



## Language and the medial temporal lobe: Evidence from H.M.'s spontaneous discourse

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### Abstract

Previous researchers have found it challenging to disentangle the memory and language capabilities of the famous amnesic patient H.M. Here, we present an original linguistic analysis of H.M. based on empirical data drawing upon novel spoken discourse with him. The results did not uncover the language deficits noted previously. Instead, H.M.'s level of oral usage was remarkably competent: he performed well within the normal range for his age and educational cohort. Thus, we found no support for the view that medial temporal lobe structures are critical for the maintenance of language comprehension and production.

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No one person seems to have contributed more to our understanding of human memory than H.M., the patient who underwent a bilateral medial temporal lobe resection in 1953 at age 27 for the relief of intractable epilepsy (Scoville, 1954, 1968; Scoville, Dunsmore, Liberson, Henry, & Pepe, 1953; Scoville & Milner, 1957). This removal resulted in a massive anterograde amnesia, underscoring the critical role of medial temporal lobe structures in human memory (Corkin, 1984; Milner, 1972; Milner, Corkin, & Teuber, 1968; Penfield & Milner, 1958; Scoville & Milner, 1957).

Recently, researchers have found it challenging to disentangle the effects of H.M.'s memory limitations and his language capabilities (James & MacKay, 2001; MacKay, Burke, & Stewart, 1998; MacKay & James, 1998, 2000; MacKay, Stewart, & Burke, 1998). These investigators have claimed that "H.M.'s operation destroyed some (but perhaps not all) of the binding nodes required for normal language comprehension" (MacKay, Stewart et al., 1998, p. 378). As a consequence, they assert that H.M. does not exhibit a "pure memory deficit" and that previously reported memory shortfalls might be compounded or explained by language comprehension and production problems (James & MacKay, 2001; MacKay, Burke et al., 1998; MacKay & James, 1998, 2001; MacKay, Stewart et al., 1998). As H.M. is a seminal contributor to our understanding of memory's dimensions, we embarked on a global evaluation of his language capacities, using

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linguistic measures applied, for the first time, in his home setting.

MacKay et al. had based most of their conclusions on transcripts from limited, forced conversations on laboratory tasks (James & MacKay, 2001; MacKay, Burke et al., 1998; MacKay & James, 1998, 2001; MacKay, Stewart et al., 1998). Using unpublished transcripts from interviews that Corkin had conducted with H.M. in 1973, MacKay and colleagues concluded, using a non-blind analysis, that H.M.'s descriptions of "ambiguous sentences" were less clear, concise, and coherent in comparison to healthy volunteers (MacKay, Burke et al., 1998). They further claimed that H.M. showed deficiency on six indicators of comprehension: "free associations," "impossible interpretations," "unusual pronoun use," "failure to follow experimenter requests," "misreadings," and "self-misconceptions." Using unpublished transcripts from conversations between H.M. and Marslen-Wilson (1970), they further concluded that H.M.'s language ranked low on measures of "comprehensibility," "grammaticality," and "focus."

In an effort to study's H.M. word discrimination, the same group of researchers asked H.M. to define 39 words and 12 pseudowords (James & MacKay, 2001). In an unbaselined, non-blind analysis, they judged that many of H.M.'s definitions were inadequate. Only one of their studies made use of H.M.'s actual speech, and even then, the analysis was confined to readings of 11 sentences that contained "complex syntactic constructions" (e.g., "Although the boys who were fed hot dogs got stomach aches, the genie ate the golden figs in the ancient temple"), 12 "short function words" (e.g., "in," "that," and "who"), 12 "content words" (e.g., "bat," "see," and "spy"), 48 "ambiguous," and 24 "unambiguous" sentences (MacKay & James, 2001). From these samples, the researchers concluded that "H.M.'s errors in novel spoken discourse were so extensive as to render his output incoherent and incomprehensible" (MacKay & James, 2001, p. 448). The researchers suggested that H.M. was similar to patients with dyslexia.

Transcripts invariably lose the robustness of language when fluid speech is reduced to written words, and the researchers' conclusion that H.M. has a severe language deficit stemmed from minor—and arguably obscure—language samples. Kensinger, Ullman, and Corkin (2001) were the first to challenge these claims by asking H.M. and 19 age- and education-matched healthy volunteers to complete 15 language skills tests, including lexical tasks (spelling, Boston Naming Test, picture naming, picture judgment, category identification, and landmark identification), fluency tasks (category fluency, letter fluency), morphology tasks (plural production, past-tense production, past-tense judgment, and derivational morphology production), and syntactic processing tasks (syntax comprehension). H.M. almost always performed within the normal range, scoring

within 1 *SD* of the healthy volunteers on the lexical, morphology, and syntax tasks, and within 2 *SDs* on the fluency tasks. In addition, analyses of H.M.'s 20 performances on four Wechsler Verbal IQ subtests (Information, Comprehension, Similarities, and Vocabulary) between 1953 and 2000 showed that his lexical memory has remained stable over the last 46 years and that he continues to perform as well as healthy volunteers (Kensinger et al., 2001).

Previous studies have also provided some anecdotal commentary on H.M.'s language. Milner et al. (1968) reported that H.M. spoke "with good articulation and a vocabulary that is in keeping with his above-average intelligence. His comprehension of language is undisturbed: he can repeat and transform sentences with complex syntax, and he gets the point of jokes, including those turning on semantic ambiguity" (p. 216). Lackner (1974) reported that H.M.'s "speech processing appears to be essentially normal" (p. 203). In one experiment, he was asked to repeat sentences that had auditory clicks at various surface-structure clause breaks. His ability to recall syntactic breaks was comparable to healthy volunteers (Lackner, 1974). In 1984, Corkin again reported that his language functions were essentially unimpaired: "H.M. is able to appreciate puns and linguistic ambiguities, and although he does not usually initiate a conversation himself, when someone begins a conversation with him, he talks readily and, in general, communicates effectively" (p. 254).

Our study extends the previous analyses by deliberately bypassing laboratory tasks and, instead, uses a more ecologically valid approach. For the first time, data was collected at H.M.'s residence, where he could perform in a relaxed, familiar setting. We studied his oral language skills using tape recordings of novel spoken discourse. These *in situ* analyses allowed us to appreciate more fully the complexity and subtleties of H.M.'s language skills and enabled us to ask what role, if any, medial temporal lobe structures play in maintenance of language production and comprehension.

## Methods

### Participants

During this study, H.M. was 74 years old. He has been profoundly amnesic since 1953 when he underwent an experimental resection of medial temporal lobe structures to relieve medically intractable epilepsy (Scoville & Milner, 1957). The resected tissue included all medial temporal lobe structures, except, approximately, 2 cm of the caudal hippocampus and parahippocampal gyrus (Corkin, Amaral, González, Johnson, & Hyman, 1997). H.M. completed 12 years of education at a technical high school.

Three experimenters spent two days conversing with H.M. in his residential setting, a healthcare facility, resulting in a total of 5–6 h of taped interactions. H.M., his conservator, and the healthcare center administration consented to this study. Two of the interviewers were linguists.

For a portion of our analyses, H.M. was compared with healthy volunteers reported in previous studies (Kemper & Sumner, 2001; Kemper, Kynette, Rash, O'Brien, & Sprott, 1989). The healthy volunteers reported in Kemper and Sumner (2001) ranged in age from 63 to 88 ( $N = 100$ ;  $M = 76.4$ ,  $SD = 6.2$ ) and had an average of 15.2 years of education ( $SD = 2.2$ ). Those from Kemper et al. (1989) ranged in age from 70 to 79 ( $N = 26$ ,  $M = 73.9$ ) and had an average of 14.2 years of education ( $SD = 1.8$ ).

### *Linguistic analysis*

During these visits, H.M. was engaged in conversation in a relaxed setting with other healthcare residents and staff present. The interviewers generally asked H.M. questions. Some of the questions allowed him to provide biographical information for up to 2 min before another question was asked. All conversations with H.M. were audiotaped and transcribed. Portions of the transcripts are reprinted here (see Appendices).

After the visit, the audiotapes and transcripts were analyzed in four distinct ways: (1) a multi-dimensional language analysis, studying the phonology, morphology, syntax, and lexical semantics of H.M.'s speech; (2) an application of the Jakobsonian speech act model (Jakobson, 1987); (3) quantitative discourse analysis, using common quantitative variables with previously published standardized norms; and (4) distinct discourse strategies not otherwise covered by the three previous analyses.

