly context-specific and detailed episodes to abstract generalized knowledge (Craik, 1979).

With respect to long-term retention of real-life information, differential rates of forgetting have been identified for different aspects of knowledge (Bahrick, 1984; Conway, 1991). The episodic
memory system is considered particularly susceptible to loss of information (Tulving, 1972), while Thorndyke (1977) suggests that within this system, the recall probability of facts depends on their centrality. These ideas were developed by observing that, after reading a narrative, participants preferentially recall high-level story-elements that affect overall plot coherence (which we refer to as gist), rather than lower-level details (Thorndyke, 1977). Tulving suggests that this loss of detail over time plays a role in the development of knowledge, as episodic memories become semanticized (Tulving, 1985). Consistent with this literature, Conway’s model (2009) proposes that conceptual knowledge is developed through the abstraction and generalization of episodic memory. All of these proposals converge on the idea that the episodic memory system is susceptible to information loss, and that memory of different qualities (for example detailed and vivid vs. gist-like or abstract or generalized) can be expressed over time, emerging from the traces initially laid down after an episode is experienced.

Even though the transformation hypothesis was advanced many decades after this research, it echoes many of the ideas put forward based on the behavioural investigation of autobiographical and narrative memory. Behavioural measures of memory and forgetting are thus consistent with our proposal that episodic memory tends to shift over time from initially detailed and specific representations to more generalized representations of an episode’s gist. Furthermore, this line of research suggests that this shift may be associated with the loss of information so that the probability of an element being retained depends more on its centrality/importance to an episode, rather than on its specific quality (e.g. perceptual vs. affective vs. cognitive). Transformation is thus characterized by a paucity of detail, but maintenance of gist (central elements) in a memory, as it becomes more remote.

1.4 Mechanisms of Transformation

Although the evidence cited above makes a strong behavioural case for transformation, it is unclear what mechanisms could be underlying such changes. Traditional views of learning in hippocampal and neocortical circuits suggest that the hippocampus is necessary for the rapid encoding of information (see Moscovitch, 2008), while the neocortex depends on the hippocampus to support its slow incorporation of information into memory (in order to avoid catastrophic interference; McClelland et al., 1995). This proposal implies that episodic memory traces are initially encoded as specific details bound to a context, with transformation the result
of gist being abstracted from details at a later time point, over the course of consolidation. If this is the case, one would expect generalized gist memory to be dependent on initial detail memory, and to exist independently only after consolidation, at which point detail may or may not be maintained.

Alternatively, it is possible that detail and gist are both encoded initially, with the behavioural measures of ‘transformation’ the result of detailed memory being lost, while gist is maintained. This proposal suggests that gist and detail can be encoded separately, and processed independently in the brain. This view does not imply that they are always independent, or necessarily contradict proposals that knowledge is abstracted from specific episodes (see Conway, 2009). Consistent with this mechanism, there is evidence for declarative memory encoding independent of the hippocampus, through neocortical fast-mapping (Sharon, Moscovitch, & Gilboa, 2010). With respect to memory in the animal literature, Beeman et al. (2013) recently demonstrated that lesions to either the hippocampus or the medial prefrontal cortex of a rat 1 day after contextual fear conditioning, in which the animal froze in the context where shock was administered, had no effect on freezing 30 days later when the animal was re-introduced to that context. This indicates not only that either of these areas can support memory, but also that multiple traces may be established during initial learning. Thus, it is possible that both a detailed hippocampal and a general neocortical trace co-exist right from the beginning, with the nature of memory being expressed determined by which trace survives or is dominant at each time-point. Furthermore, neuroimaging evidence suggests that, even in recent memories, gist and detail memory can be independent, with memory for the gist of a scene not necessarily correlated with accurate memory for details from the scene (Qin, van Marle, Hermans, & Fernández, 2011). In this case, memory for detail and gist were found to depend on different neural substrates (medial temporal cortex and prefrontal/temporoparietal cortex respectively).

Thus, the first proposal would indicate that memory for gist and detail are not independent of one another, while the second proposal suggests that detailed and generalized representations can co-exist and interact in the brain, but may also manifest independently. Although this study will not be able to differentiate conclusively between the possible mechanisms underlying transformation, we will attempt to shed light on the topic by examining correlations between detail and gist memory, and investigating how time and interference differentially affect gist vs. detail in memory.
1.5 Interference vs. Decay

Although the main goal of this study is to test theories of consolidation and memory transformation, our behavioural experiments raise different questions that are interesting in their own right. As highlighted above, issues of forgetting are central to discussions of memory transformation, which is characterized largely by a loss of detail over time. As such, the two main mechanisms of forgetting, interference and decay, are each likely to play a role in our investigation.

Interference is defined as a reduction in memory performance due to processing of material that overlaps, either qualitatively or temporally, with ‘to-be-remembered’ items (Keppel & Underwood, 1962). Decay, on the other hand, is defined as a reduction in memory performance due to gradual loss of the substrate of memory (Thorndike, 1913). Neurobiological evidence suggests that different neural structures, and therefore the memories they support, may be differentially sensitive to these two processes (Hardt, Nader, & Nadel, 2013).

The circuit architecture of the hippocampus has been shown to be specialized for ‘pattern separation’ whereby similar information is coded in orthogonal representations, preventing similar memories from interfering with each other (Yassa & Stark, 2011). Conversely, recall based on a more general sense of familiarity is thought to depend on extra-hippocampal neocortical structures (such as the perirhinal cortex; Brown & Aggleton, 2001), which represent similar experiences in overlapping networks of neurons, possibly leading to interference (Norman & O’Reilly, 2003). Thus, hippocampally-mediated memories are thought to be more resistant to interference than extra-hippocampal memories. Although they may be resistant to interference, it has been suggested that hippocampal memories are particularly susceptible to decay over time due to the weakening of synaptic potentiation (Hardt et al., 2013).

This literature suggests that, once encoded, detailed episodic memory, which we posit is mediated by the hippocampus, should be resistant to interference but sensitive to decay. However, this does not speak to loss of information before encoding is complete. Recent neuroimaging findings point to stimulus-offset as the critical time for hippocampal activity (Ben-Yakov & Dudai, 2011). This work, using film clip stimuli, demonstrates that engaging the hippocampus in a different task during this post-stimulus encoding may interfere with the registration of information to memory, resulting in poor memory. Thus, it seems as if
interference and decay may both play a role in loss of hippocampal memory, but at different time-points. Decay may exert its effects over longer durations, after encoding, whereas the effects of interference may manifest mainly during or in the seconds/minutes following encoding.

In our study we expect transformation to be characterized by the maintenance of gist, but loss of detail, over time. However, it is not clear whether the loss of these peripheral details would be through interference or decay. Though it is difficult to distinguish between the two processes, we attempt to investigate their interaction in this study. In Experiment 1, we first measure memory after a long period of study (at which point decay and interference may have both occurred), while in Experiment 2, we measure memory immediately after encoding (attenuating the effects of both interference and decay) and after 7 days (during which time, presumably, decay has been the dominant form of forgetting).

1.6 Episodic vs. Semantic and Recent vs. Remote

Although there is good neurological and behavioural support for transformation, finding conclusive evidence for one theory of consolidation over another is impeded by the difficulty associated with differentiating between episodic/semantic and recent/remote memories. This is due to the significant overlap between the characteristics of episodic and recent memories, making it difficult to determine whether a pattern of brain activation at recall (viz. hippocampal activation) is due to a memory’s recency, or its episodic nature. Both recent and episodic memories tend to contain perceptual and emotional details, are judged as vivid and coherent, and likely to be reported from the first-person perspective (Sutin & Robins, 2007). In contrast, both semantic and remote memories are associated with a paucity or lack of perceptual elements and contextual details (Sutin & Robins, 2007; Tulving, 2002).

Thus, differentiating between episodic memories that retain their detailed/specific nature and those which have become generalized/gist-like is critical to elucidating the neural basis of episodic memory over the lifetime, and resolving the debate between SCT and TTH. That is why the main objective of this study is to shed light on the type of information that is retained, and that which is lost, as an episodic memory becomes more remote and, perhaps, generalized over time. This study will focus on the distinction outlined above between detailed and gist-like
episodic memory, characterizing the rates that perceptual details, action details, and central story elements are lost from episodic memories as they become more remote.

1.7 Using Film Clips

Although many studies of episodic memory purport to be concerned with memory for real-world events and daily experiences, most protocols traditionally use stimuli consisting of individual items (i.e. single words, pictures, etc…), devoid of the contextual, perceptual, affective, and cognitive details characteristic of real-life episodic remembering (Buckner, Logan, Donaldson, & Wheeler, 2000; Tulving, 1983, 2002). For this study, film clips were chosen over such traditional laboratory stimuli, since they capture some of the complexity of real world events; they are dynamic and continuous stimuli containing perceptual and affective narrative elements within a spatial-temporal context (Furman, Dorfman, Hasson, Davachi, & Dudai, 2007; Hasson, Furman, Clark, Dudai, & Davachi, 2008). However, critically, film clips maintain the reproducibility and controlled nature of more traditional laboratory stimuli (Furman et al., 2007). Furthermore, the encoding, consolidation, and retrieval of film clip memories has been shown to resemble episodic memory both behaviourally and neurally (Furman, Mendelsohn, & Dudai, 2012; St-Laurent Doctoral Dissertation, 2012).

The Autobiographical Interview (AI) is a tool commonly used to estimate the episodicity of memories, which it achieves by classifying each element of a memory into one of nine categories (Levine, Svoboda, Hay, Winocur, & Moscovitch, 2002). Although the AI is a consistent and well-established way to characterize personal memories, it depends on subjective evaluation of each retrieved element and is a very labour-intensive tool. The present study sought to develop an additional controlled and objective method to estimate the episodicity of specific laboratory memories. Thus, we developed a series of true/false questions referring to different categories of information within our film clips (perceptual details, action details, and gist elements). These questions allow us to measure rapidly and objectively the number of details and general story elements in our participants’ memories at different time-points, providing an estimate of a memory’s episodicity and detailed vs. gist-like nature.

