Susceptibility to semantic illusions: An individual-differences perspective

BRENDA HANNON and MEREDYTH DANEMAN
University of Toronto, Mississauga, Ontario, Canada

When asked *How many animals of each kind did Moses take on the ark?*, people frequently respond “two” even though they know it was Noah, not Moses, who took animals on the ark. We replicate previous research by showing that susceptibility to semantic illusions is influenced by the semantic relatedness of both the impostor word and the surrounding context. However, we also show that the two text manipulations make independent contributions to semantic illusions, and we propose two individual-differences mechanisms that might underlie these two effects. We propose that the ability to resist the lure of a semantically related impostor word is related to the individual’s skill at accessing and reasoning about knowledge from long-term memory. And we propose that the ability to resist the lure of the surrounding sentential context is related to the individual’s capacity to simultaneously process and store information in working memory.

What passenger liner was tragically sunk by an iceberg in the Pacific Ocean? Did you answer “the Titanic”? If you did, you were victim to a semantic illusion, because the Titanic was sunk by an iceberg in the Atlantic Ocean, not the Pacific. People frequently fail to notice semantic anomalies in questions like this, even though they know that the Titanic sank in the Atlantic, and even when they are given advanced warning that there may be some trick questions (e.g., Erickson & Mattson, 1981; Reder & Kusbit, 1991; van Oostendorp & de Mul, 1990; van Oostendorp & Kok, 1990). In this paper, we explore those characteristics of the text and of the individual that influence susceptibility to these semantic illusions.

The first serious investigation of semantic illusions was by Erickson and Mattson (1981). In their study, people were required to answer a set of questions, four of which contained semantic anomalies, such as *How many animals of each kind did Moses take on the ark?* Participants were told that, usually, a one-word answer would be enough but that they were to say “don’t know” if they did not know the answer or “wrong” if the question had something wrong with it. Erickson and Mattson observed that as many as 80% of their participants failed to detect the Moses anomaly. That is, they tended to respond “two” rather than “wrong,” even though a posttest showed that they did indeed know that it was Noah, and not Moses, who took an-

imals on the ark. Erickson and Mattson also found that the Moses illusion generalized to their other three anomalous questions, although the semantic illusion rate was 40%–44% for these.

The phenomenon of semantic illusions has proved to be quite robust and to generalize over a wide range of materials and conditions (e.g., Bredart & Docquier, 1989; Bredart & Modolo, 1988; Kamas, Reder, & Ayers, 1996; Reder & Kusbit, 1991; van Oostendorp & Kok, 1990; see also Barton & Sanford, 1993). On the basis of the research so far, it would appear that people genuinely fail to detect the anomaly and are not simply withholding a detection response on the grounds that the error was inadvertently introduced by the writer of the materials (Erickson & Mattson, 1981; Reder & Kusbit, 1991). And it would not appear that people fail to detect the anomaly because they skip over the impostor word (e.g., *Moses*) or process it unduly quickly (Erickson & Mattson, 1981; Reder & Kusbit, 1991). Rather, people fail to detect the anomaly when the impostor word shares a lot of semantic features in common with the correct word; indeed, people are much more likely to fall for the illusion if the word posing for *Noah* is *Moses* than if it is *Adam*, and they never fall for the illusion if the word posing for *Noah* is *Nixon* (Erickson & Mattson, 1981; van Oostendorp & Kok, 1990). And people fail to detect the anomaly when the rest of the sentence shares a lot of features in common with the illusory answer; indeed, people are more likely to fall for the illusion when the sentence context has many words associated with the illusory answer (e.g., *What small animal hides the acorns that fall from the elm trees for his winter food supply?*) than when it has only a few (*Juneau is the capital of what city?*; Reder & Kusbit, 1991).¹

The phenomenon of semantic illusions is theoretically important because it suggests that sentences are not always subjected to the kinds of “exhaustive analysis and consis-

This research was supported by a grant from the Natural Sciences and Engineering Research Council of Canada to M.D. We thank Candice Moore for help with data collection, Mike Masson and Herre van Oostendorp for their helpful comments on an earlier draft of this paper, and Bruce Oddson, Glen Schellenberg, and Bruce Schneider for their valuable statistical advice. Correspondence concerning this article should be addressed to B. Hannon, Department of Psychology, University of Toronto, Mississauga ON, L5L 1C6 Canada (e-mail: brendah@psych.utoronto.ca).

Table 1
Examples of Anomalous Question Sets

Impostor	Context	Anomalous Question
Strong	High	(A) What passenger liner was tragically sunk by an iceberg in the <i>Pacific Ocean</i> ? (B) What board game includes <i>cardinals</i> , rooks, pawns, knights, kings, and queens? (C) What movie includes a <i>brainless</i> tinman, Dorothy, a cowardly lion, and munchkins?
Weak	High	(A) What passenger liner was tragically sunk by an iceberg in the <i>Indian Ocean</i> ? (B) What board game includes <i>monks</i> , rooks, pawns, knights, kings, and queens? (C) What movie included a <i>wicked</i> tinman, Dorothy, a cowardly lion, and munchkins?
Strong	Low	(A) What is the name of the ship that encountered an iceberg in the <i>Pacific Ocean</i> ? (B) What game includes such common things as <i>cardinals</i> , rooks, and pawns? (C) What is the name of the movie that includes a <i>brainless</i> tinman and Dorothy?
Weak	Low	(A) What is the name of the ship that encountered an iceberg in the <i>Indian Ocean</i> ? (B) What game includes such common things as <i>monks</i> , rooks, and pawns? (C) What is the name of the movie that includes a <i>wicked</i> tinman and Dorothy?