### *Multi-dimensional language analysis*

Among the measures used for this analysis, we studied the semantics of H.M.'s spoken language. In psychology, semantic memory is defined as our lifetime accumulation of universal factual knowledge and is often contrasted with episodic memory, our record of personal events (Squire, 1987; Tulving, 1972). In theoretical linguistics, however, semantics is defined as the study of language-based meaning and linguistic reference. Linguistic conceptualizations of semantics often include other related phenomena such as communication. For many linguists, a definition of communication would include the concepts of signification and intentionality (Lyons, 1977). In this report, we refer to semantics in the linguistic sense—that is, as the study of the construction of meaning and reference in language. Accordingly, we identified specific examples from H.M.'s performance over the period of 1988–2001 to shed light

on his ability to determine lexical and sentence-level meaning.

### *Jakobsonian speech act model*

Viable speech act models require a series of specific variables that serve as the basis for language production and comprehension. Most speech act models include at least a “Speaker” (or “Addresser”), “Hearer” (or “Addressee”), and a “Code” (e.g., English, French, and Russian). The Jakobsonian model requires an additional set of minimal factors (including “Context,” “Contact/Channel,” and “Message”) and further defines the relation of these factors to their corresponding functions (Fig. 1).

To describe the strengths and weaknesses of H.M.'s discourse, we analyzed each of the six factors and functions that are obligatory in any speech event. When the focus is on the addresser's meanings or intentions, the speech event is said to be dominated by the “emotive” function. When the focus is on the addressee, either in the sense of an imperative, command, or imploring the addressee to act in some way, the speech event is characterized as “conative.”

We wanted to know whether H.M. made reference to the context by talking about something beyond language itself (e.g., “Did you see the game yesterday?”). Focus on the context is called “referential.” We also analyzed how he tried to keep the channel open (e.g., saying “Uh-huh” to let the speaker know that he was listening). In such a case, the term “phatic” is used. When he focused on linguistic forms themselves (using language to talk about language), he was employing the “metalingual” function, the central function required for contemplation and discussion of language as a phenomenon (e.g., “What does the word ‘hegemony’ mean?”). We also documented the instances in which he used the “poetic” function, which is dominant in those speech acts where the focus is on the aesthetic value of the message (including structural features like alliteration and rhyme).

### *Quantitative discourse analysis*

To further delineate the complexity of H.M.'s language skills, we wanted to measure him against healthy older adults on quantitative variables that have been well studied (Kemper et al., 1989; Kemper & Sumner, 2001; Kynette & Kemper, 1986; Kemper, Thompson, & Marquis, 2001). To ensure comparability between our data and that of the previous studies, we first segmented our transcripts into utterances (Kemper et al., 1989; Kemper & Sumner, 2001). Next, we randomly selected two different sets of 10 passages from our transcripts: The first set of 10 passages were composed of 10 consecutive sentences each; the second set was composed of 50 consecutive utterances each. The lengths of these passages were chosen to match the methodology used

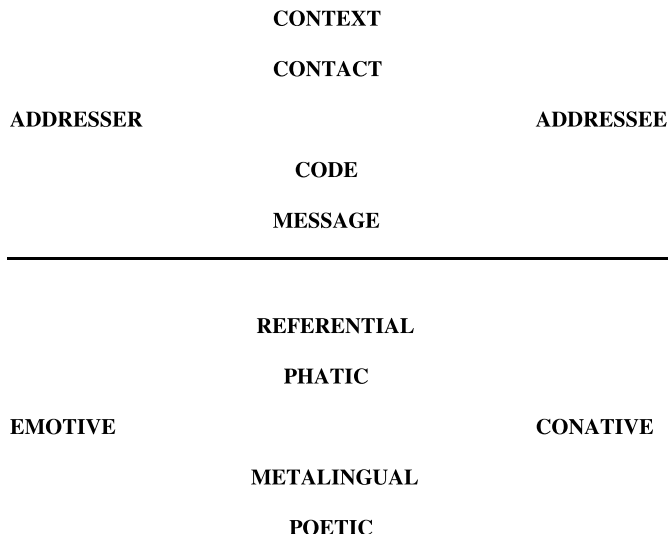


Fig. 1. Speech Act Model (adapted from Jakobson, 1987). Each of the six factors above the horizontal line corresponds uniquely to a function underneath the horizontal line. For example, “Addresser” corresponds with “Emotive,” “Context” with “Referential,” and “Code” with “Metalingual.” All six factors and functions are obligatorily present in any speech event, but they exist in a relatively determined hierarchy that is renegotiated in each instantiation.

in previous reports. To determine the beginning of our passages (the transcription of our audiotaped conversations was one continuous document), a naive volunteer blindly drew a card from two separate piles: one numbered 1–85 without replacement and another one, numbered 1–46, with replacement. The first number corresponded to the page and the second number to the line where the passage selection began in our transcription. Overlapping passages resulted in a re-draw. Ten passages were selected for each length of analysis so that an average could be calculated for H.M.’s measures.

We compared H.M. to previously published age- and near education-matched healthy volunteers on four quantitative discourse variables: Mean Length of Utterance (MLU), Mean Clauses per Utterance (MCU), Type Token Ratio (TTR), and the number of left-branching clauses (LBC). MLU was calculated by totaling the number of words in each utterance and dividing by the total number of utterances in the 10-sentence passages. MCU was tabulated by totaling the number of clauses in each utterance and dividing by 50 in the 50-utterance passages. TTR was calculated by counting the total number of different words and dividing by the total number of words in the 10-sentence passages. A TTR close to 1.0 indicates the use of a varied vocabulary, whereas a TTR close to 0 signifies a very limited word use. LBC represented the percentage of clauses in the 50-utterance passages that were left branching. Reported here for H.M. is the average for each of these variables across the 10 passages. A *z*-score is reported comparing H.M.’s mean to that of the healthy volunteers. Two researchers scored each of the four variables;

inter-rater reliability exceeded 90% agreement on all four measures. Differences were discussed and resolved.

#### *Sentence-level discourse strategies*

We wished to analyze several other discourse strategies not covered by the previous analyses. As such, we reviewed the transcripts for evidence of H.M.’s usage of tip-of-the-tongue phenomena, extended narratives, post-1953 lexical usage, self-recognition/deictic instances, second language usage, and verbal reading skills.

## **Results**

### *Physical demeanor*

During these interviews, H.M. was energetic and engaged in conversation. His high energy level was particularly noticeable during the first day of interviewing.

### *Multi-dimensional language analysis*

#### *Phonology*

In the case of H.M., we know that he has spent his entire life in New England, specifically the Hartford and East Hartford areas. His speech conforms to the expected dialect norms in terms of both phonemic usage, as well as intonational structures. He produces clear and well-formed phonological articulations that do not require the listener to strain to understand in any way. He displays no deficit of phonological production or comprehension.

Additionally, the rate of H.M.'s speech was similar in reaction/comprehension or production to that of his peers. In fact, because our interview was done in situ, many of H.M.'s friends from his healthcare facility participated in some of our conversations. Seen in his natural context ("at home"), it would be incorrect to claim that H.M.'s language abilities were different than his healthcare facility cohort in terms of rates of comprehension and production.

### Morphology

In easy conversation, H.M.'s use of English was appropriate and corresponded to that of a native speaker. During our conversations, he did not make any gross grammatical errors in verbal agreement, formation of plurals, use of articles and prepositions, verb conjugations, or tense (see Appendices A–K). Some of his vocabulary, however, was still characteristic of the era preceding 1953. For example, he said he cut the grass with a "power mower," a term that first became part of the lexicon around 1925 but has since been replaced with the more popular "lawnmower"<sup>1</sup> (Appendix A). Also worth noting is that his use of deictic forms, especially personal pronouns, was correct and, in some cases, complex.

What is conspicuously interesting about H.M.'s use of language is his robust and frequent use of pronouns. In the course of his narrations, he referred to persons in his stories with pronouns (as opposed to proper nouns). For example, when one of us told a story about a sibling who claimed to be conscious during her grand mal epileptic seizures, H.M. continued the discourse by referring to his interlocutor's narration. "*She's* lucky," he said. Another appropriate response could have been, "*Your sister* is lucky." Instead, he resorted to the use of personal pronouns instead of noun phrases with possessive pronominal forms. In another instance, he talked about his operation. When asked why he would be famous, H.M. responded, "I can think of one thing—that when *they* operated on me, it helped *them* to help other people." In this case, he used personal pronouns in lieu of the noun, "doctors" (Appendix B).

This habit could be due to his narrative style, which in some cases (but not all) seemed to be a bit disjointed. It could also just as likely be his preference, rather than an attempt to circumlocute a word that he could not find. Additionally, this usage could be due to his specific memory problem or memory difficulties typical in aging. In nearly all cases, however, it was clear to whom the personal pronouns referred. Thus, this speech usage does not necessarily point to a deficiency in language.