Furman et al. (2012) used film clips and recognition questions to investigate episodic memory in a similar way. Consistent with the literature mentioned above, they found that memory decreased in contextual detail over the hours, weeks, and months following encoding, a decrease that was
correlated with a drop in hippocampal activation (Furman et al., 2012). Importantly, consistent with TTH, hippocampal activation remained associated with accurate recall of details, even months after encoding (Furman et al., 2012). These results support our predictions that we will see a decrease in detail over time, using film clips to model episodic memory, and suggest that this should be associated with a drop in hippocampal activation. Critically, we plan to differentiate between different categories of detail information (perceptual and action) and to measure both detail and gist in each particular memory. By investigating qualitative changes in memory over time, we hope to elucidate more clearly the nature of recent and remote episodic memories and the process of consolidation.

Recently, another researcher from our group used film clip stimuli (the same ones used in this study) to investigate the neural basis of perceptual richness in episodic memory shortly after presentation (St-Laurent, 2012, Doctoral Dissertation). In this study, perceptual richness was reduced similarly for both film clip and autobiographical memories in patients with medial temporal lobe epilepsy (St-Laurent, 2012). Neuroimaging of healthy individuals further revealed that the right hippocampus was a key region sensitive to perceptual richness in these memories (St-Laurent, 2012). These results validate our use of film clips to model episodic memory, and support our proposal that the level of perceptual detail will be a good indication of episodicity. Importantly, St-Laurent only tested memory at one time point – immediately after encoding of narrative memories. Thus, our investigation will extend these findings in three critical ways: by measuring different types of information, specifically action details as well as perceptual details, by measuring memory at multiple time points, and by testing recognition rather than recall, which allows us greater control in testing memory for different types of information. This will broaden our understanding of both the quality of episodic memory and mnemonic changes over time.

To summarize, film clips are the ideal stimuli to use in our investigation of episodic memory. Using these stimuli we will measure how the number of perceptual details, action details, and overall ‘gist’ elements changes over time, in order to test different theories of consolidation. We will also investigate whether or not memory for these different categories of information is correlated, in order to inform our understanding of the mechanisms underlying a predicted transformation (and examine the independence/dependence of different memory systems).
Finally, we will take advantage of this opportunity also to explore forgetting by examining how decay and interference may interact in our experiments.

In the future, we plan to transfer this paradigm to the fMRI scanner. This will allow us to correlate neural activity during encoding, consolidation, and retrieval with our behavioural measures of memory. Once optimized, this procedure should thus allow us to investigate the neural bases of detail and gist in episodic memories. These results will help to distinguish between theories of consolidation (particularly SCT/TTH) and contribute to the resolution of the long-standing debate regarding hippocampal dependence of episodic memory over the lifetime.

2 Design

All experiments were designed and run using E-Prime 2.0 software.

2.1 Stimuli

Forty laboratory episodes, in the form of short (20 seconds long) audio-visual film clips, were used in this study. The film clips are all presented in full colour, and contain minimal or no dialogue; instead the story line is carried by the actions of the characters. Each film clip is identified by a simple but distinct title (see Appendix 1 for list of titles with a short description of each clip).

2.2 Questions

Each participant responded to a total of 320 true/false questions throughout the course of this experiment. The questions consisted of simple statements (see Appendix 2 for all the statements used), half of which (in each category) were true and half of which were false. The questions were grouped according to which film clip they referred (8 questions/clip). Although they are later divided into perceptual detail, action detail, and gist categories, the questions were written and presented during testing so that, initially, each statement was grouped into one of two categories depending on whether it referred to a perceptual (4/clip) or a story (4/clip) element.

Perceptual elements consisted of simple visual or audio information incidental to the story-line such as the appearance of characters, the colour/nature of clothing, background items, landscape, weather, and background sounds. Story elements, on the other hand, consisted of information on
the narrative story-line of each clip, such as the occurrence/non-occurrence of events and characters, temporal order of events, and existence of key items.

As stated above, the questions were written and presented during the experiments with only these two categories in mind. However, over the course of the study it became clear that two types of information were being conflated within the ‘story’ category of questions. The statements within this category referred to both gist-like general story-line elements, as well as smaller story-line/action elements less critical to the gist of each clip.

In order to differentiate between these two types of information, the story questions were subdivided into two new categories: action details or gist elements (129:31 proportions). This division was carried out by going through each statement and comparing it to the statements in the “Gist Narratives” of each clip (see Appendix 1). These 5-7 point descriptions of the gist of each clip were written to use for the scoring of a related, but independent, study (using the same film clips) where participants freely recall each clip from memory at different time points. In that study, each statement recalled by participants is scored according to whether it is ‘central’ or ‘peripheral’ to the story-line. Central elements are those that cannot be left out or replaced without causing a major change in the event (Berntsen, 2002), and these correspond to the statements in the Gist Narratives, while peripheral details correspond to any other relevant information provided. Using these Gist Narratives allowed for the objective division of story questions into gist elements (those that correspond to a point in the Gist Narratives, n=31) and action details (those that do not correspond to any of the gist points, n=129). Two independent researchers not otherwise involved in this study ensured that all questions fit their designated categories (independently categorized perceptual and story statements, then subsequently categorized story questions into either action details or gist elements based on the Gist Narratives). Since the statements were divided post-hoc and could only be categorized as ‘gist’ if they corresponded precisely to an element from the Gist Narratives, not every film clip had a ‘gist’ question. This problem is being addressed in our next experiment.

Thus, in the end, this study used three categories of questions: perceptual details, action details, and gist elements.
2.3 Control Procedure

2.3.1 Purpose

The purpose of this control procedure was to ensure that the three categories of questions could not be answered at above chance level without watching the film clips (for example through guessing). Participants were asked to answer true/false questions referring to perceptual details, action details, and gist elements from 20 film clips, without having actually watched the clips.

2.3.2 Method

Ten healthy young adults (2 male, mean age = 19.88 years; SD = 1.64, range = 18-22) participated in this testing for course credit. Participants had completed an average of 13.88 years of formal education (SD = 1.73), were all native or fluent speakers of English, had normal or corrected-to-normal vision and hearing, and no history of neurological illness or injury. All participants provided informed consent prior to participating in the experiment, in accordance with the Research Ethics Board of the University of Toronto. All 10 participants completed the entire session.

Before beginning the session, the experimenter walked each participant through the study instructions verbally, while they were displayed on the computer screen. Once the participant was comfortable with the procedure, the experimenter withdrew to another room, leaving the participant seated alone in a quiet room facing a computer screen. This testing consisted of 20 trials (each trial referring to a single film clip), randomly chosen for each participant from the bank of 40 possible film clips. For each trial, the participants answered all 8 questions for that particular film clip (randomized order of presentation).

2.3.3 Results

Mean accuracy on the true/false questions in this testing was 48.61% (SD = 2.82%) for perceptual details, 49.23% (SD = 3.34%) for action details, and 52.19% (SD = 3.18%) for gist elements. Participants were not able to answer the questions from any category at an above-chance level (perceptual $t_{(9)} = -0.771, p = 0.442$, action $t_{(9)} = -0.269, p = 0.788$, gist $t_{(9)} = 0.381, p = 0.706$), and there were no significant differences between performance in any of the 3 categories ($F_{(2,325)} = 0.217, p = 0.805$).
These results demonstrate that participants, when forced to guess, do not perform significantly better than chance across the categories of true/false questions design for this study. This was important to establish since the questions may have been worded unwittingly in a way that made it possible to guess the proper responses without any memory for the film clips. Furthermore, it is possible that the different categories could have been differentially conducive to guessing (for example due to pre-existing knowledge or schemas of participants being more applicable to gist information, than to perceptual or story details). Thus, it is important that performance was equivalent for perceptual detail, story detail, and gist questions (no category was inherently easier to answer correctly than another).

3 Experiment 1

3.1 Purpose

The purpose of this experiment was to determine the rates at which perceptual details, action details, and gist elements are lost from episodic memory over time, as memories for narrative film clips become more remote. Memory was tested using true/false questions both after viewing all of the clips, and after a delay of either 3 or 7 days.

3.2 Prediction

Due to their centrality to each episode, memory for gist elements will be preferentially preserved in comparison to memory for perceptual or action details (which are more peripheral and thus will be more easily lost, see introduction), over the week following encoding.

3.3 Methods

3.3.1 Participants

Twenty healthy young adults (9 male, mean age = 21.67 years; SD = 3.96, range = 17-31) participated in the experiment, either for course credit or for monetary compensation (10$/hour). Participants had completed an average of 14.78 years of formal education (SD = 2.65), were all native or fluent speakers of English, had normal or corrected-to-normal vision and hearing, and no history of neurological illness or injury. All participants provided informed consent prior to participating in the experiment, in accordance with the Research Ethics Board of the University of Toronto. One participant was dropped due to a technical malfunction.
3.3.2 Procedure

This experiment consists of a practice session (5 minutes), an encoding session (20 minutes), and two retrieval sessions (30 minutes each), one immediately after encoding (average time between encoding and retrieval of a particular film clip 30 minutes) and one after either 3 (n=10) or 7 (n=9) days.

Before beginning the study, the experimenter walked each participant through the instructions verbally, while they were displayed on the computer screen. Participants then completed a practice session, during which they watched 2 film clips of the same length and similar quality as the clips used in the actual experiment, and answered 4 true/false questions for each clip. These questions were of the same format and nature as the questions used in the experiment. Once the participant was comfortable with the procedure, the experimenter left the participant seated alone and facing a computer screen in a quiet room.

During the encoding session participants watched all 40 film clips. Titles were displayed on the screen for 2 seconds before, and 2 seconds after, each clip. Participants were instructed to pay attention to the titles, since they are used later in the experiment to identify to which film clip each question is referring. The order of clip presentation was randomized for each participant.

The encoding session was followed by the first retrieval session. The retrieval session was composed of 40 trials, with each trial consisting of questions for a single film clip. The trial order was randomized for each participant. Within each trial, 4 questions were randomly selected for each clip (2 perceptual and 2 story, with story questions divided post-hoc into action and gist so that there are either 1 or 2 action and 1 or 0 gist questions per clip; this imbalance in the number of questions in each category will be remedied in the next experiment). The remaining 4 questions are later used during the second retrieval session. At the start of each trial, a white screen displayed the title of the clip being retrieved. A statement referring to that particular clip then appeared on the screen, along with a reminder to press “1” to answer “true” and “2” to answer “false”. Each statement remained on the screen until the participant responded, at which point a slide was displayed inquiring about his or her confidence in the response, on a scale of 1 to 5 (1 = response based on a complete guess, 3 = response based on a general ‘feeling of knowing’, 5 = response based on a vivid memory for the clip). After the confidence rating was recorded, the next statement for that particular clip was displayed, until responses were recorded.
for all 4 questions. At that point, the title of the next clip was displayed and the procedure was repeated, until all 40 clips were retrieved.