Note—Impostor words are italicized. They were not italicized during presentation.

tency checks during processing” (Erickson & Mattson, 1981, p. 541) that many models of sentence and discourse comprehension assume (see Just & Carpenter, 1980; Kintsch & van Dijk, 1978). Although the goal may be to construct a coherent mental representation of what is in a text, the comprehension system will accept partial matches with knowledge retrieved from long-term memory (Kamas et al., 1996; Reder & Kusbit, 1991) and partial analyses of the information in the text (Barton & Sanford, 1993; Erickson & Matson, 1981; Glenberg, Wilkinson, & Epstein, 1982). Partial processing is particularly evident in the case of a strongly related impostor word and a strongly related sentence context, because the high degree of semantic overlap “gives the impression of sufficient cohesion” (van Oostendorp & Kok, 1990, p. 107) and preempts an exhaustive check.

Our research replicates previous research by showing that susceptibility to semantic illusions is influenced by the semantic relatedness of both the impostor word and the surrounding context. However, we also show that the two text manipulations make independent contributions to semantic illusions, and we propose two individual-differences mechanisms that might underlie these two effects. We propose that the ability to resist the lure of a semantically related impostor word is related to an individual’s skill at accessing and reasoning about knowledge from long-term memory. And we propose that the ability to resist the lure of the surrounding sentential context is related to an individual’s capacity to simultaneously process and store information in working memory.

Text Effects

Although researchers have shown that the semantic relatedness of the impostor word (Erickson & Mattson, 1981; van Oostendorp & Kok, 1990) and the sentence context (Reder & Kusbit, 1991) both influence susceptibility to semantic illusions, they have not investigated the two effects simultaneously, so it is impossible to tell whether the same *partial-processing* mechanism underlies both effects or whether impostor relatedness and context strength make independent contributions to se-

mantic illusions. Nevertheless, it would appear that some researchers have simply assumed that the same mechanism underlies both effects. For example, when Reder and Kusbit claim that “the partial match process must be sensitive to the similarity of all the concept words (in the query) to the stored representation of the correct answer” (p. 402), we would argue that they, at least, are not making a distinction between the partial processing that is induced by the two sources of semantic relatedness.

We believe that the assumption of a single partial-processing mechanism may not be justified. There is evidence from the reading literature that suggests a dissociation between knowledge-based processes and text-based processes (Hannon & Daneman, 2001; Kintsch, 1988)—that is, between the processes that rely on the incorporation of world knowledge with text information (as in detecting a discrepancy between the impostor word and knowledge about the correct word retrieved from memory) and the processes that rely on the integration of information explicitly available from the text (as in integrating the contextual cues and detecting an anomaly among them). To test this possibility, we combined impostor relatedness and contextual strength into a single design by varying impostor relatedness (strong or weak) and number of contextual cues (high or low) orthogonally (see Table 1). This allowed us to investigate the relative influences of the two text manipulations on people’s susceptibility to semantic illusions, as well as the extent to which the two text effects were additive or interactive. We predicted that people would succumb to the illusion most often in the strong-impostor/high-context (SI/HC) condition (e.g., *What passenger liner was tragically sunk by an iceberg in the Pacific Ocean?*) and that they would succumb to the illusion least often in the weak-impostor/low-context (WI/LC) condition (e.g., *What is the name of the ship that encountered an iceberg in the Indian Ocean?*). However, we predicted that the two effects would be additive, rather than interactive, because skill at resisting the lure of a strongly related impostor word involves skill at knowledge access processes, whereas skill at resisting the lure of the surrounding sentential context

involves skill at text integration processes. The rationale behind these predictions is discussed in more detail below.

Cognitive Mechanisms Underlying the Text Effects

Although a semantically related impostor word and a semantically related context both encourage a kind of partial or incomplete processing that leads to semantic illusions, we argue that the mechanisms underlying the two effects are different. The impostor-word effect can be attributed to a comprehension system that either retrieves partial knowledge from long-term memory or accepts *partial matches* between the impostor word and knowledge retrieved from long-term memory. In contrast, the context effect can be attributed to a comprehension system that accepts *partial analyses and integration* of the text information itself.

Take the impostor-word effect for starters. To detect the anomaly, readers must access prior knowledge about the impostor word (e.g., *Pacific* or *Indian*) and prior knowledge about the scenario represented in the sentence (e.g., the sinking of the Titanic in the Atlantic) and then detect discrepancies between these two sources of knowledge. Readers could fail to detect the discrepancy if the knowledge *access* process is incomplete or if the knowledge *matching* process is incomplete. In other words, even though a reader possesses the knowledge that the Titanic sank in the Atlantic off the coast of Canada, that reader might *access* only some of the features of the scenario as he or she reads the anomalous question. If the detail about where exactly the Titanic sank is not accessed, that reader might fail to notice the impostor ocean (*Pacific* or *Indian*) and, consequently, fall for the semantic illusion by providing the answer "Titanic." However, even if readers do access their knowledge that the Titanic sank in the Atlantic (off the coast of Canada), they would still have to note the discrepancy between that knowledge and the knowledge retrieved about the *Pacific* or *Indian* Oceans. If a reader does only a partial or superficial *match* of features, focusing only on features that the *Pacific* Ocean or the *Indian* Ocean has in common with the Atlantic (e.g., big oceans, ships can sink in them), that reader may fail to note the discrepancy between the *Pacific* Ocean or the *Indian* Ocean, on the one hand, and the Atlantic Ocean, on the other hand, and consequently fall for the semantic illusion. Although discrepancy detection failures are likely to occur for both the strong impostor (*Pacific*) and the weak impostor (*Indian*), because both share many features in common with the correct target (Atlantic), the likelihood of an incomplete matching process would be greater for the more strongly related impostor, because it shares additional features in common with the correct target (e.g., an ocean that borders on Canada/North America). The strong semantic overlap would give the impression of sufficient cohesion, preempting a more exhaustive check. According to this account, failure to detect the anomaly is a result of incomplete access of world knowledge or incomplete matching of accessed knowl-