### Syntax

Consistent with previous reports (Corkin, 1984), H.M.'s construction of sentences was generally correct and included subordinate clauses and complex construction. For example, when H.M. said, "I can think of one thing: that when they operated on me, it helped them to help other people" (Appendix B), he made appropriate use of a prepositional phrase, "of one thing," and a left-branching subordinate clause, "that when they operated on me." H.M. went on to further explain, "And what they learned about that from me would help them to help others around the world"; and in reflecting on why he might be famous, he stated, "Well, you come to a realization that maybe you are because it helps others." In these instances, H.M. makes appropriate usage of prepositional phrases ("of one thing," "around the world"), left-branching subordinate clauses ("that when they operated on me"), right-branching subordinate clauses ("that maybe you are because it helps others"), and complex constructions ("what they learned about that from me").

In a different conversation, H.M. described his past musical interests. "The only time I took lessons was for the banjo," he stated (Appendix F). And of his instructor, he added, "Oh, I know a woman who used to teach the banjo—and teach the piano." In these sentences, H.M. again demonstrates usage of right-branching subordinate clauses ("who used to teach the banjo—and teach the piano").

Complex syntax was also evident in H.M.'s discussions about his childhood interests of becoming a brain surgeon. In our conversations, he argued that his seizure activity would be dangerous for such a profession. "Because if I had one when I was doing something for somebody, performing an operation, I could make the wrong movement," he stated (Appendix C). Here, H.M. uses a long and syntactically complex left-branching clause ("if I had one when I was doing something for somebody," followed by an appositional gerund ("performing an operation").

As part of his syntax, H.M. used parenthetical expressions frequently. His repertoire of interjections includes "Boy, oh, boy!"; "It's funny"; "It was funny"; and "In a way." In one case, while there were several conversations going on simultaneously in the room, H.M. turned to one of the interviewers and began his sentence with, "I came to the realization that..." When responding to the comment that he is famous, he stated, "Well, you come to the realization that maybe you are because it helps others" (Appendix B, Conversation 2). Of these parenthetical expressions, at least one of them ("in a way") is found in transcripts from 1973 (Corkin, 1973). Other common expressions that H.M. has been known to use (e.g., "I was having an argument with myself") did not occur during our two days of interviews.

<sup>1</sup> One of the first usages of "power mower" appeared in the *Daily Promoter* of Havre, Montana, on January 25, 1925.

### *Semantics*

We investigated H.M.'s ability to understand English lexical semantics and referential-based, sentence-level semantics (MacKay, Burke et al., 1998; MacKay & James, 1998, 2001; MacKay, Stewart et al., 1998). For example, when we asked him whether he knew what the Challenger was, he responded with a synonym, "the darer" (Appendix D). Later in that same conversation, he said that the Challenger was a "fast car"—perhaps related to Dodge's famous Challenger car series that debuted during the summer of 1969 or, perhaps, an educated guess based on the definition of "challenger," itself. He also had a notion of the 1986 Challenger disaster, as evidenced from his use of the word "astronaut." In sum, H.M. was able to describe three distinct meanings for the word "Challenger," two of which incorporated post-1953 information.

When asked whether he ever ate at McDonald's, H.M. responded that he frequently ate at a local restaurant owned by a man named Jack McDonald (Appendix E). Such an interpretation of our question was appropriate—Ray Kroc opened the first McDonald's in Des Plaines, Illinois, in 1955, nearly two years after H.M.'s operation. Because H.M. is probably not familiar even with the notion of a fast-food chain, he used an alternative and more personally relevant response to the question. Taken together, these data demonstrate that he is able to detect multiple meanings in a creative and developed way, including comprehension of puns, appropriate metalingual ability, and identification and understanding of lexemes and collocations. These results support the inference that H.M. is capable of responding to and generating appropriate and meaningful responses to spoken language.

### *Jakobsonian speech act model analysis*

We used the Jakobsonian speech act model to characterize H.M.'s speech by six functions:

#### *Emotive*

The emotive function was appropriate in terms of his affect, sense of humor, laughter, eye contact with interlocutors, body language, gestures accompanying speech, and tonal changes, but H.M.'s desire to share verbally was more reactive than initiatory.

H.M. also used different "registers" of discourse when talking to different people. In general, he was urgent and supplicating with the healthcare staff, cordial and joking with his peers, and welcoming and helpful with the interviewers. His ability to use these different registers is another aspect of the appropriateness of his pragmatic verbal and social skills in determining whom his interlocutors were and what his relationships were to them.

#### *Conative*

H.M.'s conative responses were robust, but one-sided. He always responded quickly (exhibiting full

comprehension of our questions), but he did not engage in asking follow-up questions. He rarely initiated conversations on his own and certainly did not issue imperatives or commands. He never implored his addressee to act in a particular way.

#### *Referential*

H.M. could make direct reference to persons and things, although he made limited reference to the extralinguistic context surrounding his narratives. One of the most interesting—although rare—vocative function episodes occurred when his former roommate, Emil,<sup>2</sup> entered the room. While Emil, an older man with extensive hearing loss, was introducing himself to us, H.M. said, "Emil and I went to school together." At this point, one of the other members of the retirement group said, "I didn't know that you two went to school together." H.M. smiled broadly and said, "Yes." This is the singular instance where H.M. referred to someone in the present by name. We should note that Emil did not, in fact, go to school with H.M., but it was obvious from their hand shaking and affection that H.M. certainly recognized his former roommate. In an effort to explain the familiarity to us, H.M. seemed to have linked his roommate with an event in his youth, suggesting that H.M. does recognize people even if he rarely calls them by name.

#### *Phatic*

H.M.'s phatic function (including his ability to initiate conversation, to continue a previously given topic of conversation, or to interact with his interlocutor's narrative if he were asked a question) was weak, and exceptions to this characterization were rare. When questions referred to his personal biography and that of his family, he was eager to share information and structured his answers in the form of narratives that lasted, in several instances, for 2–3 min. There were also a handful of episodes when H.M. did initiate and continue conversations. These episodes occurred for the most part during times when several people were talking at once. In these instances, he jumped into the conversation either to answer a question that had been directed to another person or to continue speaking with one of the three interviewers while the other two were talking to others in the room.

#### *Metalingual*

H.M.'s metalingual function was highly developed and exceeded expectations for our experience with healthy volunteers of his educational, socioeconomic, and age group. "Hey, that's the words I wanted to

<sup>2</sup> The name of H.M.'s roommate was changed to protect his identity.

use, too!” H.M. responded after one of us had supplied some missing words (Appendix B). “Live and learn,” he continued, “and you learn more by me.” In these examples, H.M. used language to talk about language and, in the second instance, verbiage to explain the meaning of his own words. When talking about the Challenger disaster, one of the interviewers asked H.M., “What’s the Challenger?” He interpreted this as a metalingual question and responded, “the darrer” (Appendix D).

### Poetic

H.M.’s poetic function was developed, especially in punning and humorous turns of phrase. Milner et al. (1968) and Schmolck, Kensinger, Corkin, and Squire (2002) reported that H.M. spoke in a monotone. During our interviews reported here, however, he often changed his voice intonation to signal humorous episodes. When recalling his favorite radio shows, for example, H.M. mentioned “The Shadow” (which was first aired on July 31, 1930, broadcasted for two decades, and then revived in the 1960s). As he was moving away from the table where we were speaking, he lowered his voice and began to imitate the famous opening lines of the show: “who knows what evil lurks in the hearts of men? The Shadow knows!” His enactment and tone elicited laughter, and he seemed to enjoy the opportunity to create humor.

H.M. was able to make the interviewers laugh by his dramatic tone when he talked about milking cows, an activity that he often did at his relatives’ farm. He suggested that it would be convenient to simply yank a cow’s tail to milk it. “As odd as it is to milk a cow, sometimes you want to have it the other way—just have to pump it with the tail,” he said as he made a pumping motion with his hands. In the context and flow of the conversation, H.M. elicited laughter from all of the interviewers (Appendix K).

### Spoken discourse analysis

When H.M.’s spoken discourse was analyzed using quantitative measures, he performed within 1.7 *SD* of healthy volunteers (Table 1). His MLU and MCU scores were smaller when compared with the healthy volunteers, but his TTR score was higher, at a level that was statistically significant. H.M. and the healthy volunteers scored similarly on the LBC measure.

### Sentence-level discourse strategies

#### Tip-of-the-tongue phenomena

On several occasions, H.M. was searching for the right word, and with a little help (either in the form of a first sound or the first half of a name), he came up with the needed form. For example, he often was able to come up with the name “Onassis” if provided with the word “Jackie” or “Jackie O” (Appendix H).