The second retrieval session took place either 3 or 7 days after the encoding and first retrieval sessions. This retrieval session followed the same procedure as the first, except that the remaining 4 statements for each clip (those not selected during the first retrieval session) were used. Thus, participants answered 160 questions during each retrieval session (4 questions/clip, for 40 clips).

3.4 Results

3.4.1 Memory Performance (Accuracy)

Memory performance is measured as mean accuracy (percentage correct) on the true/false questions within each category. There was a main effect of question type ($F_{(2,102)} = 85.470, p < 0.001$), with participants demonstrating the best memory for gist elements, followed by action details, then perceptual details (Bonferroni corrected post-hoc pairwise comparisons, all $p$’s < 0.001). There was also a main effect of time ($F_{(1,102)} = 20.996, p < 0.001$), which was entirely driven by significantly lower memory at 7 days than at the first retrieval session ($p = 0.016$, all other $p$’s > 0.315). However, the interaction between these two factors was not significant ($F_{(2,102)} = 0.129, p = 0.879$), suggesting that the three types of information were forgotten at similar rates. Performance on all categories remained above chance at all time-points (all $p$’s < 0.040).

Figure 1: Memory performance, all participants (n=19)
Notably, performance on the perceptual and action questions was much lower than performance on the gist questions, even at the first time point, indicating that participants had either not encoded, or had already forgotten, many of the details being queried. Furthermore, there was a huge range of scores across participants on the different categories at the first retrieval session (lowest score was 52.50% on perceptual questions; highest score was 100% on gist elements). This large variance across individuals and across categories, and the fact that performance at each condition started from different baselines at Day 1, makes it difficult to interpret the data.

When controlling for baseline performance by assessing only those participants who began with relatively equivalent accuracy scores at the first retrieval session (performance on perceptual, action and gist questions all within 10%, n=6), a different pattern emerged. As shown in Figure 2, when a participant began with equivalent memory for the perceptual, action and gist elements of a clip, it appears as if the perceptual and action details were forgotten, while memory for the gist was preserved in the week following encoding (although this pattern did not reach significance, perhaps due to the small sample size). In this analysis the only significant effect was of question type ($F_{(2,30)} = 14.454, p < 0.001$), with perceptual and action details being remembered more poorly than gist elements ($p = 0.001$ and $p = 0.029$ respectively), but not significantly different from each other ($p = 0.0764$).

Figure 2: Memory performance, participants who began equivalently (n=6)
Because we noted differences between analyses for groups matched, and unmatched, for memory performance at baseline, we continue providing analyses for both for all subsequent measures.

### 3.4.2 Confidence Ratings

As shown in Figure 3a and Figure 3b, participants are the least confident in their responses to perceptual questions (main effect of question type $F_{(2,102)} = 34.330, p < 0.001$; perceptual lower than action or gist, $p$'s < 0.001; difference between action and gist not significant, $p = 0.127$). Confidence also tends to decrease over time (main effect $F_{(1,102)} = 24.151, p < 0.001$; only Day 1 and 7 are significantly different, $p = 0.001$, all other $p$'s > 0.131).

Although the results are not identical when only those participants who began equivalently are considered, there were no qualitative differences between the two groups in the results of ANOVAs or post-hoc tests.

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**Figure 3a:** Confidence (n=19)  
**Figure 3b:** Confidence (n=6)
3.4.3. Reaction Times

As shown in Figure 4a and Figure 4b, people tended to answer the gist questions more quickly than the detail questions. There was a main effect of question type ($F_{(2,102)} = 3.989, p = 0.215$), driven by faster reaction times for gist questions than action details ($p = 0.0280$). There was no significant effect of time ($p = 0.410$) or interaction between time and type ($p = 0.962$). Once again, though not identical, analysis of reaction times for the two groups did not differ qualitatively.

Figure 4a: Reaction times (n=19)  
Figure 4b: Reaction times (n=6)

3.5 Discussion

3.5.1 Discussion of Experiment 1

One of the most consistent trends observed in this experiment is that questions pertaining to the gist of the film clips were easier to answer correctly than questions pertaining to details from the same clips (at all time-points, and across all participants). This trend reflects long-standing knowledge in the field that people more easily recall information that is central to a story-line (Thorndyke, 1977). This makes sense since one likely purpose of extracting the gist of an episode is to aid both comprehension and memory (Furman et al., 2012; Kintsch et al., 1977). Distilling each episode to its most essential aspects would support more efficient storage of, and access to, information. Participants also seem less likely to miss encoding an important part of
the story-line than to miss encoding a perceptual or action detail, due to the transience of some of the details in the episodes.

Contrary to our predictions, the results from the primary analysis on all participants suggest that perceptual details, action details, and gist are all forgotten at the same rate over the week following encoding. This may be due to a floor effect. Because performance on the perceptual questions is already very low at the first retrieval session (mean accuracy = 67.15%), there is not much opportunity to demonstrate significant forgetting before performance falls to chance (50%). Performance on the action questions is not quite as poor (mean accuracy = 77.29%), but is still much lower than gist accuracy (92.15%), even when memory is tested only an average of 30 minutes after encoding. Since the first test occurred after all the clips had been presented, and since the clips may have proactively and retroactively interfered with one another during presentation, memory had already suffered significant declines by the first retrieval session (see more below). Thus, even though performance is still high for gist questions by Day 7 (mean accuracy = 82.30%), it has decreased as much as performance on the perceptual (falls to mean accuracy of 57.50%) or action (falls to 69.66%) questions. This extreme disparity between memory for the different types of information at the first retrieval session, combined with the high level of variance observed across participants and categories, make the results difficult to interpret.

However, when one examines memory in only those participants who began with relatively equivalent performance across the different categories of questions, a different pattern emerges. It appears as if, when participants retain perceptual, action, and gist information half an hour after encoding, details are forgotten while gist is preferentially preserved in memory over the week following encoding. Although the small sample size prevents this trend from reaching significance, this pattern is consistent with our predictions. These results suggest that if initial memory for the perceptual and action details is improved, this paradigm may be able to more clearly reveal how information is either forgotten or maintained in episodic memories over time.

The low performance on the perceptual and action questions is likely due to one of two phenomena - either participants failed to encode the details initially, or, the information was encoded but then forgotten rapidly (within minutes, before the first retrieval session). Similar work using film clips is consistent with the second possibility, and further suggests that
forgetting may be attributable to interference. Ben-Yakov & Dudai (2011) found that post-stimulus activity in the hippocampus was predictive of subsequent memory for film clips, though they did not distinguish, as we have, among various categories of information. Interestingly, there was no significant difference in hippocampal activity for remembered vs. forgotten items during stimulus presentation, suggesting that the critical time for the hippocampal encoding of a memory is at the offset of a stimulus (Ben-Yakov & Dudai, 2011). It is possible that engaging the hippocampus in a different task during this post-stimulus encoding interferes with the registration of information to memory, resulting in poor memory. Further evidence consistent with this possibility has since emerged from the same lab, where they found that introducing a new film clip within 6 seconds of stimulus-offset impairs memory (Dudai, personal communication, 2013). Since each film clip in this experiment was shown within 4 seconds of the previous clip, the encoding procedure may have taxed the hippocampal system too heavily, reducing registration to memory.

Furthermore, watching all 40 clips in rapid succession may have further increased interference (both pro-active and retro-active) between memories for the different film clips. It has been asserted that a repetition of high-level story elements facilitates recall, while repetition of low-level content in narratives produces interference (Thorndyke, 1977), indicating that the perceptual elements of these memories may be especially susceptible to interference. One possible reason for this effect is that there is much greater overlap between the perceptual elements of the different clips (similar colours, textures, shapes) than there is between the story-lines, which are all fairly distinct, with action details occupying a middle ground. This possibility is consistent with extremely low accuracy of perceptual memory, higher performance on action details, and most accurate memory for the gist of clips at the first retrieval session.

Interestingly, there seems to be some correspondence between our objective measure of memory (accuracy on the true/false questions) and participants’ subjective ratings of confidence in their memories, as the pattern of results is consistent across these two measures (gist > action > perceptual, and Day 1 > Day 7) for both matched and unmatched samples. This indicates that participants have at least some idea of how well/poorly they remember the clips. However, there is no such correspondence between accuracy and reaction times. Although reaction times generally increase over time and are faster for gist than for the details, consistent with forgetting over time and poorer memory for detail than for gist, the patterns here are not as clear. It is also
difficult to draw any conclusions based on reaction times since we did not control for sentence length in our true/false questions, meaning that the time to read the questions could vary across the different categories of information.

3.5.2 Implications for Experiment 2

Experiment 2 addresses the possibility that detail memory in Experiment 1 was adversely affected by rapid decay and/or interference by testing memory immediately after viewing each individual clip. Although this change in procedure was implemented in order to improve memory at the first retrieval session by decreasing both memory decay and interference, unhappily, it will not allow for the differentiation of these effects. The shorter delay between encoding and retrieval (mere seconds vs. an average of 30 minutes) attenuates the opportunity for decay, while answering the questions immediately after watching each clip prevents (at least retroactive) interference from other film clips. This modification of the procedure should thus result in more consistent memory scores across the three categories of information at the first retrieval session. This consistent baseline should facilitate our examination of how memory changes over the week following encoding.

One prediction that stems from the transformation hypothesis is that the gist can be maintained, while the details are lost, within a single memory. The design of Experiment 1 was not conducive to determining whether gist could be maintained, while details are lost from one particular clip since there were only 1 or 2 questions from each category at each retrieval session. Thus, for Experiment 2 the procedure was also modified so that all 8 questions pertaining to a clip are asked during the same retrieval session. This should provide a better indication of the nature of each memory (detailed vs. gist-like) at each time point, allowing us to examine the interaction between different types of information within memory for a single episode. Furthermore, this modification will eliminate repeated retrieval of the same film clips.