edge. Previous research has shown that readers do differ in how well they access simple facts from long-term memory knowledge and reason about these facts (Hannon & Daneman, 2001). Thus, it seems reasonable to predict that readers who are less skilled at accessing and reasoning about world knowledge will be more susceptible to semantic illusions, because of imperfect or incomplete memory access and comparison processes. They should be susceptible to the lure of all semantically related impostor words (e.g., *Pacific*, *Indian*) and particularly susceptible in the trickier situations in which impostor relatedness is very high (*Pacific*). This prediction was tested by administering the anomaly detection task in conjunction with a measure of individual differences in knowledge access (Hannon & Daneman, 2001).

In contrast, resisting the lure of the surrounding context appears to depend on the reader's ability to integrate successively encountered semantic cues in the context and notice a discrepancy among them, a process that becomes more difficult or is preempted prematurely when there are lots of cues consistent with the targeted scenario (the sinking of the Titanic), rather than with the discrepant concept (the *Pacific* or the *Indian* Ocean). Previous research has shown that readers differ in their ability to integrate successive ideas and detect inconsistencies among the ideas (Daneman & Carpenter, 1983; Garner, 1980) and that individual differences in these abilities are related to readers' capacities to process and store the successive ideas in working memory (Daneman & Carpenter, 1983). Thus, it is reasonable to predict that readers with smaller working memory capacities will be more susceptible to missing the anomalies and hence falling for the semantic illusions in both the low-context and the high-context conditions because, in both cases, there are lots of cues consistent with the targeted scenario. However, readers with smaller working memories may be particularly susceptible in the trickier cases in which the context strength is very high. This prediction was tested by including a measure of working memory capacity (Daneman & Carpenter, 1980).

Including the two individual-differences measures served two functions. First, we could examine the extent to which our two theoretically motivated individual-differences measures, knowledge access and working memory span, contributed to anomaly detection. This was accomplished by examining how well the two measures predicted overall performance at detecting anomalous questions. Second, we could test our predictions that knowledge access operates on impostor words, whereas working memory operates on sentence context. This was accomplished by showing that knowledge access was the better of the two measures at predicting anomaly detection when impostor strength was high (as in the strong-impostor/low-context [SI/LC] condition), whereas working memory span was the better of the two measures at predicting anomaly detection when contextual strength was high (as in the weak-impostor/high-context [WI/HC] condition).

METHOD

Participants

The participants were 136 University of Toronto students, who were tested individually in two sessions that occurred exactly 1 week apart. In the first session, all 136 participants were administered the anomaly detection task, and only the last 80 participants were administered the knowledge access and working memory span measures. In the second session, the participants answered questions that tested their knowledge about the facts targeted in the anomalous questions.

Anomaly Detection Task

The participants read 112 questions presented one at a time on the computer screen. They provided an answer for each question or said "don't know" if they did not know the answer or "wrong" if they detected something wrong with the question.

Materials and Procedure. The experimental materials were 56 questions constructed around facts well known to a Canadian university student population. One third of the questions were adapted from previously published studies (e.g., Erickson & Mattson, 1981; Reder & Kusbit, 1991); the others were constructed by ourselves. For each question, four anomalous versions were created: (1) SI/HC, (2) WI/HC, (3) SI/LC, and (4) WI/LC (see Table 1). Both the strong- and the weak-impostor words were semantically related to the correct word. However, the strong impostor (e.g., *Pacific*) had a stronger relationship to the correct target (e.g., *Atlantic*) than did the weak impostor (e.g., *Indian*). High-context versions had more words (besides the impostor word) related to the illusory answer than did low-context versions (e.g., *passenger, liner, tragically, sunk, iceberg, ocean* vs. *ship, iceberg, ocean*).

As a check that our strong- and weak-impostor words did indeed differ in their degree of semantic relatedness to the correct target, four independent raters read both the strong- and the weak-impostor versions of a question (e.g., *What passenger liner was tragically sunk by an iceberg in the PACIFIC Ocean? What passenger liner was tragically sunk by an iceberg in the INDIAN Ocean?*), checkmarked the question judged to be the more misleading, and then rated on a 5-point scale how much more misleading they perceived the checked question to be (1 meant *there was no difference between the questions*; 5 meant *that the checked question was much more misleading*). Strong-impostor versions were chosen as more misleading than weak-impostor versions 98% of the time. The mean rating for checked questions was 3.08 ($SD = 0.53$) and suggests that strong-impostor questions were judged to be moderately more misleading than weak-impostor questions.

As a check for our context strength manipulation, the four independent raters identified the contextually relevant words for each question. They read the correct versions of each high- and low-context question (e.g., *What passenger liner was tragically sunk by an iceberg in the Atlantic Ocean? What is the name of the ship that encountered an iceberg in the Atlantic Ocean?*) and identified all the words that they considered to be valuable cues to the targeted answer (e.g., the *Titanic*). The mean number of words identified as contextually relevant was 5.34 ($SD = 1.23$, range = 3.75–8.75) for the high-context questions and 2.65 ($SD = 0.63$, range = 1.25–3.5) for the low-context questions.