Table 1  
Comparison between H.M. and healthy volunteers on spoken discourse analysis variables

	Healthy Volunteers <sup>a</sup>		H.M.		<i>SD</i> difference from healthy volunteers
	<i>M</i> <sup>b</sup>	<i>SD</i>	<i>M</i> <sup>c</sup>	<i>SD</i>	
MLU	9.2	4.2	4.6	0.9	−1.1
MCU	1.2	0.3	0.7	0.1	−1.7
TTR	0.58	0.13	0.67	0.06	+0.69
LBC	3%	3%	1.3%	2%	−0.57

MLU, mean length of utterance; MCU, mean clauses per utterance; TTR, token type ratio; LBC, left-branching clauses.

<sup>a</sup> MLU and TTR from Kemper and Sumner (2001); MCU and LBC from Kemper et al. (1989).

<sup>b</sup> *N*, 100 for MLU and TTR; *N*, 26 for MCU and LBC.

<sup>c</sup> *N*, 10 passages.

In another instance, he was describing the benefit of his operation for others (Appendix B, Conversation 2). One interviewer asked, “So you feel good about that, then?” After a pause, another interviewer who had worked with him for four years said, “Sometimes, you just live and learn, right?” H.M. became alert, pointed to the interviewer, and said, “That’s it! Hey, that’s the words I wanted to use, too!” H.M. had used the phrase “you just live and learn” in the past, and the interviewer had anticipated that this phrase was on the tip of H.M.’s tongue.

### Extended narratives

Given the length of many of H.M.’s narratives, it seems controversial to claim that he was working within a narrow short-term memory window of a few seconds. In fact, as several of the narratives demonstrate, he was able to come back to a topic mentioned as long as 3 min earlier and fill in details that he was unable to state at the onset of the new topic. We believe that his repetitions were not mere repetitions, but reluctance on his part to change the topic of conversation as quickly as his interlocutors (Tannen, 1994). Consider, for example, the conversation about H.M.’s hobbies (Appendix F). At one point, an interviewer asked, “Did you like the banjo?” Approximately 18 s went by without a response from H.M., so the interviewers conversed among themselves and asked him whether they were boring him. He later chuckled and responded, “Oh, I know a woman who used to teach the banjo . . .” While the conversation had long since shifted away from the banjo, he came back to the topic to fill in the fact that he knew a female instructor. In another example, he talked about his past girlfriends—one tall and one short. At one point, an interviewer asked, “Do you remember what the short one was called?” He could not remember her name but mentioned that she had lived “way out in the other end of town.” The conversation then shifted to how

young he was when he was dating. One interviewer proceeded to argue that dating is like when you get in a car and go somewhere. H.M., however, jumped in and said, “Because that girl was way out . . . oh . . . where the rocks were.” He was obviously still trying to think of the girl’s name and location and was reluctant to talk about the new tangent of the dialog.

H.M.’s extended narratives also showed that he repeated himself, but never verbatim. The changes in his narration, even if the basic idea was repeated several times within 1 h, indicated that the level of codification of his stories was more semantically (meaning) based and less formally tied to specific linguistic forms. A long, but generally repetitive, narrative was triggered when we asked H.M. what profession he would have chosen for himself. He wanted to be a brain surgeon. This narrative has been repeated many times over the past decades, but there has been an interesting shift in the story’s details from 1991 to 2001. In 1991, Ogden and Corkin transcribed a conversation in which H.M. explained that he could not be a surgeon because he could get blood on his glasses, preventing him from seeing his incisions. Later in that same conversation, he explained that he could not be a surgeon because an attendant might mop his brow, shifting his glasses, and preventing him from seeing. In 1998, he explained that he could not become a surgeon because he was fearful that his glasses would fall off, and he might accidentally sew them up into the patient (personal communication with Skotko). On the first day of our visit, he explained that he could not become a surgeon because he could not see very well with his glasses. On the second day of our visit, he said that his petit mal seizures (“small ones”) would prevent him from remaining still during the operation. He feared that he might have one while performing an operation (Appendix C).

H.M. has also used certain predictable stories for describing his family, especially his mother and father, but these scenarios also showed variability during the interviews. Some of his “stock” responses have even been completely modified over the years. For example, when asked in 1998, “H\_\_\_, did you know you’re famous?” he would often respond, “I’m infamous!” Yet, during our visit in 2001, his response was simply “No” or “Really?” (Appendix B). In short, it is important to note that H.M. may repeat a repertoire of narratives that are evoked in the form of responses to questions, but these repetitions have always included slight modifications either at lexical and/or syntactic levels.

#### *Lexical use and narratives of post-1953 phenomena*

H.M.’s English vocabulary is not only rich and expansive, but, in fact, shows new lexical acquisition since 1953 (Skotko et al., 2004). As we illustrate below, those lexemes that he has acquired since his operation

include not only proper names but also common nouns, compounds, and, in some cases, the context in which the lexemes were learned.

H.M. used the word “astronaut” in one of our conversations about the Challenger disaster (Appendix D). While this term was in the dictionary prior to 1953 (according to Merriam Webster, its etymology dates back to 1929), it did not become part of common usage in the United States until the manned space flight program began in 1958. The term “astronaut” is even absent from the popular 1957 *Space Encyclopedia: A Guide to Astronomy and Space Research*, providing strong evidence that the word was not really used until after 1957. Even the 1955 space book *Men, Rockets, and Space Rats* (Mallan, 1955) does not list the word “astronaut” in its glossary of terms. Yet, H.M. used this word, providing more evidence that he was able to acquire post-1953 lexemes.

In many of his narratives, H.M.’s initial verbal response to a seemingly unknown topic was to say that he did not know the answer. As we continued to converse, however, he began to piece together some stories, based on events that occurred from the late 1950s until the 1980s. Such evidence is also consistent with Skotko et al. (2004), where H.M. was able to anchor new semantic information to old semantic memories. We describe some of these conversations in detail.

(1) JFK and the JFK assassination (six Conversations; Appendix H). Milner et al. (1968) reported that H.M. was able to recall, albeit in an inconsistent and transitory way, that Kennedy had been assassinated. On both days of our visit, we asked H.M. if he could name any American presidents. He named Roosevelt on one try, Lincoln on another. On his own, H.M. never uttered the name of JFK, either as initials or using his full name. We asked him directly at multiple times: (a) “Do you know who JFK is?”; (b) “Who is John F (itzgerald) Kennedy?”; (c) “Do you remember Kennedy’s first name?”; (d) “Do you know what happened to JFK?”; (e) “What happened to JFK?”; (f) “Who was JFK (or John F. Kennedy) married to?” His first responses to all of these questions was usually “No,” “I don’t know,” or a similar variation. After several repetitions of the same question (in particular, questions “d” and “e”), however, he stated correctly that Kennedy was President and had been assassinated. At one time, H.M. specifically said, “Kennedy was slain.” (JFK was inaugurated in 1961 and assassinated in 1963.) In response to question “f” on the first day of interviews, we provided the name “Jackie,” and H.M. said “Jackie Onassis.” One time, during the second day of interviews, H.M. mentioned “Jackie Onassis” as John Kennedy’s wife without any prompting whatsoever. (Jackie took on the last name “Onassis” when she married for a second time in 1968.)



(2) Marilyn Monroe and Joe DiMaggio (three Conversations; Appendix I). Given H.M.'s success with Jackie Onassis, we decided to talk about some other well-known married couples. Marilyn Monroe seemed an appropriate topic extension, so the interviewers asked H.M. as well as other members of the healthcare facility who were participating in the discussion whom Marilyn Monroe had married. On the second day of our visit, one of the residents said, "Lou Gehrig," and before we could respond, H.M. jumped in, smiled, and said, "Joe DiMaggio." (Monroe and DiMaggio married in 1954.) On the first day of our visit, H.M. also had an opinion about Marilyn Monroe. "She thinks she's something, but she's not," he said.

(3) The Challenger disaster (three Conversations; Appendix D). In Ogden and Corkin (1991), H.M. appeared to have a vague recall of the Challenger nearly two weeks after the disaster. The space shuttle exploded in 1986, and one would not expect H.M. to have any preoperative memories of either the Challenger or Christa McAuliffe. The interviewers asked H.M. three times if he knew about the Challenger and what had happened to it. His responses were variable and once included, "the darer," a synonym for "the challenger." At another time, he said, "I don't know." Still later, he said, "It sank after it left London." Here, the present interviewers shifted the conversation and referred to the Titanic. Suddenly, though, H.M. started to talk about an "astronaut" and a "woman" in relation to the Challenger disaster.

(4) Raymond Burr (one Conversation; see Appendix J). Corkin reported in 1984 that H.M. correctly knew that "Raymond Burr played the part of a detective on television." However, Perry Mason—the detective-like attorney role for which Burr is best remembered—was first broadcast on September 21, 1957, nearly 4 years after H.M.'s operation. Burr further played the role of a detective on the television show, "Ironside," from 1967–1975. Our results are consistent with this finding. In our conversation, H.M. said, "He played more of a detective, in a way," but he could not generate the name "Perry Mason" on his own.