Finally, in Experiment 1 the clearest and most consistent differences between memories for the different types of information seem to be emerging by 7 days after encoding. Thus, in Experiment 2, the Day 3 retrieval session was eliminated.
4  Experiment 2

4.1  Purpose

By reducing the opportunity for interference and decay before the first retrieval session, our aim in this experiment was to characterize what type of information is lost, and what is retained, as memories become more remote in the week following encoding. To this end, memory for perceptual details, action details, and the gist of film clips was tested using true/false questions immediately after viewing individual clips, and after a delay of 7 days. We will also examine correlations between memory for perceptual details, action details and gist in order to shed light on the independence/dependence of different information in memory.

4.2  Predictions

i) Memory for perceptual and action details will be improved by moving the first retrieval session to the time immediately after watching each individual clip. This change will not have as large of an effect on gist memory since it already was very good even when tested after all the clips were presented in Experiment 1.

ii) The different types of information tested in this experiment will be differentially retained and lost over the week following encoding; perceptual and action details will be forgotten more rapidly, while gist elements will be maintained in memory.

iii) No predictions are made regarding the correlation of one type of memory with another.

4.3  Methods

4.3.1  Participants

Twenty healthy young adults (9 male, mean age = 22.40 years; SD = 5.20, range = 18-35) participated in this experiment, either for course credit or for monetary compensation (10$/hour). Participants had completed an average of 15.05 years of formal education (SD = 2.04), were all native or fluent speakers of English, had normal or corrected-to-normal vision and hearing, and no history of neurological illness or injury. All participants provided informed consent prior to participating in the experiment, in accordance with the Research Ethics Board of the University of Toronto. All participants completed the full experiment.
4.3.2 Procedure

This experiment consists of a practice session (5 minutes), followed by an encoding/first retrieval session (50 minutes), then, 7 days later, a second retrieval session (30 minutes).

The practice session took place before the encoding/retrieval session and followed the same procedure as Experiment 1. Once the participant was comfortable with the procedure, the experimenter left the participant seated alone in a quiet room facing a computer screen.

The encoding/first retrieval session consisted of 40 trials (trial order randomized for each participant). In this experiment, unlike the previous one, there were two possible types of trials: encoding (20 clips) or encoding + retrieval (20 clips). During encoding trials, the participant simply watched a film clip (preceded and followed by its title). During encoding + retrieval trials, the participant watched a film clip, and then immediately answered all 8 questions pertaining to that clip (order of question presentation randomized), and rated his/her confidence in the answer. Thus, as in Experiment 1, the first day consisted of encoding 40 film clips and answering 160 true/false questions. However, unlike Experiment 1, the first retrieval session came immediately after each individual clip instead of after encoding all 40 clips, and memory was only assessed for half of the clips.

The second retrieval session took place 7 days after encoding/first retrieval. This session consisted of 20 trials (presented in random order). Each trial pertained to a clip that had been previously encoded, but not retrieved, on the first day of the experiment. Within each trial the participant responded to all 8 true/false questions, and rated his/her confidence in the response, for each of the 20 clips being retrieved. Thus, as in Experiment 1, the second retrieval session consisted of answering 160 true/false questions. However, unlike Experiment 1, the second retrieval session took place after 7 days for all participants (no Day 3 retrieval), and memory was assessed only for half of the clips.

4.4 Results

4.4.1 Memory Performance (Accuracy)

Importantly, performance on the perceptual questions at the first retrieval session was significantly higher in this Experiment than in Experiment 1 (75.50% vs. 67.15%, p < 0.001).
Performance on the action questions also increased, though the difference did not quite reach significance (81.11% vs. 77.29%, p = 0.0562), while memory for the gist actually decreased slightly, though not significantly (91.88% vs. 92.15%, p = 0.880).

As shown in Figure 5, performance on the perceptual and action questions was initially worse than performance on the gist questions (significant main effect of question type; F(2,38) = 100.3, p < 0.001), while information in all three categories was lost over the week following encoding (significant main effect of time; F(1,19) = 117.2, p < 0.001). However, in this experiment, there was a significant interaction (F(2,38) = 6.982, p = 0.002), suggesting that the different types of information were differentially affected by time. Post-hoc pair-wise comparisons (Bonferroni corrected) revealed that memory at the first retrieval session was significantly higher for gist than for action details (p = 0.003), which were remembered significantly better than perceptual details (p = 0.042). Memory for both perceptual and action details decreased significantly over the 7 days following encoding (p < 0.001 for both), while memory for gist did not differ significantly between the first and second retrieval sessions (p = 0.099).

Figure 5: Memory performance in Experiment 2 (all participants)

![Figure 5](image)

Interestingly, the loss of perceptual and action information from memory was not simply due to this information being inherently more difficult to encode. This is demonstrated by median splitting the perceptual and action questions into ‘easy’ and ‘hard’ categories based on performance at the first retrieval session. As shown in Figure 6, even those perceptual and action
questions for which performance was as high as gist at the first retrieval session were forgotten over the week following encoding. In fact, at the second retrieval session, memory for the ‘easy’ perceptual and action questions was equivalent to memory for the ‘hard’ questions. Notably, there was no significant difference between the number of correct ‘true’ and the number of correct ‘false’ responses in the easy/hard questions (p = 0.375 for perceptual and p = 0.915 for action). Thus, it was not inherently easier to correctly accept, rather than correctly reject, an item in this experiment.

Figure 6: Memory performance based on easy/hard median split

Not only were perceptual and action details lost from memory at similar rates, performance on these questions was also correlated with one another (r = 0.526, p = 0.017, see Figure 7a) across participants. Interestingly, detail memory seems to be uncorrelated with gist memory, as neither performance on perceptual (see Figure 7b) nor action details (see Figure 7c) was correlated with memory for gist (r = 0.070, p = 0.768 and r = 0.204, p = 0.388 respectively).

Figure 7a: Correlation between memory for perceptual and action details  
Figure 7b: Correlation between memory for perceptual details and gist
Analysis of accuracy on a clip by clip basis also indicates that memory for the gist of a particular clip can be maintained after 7 days, independently from memory for the perceptual and action details in that clip. When the Day 7 retrieval data is median split into two groups, based on accuracy of gist memory, there are no significant differences in memory for the perceptual (58.25% for high gist clips vs. 56.79% for low gist clips, p = 0.762) or action details (63.32% for high gist clips vs. 62.68% for low gist clips, p = 0.915).

### 4.4.2 Confidence Ratings

Replicating the results of Experiment 1, confidence decreased significantly over the week following encoding (see Figure 8; $F_{(1,19)} = 92.32$, $p < 0.001$), and differed significantly between the categories of questions ($F_{(2,38)} = 116.01$, $p<0.001$; perceptual $<$ action $<$ gist, all $p$’s $< 0.001$). The interaction of type with time was once again not significant ($F_{(1,19)} = 4.03$, $p = 0.059$).
** Analysis of confidence ratings and reaction times based on the easy/hard median split did not reveal any qualitative differences in the patterns of results.

### 4.4.3 Reaction Times

Unlike Experiment 1, reaction times in this experiment demonstrated a clear and significant increase over time (see Figure 9; $F_{(1,19)} = 23.69, p < 0.001$). Furthermore, reaction times for the gist questions were reliably faster than for either type of detail (main effect of type $F_{(1,19)} = 13.85, p = 0.001$, Bonferroni corrected pairwise comparisons revealed gist < perceptual $p = 0.001$, perceptual < action $p < 0.001$). The interaction of question type with time was not significant ($F_{(1,19)} = 2.37, p = 0.14$), indicating that remoteness affected retrieval time similarly across the three different categories of information.

### 4.5 Discussion

As predicted, moving the first retrieval session to immediately after presentation of each clip improved performance on the detail questions. This drastic improvement in memory accuracy suggests that the low performance in Experiment 1 was due to rapid decay and/or interference from the other film clips, rather than due to participants failing to encode the information initially. Furthermore, this modification had twice as large of an effect on memory for the perceptual details as the action details (8% vs. 4%), and no effect on gist memory, consistent with the ‘interference’ proposal. Attenuating interference is hypothesized to have had a differential effect on memory since there is much more overlap between the perceptual elements
of the different clips, than between the story-lines (for example there are 7 perceptual questions about hair and multiple questions each about suits/dresses/shirts, but minimal overlap between the action/gist questions except that two clips involve cameras and two clips involve balloons). Thus, one would expect that reducing the opportunity for interference from overlapping information in other film clips would affect memory for perceptual details more drastically than memory for story-line elements. Whether this change to the procedure was due to the elimination of interference or to the reduction of decay (which cannot be determined based on these results), it is interesting that perceptual and action detail memory were affected, while memory for gist was consistent across both experiments. This suggests that gist memory may be maintained at a relatively stable level right from the time it is encoded, while memory for details may be particularly susceptible to interference and/or rapid decay within the first half hour after encoding.

Consistent with our hypothesis and the results using matched samples in Experiment 1, the different types of information tested in this experiment were differentially remembered over the week following encoding. Perceptual and action details of the film clips were forgotten, while gist elements were maintained in memory.

Based on the initial analysis of the results from this experiment, it was possible that the greater loss of perceptual and action details may have been due to these questions being inherently more difficult to answer (performance on both perceptual and action questions is significantly lower than performance on gist questions at the first retrieval session). However, further analysis suggests that this is not the case. Instead, even those perceptual and action details which tended to be remembered easily at the first retrieval session were forgotten over the week following encoding. These results are consistent with the proposal that the decline in performance on the action and perceptual questions is due to the preferential loss of this type of information from memory over time, rather than due to any differences in difficulty between the perceptual/action questions and the gist questions. Furthermore, this pattern does not seem to be due to ceiling effects in the gist data since the easy perceptual and action questions are answered more accurately than the gist ones at first retrieval, while performance falls drastically by the second retrievals session. Thus, memory for gist begins from a slightly lower point, but is still preferentially maintained.
The correlations seen in memory performance in this experiment support the assertion that central and peripheral elements of episodic memories can be processed independently in the brain. Across participants, memory for perceptual and action details is highly correlated, while memory for both types of information is not correlated with memory for gist. Even participants who performed near chance levels for perceptual accuracy could remember the gist of the film clips. Furthermore, when memory is examined on a clip by clip basis, high gist memory was not associated with greater detail memory. Instead, memory for both perceptual and action details was equivalent across clips with the highest and the lowest gist memory scores. With respect to consolidation, these independent analyses across both participants and clips are consistent with the TTH proposal that memory for the gist of an episode can be maintained and expressed independently of memory for details (Winocur et al., 2010), though they do not imply that gist and detail memory do not interact in the intact brain. Thus, multiple memory traces may co-exist in the intact brain, with the quality of memory expressed (detailed/context-specific and hippocampal vs. generalized/gist-like and neocortical) dependent on which trace is dominant at a particular time (Winocur et al., 2010).