The location of the impostor words (early, middle, or late), the number of words per question, and the type of impostor words (noun, adjective, or verb) were also controlled. The mean word length was 12.02 for high-context and 11.90 for low-context questions, and there was a low .19 correlation between total number of words and number of contextually relevant words in a question. In addition, 36 of the impostor words were nouns, and 20 were adjectives, adverbs, or verbs. The complete set of anomalous questions is listed in the Appendix.

The four versions of an anomalous question were randomly assigned to one of four stimulus files, with the constraint that there be 14 of each type per file. The participants were randomly assigned to read one of the four stimulus files. In each file, the 56 anomalous questions were randomly interspersed with 56 nonanomalous filler questions. The filler questions were relatively easy trivia questions (e.g., *What are the three colors found in the American flag?*).

The instructions were identical to those used by Erickson and Mattson (1981). The participants were told that each question would appear briefly on the computer screen and that their task was to read the question out loud and then answer it out loud as quickly as possible. They were told that usually a one-word answer was sufficient. If they did not know the answer or could not recall it right away, they were to say "don't know." They were also warned that occasionally they would encounter a question that had something wrong with it and that, when they did so, they should say "wrong." The order of presentation of the 56 anomalous and 56 filler questions was randomized for each participant. Each question was presented for 5 sec. The participants read the question out loud, gave their response out loud, and then pressed the space bar for the next question.

Knowledge Check

In the second session, the participants completed a test to check their knowledge of the facts that would have been the correct answers to the questions had they not contained anomalous words. There were 56 multiple-choice items corresponding to the 56 anomalous questions. For each item, the participants selected an answer from four choices (a) the strong impostor, (b) the weak impostor, (c) the correct target, and (d) don't know (e.g., *The Titanic sank in the ——— Ocean; (a) Pacific, (b) Indian, (c) Atlantic, (d) don't know*). Mean performance was 48.43 out of 56 ($SD = 4.70$).

Knowledge Access Measure

Our knowledge access measure was actually one component of a more complex component processes task developed by Hannon and Daneman (2001) to measure individual differences in four components of reading comprehension—the ability to access prior knowledge, to integrate accessed knowledge with text information, to make inferences based on information provided in the text, and to recall new text information from long-term memory. The component processes task requires participants to study three-sentence paragraphs that describe the relations among a set of real and nonsense terms, such as *A MIRT resembles an OSTRICH but is larger and has a longer neck, A COFT resembles a ROBIN but is smaller and has a longer neck, or A FILP resembles a COFT but is smaller, has a longer neck, and nests on land*. By using the relations described in the three sentences, participants can construct a number of linear orderings (e.g., a size ordering, a neck length ordering); however, some of the information is not explicitly mentioned in the paragraph, and so to complete the ordering (e.g., the size ordering: $MIRT > OSTRICH > ROBIN > COFT > FILP$), participants need to access their prior knowledge (that an ostrich is larger than a robin). After studying the paragraphs, the participants are given a series of test statements to tap knowledge access, knowledge integration, text inferencing, and text memory. So for example, such text memory statements as *A MIRT is larger than an OSTRICH* can be answered from new information provided explicitly in the text; no prior knowledge is required. In contrast, the knowledge access statements, the ones of interest in the present study, require participants to access and reason about prior knowledge in long-term memory; the text does not provide the information. For example, the knowledge access statement *A ROBIN lives in Canada, whereas a PENGUIN typically doesn't* requires participants to access their prior knowledge about robins and penguins and to reason about where these birds typically live; the answer to this statement is not provided by information in the paragraph itself. Hannon and Daneman (2001)

Table 2
Sample Paragraphs and Questions from Component Processes Task

Vehicle Item		
Paragraph		
A NORT resembles a JET but is faster and weighs more.		
A BERL resembles a CAR but is slower and weighs more.		
A SAMP resembles a BERL but is slower and weighs more.		
Features/relations		
speed	nort > JET > CAR > berl > samp	
weight	nort > JET > CAR; samp > berl > CAR	
Test statements		
Knowledge access		
A JET has a pilot, whereas a MOTORCYCLE doesn't.		(true)
A CAR has a driver, whereas a ROCKET doesn't.		(true)
A JET has a driver, whereas a MOTORCYCLE doesn't.		(false)
A CAR has a pilot, whereas a ROCKET doesn't.		(false)
Text memory		
A NORT is faster than a JET.		(true)
A JET is faster than a NORT.		(false)
Text inferencing		
A SAMP is slower than a CAR.		(true)
A CAR is slower than a SAMP.		(false)
Knowledge integration		
A NORT weighs more than a CAR.		(true)
A CAR weighs more than a NORT.		(false)
Bird Item		
Paragraph		
A MIRT resembles an OSTRICH but is larger and has a longer neck.		
A COFT resembles a ROBIN but is smaller and has a longer neck.		
A FILP resembles a COFT but is smaller, has a longer neck, and nests on land.		
Features/relations		
Size	mirt > OSTRICH > ROBIN > coft > filp	
Neck length	mirt > OSTRICH > ROBIN; filp > coft > ROBIN	
Nests on land	filp, OSTRICH	
Doesn't nest on land	coft, ROBIN	
Test statements		
Knowledge access		
A ROBIN lives in CANADA, whereas a PENGUIN typically doesn't.		(true)
A BLUEJAY lives in CANADA, whereas an OSTRICH typically doesn't.		(true)
A PENGUIN lives in CANADA, whereas a ROBIN typically doesn't.		(false)
An OSTRICH lives in CANADA, whereas a BLUEJAY typically doesn't.		(false)
Text memory		
A MIRT is larger than an OSTRICH.		(true)
An OSTRICH is larger than a MIRT.		(false)
Text inferencing		
A FILP is smaller than a ROBIN.		(true)
A ROBIN is smaller than a FILP.		(false)
Knowledge integration		
A MIRT has a longer neck than a ROBIN.		(true)
A ROBIN has a longer neck than a MIRT.		(false)