#### *Self-recognition and deictic categories*

When asked if his parents were alive, H.M. said "no" in a declarative intonation. On another occasion when asked where were his parents, H.M. responded, "Well, to tell you the truth, I think one of 'ems passed away" (Anne Krendl, personal communication, 2003). He further explained, "To tell you the truth, I don't know . . . . One of 'em, my father possibly, and then it could be my mother . . ." As evidenced here, he did substitute pronouns for proper names and kinship terms with high frequency. In a different dialogue, when recalling an episode between his mother and aunt, H.M. said, "My mom told *her* to go to 'h.'" (H.M.

did not use any obscenities and, even with prompting, was unwilling to say "hell.") He also had no problem using deictic categories, including use of the first-person pronoun.

#### *Answering questions*

H.M. initiated conversations only when people were already talking (not necessarily to him), and he would jump in either by answering someone else's question or by referring to some episode from his family history. It is also notable that when he answered a question with a negative response or claimed not to know the answer, this initial negative response was often followed by a correct answer. One of the most interesting examples deals with his knowledge of a second language.

#### *Second language knowledge*

H.M. often referred to the fact that his father was of French heritage. When the interviewers asked H.M. whether his father or he spoke French, his answers were varied—he did not know French, his father did not speak French at home, or his father spoke a little. One of us, however, began to speak in French during lunch and asked H.M., "*Tu aimes le poisson?*" (Do you like fish?) After a slight pause, the interviewer then asked, "*Tu comprends?*" (Do you understand?) H.M. responded, "I don't *comprend*." Curiously enough, his response showed that he did understand. A few moments later, while speaking of his father, H.M. said, "*Mon père, my father . . .*" Later, while eating lunch on the second day, we asked H.M., "*C'est bon?*" (Is it good?) He responded without hesitation, "*C'est très bon!*" (It's very good!) Finally, in a different context, H.M. was shown some children's books written in French and was asked whether he knew the language in which they were written. H.M. correctly identified the language as French without hesitation.

While it is clear that H.M. is not a fluent French speaker, to our knowledge it is the first time since his operation that he has been asked to speak French and was successful in doing so. In fact, his pronunciation was good. Once we realized that there appeared to be some unpleasant associations with his father and French, we did not question him further in French. With respect to his general language competency, though, it is not trivial to note that in addition to well-maintained English language abilities, in a limited fashion, he can successfully comprehend and produce French language forms.

#### *Reading*

The interviewers asked H.M. whether he knew what month and year it was. When we mentioned that there was snow on the ground, he looked out the window and said, "I don't know." On the table near him were

several new crossword puzzle books, and an interviewer suggested that the date might appear somewhere in the books. H.M. picked up one of the books and opened it to the title page. Within approximately 20 s, he found the date and read out loud, “April, two thousand and one.” He then smiled, closed the book, and repeated the procedure with another puzzle book. What is interesting about this episode is that he was able to read and say the year correctly and with little hesitation. Because there are other potential readings possible, it is interesting that he chose the contemporary one without problems, suggesting that he has an ear for changes in contemporary language usage.

## Discussion

The results support Corkin’s original conclusion that H.M.’s language functions are minimally impaired (Corkin, 1984). In fact, his level of oral performance was remarkably competent: he performed well within the normal range for his age and educational cohort. (This finding is strengthened when one considers that his educational cohort is not mainstream high school students but technical high school students.) He made no gross grammatical mistakes in terms of verbal agreement, use of articles and prepositions, verb conjugation, or tense. He was able to construct syntactically complex sentences and was even able to detect multiple word meanings in creative, developed ways. He had a repertoire of parenthetical phrases and did not repeat his stories verbatim. Instead, the details or endings of his stories showed variability, a signal that his oral production skills were not rote memory recalls, but instead new linguistic creations during each instantiation. Contrary to previous reports (Milner et al., 1968; Schmolck et al., 2002), he did not speak in monotone. His voice fluctuations were appropriate and, at times, humorous. His emotive, conative, metalingual, and poetic functions were robust, and he even had some limited use of a second language. His reading skills appeared intact, and his oral language production and comprehension were well within the normal range for his age and educational group.

H.M.’s linguistic weaknesses lie in the referential and phatic functions. He rarely made reference to extralinguistic context surrounding a narrative and was often reluctant to initiate or continue a conversation on his own. If a question was not asked directly to him, he customarily did not engage in conversation. One interpretation of these deficits is that his severe anterograde amnesia may complicate his ability to initiate new trains of conversation. Because of his amnesia, virtually everyone is a stranger to him; he did not readily remember his interlocutors and may have been hesitant to converse with unfamiliar people. Second, the removal of H.M.’s

amygdalas during his bilateral medial temporal lobe resection may also contribute to this reluctance. Previous research suggests that bilateral amygdalectomies have taming effects on animals (Aggleton, 1992; Gloor, 1997) and humans (Heimbürger, Whitlock, & Kalsbeck, 1966; Narabayashi, Nagao, Saito, Yoshida, & Nagahata, 1963). Alternatively or additionally, this hesitancy to initiate or maintain conversation could be one of personal preference or family upbringing. H.M. and his father “were alike in gesture and temperament: placid, short-focused, and shy. They did not join in conversation easily but could sometimes be started into stories of the family or some hunting trip” (Hilts, 1995, p. 83). Further, H.M. may have derived self-conscious tendencies from the stigma of his seizure disorder. Thus, it may not be correct to conclude that H.M.’s weaknesses in the referential and phatic functions point to a deficit in his oral language skills.

H.M. also used a robust number of personal pronouns during conversation. When given the opportunity to use a proper or common noun (such as “doctors”), he almost always substituted a personal pronoun (such as “they”). This usage, however, rarely complicated the conversation. Within the context of the dialogue, it was usually possible to discern to whom the personal pronouns referred. In addition, they were always of the correct number, gender, and case. Several explanations could account for his excessive pronoun usage. First, his profound anterograde amnesia no doubt limits his ability to remember names and identifiers other than the sex of an individual. Further, many different theoretical models demonstrate that proper names are inherently difficult to remember (*Sequential Stage Model*: Bruce & Young, 1986; McWeeny, Young, Hay, & Ellis, 1987; Young, Hay, & Ellis, 1985; *Interactive Activation and Competition Model*: Burton & Bruce, 1992; *Representational Model*: Cohen, 1990; *Node Structure Theory*: MacKay, 1987; *Token Reference Model*: Semenza & Zettin, 1988). Proper-name recall is disadvantaged because names are low in meaning, and, as a result, only a single connection is often made between an individual and his or her name. In addition, memory for proper names declines during normal aging (Burke, MacKay, Worthley, & Wade, 1991), further disadvantaging H.M.’s ability to recall proper names in conversation. Alternatively or additionally, H.M.’s robust use of pronouns may point to a preference or a habit and not to any deficiency. The preference or habit might also have developed in response to his memory deficit.

When compared with healthy volunteers on quantitative discourse measures, H.M.’s utterances were shorter and contained fewer clauses. Multiple explanations exist: (1) H.M. was slightly disadvantaged to the healthy volunteers by having less education; (2) H.M. engaged in a dialogue with us, generally responding to our

questions and thus lending his speech to shorter responses and oftentimes one-word answers, whereas the healthy volunteers were asked to speak at length about one topic, offering more opportunities to speak in longer sentences; (3) H.M.'s conversational manner could be naturally briefer than his age-matched cohorts; or (4) a combination of the any or all of the above could be true. It should be noted that H.M. was comparable to the healthy volunteers in his use of left-branching clauses. More impressively, he also performed better than his age-matched counterparts on the TTR score, suggesting that his vocabulary is more varied and his usage more robust than that of his peers.

In addition, H.M. has continued to acquire new lexemes after his operation. In several conversations, he was able to speak about events that occurred from the late 1950s until the 1980s. This finding is consistent with a previous report, demonstrating that H.M. was able to bind new semantic information to old semantic memories (Skotko et al., 2004). Similarly, where he had established preoperative memories, he was able to anchor new postoperative lexical information to these events, at least temporarily. This same phenomenon—attaching new lexical information to old memories—appears to be the case with our conversations about Marilyn Monroe and Raymond Burr. Monroe was first photographed in 1944 and, within a year, appeared on the cover of more than 33 magazines. In 1947, she starred in her first film, *The Shocking Miss Pilgrim*, and continued to act thereafter. It is likely that H.M. had established a memory of Monroe before his operation. Monroe did not wed DiMaggio until 1954, however. Still, H.M. said “DiMaggio” when asked which baseball player she had married. He seems to have linked this name with his previous memory of Monroe, as well as potentially being assisted by a preoperative knowledge of famous baseball players. Similarly, Raymond Burr first appeared in the 1948 film “*Pitfall*” and worked on 90 films in the next 11 years before starring as Perry Mason. In short, there were numerous opportunities for H.M. to have developed semantic memories about Burr preoperatively. However, Perry Mason—the detective-like attorney role for which Burr is best remembered—was first broadcast on September 21, 1957, nearly four years after H.M.'s operation. Regardless, H.M. was able to link “detective” with Burr.