Using optogenetics in rodents, Goshen et al. (2011) shed light on the existence of such multiple memory traces. This group demonstrated that contextual fear memories are sensitive to hippocampal-inactivation not only at recent time-points, but also at remote time points when there is very precise inactivation of the hippocampus during testing (Goshen et al., 2011). Notably, at remote time points, memory was additionally sensitive to mPFC inactivation, suggesting that multiple memory traces co-exist in the brains of intact rodents (Goshen et al., 2011). The attenuation of hippocampal activation that is generally reported during retrieval of remote memories may thus indicate inhibition by a dominant (perhaps mPFC mediated) generalized trace, resulting in the expression of a more gist-like memory, rather than the absence of a hippocampal trace.

Using multi-voxel pattern analysis in humans, Bonnici et al. (2012) similarly demonstrated the existence of multiple memory traces. Assessing only memories rich in detail, Bonnici et al. (2012) found information about both recent and remote memories in the hippocampus, suggesting that it is important for the retrieval of vivid autobiographical memories regardless of age. Notably, the mPFC also contained information about both recent and remote memories, although in this region, classification accuracy was higher for remote memories (Bonnici et al.,
Thus, these memory traces co-existed in the brains of participants. TTH provides a parsimonious account of all these data, asserting that multiple memory traces can interact dynamically in the intact brain, with the system that is dominant at recall determining whether the memory retrieved is detailed and context-specific, or more generalized in nature (Winocur et al., 2010).

Notably, although memory for gist is maintained over the week following encoding, while details are forgotten, participants’ confidence in their memories declines and reaction times increase similarly for all types of information. These confidence ratings and reaction times reflect the informal reports of participants after the second retrieval session, when most people expressed fear that they had forgotten everything since their last session. People seem to have low confidence in their memories a week after encoding, despite the fact that their performance suggests they remember quite a bit about the gist of episodes they have witnessed.

5 General Discussion

5.1 Summary

The main goal of this study was to characterize the rates that detail and gist information are lost from episodic memories as they become more remote. The results of Experiment 2 (and matched samples in Experiment 1) are consistent with the hypothesis that memories tend to lose detail over time as they are transformed into more generalized, gist-like representations. Notably, the type of information tested (audio/visual/story-line) was not as critical as the quality of the information (central vs. peripheral to the main story line) in determining how well it was remembered over time. This is consistent with previous research demonstrating that the recall probability of facts from narrative stories depends on the centrality of the elements (Rumelhart & Ortony, 1977; Thorndyke, 1977). Our hypothesis that the centrality of an element determines how well it will be remembered is further supported by the demonstration in Experiment 2 that the difficulty of a question is not the main determinant of how well it will be answered after a week. Instead, performance on both easy and difficult detail questions fell to the same level over the days following encoding, while gist memory remained relatively preserved.
5.2 Generalization of Memory

When considering both experiments, a similar pattern is seen for memory of perceptual details and memory of action details, even though the quality of information being tested by those two categories of questions is completely different (audio and visual elements of the film clips vs. actions of the characters and story-line details). This is particularly striking in light of the very different pattern seen for memory of action details and memory for gist, considering that these two elements had initially been grouped together under the category of ‘story’ elements. Even though these statements were written in reference to the same type of information (aspects of the story-line), it appears as if those questions that relate to the central aspects of the narrative (the gist) are remembered differently from those that relate to more peripheral details. These results support our hypothesis that, for episodic memories, the nature of an element (central vs. peripheral) is one of the key determinants of how it will be remembered over time. This evidence that memories are transformed over time, from representations that are rich both in detail and gist, to representations that are primarily gist-based, is consistent with TTH but inconsistent with SCT, which maintains that memories retain their original character as they are consolidated extra-hippocampally (Squire & Alvarez, 1995).

The loss of detail observed in this study is reminiscent of the phenomenon of contextual memory generalization in rodents. In contextual fear conditioning, soon after training fear is context specific: an animal will only freeze when returned to the same context in which they were shocked, not any other (Wiltgen & Silva, 2007; Wiltgen et al., 2010). This indicates that the details of the original environment and training are still linked and accessible in memory (Winocur et al., 2007). However, within two weeks, animals will begin to freeze when placed in any context that generally resembles the training context, indicating that the details of the original context have been forgotten, but a general memory of the training maintained (Winocur et al., 2007). Similar generalization of memory has been demonstrated with social-food-preference, and in compound conditioning with auditory stimuli (Thomas & Riccio, 1979; Winocur et al., 2007). Thus, instead of remembering the details it seems as if rats begin to rely on a more gist-like representation of an event, a behaviour which may correspond to the loss of detail but maintenance of gist we observe over the week following encoding of film clip memories.
Generally, in such research using rodents, deactivation of the hippocampus is reported to disrupt recent but not remote memories, while deactivation of the medial prefrontal cortex (mPFC) results in the opposite pattern of effects (Maviel, Durkin, Menzaghi, & Bontempi, 2004).

Furthermore, using different spatial memory tasks and mapping of either metabolic activity or immediate early gene expression, the hippocampus is shown to be preferentially activated during the encoding and retrieval of recent memories, while the mPFC is activated for the retrieval of remote memories (Bontempi, Laurent-Demir, Destrade, & Jaffard, 1999; Maviel et al., 2004). Some proponents of SCT use this evidence to suggest that the mPFC acts to link neocortical representations in remote memory, analogous to the role of the hippocampus in recent memory (for ex. Frankland & Bontempi, 2005). However, critically, the research on contextual fear generalization mentioned above hints at the idea that this neural shift may not be due to time passing, per se. Instead, it suggests that any observed shifts in the neural bases of memory may be due to changes in the nature of memory over time, specifically, transformation from detailed/context-bound to generalized.

Consistent with this theory, while no memory loss occurs if hippocampal lesions are sustained after fear has generalized, detailed memory for fear conditioning is sometimes retained even after considerable delays, at which point it is associated with hippocampal activation and is sensitive to hippocampal lesions regardless of a memory’s age (Gafford, Parsons, & Helmstetter, 2013). In line with TTH, this pattern of results suggests that generalized responses depend on a less detailed representation of the training established extra-hippocampally (Wiltgen & Silva, 2007; Wiltgen et al., 2010; Winocur et al., 2007). Conversely, SCT, which suggests that the consolidated neocortical trace retains all essential features of the initial hippocampal representation (Squire & Alvarez, 1995), cannot as easily account for these effects. Thus, work on contextual fear conditioning suggests that as long as the memories remain detailed they will be associated with hippocampal activation, while memories that retain only the gist of an episode will depend on extra-hippocampal neocortical structures.

### 5.3 Hippocampal-Dependence of Episodic Memory

Generally, recent findings in humans and animals suggest that the quality of a memory’s content is the best indication of the neural basis of that memory (e.g., Wiltgen & Tanaka, 2013; Winocur and Moscovitch, 2011). Contrary to this assertion, some neuroimaging studies report that
hippocampal activation diminishes with the age of a memory, regardless of its nature (Haist, Bowden Gore, & Mao, 2001; Smith & Squire, 2009). Similarly, word pairs, images, and emotional pictures have all been used to demonstrate a general decrease in hippocampal activity along with an increase in mPFC activity, in the days, weeks and months following encoding (Gais et al., 2007; Sterpenich et al., 2009; Takashima et al., 2006). However, studies on autobiographical memory, which tend to use memories that have survived a delay and remain vivid, don’t find similarly uniform decreases in hippocampal dependence over time. Instead, such studies tend to find hippocampal activation independent of a memory’s age. Different groups have variously associated hippocampal activation during AM recall with the level of visual imagery/vividness (Piolino, Desgranges, & Eustache, 2009; Viard et al., 2010), detail, emotionality (Addis, Moscovitch, Crawley, & McAndrews, 2004), and sense of re-experiencing (Gilboa, Winocur, Grady, Hevenor, & Moscovitch, 2004) that accompanies memory retrieval. None of these studies found hippocampal activation to be directly dependent on the age of the memory, consistent with TTH.

This evidence indicates that the decline in detail observed in this study should be accompanied by a shift from hippocampal dependence to independence over time, while any film clip memories which retain their detailed and vivid quality should remain dependent on the hippocampus.

The decline in detail observed over time in this study is reminiscent of the attenuated perceptual detail measured in memories for these same film clips in patients with temporal lobe epilepsy (St-Laurent, 2012, Doctoral Dissertation). Patients with temporal lobe epilepsy also demonstrate reduced perceptual richness in both recent and remote autobiographical memories (St-Laurent, Moscovitch, Levine, & McAndrews, 2009), and retrieve skeletal memories for which gist is maintained but specific temporal details are lost (St-Laurent, Moscovitch, Tau, & McAndrews, 2011). Furthermore, even patients with lesions limited to the CA1 neurons of the hippocampus demonstrate impaired retrieval of detailed autobiographical memories from all time-points (Bartsch, Döhring, Rohr, Jansen, & Deuschl, 2011). These data bolster the proposal that the attenuation of detail but maintenance of gist measured in this study should be associated with a decline in hippocampal-dependence of memory.
5.4 Next Steps

It will be critical in the future to re-develop our true/false questions so that we have equal numbers of statements in each category. Thus, our next step will be to write more action and gist questions so that we have 4 questions in each of the three categories in future experiments. This will allow us to be more confident in our characterization of the rates at which detail and gist are lost from our film clip memories.

Once these questions are developed, we hope to move our optimized paradigm into the fMRI scanner. Critically, Furman et al. (2012) demonstrate that the retrieval of film clips using recognition questions spontaneously evokes re-experiencing of the witnessed event. This report suggests that we should be able to similarly trigger re-experiencing of episodic memories during fMRI, using our film clips and true/false questions. Thus, this paradigm will allow us to correlate neural activity during encoding, consolidation, and retrieval with our behavioural measures of memory, as well as investigate the neural bases of detail and gist in episodic memories.