showed that the knowledge access component is correlated with global reading comprehension, as well as with simple reading tasks that load heavily on knowledge access, such as Smith, Shoben, and Rips's (1974) verification task, in which participants verify simple statements, such as *An apple is a fruit*, *A cantaloupe is a fruit*. We predicted that this knowledge access component would be sensitive to individual differences in detecting anomalous questions in general, because the anomalous questions require readers to access knowledge from long-term memory and to do thorough knowledge comparisons to avoid falling for the illusions. We also predicted that the knowledge access component would be particularly sensitive to individual differences in the trickier knowledge access and reasoning conditions that involved detecting impostor words that have very strong semantic relations to the correct target.

Materials and Procedure. The materials and procedure were identical to those used by Hannon and Daneman (2001). The task

consisted of six three-sentence paragraphs (see Table 2 for examples). The sentences for each paragraph appeared one at a time on a computer screen. Each paragraph included three nonsense terms, two real terms, and two, three, or four semantic features. After studying a paragraph, the participants responded to true/false statements about it. There were four types of test statements: knowledge access, text memory, text inferencing, and knowledge integration (see Table 2). The participants responded to all four types of test statements; however, only their scores on the 24 knowledge access statements were used in the analyses reported here.

The *knowledge access* statements tested access to and reasoning about prior knowledge; no information from the paragraph was required. There were two types of knowledge access statements. The simpler type (e.g., *An OSTRICH is larger than a ROBIN*) tested access to a fact not presented in the paragraph but included two real terms (OSTRICH and ROBIN) and a feature (*larger than*) that appeared in the

paragraph. The more complex type (e.g., A BLUEJAY lives in Canada whereas an OSTRICH typically doesn't) tested access to a fact not presented in the paragraph and included a real term (OSTRICH) that was presented in the paragraph, as well as a real term (BLUEJAY) and a semantic feature (*lives in Canada*) not presented in the paragraph. By including a term and a feature not explicitly mentioned in the paragraph, the second type of knowledge access statements required more sophisticated access to and reasoning about the relations among sources of prior knowledge. It was this second type of knowledge access statement that was analyzed in the present study. For each paragraph, there were two true and two false knowledge access statements of this type.²

The participants were informed that they would see a three-sentence paragraph, presented one sentence at a time. Some of the terms in the sentences would represent real items that should be familiar to them. Other terms, denoted by nonsense syllables, would represent imaginary items unfamiliar to them. Once they had learned the paragraph, they were to respond "true" or "false" to a series of test statements. They were explicitly instructed to use their world knowledge. In other words, they were told that some of the statements should be considered true because the information in those statements was actually presented in the paragraph; other statements should be considered true because the information described in them could be deduced from their real-world knowledge.

The participants controlled the display time for each sentence of the paragraph by pressing the + key when they were ready for the next sentence. Once all three sentences of a paragraph were learned, the test statements were presented one at a time in a random order. The participants had a maximum of 12 sec to read and respond. If they failed to respond within the 12-sec deadline, the test statement was removed and replaced by the next test statement. All response failures were classified as errors.³ Mean accuracy on the 24 knowledge access questions was 21.13 ($SD = 2.04$, range = 14–24).

Working Memory Span Measure

Our working memory span measure was a variant of Daneman and Carpenter's (1980) reading span test, which was designed to measure the combined processing and storage capacity of working memory during reading. Participants read aloud increasingly longer sets of unrelated sentences (e.g., *Torrential rains swept across the tiny deserted island* and *The starving hamburger bit into the juicy man*) and make judgments about the sensibility of each sentence. Then at the end of a set, they attempt to recall the final word of each sentence in the set (e.g., *island*, *man*). Working memory span has been shown to correlate well with global reading comprehension, as well as with specific tests that tap readers' abilities to integrate successively encountered ideas and to detect inconsistencies among them (e.g., Daneman & Carpenter, 1980; Daneman & Merikle, 1996; Masson & Miller, 1983; Turner & Engle, 1989). We predicted that working memory span would be sensitive to individual differences in detecting anomalous questions and particularly sensitive in the trickier high-context conditions that involved integrating and resisting multiple contextually misleading cues.

Materials and Procedure. The participants read aloud a set of unrelated sentences, made a sensibility judgment for each one, and then at the end of the set, attempted to recall the last word of each sentence in the set (see Daneman & Hannon, in press). Sentences that were 8–12 words in length were presented one at a time on the screen. After the participant responded "yes" or "no" as to sentence sensibility, he or she pressed the space bar for the next sentence. The procedure was repeated until a blue screen indicated that the trial was over, at which point the participant recalled the last word of each of the sentences in the set. The sentences were arranged in five sets each of two, three, four, five, and six sentences, in ascending order. Working memory span was the total number of final words out of 100 recalled. Mean span was 59.53 ($SD = 11.91$, range = 37–95). Working memory span and knowledge access were

not significantly correlated [$r(78) = .16$, $p > .15$; see also Hannon & Daneman, 2001].