In the case of the Challenger disaster, H.M.'s responses were even more extraordinary. The space shuttle certainly dominated the news, as it was destined to carry Christa McAuliffe, a high school teacher, into space. The space shuttle exploded in 1986, however, and H.M. did not have previous preoperative memory on which to tag this postoperative event. Ogden and Corkin (1991) reported that he had a vague recall of the Challenger nearly two weeks after the disaster, and

in the present study, he was able to link “astronaut” and “woman” with the concept of “Challenger,” despite his confounding with the sinking of the Titanic. In this instance, H.M. was able to acquire lexical information from 1986 without any apparent preoperative memory. In all of these dialogues, it is important to keep in mind that H.M. was unable to retrieve the narratives in a consistent way. Whatever pathways were available for retrieval were restricted, inconsistent, and oftentimes unpredictable.

## General discussion

This study demonstrates and continues to support the notion that H.M.'s language skills are intact. His performance during two days of interviews demonstrated that his language was logical, robust, and appropriate given his age and educational background. Key among our findings was the evidence that H.M. used appropriate grammar, formed syntactically complex sentences, detected multiple word meanings, understood, recognized (and to a limited extent used) a second language, and incorporated postoperative semantic facts into his language repertoire.

Our findings contradict other studies of H.M.'s language that stemmed from written transcripts or laboratory experiments (James & MacKay, 2001; MacKay, Burke et al., 1998; MacKay & James, 1998, 2001; MacKay, Stewart et al., 1998; Schmolck et al., 2002). We found no evidence to support the assertion that H.M. made so many errors in novel spoken discourse that his speech was incoherent or incomprehensible or that he had dyslexia<sup>3</sup> (MacKay & James, 2001). Also, in contrast to findings reported by Schmolck et al. (2002), we did not find that H.M. made a large number of grammatical errors in either his crossword puzzles or spoken discourse. It is possible that the discrepancy in results exists because the current studies were conducted in familiar circumstances: the analysis of his oral language skills was based on conversations with him in his healthcare facility. He was relaxed and we were able to analyze

<sup>3</sup> The difference between our findings might result from the fact that MacKay and James did not match H.M. and controls on eyesight (2001). According to H.M.'s medical charts from March of 1997 (about the time of MacKay's study), his visual acuity was poor. H.M. had cataracts at the time, and the notes in H.M.'s medical chart indicate that his retinal degeneration was worse. His best visual acuity score, with or without corrective lenses, was 20/30; and in 1998, it had further declined to 20/50. By no accounts, was his vision normal. It is probable, then, that the slower speech conduction and sentence-reading deficits reported by MacKay and James (2001) were a result of H.M.'s poor vision.

his speech in his familiar home setting. We believe, therefore, that the current study is a more ecologically valid analysis of H.M.'s language skills than were previous attempts to analyze his discourse on forced topics in unfamiliar laboratory settings.

#### *Role of the medial temporal Lobe in language*

Little evidence exists to suggest that the hippocampus is needed to maintain language production or comprehension (Price, 2000). Despite suggestions that medial temporal lobe structures contribute to the maintenance of language comprehension and production in H.M. (MacKay, Burke et al., 1998), the conclusion that left hippocampal damage is responsible for his deficits in language comprehension is not supported by the present study. Our results are consistent with the findings in three other reports (Kensinger et al., 2001; McClelland, McNaughton, & O'Reilly, 1995; Schmolck et al., 2002).

The most current models of language production and comprehension, based on functional neuroimaging studies, contend that the superior temporal gyrus is heavily involved in acoustic processing of spoken words, and the posterior fusiform and lingual gyri are heavily involved in the visual processing of written words. The posterior superior temporal sulcus has involvement in phonological processing of speech, and extrastriate temporoparietal regions carry out semantic decisions. Additionally, the posterior inferior temporal and mid-fusiform regions are involved in retrieval of names. Articulatory planning is believed to occur in the frontal operculum and anterior insula, while motor output of speech uses Broca's area and sensorimotor cortices (Binder & Price, 2001; Damasio, 1998; Kertesz, 1983; Luria, 1973; Metter, 1995; Price, 2000; Roland, 1993). In this pathway from initial auditory or visual comprehension to motor production of language, no role has been posited for the hippocampus.

#### *Postoperative semantic knowledge*

At several points during our oral interviews, H.M. incorporated postoperative semantic facts into his discourse. While examples from this study mainly extend information about high-profile persons, previous studies with H.M. demonstrate that postoperative semantic facts can be extended on places, things, and events (Corkin, 1984, 2002; Marslen-Wilson & Teuber, 1975; O'Kane, Kensinger, & Corkin, 2004; Skotko et al., 2004). Studies of other amnesic patients further indicate that individuals with global amnesia can acquire new postoperative factual information (Bayley & Squire, 2002; Glisky & Schacter, 1988; Glisky, Schacter, & Tulving, 1986a, 1986b; Hamann & Squire, 1995;

Hayman, Macdonald, & Tulving, 1993; Hirst, Phelps, Johnson, & Volpe, 1988; Kitchener, Hodges, & McCarthy, 1998; Kovner, Mattis, & Goldmeier, 1983; Mattis & Kovner, 1984; McAndrews, Glisky, & Schacter, 1987; Schacter, Harbluk, & McLachlan, 1984; Shimamura & Squire, 1987; Tulving, Hayman, & MacDonald, 1991; Van der Linden & Coyette, 1995; Van der Linden, Brédart, Depoorter, & Coyette, 1996, 2001; Verfaellie, Koseff, & Alexander, 2000; Westmacott & Moscovitch, 2001). In nearly all of these cases, the patients had previously established knowledge or meaningful experiences with the postoperatively acquired semantic facts. For example, the severely amnesic patient who acquired substantial information about politicians had a master's degree in history and was employed as a teacher prior to his injury (Van der Linden et al., 1996). Skotko et al. (2004) postulated that H.M., like these other amnesic patients, could acquire new semantic knowledge, at least temporarily, when he could bind it to mental representations established preoperatively. Thus, temporary acquisition of semantic knowledge does not appear to be solely dependent on medial temporal lobe processes.

An open question remains, however: do these relatively rare examples of postoperative facts exist as *bona fide* memories or as mere linguistic representations without corresponding extralinguistic representations? That is, does H.M. really "know" who Jackie Onassis is, or is her name simply attached as a proper noun to the pre-established memories of the Kennedys? This question is difficult to address. The report of K.C., a 47-year-old patient with complete bilateral destruction of the hippocampus, supports the idea that the medial temporal lobe structures contribute somewhat to the acquisition of language. K.C., like H.M., was able to acquire explicit postoperative semantic knowledge (Westmacott & Moscovitch, 2001). His ability to recall such information, however, "appeared to be limited to simple unelaborated semantic, lexical, and orthographic representations, even when tested with recognition paradigms" (p. 592). The postoperative knowledge he acquired was "vague, impoverished, and fragmentary" (p. 593).

The extent to which H.M. remembers the "gist" of his postoperative semantic constructions remains unclear. Gist recall, or the ability to derive the most important ideas from narrative verbal information, is better retained over time than verbatim memory or memory for details (Brainerd & Reyna, 1993; Koriati, Goldsmith, & Pansky, 2000; Sachs, 1967, 1974). Additionally, research suggests that older adults may become more reliant on gist processes as a compensation for declining recall of details (Reder, Wible, & Martin, 1986; Tun, Wingfield, Rosen, & Blanchard, 1998). In patients with amnesia and temporal lobe seizures (Prevey, Delaney, & Mattson, 1988), however, gist representations have

been degraded. This appears to be the case for H.M. as well; with respect to his newly acquired postoperative semantic knowledge, he can anchor only a few extensions to pre-established memory traces.

The results from the present study show that in spite of his profound anterograde amnesia, H.M. displays dynamic language skills. His oral use of language are not significantly weaker than that shown by controls in numerous domains, including spelling, the generation of appropriate responses and appropriate parts of speech, use of proper nouns and adjectives, morphology, syntax, semantics, and discourse. He is even able to ascertain the use of a second language and participate in a conversation with the few words that he knows. In sum, in the context in which we studied H.M.'s oral language skills, we found no evidence that they are impaired beyond what might be expected normally for his age and socioeconomic status. In fact, the results presented here demonstrate that his oral language skills are dynamic, subtle, emotive, and completely appropriate to the circumstances.