Based on the array of evidence discussed above, we expect memory generalization over time to be associated with a general shift from hippocampal to mPFC representation. However, critically, we expect hippocampal activation to be modulated by the level of detail recalled at all time-points, rather than by the age of a memory per se. These predictions are consistent with the results of Furman et al. (2012), who found decreased hippocampal activation for recall of a documentary film over the months following encoding, but that accurate memory for detail remained associated with hippocampal activation at all times. Interestingly, although a decrease in activation over time was observed for most regions within the memory network identified in this study, activity within the mPFC did not decrease (Furman et al., 2012). As mentioned in the introduction, although this study found the expected decrease in hippocampal recruitment for recall over time, they did not investigate how different types of information are maintained in memory. Thus, by differentiating between memories rich in perceptual details, action details, and/or gist elements, we hope to qualify more precisely any observed shifts in the neural basis of memory over time.

Imaging encoding, as well as both retrieval sessions, will also allow us to investigate whether hippocampal activity at encoding is predictive of accurate memory for the elements of a clip. Gelbard-Sagiv et al. (2008) found that the hippocampal neurons which fired to certain elements
during the encoding of short narrative film clips fired selectively to the same elements during free recall. This hippocampal activity indicates that the same regions used to encode information initially may be critical in the representation and retrieval of that information. Additionally, hippocampal activity was associated with subjective reports of vividly re-experiencing a film clip (Gelbard-Sagiv et al., 2008), consistent with our predictions that the hippocampus may be the neural substrate of detailed episodic memory. When carrying out the fMRI version of this procedure, it may also be interesting to look at activity after each clip’s presentation. As mentioned in Experiment 1, Ben-Yakov and Dudai (2011) suggest that this post-stimulus activity is even more predictive of subsequent memory than online neural activation.

5.5 Why multiple memory systems?

Generalization of memory may increase biological fitness in many ways: making our memories more accessible by widening the variety of cues that support recall of important information, abstracting knowledge so that the referent of new concepts is narrowed to the appropriate element of an experience, as well as allowing us to apply old knowledge in novel contexts and make inferences from our limited experiences (Conway, 2009). Although it entails the loss of perceptual, emotional, and personal details from memories, generalization may therefore make our memories both more useful, and more usable, in certain situations.

The maintenance of detailed episodic memories, on the other hand, may serve an entirely different purpose. The similar hippocampal-activation observed during tasks that require imagination, prediction of the future, or problem solving, as is seen during episodic memory retrieval suggests that common mechanisms may underlie all these functions (Hassabis & Maguire, 2009; Schacter et al., 2012). Thus, if the purpose of the hippocampus is to support the association of events and details from memory into a coherent narrative of a past event, it may also support the re-construction of various details and elements of memories into novel combinations (Buckner, 2010; Rosenbaum, Gilboa, Levine, Winocur, & Moscovitch, 2009). This process may be crucial for the simulation of future events, imagination, decision making, and planning, where specificity in sometimes required, rather than generality. For example, when solving a problem such as the best way to get from your home to work when there is construction blocking your regular route, it is not enough to know the gist of a solution (i.e. drive your car, but take a shortcut). Instead you need to plan out a particular detailed route to take, a process
which may require the hippocampus for specificity. In line with this proposal, Sheldon et al. (2011) demonstrated that patients with medial temporal lobe lesions provide fewer relevant steps in their solutions to open-ended problems. Even imagining non-personal future events may be dependent on the hippocampus for any degree of specificity, as evidenced by the impoverished descriptions of future events in the public domain produced by patients with MTL lesions (Race, Keane, & Verfaellie, 2012). Thus, detailed memory traces are also useful and necessary to maintain over the lifetime; allowing us to predict the results of different courses of action before choosing one, come up with creative new solutions to problems, and follow through with specific plans.

5.6 Conclusion

A century of neuropsychological research, rather than solving the mysteries of memory encoding, consolidation and retrieval, has highlighted the complexity of these processes. For example, there remains no consensus on the nature and hippocampal-dependence of episodic memories over the lifetime. This study sheds light on the first issue by demonstrating that details are forgotten, while the gist of an event is maintained, in memory over the week following encoding. When this procedure is transferred to fMRI, it will also address the second issue, clarifying the neural basis of recent/remote and detailed/generalized episodic memories. Results from these studies will help distinguish between theories of consolidation and contribute to our understanding of this complex and fascinating neural process.
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Appendices

Appendix A: List of all film clips used, with Gist Narratives

Boy and his jersey
- Boy is colouring a shirt
- Boy puts shirt on
- Boy looks at self in mirror
- Boy is excited/happy
- Boy puts shirt over his face

Boy, Girl, and Balloons
- Boy and girl each have large balloons
- Boy walks away
- Girl’s balloon floats towards boy
- Boy catches girl’s balloon
- Girl retrieves her balloon from the boy
- Children walk in opposite directions

Boys Faking a Car Accident
- Group of boys walking down street
- Cars are stopped
- Boy steps on bumper of stopped car
- Front driver thinks he has been rear-ended
- Front driver gets out of car
- Front driver yells at driver behind him
- Rear driver gets out of his car
- Boys laugh

Boys Playing at the park
- One boy sitting on a swing
- One boy spinning in circles
- Boy jumps on rocking horse toy
- Boy runs over to friend on swings
- One boy turns upside down on the swing

Boys Watching Soccer
- Two boys watching soccer on TV
- Soccer player scores
- Boys cheer
- Boy rewinds video
- Boys rewatch the goal
- Boys cheer just as loudly as the first time

Chasing the red balloon
- Boy walking alone with balloon
- Group of kids chase him
- Boy runs up stairs
- Second group of kids runs towards him
- Boy loses his balloon
- Boy catches balloon
- Boy runs off safely
Couple at the beach
• Couple standing by the shore
• Boy taking picture of girl
• Little wave splashes girl
• Boy offers tissue
• They both get splashed by giant wave
• Their clothes are ripped off/soaking wet

Couple Fighting in the Car
• Couple arguing in a car
• Heavy rain outside
• Man stops the car
• Woman gets out
• Car drives off
• Woman walks off in the rain

Couple in the Kitchen
• Man standing and thinking
• Woman cooking/preparing food/washing dishes
• Man approaches her
• Man hugs woman
• Woman stops working

Couple Meeting at the restaurant
• Man waiting for a woman in a restaurant
• Woman enters restaurant
• Woman sits down
• Man offers her his glass
• Woman takes a sip

Couple Taking a Photograph
• Man sets up camera timer
• Man goes back to his wife
• Wife tries to hold his arm
• Man shakes the woman off
• Car drives between camera and couple
• Camera takes a picture of the car
• Couple laughs

Crashing the Bicycle
• Man and boy on bicycle
• Going down a hill
• Man finds out brakes don’t work
• Man tries to slow down
• They crash into tree
• They fall off of bike

Cyclist Waiting for Her
• Man waiting with his bicycle
• Woman walks out right past him
• They greet each other
• Man chases her
• Man must return for his bicycle
• Couple walks and talks
Family Dessert
- Mother, father, son sit down at dining room table
- Boy eats all his fruit
- Boy doesn’t eat rest of dessert
- Parents look at each other, upset/confused
- Mother scolds son

Family painting a cottage
- 2 women painting a house
- Man walks up
- Man puts a bucket down
- Man takes over from one of the women
- That woman walks to front of house

Girl Chasing her Shoe
- A girl loses her shoe in the gutter
- Shoe is carried away by the water
- Girl chases her shoe down the street
- Shoe gets caught
- Girl is sad/upset

Grandfather babysitting
- Grandfather squeezes squeaky toy
- Grandfather lights cigarette
- Grandfather sits down by baby carriage
- Grandfather speaks to baby
- Baby starts crying
- Grandfather swears/is upset/is angry

Gunman at the window
- Gunman retrieves gun
- Gunman opens up window
- Gunman aims outside
- Gunman shoots toy dog
- Woman looks up at the gunman

Husband Smokes
- Husband and wife are standing on their stoop/in backyard/on porch
- Husband gets out a cigarette
- Wife goes inside house
- Wife returns outside with lighter
- Husband lights his cigarette
- Wife returns inside

Leaving Home
- Parents and son standing in front of house
- Son gets last box to put in his car
- Son sits in driver’s seat of car
- Son and parents say goodbye
- Son drives off
- Unattached trailer is left behind

Lone Man at the theater
- Theater in the middle of nowhere
• Man buys ticket
• Man sits down alone in theater
• Projectionist yells
• Movie starts

Man Against Door
• Man knocks on closed door
• Two men are waiting on the other side of the door
• Man tries to force the door open
• The men on the other side unbar the door
• The door opens the next time the man bangs against it
• The man falls to the floor
• They all shake hands in the end

Man, Bird, and Window
• A man is opening/closing a window
• He notices that the window is focusing light on neighbour’s wall
• Neighbour bird is singing
• The man moves the window/bar of light back and forth
• The man closes the window

Meeting at the mosque
• Young man waiting outside
• Girl comes out from mosque
• Both happy to see each other
• Father comes out
• Boy looks upset/sad

Meeting the flute player
• A man is playing a flute
• A woman hears the flute
• The woman goes towards the man
• He tries to find her
• She surprises him
• She grabs his flute

Men Toasting
• Man #1 enters the living room
• Man #1 turns a light on
• Man #2 is waiting on the couch
• Man #1 sits down beside Man #2
• Man #1 pours two drinks
• The men toast

Mom putting boy into car
• Boy gets into car
• Mother hands him briefcase
• Car drives away
• Mother follows behind car for a short while
• Mother waves goodbye
• Overall gist point: mother cleaning everything

Parents fighting
• Couple is fighting
- Girl is playing the piano
- The piano is being played violently
- Parents stop arguing
- Man stops the girl’s piano playing

**Penalty Kick**
- Group of people are playing soccer
- One player places a soccer ball
- Referee blows the whistle
- Player kicks the ball
- Ball flies way over the net
- Ball hits something in the background

**Picking up a Hitchhiker**
- Man is driving down desert road
- Driver sees female hitchhiker
- Hitchhiker has a sign
- Driver stops the car
- Hitchhiker runs up to the car window

**Picking up Mangos**
- Boy is picking up mangos
- Mangos get dropped down from tree
- Boy leaves tree with full basket
- Boy puts basket down
- Boy pockets some mangos
- Boy grabs a new empty basket

**Policeman Flirting**
- Policeman sees a woman with her daughter
- Policeman blows whistle to stop traffic
- Policeman crosses the road
- Policeman and woman talk
- He helps her across the road