RESULTS AND DISCUSSION

Text Effects

Figure 1 provides the mean percentage of anomalies detected as a function of impostor relatedness and context strength. For each participant, these percentages were based only on those items that a participant answered correctly on the knowledge check. In other words, for each participant, the percentage of anomalies detected was based on the number of correct "wrong" responses that the participant gave for questions answered correctly on the knowledge check.⁴

Both impostor relatedness and context strength influenced anomaly detection, with impostor relatedness having the greater impact of the two text manipulations on detection performance. As Figure 1 shows, people detected only 54% of the anomalous questions when the impostor word had a strong semantic relation to the correct target, as compared with 66% when the impostor word had a weaker semantic relation to the correct target. This 12% difference was significant [$F(1,135) = 107.03$, $MS_e = 180.73$, $p < .0001$] and replicates the finding of van Oostendorp and Kok (1990). In addition, Figure 1 shows that people detected 58% of the anomalous questions when the sentence context was highly related to the correct answer, as compared with 62% when the sentence context was less highly related to the correct answer. This small 4% difference was significant [$F(1,135) = 11.59$, $MS_e = 191.78$, $p < .001$] and replicates the finding of Reder and Kusbit (1991). Finally, the effects of impostor relatedness and contextual relatedness on anomaly detection appear to be independent of each other, because there was no hint of a significant interaction between the two text manipulations [$F(1,135) = 0.31$, $MS_e = 182.18$, $p = .58$]. Moreover, the effects of impostor relatedness and context strength were not correlated [$r(134) = .02$].⁵ This new finding suggests that although a semantically related impostor and a semantically related context both lead to shallower processing and, hence, more semantic illusions, the cognitive mechanisms underlying the two effects might be different.

One might wonder whether the lack of a significant interaction between the two text manipulations is a consequence of the small 4% context effect. To test this possibility, we repeated our analysis on a subset of approximately half the stimuli, using only those stimuli whose context strength rating was above the mean for high-context sentences (i.e., >5.34 context words) or below the mean for low-context sentences (i.e., <2.65 context words). The results showed a much larger context effect—namely, an 11% difference between anomaly detection for high- versus low-context questions [$F(1,135) = 28.47$, $MS_e = 574.12$, $p < .0001$]. There was also a significant 15% effect of impostor relatedness [$F(1,135) = 53.98$, $MS_e = 543.30$, $p < .0001$]. Nevertheless, despite the

Figure 1. Percentage of anomalies detected as a function of impostor relatedness and context strength.

larger context effect, there was still no hint of an impostor relatedness $\times$ context strength interaction [$F(1,135) = 0.08$, $MS_e = 461.70$, $p = .78$]. These findings suggest that the lack of a significant interaction for the complete stimulus set is unlikely to be a consequence of the small context effect.

Subsequent effect size calculations (Cohen, 1988) for this subset of data suggest that the lack of a significant impostor $\times$ context interaction was a consequence of an effect that was 1/10th the size of what Cohen classified as a small effect, and not a consequence of the effect sizes of the text manipulations. The sizes of the impostor and context effects were moderate (Cohen's $f = .36$ and $.26$, respectively), but the size of the interaction effect was trivial ($f = .01$). What $f = .01$ means is that the interaction accounts for considerably less than 1% of the total variance (i.e., 0.01%, using η^2). In other words, the interaction was trivial even when we increased the power of our design by increasing the sensitivity of our context manipulation. Moreover, even for the complete set of stimuli, the effect size for the interaction (i.e., $f = .024$) was 1/4th the size of what Cohen deemed to be a small effect (.10). This effect size again accounts for considerably less than 1% of the total variance (i.e., 0.06%, using η^2). In the context of our study, this 0.06% of variance contrasts strikingly with the 20.1% variance accounted for by the impostor manipulation and accounts for 39 times less variance than does our context manipulation. Given that the amount of variance accounted for by the interaction is so trivial, we

argue that the interaction is not worthy of further investigation.

Cognitive Mechanisms Underlying the Text Effects

The first question of interest was the extent to which the theoretically motivated knowledge access and working memory capacity measures contributed to anomaly detection. We examined this by conducting two regression analyses on the overall anomaly detection data for the 80 participants who were administered the individual-

Table 3
Regression Analyses ($n = 80$)

Type of Anomalous Question	<i>R</i>	<i>R</i> ²	ΔR^2	<i>F</i>
Overall anomaly detection				
(A) Knowledge access	.48	.23	.23	22.96
Working memory span	.60	.36	.13	15.69
(B) Working memory span	.43	.19	.19	18.00
Knowledge access	.60	.36	.17	20.49
Strong impostor/low context				
(C) Knowledge access	.39	.15	.15	13.57
Working memory span	.43	.19	.04	3.54
(D) Working memory span	.25	.06	.06	5.30
Knowledge access	.43	.19	.13	11.54
Weak impostor/high context				
(E) Knowledge access	.29	.08	.08	7.06
Working memory span	.43	.19	.11	9.62
(F) Working memory span	.36	.13	.13	11.68
Knowledge access	.43	.19	.06	5.15

Note— ΔR^2 = change in R^2 .