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### Appendix A

#### Conversations about power mower on day 2

Speaker	Transcript
Interv 2:	I used to love to cut the grass. Did you ever cut the grass?
H.M.:	Yeah, well, we had a power mower.
Interv 2:	You had a power mower?

### Appendix A (continued)

Speaker	Transcript
H.M.:	Uh-huh.
Interv 1:	Did you ride it?
H.M.:	I don't know.
Interv 3:	Did you push it?
H.M.:	Guided it.
Interv 3:	You guided it!
Interv 2:	That's right.
H.M.:	That's when we lived way out in the country.

Note. Interv, interviewer.

### Appendix B

#### Conversations about being famous

Speaker	Transcript
Conversation 1 (Day 1):	
Interv 1:	H____, did you know you're amazing?
H.M.:	Yeah?
Interv 1:	Yeah.
H.M.:	Why?
Interv 1:	I'm one of your biggest fans.
H.M.:	<<chuckling>> Well, I don't know why.
Interv 1:	Did you know you're famous?
H.M.:	I am? I still don't know why.
Interv 1:	Why would you think you'd be famous? Is there anything you've done?
H.M.:	I can think of one thing: that when they operated on me, it helped them to help other people.
Interv 2:	Uh-huh.
Interv 1:	And you've helped a lot of people.
H.M.:	I know that they . . . what they learned in the operation was upstairs here <<pointing to his head>>
Interv 2:	Mm, hmm.
H.M.:	And what they learned about that from me would help them to help others around the world.
Interv 3:	That's right.
Conversation 2 (Day 2):	
<<We asked H.M. if he would like to tell us anything>>	
H.M.:	Well, I know of one thing—what's found out about me will help others be.
Interv 2:	That's right. You're a hero. Did you know that? You're a national hero.
Interv 3:	Did you know that you are famous?
H.M.:	No.
Interv 3:	Yeah, you're famous. You are! <<laughter>>
Interv 2:	Are you glad? Is that nice to know?
H.M.:	Well, it's nice to know in a way. <<chuckles>>
Interv 1:	Not everyone gets to be famous, sir, but you are!

(continued on next page)

**Appendix B** (continued)

Speaker	Transcript
H.M.:	Well, you come to a realization that maybe you are because it helps others.
Interv 3:	You're right. That's what we're here for probably—to help other people.
H.M.:	That's it. I know it.
Interv 2:	So do you feel good about that, then?
H.M.:	Yeah.
Interv 2:	You feel good?
Interv 1:	Sometimes, you just live and learn, right?
H.M.:	That's it! Hey, that's the words I wanted to use, too! <<pointing to Interviewer 1 and smiling>>
Interv 1:	I know it.
H.M.:	Live and Learn. And you learn more by me
Interv 2:	Uh-huh.
H.M.:	and it helps others, too.

Note. Interv, interviewer.

**Appendix C**

## Conversations about becoming a brain surgeon on day 2

Speaker	Transcript
H.M.:	Because at one time that's what I wanted to be is a doctor.
Interv 3:	You wanted to be a doctor?
H.M.:	Yeah and I said, "No," because if I have one of these small ones <<points to head>> but they can learn more about me and others. And would help others.
Interv 2:	What kind of doctor did you want to be?
H.M.:	I wanted to be a surgeon.
Interv 2:	Wow! That's a hard job, very stressful.
H.M.:	Yeah, and I wanted to be the kind up here. <<points to head>> <<laughter>>
Interv 3:	Oh, that sounds really exciting.
Interv 1:	What stopped ya?
H.M.:	I started to have these <pause> small ones.
Interv 3:	Yeah, yeah.
H.M.:	And I said to myself, "No."
Interv 3:	Right.
H.M.:	Because if I had one when I was doing something for somebody, performing an operation, I could make the wrong movement.
Interv 3:	Yes, that's dangerous.
Interv 2:	Yeah, that's right.
H.M.:	Yeah.
Interv 2:	Yeah, you haven't had any grand mal seizures for a long time, have you?
H.M.:	I don't think so.
Interv 2:	Yeah.
H.M.:	Tell you, I don't know.

Note. Interv, interviewer.

**Appendix D**

## Conversations about the Challenger disaster

Speaker	Transcript
Conversation 1 (Day 1):	
Interv 1:	H____, do you remember anything about the Challenger?
H.M.:	It was a big submarine.
Interv 1:	What happened to it?
H.M.:	It sunk when they tried it out.
Interv 3:	Gosh, that's right . . . almost . . . close enough.
Interv 1:	Why was it special?
H.M.:	It was so long underwater . . . but it didn't . . . it was . . . it sank after it left London.
Interv 3:	Aah . . . it sank after it left London, that's right.
Interv 1:	What was the name of it?
Interv 3:	Yeah.
H.M.:	Huh?
Interv 1:	What's the name of that ship that sank after it left London?
H.M.:	I don't know.
Interv 3:	Well . . .
H.M.:	Astronaut
Interv 3:	Oh man, that's amazing.
Interv 1:	And who was that—that astronaut? Was that astronaut a man or a female that was very popular?
H.M.:	I think it was a woman.
Interv 1:	And what was her profession?
H.M.:	Astrologer.
Interv 3:	Huh.
Interv 2:	You weren't alive when the Titanic sunk? You ever heard of the Titanic?
H.M.:	Uh, huh.
Interv 2:	Uh, huh.
H.M.:	That was a ship.
Interv 2:	Uh-huh.
Interv 3:	Uh-huh.<<simultaneous with Interv 2 above>>
Interv 2:	Did you ever see the movie?
H.M.:	No.
Interv 2:	I think there has now been four of them. You probably could have seen at least two of them.
Conversation 2 (Day 1):	
Interv 1:	What's the Challenger?
H.M.:	The darer.
Interv 1:	The what?
H.M.:	The darer.
Interv 2:	<<chuckling>> The darer. He said someone who dares. The Challenger is someone who dares. Absolutely!
Interv 3:	<<simultaneous with above comment from Interv 2>> Yes. That's exactly right. Yes.
Interv 2:	Very astute.
Interv 1:	Is it the name of any other kind of boat or car or anything like that? Do you remember anything about the Challenger?
H.M.:	Oh . . . yeah . . . it's a car.
Interv 1:	A car?
Interv 2:	Actually, there is a car.

**Appendix D** (continued)

Speaker	Transcript
Interv 3:	I think there is a car.
Interv 2:	There is a car Challenger. You're absolutely right.
H.M.:	Yeah . . . and it's a fast car.
Interv 1:	Is it a spaceship by any chance?
H.M.:	I don't know about being a spaceship, but it's a fast car.

Note. Interv, interviewer.

**Appendix E**

## Conversations about McDonald's on day 2

Speaker	Transcript
	<<Conversation occurs while we are all eating lunch together>>
Interv 1:	Did you ever go out to eat at restaurants?
H.M.:	Yeah!
Interv 1:	Yeah?
Interv 2:	You did?
Interv 1:	With the family?
H.M.:	<<nod>>
Interv 1:	What were some of your favorite restaurants?
H.M.:	Oh, I liked the fried stuff.
Interv 1:	Did you ever go to McDonald's?
H.M.:	Jack? I know him.
Interv 2:	You know Jack McDonald?
Interv 3:	Jack McDonald?
H.M.:	Yeah, he used to have a place over on _____ Lane. <sup>a</sup>
Interv 2:	He had a restaurant?
H.M.:	He had a restaurant.

Note. Interv, interviewer.

<sup>a</sup> Actual location omitted to protect H.M.'s identity.

**Appendix F**

## Conversation about H.M.'s hobbies on day 1

Speaker	Transcript
Interv 1:	Do you like to listen to music, H_____?
H.M.:	Yeah.
Interv 1:	What types of music do you listen to?
H.M.:	Anything that's good.
Interv 2:	Did you ever play an instrument like the piano or guitar?
H.M.:	No.
Interv 2:	No . . . did you ever
H.M.:	<<jumping in>> The only time I took lessons was for the banjo.
Interv 2:	You took banjo lessons . . . my goodness.
Interv 3:	That's pretty good.
Interv 2:	That's pretty fun. Did you like the banjo?
	<<no response; interviewers converse among themselves for 18 s>>
Interv 2:	H_____, we're not boring you are we?
H.M.:	No.

**Appendix F** (continued)

Speaker	Transcript
Interv 2:	You like us being here? Is that okay?
H.M.:	Yeah.
Interv 2:	Yeah? Because we're enjoying being with you.
H.M.:	<<chuckling>> Oh, I know a woman who used to teach the banjo . . . and teach the piano.

Note. Interv, interviewer.