**Sleeping Boy**
- Boy #1 is pulling a cart down a road
- Boy #1 sees Boy #2 sleeping
- Boy #1 pours water from a bottle into its cap
- Boy #1 pours water on Boy #2
- Boy #2 wakes up

**Snowy Car**
- Man finds car covered in snow
- Man starts cleaning car
- Man finishes cleaning car
- Man tries to unlock car
- Car in front is unlocked instead
- Man realizes he has been cleaning wrong car

**Teenagers teasing**
- Boy shows a note to his friend
- Friend teases him
- Friend leaves
• Friend steals fruit
• Fruit vendor is angry
• Friend throws fruit back to boy with note
• Boy returns the fruit

Thief
• Girl is walking around record store
• Girl puts record in her folder
• Girl tries to leave store
• Clerk stops her
• Girl passes clerk her folder

Waitress and the Pianist
• Waitress knocks on the door
• Pianist doesn’t stop playing piano
• Waitress lets herself into the room
• Waitress places tray down on a table
• Pianist hears the noise the tray makes
• Pianist stops playing the piano

Woman Buying Lettuce
• Woman picks up head of lettuce
• Woman looks to the vendor for approval
• He shakes his head no
• She picks up another head of lettuce
• The vendor approves
• She takes two heads of lettuce in the end
• Woman leaves some money

Woman Dropping a Shell
• Woman enters a museum
• Woman picks up a shell
• Woman drops the shell
• The shell breaks
• The noise wakes up a security guard
• Woman replaces the shell with a piece of pasta
• Woman writes a note
• Woman leaves the museum

Woman Squeezing Food
• Woman in grocery store
• Woman is squeezing a peach
• Woman squeezes so hard juice squirts out
• Cashier is angry/surprised
• Woman runs away
• Cashier follows her
• Woman squeezes a round of cheese

Appendix B: All statements used for true/false questions
** Highlighted Statements are those used as ‘Gist’ elements

Boy Getting In Car
Perceptual
1. The woman is wearing a green dress (T)
2. The car drives past grey houses (T)
3. The car is blue (F)
4. The man honks the car’s horn (F)

Story-Line
1. The woman is cleaning with a rag (T)
2. The woman follows the car, still wiping it clean (T)
3. The woman wipes the boy’s face with the rag (F)
4. The woman throws the dirty rag away (F)

Boy, Girl, and Balloons
Perceptual
1. The girl’s hair is blonde (T)
2. The boy is carrying a briefcase (T)
3. The boy’s balloon is green (F)
4. The children are walking in front of a black fence (F)

Story-Line
1. At the start the boy walks away from the girl (T)
2. In the end, the children walk away from each other in opposite directions (T)
3. The boy loses his balloon (F)
4. The boy walks back to the girl to give her the balloon (F)

Boys Faking Car Accident
Perceptual
1. The main boy is wearing khaki shorts (T)
2. The cars stop in front of a large grey building (T)
3. The car stops at a stop sign (F)
4. The boys are walking in a gang of around 10 (F)

Story-Line
1. The driver is angry because he thinks the man behind him rear-ended his car (T)
2. The boys watch the men yell at each other (T)
3. Two boys jump on the back of the man’s car (F)
4. The man yells at the boys (F)

Boys Watching Soccer
Perceptual
1. The boys are wearing different soccer jerseys- one red, one white (T)
2. The boys have short hair- one red, one brown (T)
3. The boys are sitting on a leather couch (F)
4. The announcer of the soccer game has a French accent (F)

Story-Line
1. Two boys are watching a large television (T)
2. The boys cheer loudly when their soccer team scores (T)
3. The boys turn the volume up, then finish watching the game (F)
4. The boys become bored with the game (F)

Bullied Boy and Mimes
Perceptual
1. The boy has a leather bag (T)
2. There are birds singing (T)
3. One of the mimes is wearing glasses (F)
4. In the end, the boy runs towards a stone fountain (F)

Story-Line
1. The mimes smile at the boy (T)  
2. There are two bullies (T)  
3. In the beginning, the boy is running away from the bullies (F)  
4. In the end, the boy runs away because he is afraid of the mimes (F) 

**Couple Taking a Photograph**  
Perceptual  
1. The woman is wearing a red baseball cap (T)  
2. The man is wearing a black suit (T)  
3. The couple is standing in front of a stone sculpture (F)  
4. The camera flashes when it takes a picture (F) 

Story-Line  
1. A jeep drives between the couple and the camera (T)  
2. The woman tries to hold the man’s arm but he yanks it away (T)  
3. A woman sets a camera up on a fence (F)  
4. The man is angry when the photo is ruined (F) 

**Crashing the Bicycle**  
Perceptual  
1. The man has curly hair (T)  
2. The bicycle falls on top of the boy (T)  
3. The boy has blonde hair (F)  
4. The boy is sitting on the handlebars of the bicycle (F) 

Story-Line  
1. The bicycle’s brakes are broken (T)  
2. The bicycle hits a tree (T)  
3. First, the man tries to brake with his feet (F)  
4. The boy falls off the bike before it crashes (F) 

**Waiting for her**  
Perceptual  
1. The man is wearing a jean jacket (T)  
2. Flute and tuba music is playing (T)  
3. The woman is wearing a black coat (F)  
4. When the man catches up with the woman they pass in front of a church (F) 

Story-Line  
1. The man is waiting with his bicycle for a woman (T)  
2. The man cycles next to the woman as they chat (T)  
3. The woman stops to talk to the man when he greets her (F)  
4. The man follows the woman but forgets his backpack and goes back for it (F) 

**Girl Chasing her Shoe**  
Perceptual  
1. The girl is wearing a backpack as she chases her shoe (T)  
2. The girl’s shoe is white (T)  
3. The girl is wearing a blue headscarf (F)  
4. The girl stops by a red fire hydrant when she tries to grab her shoe (F) 

Story-Line  
1. The shoe becomes lodged in some debris (T)  
2. The little girl cannot reach her shoe so she begins to cry (T)  
3. A bully throws the girl’s shoe into the street gutter (F)  
4. The shoe becomes trapped but the girl doesn’t notice and continues running (F)
Meeting at the mosque
Perceptual
1. The boy is waiting in front of a fence (T)
2. The mosque has a brown front door (T)
3. The girl is wearing a white dress (F)
4. The boy is wearing glasses (F)

Story-Line
1. An older man exits the mosque after the girl (T)
2. The boy is not happy to see the girl with her father (T)
3. The boy is waiting with a group of friends (F)
4. The girl and boy walk towards each other (F)

Grandfather Babysitting
Perceptual
1. The stroller is parked in front of a flower bed (T)
2. One can hear footsteps in the background (T)
3. The man shakes a rattle at the baby (F)
4. There is a yellow sign behind the man (F)

Story-Line
1. The man smokes a cigarette (T)
2. The man sits down beside the stroller (T)
3. The baby giggles when the man passes it a toy (F)
4. The man picks up the baby to soothe it (F)

Gunman at the window
Perceptual
1. The toy dog has white and brown fur (T)
2. One can hear the sound of cars in the background (T)
3. The man with the gunman is wearing a black sweater (F)
4. The woman is wearing a skirt (F)

Story-Line
1. The man shoots a toy dog (T)
2. The man retrieves a gun from a cupboard (T)
3. The other man opens the window for the gunman (F)
4. A woman is startled and runs away (F)

Man against Door
Perceptual
1. The man trying to get through the door is wearing a black suit (T)
2. The room on the other side of the door is red (T)
3. There is trumpet music in the background (F)
4. The door is brown (F)

Story-Line
1. Two men are waiting on the other side of the door (T)
2. The man falls to the floor when the door opens (T)
3. The man tries to kick the door in (F)
4. The man who fell is angry at the other men (F)

Man stuck in phone booth
Perceptual
1. The man has a dark mustache (T)
2. The man is wearing a suit (T)
3. There is a road behind the phone booth (F)
4. The phone is black (F)

Story-Line
1. The man hangs up the phone, exasperated (T)
2. The man pushes on the door with both hands but it doesn’t open (T)
3. A man reads a phone number out of his notebook (F)
4. The man realizes he has no change to pay for the phone call (F)

No paper in the washroom
Perceptual
1. The walls of the washroom are white (T)
2. The paper towel dispenser is next to the sinks (T)
3. The man has a beard (F)
4. The doors are open on a row of toilets (F)

Story-Line
1. The hand dryer is very weak and short lasting (T)
2. First, the paper towel dispenser is empty so he then turns to the hand dryer (T)
3. There is no soap in the washroom (F)
4. In the end he is forced to use toilet paper to dry his hands (F)

Parents arguing
Perceptual
1. The parents are fighting in the kitchen (T)
2. The mother has shoulder length black hair (T)
3. The girl is wearing a purple sweater (F)
4. The girl is playing a black piano (F)

Story-Line
1. The couple is pointing angrily at each other as they yell (T)
2. The young girl overhears the fight and begins pounding on the piano (T)
3. The parents notice the girl on the piano and close the door so she can’t hear them (F)
4. The mother grabs the girl’s hand (F)

Son leaving home
Perceptual
1. The boy is wearing a blue t-shirt (T)
2. The car is pulling an orange and white trailer (T)
3. There are green bushes in front of the house (F)
4. The mother is wearing a pink sundress (F)

Story-Line
1. The son honks and then waves good-bye (T)
2. The father tells his son to drive safely (T)
3. The father passes his son a box to pack in the car (F)
4. A box falls out of the trailer as the son drives away (F)

Teenagers Teasing
Perceptual
1. The teenagers are standing in front of a sandy-coloured stone wall (T)
2. The fruit seller’s produce is in a wooden wagon (T)
3. The teenagers are wearing light coloured shirts and dark pants (F)
4. The fruit is red (F)

Story-Line
1. The boy with the note gives the fruit back to the fruit seller (T)
2. The teasing friend walks away on his own (T)
3. The teenagers steal a couple of pieces of fruit from the fruit seller (F)
4. A teenage boy grabs a note out of his friend’s hand (F)

**Woman Squeezing Food**
Perceptual
1. The grocery store is silent (T)
2. The grocer is standing in front of a shelf of liquor bottles (T)
3. The woman is wearing a black overcoat (F)
4. The woman is wearing purple nail polish (F)