Figure 2. Three path diagrams depicting (A) the basic structure of our models, (B) the nonindependent model, and (C) the independent model. The ellipses represent latent variables, and the rectangles represent the observed measures. Paths with one arrow leading from one variable to another indicate direction of influence, whereas paths with two arrows represent correlations. Significant paths are represented by solid lines, and nonsignificant lines are represented by dashes.

differences measures. In one analysis, knowledge access was entered as the first predictor, and working memory span as the second predictor. In the other analysis, the order of the two predictors was reversed. The results of

these regression analyses are presented in Tables 3A and 3B. Knowledge access was slightly better than working memory span at predicting overall anomaly detection, in that knowledge access accounted for 23% of the variance

Table 4
Goodness-of-Fit Statistics for the Structural Equation Models

Model	df	χ^2	$\chi^2 p(\text{exact})$	$\chi^2 p(\text{close})$	GFI	AGFI	CFI	RMSEA
Basic structure	5	7.40	.19	.29	.96	.89	.97	.08
Nonindependent	1	1.85	.17	.22	.99	.86	.99	.10
Independent	3	2.32	.51	.59	.99	.94	1.00	.00

Note— $\chi^2 p(\text{exact})$ = traditional chi-square test of *exact* model fit, $\chi^2 p(\text{close})$ = the chi-square test of *close* model fit, GFI = the goodness-of-fit index, AGFI = the adjusted GFI, CFI = the comparative fit index, and RMSEA = the root-mean square error of approximation. Note that for the chi-square tests, the hypothesis being tested assumes either an exact model fit for the data or a model fit that is acceptable, and so a good-fitting model is indicated by nonsignificant results from these tests (i.e., $p > .05$). For the GFI, AGFI, and CFI indices, good-fitting models are indicated by a value of .90 or more. For the RMSEA statistic, values of .05 or less indicate a good-fitting model.

when entered into the equation first, whereas working memory span accounted for 19% of the variance when entered into the equation first. However, the most striking feature of the results of the two regression analyses is that both knowledge access and working memory span accounted for substantial proportions of unique variance regardless of the order in which they were entered into the equation. This finding suggests that both play an important and independent role in anomaly detection. Together, the two individual-differences measures accounted for 36% of the variance in anomaly detection and supported our prediction that individuals with poor knowledge access and individuals with small working memory capacities are more susceptible to semantic illusions.

Of course, the analyses of the overall anomaly detection data do not tell us whether knowledge access is the better predictor when impostor relatedness is high and whether working memory span is the better predictor when context strength is high. The best conditions for testing these predictions are the SI/LC and the WI/HC conditions. In the SI/LC condition, impostor relatedness is high, and the context manipulation is minimized; in the WI/HC condition, context strength is high, and impostor relatedness is minimized. If our hypotheses are correct, knowledge access should be a better predictor of anomaly detection when impostor relatedness is emphasized (the SI/LC condition), whereas working memory span should be the better predictor when context strength is emphasized (the WI/HC condition).

Tables 3C and 3D show the results of two regression analyses on the anomaly detection data for the SI/LC condition. As we hypothesized, when impostor relatedness was emphasized, knowledge access was a better predictor than was working memory span; it accounted for 15% of the variance when entered into the regression equation first, whereas working memory capacity accounted for only 4% of the residual variance (see Table 3C). Moreover, knowledge access still accounted for considerably more of the variance in anomaly detection than did working memory, even when it was entered into the regression equation after working memory span (see Table 3D). Thus, the results of these two regression analyses support our hypothesis that skills having to do with knowledge

access underlie the ability to resist semantically related lures.

Tables 3E and 3F show the results of the two regression analyses on the anomaly detection data for the WI/HC condition. As we hypothesized, when context strength was emphasized, working memory span was a better predictor than knowledge access; it accounted for 13% of the variance when entered into the regression equation first, whereas knowledge access accounted for only 6% of the residual variance (see Table 3F). Moreover, working memory span still accounted for more unique variance in anomaly detection than did knowledge access even when it was entered into the regression equation after knowledge access (see Table 3E). Thus, the results of these two regression analyses support our hypothesis that working memory capacity underlies skill at integrating multiple contextual cues and detecting an inconsistency among them.⁶

To further evaluate the independent influences of knowledge access on the impostor effect and working memory span on the context effect, we used structure equation modeling. We first isolated the impostor effect and the context effect and then tested two structure equation models (SEMs): one in which knowledge access and working memory influence both the impostor effect and the context effect (nonindependent model), and a second in which knowledge access influences only the impostor effect and working memory influences only the context effect (independent model). The results support our prediction that knowledge influences the impostor effect, whereas working memory influences the context effect. For all our SEMs, we used LISREL 8 (Jöreskog & Sörbom, 1993), and we followed the recommendations of Hoyle and Panter (1995) by performing six different fit statistics. Figure 2 depicts the SEMs tested, and Tables 4 and 5 report the fit statistics.

To isolate the impostor and context effects, we factored out the shared variance between the baseline illusion condition of WI/LC and the two other important illusion conditions, SI/LC and WI/HC. By factoring out the shared variance between the baseline illusion and the SI/LC conditions, the remaining variance for the SI/LC condition can be attributed to the difference between the weak and

Table 5
Z Scores for the Factor Loadings for
Each Illusion Condition in Each SEM

Model	Illusion Condition	
	Strong Impostor/Low Context (Isolated Impostor Effect)	Weak Impostor/High Context (Isolated Context Effect)
Nonindependent		
Knowledge access	1.80†	.65
Working memory	.24	1.57*
Independent		
Knowledge access	1.72†	—
Working memory	—	1.56*

Note—* $p < .06$. † $p < .05$.

the strong impostors (i.e., the impostor effect). By factoring out the shared variance between the baseline illusion and the WI/HC conditions, the remaining variance for the WI/HC condition can be attributed to the difference between the low and the high context (i.e., the context effect).