**Appendix G**

## Conversations about H.M.'s girlfriends on day 1

Speaker	Transcript
Interv 1:	Did you ever have a girlfriend?
H.M.:	Yeah.
Interv 1:	Yeah?
H.M.:	Well . . . she was very short.
Interv 1:	Very short?
H.M.:	Yeah.
Interv 1:	What was her name?
H.M.:	Well, there was one I had
Interv 1:	<<jumping in and chuckling>> Oh, you had many girlfriends, it sounds like.
H.M.:	I did. And one was . . . oh . . . Elizabeth . . . not Elizabeth.
	<<approximately 20 s pass as H.M. thinks of name>>
H.M.:	One that I can think of was Mildred.
Interv 2:	Mildred.
Interv 1:	What was Mildred like?
H.M.:	She was tall.
Interv 2:	So you had a short girlfriend and a tall girlfriend?
H.M.:	Uh-huh.
Interv 2:	And Mildred was the tall one. Do you remember what the short one was called?
H.M.:	She lived out . . . oh . . . oh . . . she lived way out in the other end of town.
Interv 2:	Who? Mildred?
H.M.:	No.
Interv 2:	The short one?
H.M.:	The short one.
Interv 1:	And when did you have this girlfriend? What grade were you in?
H.M.:	Oh, I think I was very, very young.
Interv 1:	So you started dating as a young boy; you had your girlfriends all lined up, huh?
Interv 2:	So you weren't really dating . . . I mean you were meeting, right? Dating . . . well, I don't know . . . dating is like you go . . . well, maybe you were dating. You know, I think of dating as being in a car, but I guess that may not be
	<<cuts off Interv 2 with his laughter>>
Interv 1:	Because that girl was way out . . . oh . . . where the rocks were
Interv 1:	How did you meet her?
H.M.:	At roller skating.

Note. Interv, interviewer.

## Appendix H

## Conversations about JFK

Speaker	Transcript
Conversation 1 (Day 1):	
Interv 1:	Who is JFK?
H.M.:	John F. Kennedy.
Interv 1:	What happened to Kennedy?
H.M.:	He was . . . assassinated.
Interv 1:	Why was he assassinated?
H.M.:	They never figured out just why.
Interv 3:	Yeah.
Interv 2:	Who was JFK? It was John F. Kennedy, but what was his job? Do you know?
H.M.:	President.
Interv 2:	He was President?
Interv 3:	He was President. That's right.
Interv 1:	Do you remember who he was married to?
H.M.:	I can't think of her name.
Interv 3:	Was it at all like Jack?
H.M.:	Yeah.
Interv 3:	Jack Kennedy and . . . <<pause of 20 s while H.M. thinks>>
Interv 1:	Her name was Jackie . . .
H.M.:	Onassis.
Interv 3:	Yes, that's right. Jackie Onassis.
Interv 2:	Yes. <<break in tape recording>>
Interv 2:	Did they have children?
H.M.:	They had children.
Interv 2:	They had some children . . . yeah.
Interv 1:	Do you remember like boys? girls? Do you remember their names at all or anything like that?
H.M.:	No, I don't know their names at all.
Interv 3:	But do you remember seeing like President Kennedy on television?
H.M.:	Yeah, sometimes.
Interv 3:	Sometimes.
H.M.:	But I can't remember exactly when.
Conversation 2 (Day 2) <<previously, we were discussing H.M.'s school days>>	
Interv 1:	Did they ever teach you about people like JFK in school?
H.M.:	No.
Interv 1:	No?
H.M.:	They only taught us the right way to do things.
Conversation 3 (Day 2) <<previously, we were discussing our favorite Presidents>>	
Friend 1:	I liked Kennedy, too, but he wasn't there long.
Interv 3:	Yeah.
Interv 1:	H____, did you like Kennedy?
H.M.:	He was all right.
Friend 2:	He was the best one!
Friend 1:	First Catholic President, I think.
Interv 2:	And the only Catholic President—the first and only so far. [25 s passes with us talking about the prospect of getting a female President]
Interv 2:	Do you remember Kennedy's first name? H____? No?

## Appendix H (continued)

Speaker	Transcript
H.M.:	No, I don't.
Friend 1:	<<chuckling>> Jack, wasn't it?
H.M.:	Jack. [25 s passes with the rest of us talking about Kennedy's siblings]
Interv 2:	Do you remember Jack Kennedy's wife? He had a very famous wife.
Friend 1:	Oh yeah, she married someone from India.
Interv 2:	Greek.
Friend 1:	What was her name?
Interv 1:	What was her name, H____?
H.M.:	Oh, God . . .
Friend 1:	Geeze, I know it, too, and I can't . . .
H.M.:	I can't think of it myself.
Interv 1:	Really?
Interv 2:	It starts with Jack.
Interv 1:	Jackie.
H.M.:	Kennedy.
Interv 1:	Jackie.
Friend 2:	Jacqueline, wasn't it?
Interv 3:	Jackie, yeah, Jackie . . .
Interv 2:	Jackie.
Friend 2:	Jackie Kennedy?
Interv 1:	Jackie O.
H.M.:	Onassis.
Interv 2:	That's it! There you go.
Friend 1:	<<impressed>> Very good, H____.

*Note.* Interv, interviewer. Friend refers to one of H.M.'s friends at the healthcare facility who joined us for the conversation.

## Appendix I

## Conversation about Marilyn Monroe

Speaker	Transcript
Conversation 1 (Day 2):	
Interv 1:	Do you remember Marilyn Monroe? <<pause>>
Friend 1:	He doesn't remember Marilyn Monroe?
Interv 1:	Oh, he does.
Interv 3:	He does. Do you remember Marilyn?
H.M.:	Yeah.
Friend 1:	She was quite a name.
Friend 2:	She was hot stuff—oh, boy!
Interv 1:	Was she hot stuff, H____?
H.M.:	Huh?
Interv 1:	Was Marilyn Monroe hot stuff?
H.M.:	She pretended she was.
All:	<<laughter>>
Interv 1:	Who did she end up marrying?
Interv 2:	Which time? <<laughter>>
Interv 1:	Wasn't it that baseball player?
Friend 1:	Yeah, I think it was. It wasn't Lou Gehrig, was it?
Interv 3:	No . . .
H.M.:	Joe DiMaggio
All:	Yeah, yeah, yeah . . .

*Note.* Interv, interviewer. Friend refers to one of H.M.'s friends at the healthcare facility who joined us for the conversation.



## Appendix J

## Conversations about Raymond Burr on day 1

Speaker	Transcript
Interv 1:	Did you ever follow the actor Raymond Burr by any chance?
H.M.:	No . . . why, yes!
Interv 1:	Yeah? What were some of the thing—roles—that Raymond Burr played?
H.M.:	He played more of a detective, in a way.
Interv 2:	Uh-huh.
Interv 1:	And do you remember the name of the detective?
H.M.:	No.
Interv 1:	Do you remember Perry something?
H.M.:	<<chuckling>> I think of the other Perry.
Interv 1:	Perry who?
Interv 3:	The singer?
H.M.:	<<nodding>> yeah.
Interv 3:	The singer. Yeah.
Interv 1:	And what was the singer's last name?
H.M.:	Como.
Interv 2:	Yeah. That's right. So there's Perry Como, and Raymond Burr played the detective . . . Perry . . . Mason.
H.M.:	Yeah, Mason.

Note. Interv, interviewer.

## Appendix K

## Conversations about crossword puzzles

Speaker	Transcript
Conversation 1 (Day 1):	
Interv 2:	So you love puzzles?
H.M.:	Yeah.
Interv 2:	You've done them all your life?
H.M.:	Yes . . . most of my life.
Interv 2:	And did you do them when you were . . . aah . . . did you start doing them when you were in school?
H.M.:	I started doing them mostly when I was after school.
Interv 2:	Uh-huh. Did you do them out of a newspaper or did you
H.M.:	<<jumping in>> Started in the newspaper.
Interv 1:	What newspaper?
H.M.:	Well, didn't make any difference . . . mostly <i>The Times</i> .
Interv 3:	Oh, <i>The New York Times</i> ?
H.M.:	No . . . the regular <i>Times</i> .
Interv 3:	Oh, yes.
H.M.:	<i>The Hartford Times</i> !
	<<extended conversation about checking answers in the back of the book>>
Interv 1:	Why do you like to do crossword puzzles?
H.M.:	Cause you learn from them.
Interv 1:	What do you think you learn from them?
H.M.:	Well . . . you learn what is . . . oh . . . the word is what it is supposed to be . . . it can be used in other ways.

## Appendix K (continued)

Speaker	Transcript
Interv 2:	Uh-huh. That's right.
Conversation 2 (Day 2):	
Interv 1:	You don't make many mistakes, do you?
H.M.:	I try not to.
Interv 1:	Yeah.
H.M.:	You can learn from them, and that's what I like about them. You can learn something.

Note. Interv, interviewer.

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