Story-Line
1. The woman is squeezing a peach (T)
2. The woman reaches another area of the store and begins squeezing a round of cheese (T)
3. The grocer is angry because she is squeezing so many pieces of fruit (F)
4. The grocer catches the woman in the end (F)

**Boy making soccer jersey**
Perceptual
1. The boy’s jersey is red (T)
2. The carpet of the room is pink (T)
3. In the beginning, the boy is sitting cross-legged (F)
4. The boy’s father is sitting behind him on the couch (F)

Story-Line
1. A boy is using a marker to draw on his shirt (T)
2. **The boy looks at himself in a full-length mirror (T)**
3. The boy changes out of a t-shirt to put the jersey on (F)
4. The boy turns away from the mirror to do a dance after folding the shirt over his head (F)

**Chasing the Red Balloon**
Perceptual
1. The bullies chase the boy with the balloon past a chain-link fence (T)
2. The boy reaches a cobblestone road at the top of the stairs (T)
3. In the beginning, the bullies are hiding behind a car (F)
4. The bullies are wearing backpacks (F)

Story-Line
1. The bullies wait until the boy with the balloon passes them, and then begin chasing him (T)
2. **The boy gets away safely with his balloon (T)**
3. The boy with the balloon runs towards another group of boys on the staircase for help (F)
4. The boy lets go of his balloon, but catches it again while on the staircase (F)

**Couple by the sea**
Perceptual
1. There is a green island in the background (T)
2. The man is wearing a camera around his neck (T)
3. The woman is wearing a purple sundress (F)
4. The couple is standing in the sand (F)

Story-Line
1. In the beginning, a small wave splashes the woman (T)
2. **Both people end up soaked in the end (T)**
3. The man retrieves a cotton handkerchief from his pocket (F)
4. A gigantic wave rips the woman’s clothes off (F)

**Couple meeting at the café**
Perceptual
1. The woman is wearing a red coat (T)
2. The man is sitting on a padded bench (T)
3. There is white wine on the table (F)
4. The walls of the dining room are light blue (F)

Story-Line
1. The woman takes a large sip out of the glass (T)
2. The man kisses her on the cheek, and then she takes a seat at the table (T)
3. The woman is shown to her table by a waiter (F)
4. The man offers her a glass of water (F)

Dog escaping
Perceptual
1. The front of the house is green (T)
2. The girl is wearing a skirt (T)
3. The dog is sandy-coloured (F)
4. A person on a bicycle passes by the house (F)

Story-Line
1. The girl returns to the apartment and disappears inside (T)
2. The girl yells the dog’s name (T)
3. As a girl is leaving her apartment a large dog follows her out (F)
4. The girl catches the dog (F)

Waitress and the Pianist
Perceptual
1. There is a clear bottle on the tray (T)
2. There are red drapes behind the pianist (T)
3. The pianist is playing a soothing jazz melody (F)
4. The waitress is wearing a red shirt (F)

Story-Line
1. The waitress places the tray on a table (T)
2. The pianist continues playing the piano as the waitress crosses the room (T)
3. The waitress enters the hotel room without knocking (F)
4. The pianist thanks the waitress (F)

Family painting a cottage
Perceptual
1. The women are wearing head-scarves (T)
2. The cottage is by a brown dirt road (T)
3. The women are using yellow paint (F)
4. There is a black dog lying by the women (F)

Story-Line
1. The man grabs a paint brush from one of the women and begins painting (T)
2. A man carries over a new bucket of paint (T)
3. Three women are painting a cottage (F)
4. The woman happily welcomes the man (F)

Girl breaking an egg
Perceptual
1. The girl has short black hair (T)
2. The girl is sitting at a table covered by a white table-cloth (T)
3. The girl is wearing a blue shirt (F)
4. The girl is using a stainless steel bowl (F)
Story-Line
1. The children laugh when the egg falls on the table (T)
2. As the girl cracks the egg some of it splatters in her eye (T)
3. The little girl uses a spoon to crack the egg (F)
4. An adults scoops the egg off the table into the garbage (F)

Boy sitting at school
Perceptual
1. The boy is wearing a collared shirt with a sweater-vest (T)
2. The door to the classroom is grey (T)
3. The boy is wearing a backpack (F)
4. The walls of the classroom are covered in children’s drawings (F)

Story-Line
1. A boy walks into a classroom where everyone else is sitting down (T)
2. Two of the boy’s bench-mates get up so that he can take his seat (T)
3. The boy walks across the room, leaving the door open (F)
4. After he takes his seat, the boy begins to chat with his classmates (F)

Meeting the flute player
Perceptual
1. The girl is wearing a blue dress (T)
2. The building is made of light coloured brick (T)
3. The flute player is sitting on a bench by a window (F)
4. The flute player is wearing a hat (F)

Story-Line
1. The girl grabs the flute from the man (T)
2. In the beginning the girl smiles and heads towards the flute player (T)
3. The flute player sneaks up behind the girl (F)
4. The flute player is waiting, holding his instrument, as the girl enters (F)

Old man at the movie
Perceptual
1. A building sits alone in the middle of a green field (T)
2. The theater has wooden seats (T)
3. The man is wearing a black baseball cap (F)
4. There is a yellow handwritten sign on the ticket window (F)

Story-Line
1. The man buys a ticket from a person behind a glass window (T)
2. The man smokes a cigarette in the theater (T)
3. The man waits in line to buy his ticket (F)
4. The movie begins, but then the projector malfunctions (F)

Picking a Hitchhiker
Perceptual
1. The driver has dark brown hair (T)
2. The hitchhiker is wearing a cowboy hat (T)
3. There are large cacti growing by the side of the road (F)
4. The hitchhiker is wearing a black blouse (F)

Story-Line
1. The hitchhiker is an attractive female traveling alone (T)
2. The hitchhiker runs up to the car then the driver opens his window (T)
3. The driver and his friend decide to pick up the hitchhiker (F)
4. The driver pulls right away, upon seeing the hitchhiker (F)
Policeman flirting
Perceptual
1. There is a yellow sign on the woman’s cart (T)
2. In the beginning, there are trees behind the policeman (T)
3. The policeman is wearing a blue uniform (F)
4. The woman is wearing a red dress (F)

Story-Line
1. The policeman blows his whistle to stop the traffic (T)
2. The policeman takes off his sunglasses before he begins walking (T)
3. A traffic officer spots a lone woman waiting to cross the street (F)
4. The woman gratefully allows the policeman to push her cart (F)

Sleeping by the road
Perceptual
1. The sleeping boy is wearing a red head-band (T)
2. The boy is sleeping in front of a tree (T)
3. The boy’s cart is empty (F)
4. The boy with the cart wearing a brown t-shirt (F)

Story-Line
1. A poor boy is pulling a cart on an empty road (T)
2. First, the boy pokes the sleeper’s cheek (T)
3. The boy approaches the sleeper, carrying a metal jug of water (F)
4. The sleeper rolls over, ignoring the other boy (F)

Couple in the kitchen
Perceptual
1. The woman is facing a window (T)
2. The woman is humming as she works (T)
3. The man is wearing a black sweater (F)
4. There is a wine-rack on the wall by the woman (F)

Story-Line
1. In the beginning, the man looks across the room at his wife (T)
2. The woman is working at the counter (T)
3. The woman turns around to face her husband (F)
4. The woman kisses her husband on the cheek (F)

Husband Smokes
Perceptual
1. The man is wearing a grey suit (T)
2. There is a repetitive tapping noise in the background (T)
3. The woman is wearing a light-blue dress (F)
4. The man is standing in front of a flower-bed (F)

Story-Line
1. In the end, the woman returns inside the house as her husband smokes his cigarette (T)
2. The woman retreats back into the house and returns with a lighter (T)
3. A woman passes her husband a pack of cigarettes, then he steps out onto the porch (F)
4. The woman lights the cigarette for her husband (F)

Men toasting
Perceptual
1. The older man is wearing a pink button-down shirt (T)
2. The men are sitting in front of a brick wall (T)
3. There is a blue lamp beside the couch (F)
4. The younger man has short black hair (F)

Story-Line
1. The younger man is waiting on the couch (T)
2. The older man puts two glasses on the table (T)
3. The younger man pours the drinks (F)
4. The two men silently drink their wine (F)

Snowy Car
Perceptual
1. The man is wearing a beige overcoat (T)
2. The car is light-coloured (T)
3. The man is wearing a hat (F)
4. The car is parked in front of a hedge (F)

Story-Line
1. The man wipes the wind-shield off with his arm first (T)
2. The man falls in the snow (T)
3. The man cleans the mirrors with the corner of his briefcase (F)
4. When the man presses the button to unlock his car nothing happens since the battery is dead (F)

Finish Your Dessert
Perceptual
1. The boy is wearing a grey hooded-sweatshirt (T)
2. The mother has red hair (T)
3. The fruit in the bowl is blueberries and melon (F)
4. The dining room is pale green coloured (F)

Story-Line
1. The boy only wants to eat his fruit (T)
2. The boy is a teenager (T)
3. The father scolds the boy for not eating his ice cream (F)
4. A mother, father, and 2 sons are sitting at a dining room table (F)

Picking Up Mangos
Perceptual
1. The boy is using a wicker basket (T)
2. There are mountains in the background (T)
3. The boy is wearing brown pants (F)
4. You can hear birds singing in the background (F)

Story-Line
1. There is a boy up in the tree at the end of the clip (T)
2. The boy sets his basket down to collect fallen mangos from the ground (T)
3. The boy works alone (F)
4. In the end, the boy walks towards his house with the basket of mangos (F)

Thief
Perceptual
1. The thief has black hair (T)
2. The store looks out onto a busy street (T)
3. The thief is wearing a sundress (F)
4. The store clerk is wearing a suit (F)

Story-Line
1. The thief is a teenage girl (T)
2. The thief slips the item into a large folder (T)
3. The thief steals a book (F)
4. The thief makes it past the store clerk (F)

PRACTICE

**Man, Bird, and Window**

Perceptual
1. The man is wearing a brown hat (T)
2. The window faces onto a park (F)

**Story-Line**
1. The bird is singing throughout the clip (T)
2. The man is using a mirror to focus light (F)

**Woman buying lettuce**

Perceptual
1. The vendor is sitting at a table (T)
2. One can hear traffic in the background (F)

**Story-Line**
1. The woman picks two heads of lettuce in the end (T)
2. The vendor approves of the first head of lettuce the woman picks up (F)