The basic structure of our two SEMs is depicted in Figure 2A. Note that in this structure, there are no direct paths from knowledge access and working memory to the two illusion conditions of interest (SI/LC and WI/HC); however, they have indirect influences through the baseline illusion condition (WI/LC). As Table 4 shows, two of the six fit statistics for this structure did not meet the established criteria for a good-fitting model (adjusted goodness-of-fit index [AGFI] $< .90$, and root-mean square error of approximation [RMSEA] $> .05$).

Figure 2B shows our nonindependent SEM that tested the influence of knowledge access and working memory on both isolated text effects by adding direct paths from knowledge access and working memory to the two illusion conditions of interest. As Table 4 shows, this nonindependent SEM cannot be considered an adequate model, because two of the six fit statistics did not meet the established criteria for a good-fitting model (AGFI $< .90$, and RMSEA $> .05$) and the $\chi^2 p(\text{exact})$ shows that the model explains the data only 17% of the time. Table 5 shows the most likely causes of this poor fit. As Table 5 shows, knowledge access influenced the SI/LC condition ($z = 1.80$), whereas working memory did not ($z = 0.24$); in contrast, working memory influenced the WI/HC condition ($z = 1.57$), whereas knowledge access did not ($z = 0.65$). In other words, when the shared variance between the baseline illusion and the SI/LC conditions is accounted for, knowledge access predicts performance on the impostor effect (SI/LC), but working memory does not, and when the shared variance between the baseline illusion and WI/HC conditions is accounted for, working memory predicts performance on the context effect (WI/HC), but knowledge access does not. The nonsignificant paths are represented by dashes in Figure 2B.

Figure 2C shows our independent SEM, which tested the separate influences of knowledge access on the impostor effect and working memory on the context effect (i.e., by eliminating the nonsignificant paths between knowledge access and WI/HC and between working memory and SI/LC). As Table 4 shows, this model fits the data

well, because it met all the established criteria for a good-fitting model, and the $\chi^2 p(\text{exact})$ shows that the model explains the data 51% of the time. Because the independent model has an excellent fit, whereas the nonindependent model has an inadequate fit, and because the independent model is the more parsimonious of the two (has fewer paths), we favor the independent model. In other words, a model that has knowledge access operating only on the impostor and working memory operating only on the context explains our data best. Thus, the SEM findings, together with the regression analyses, show that knowledge access appears to be important for resisting highly related impostor words, and working memory capacity appears to be important for integrating and resisting multiple contextually misleading cues.

SUMMARY AND CONCLUSIONS

Our research replicates previous findings concerning the phenomenon of semantic illusions. Consistent with previous studies, we found the phenomenon to be robust; our participants missed the anomalous questions 40% of the time, despite being warned to be vigilant for anomalous questions (Erickson & Mattson, 1981; Reder & Kusbit, 1991). We also found that the semantic relatedness of the impostor word and the semantic relatedness of the surrounding context both influenced susceptibility to semantic illusions (Reder & Kusbit, 1991; van Oostendorp & Kok, 1990).

However, our research also makes some important new contributions to our understanding of semantic illusions. We showed that the two text effects were additive, rather than interactive, a finding that suggested to us that the mechanisms underlying these effects might be different. The important theoretical contribution of the present research was to provide some evidence concerning what these mechanisms might be. By using an individual-differences approach, we isolated two characteristics of a reader that play a significant and independent role in anomaly detection: knowledge access and working memory capacity. Knowledge access was the better predictor of anomaly detection when the reader had to resist the lure of an impostor that was strongly related to the correct target. On the other hand, a measure of the reader's working memory capacity, which has been shown to be sen-

sitive to the ability to integrate successive ideas in a text and to detect anomalies among them, was the better predictor of anomaly detection when the reader had to resist the lure of multiple contextually misleading cues. These individual-differences findings suggest that the impostor effect can be attributed to imperfect or incomplete memory access and comparison processes and that the context effect can be attributed to imperfect or incomplete text analysis and integration processes.

The phenomenon of semantic illusions has important implications for models of text comprehension. Although most models of comprehension assume that the goal of comprehension is to establish a coherent representation of the text (e.g., Just & Carpenter, 1980; Kintsch & van Dijk, 1978), the prevalence of semantic illusions suggests that the comprehension system is not scrupulous about processing and integrating every word into the representation and does not proceed in a strict left-to-right fashion, processing each word as deeply as possible before proceeding to the next word, as some models assume (see Just & Carpenter, 1980). In fact, partial processing may be a common strategy, and the comprehension system may assume coherence as a default, as long as there is sufficient global coherence (see also Barton & Sanford, 1993; Glenberg et al., 1982). Our research also shows what kind of readers have a greater tendency to engage in shallow processing than do others: readers who are less skilled at accessing prior knowledge from long-term memory and readers who have less capacity to simultaneously process and store information in working memory.

REFERENCES

- BARTON, S. B., & SANFORD, A. J. (1993). A case study of anomaly detection: Shallow semantic processing and cohesion establishment. *Memory & Cognition*, **21**, 477-487.
- BREDART, S. B., & DOCQUIER, M. (1989). The Moses illusion: A follow-up on the focalization effect. *Cahiers de Psychologie Cognitive*, **9**, 357-362.
- BREDART, S. B., & MODOLO, K. (1988). Moses strikes again: Focalization effect on a semantic illusion. *Acta Psychologica*, **67**, 135-144.
- COHEN, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd Ed.). Hillsdale, NJ: Erlbaum.
- DANEMAN, M., & CARPENTER, P. A. (1980). Individual differences in working memory and reading. *Journal of Verbal Learning & Verbal Behavior*, **19**, 450-466.
- DANEMAN, M., & CARPENTER, P. A. (1983). Individual differences in integrating information between and within sentences. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **9**, 561-584.
- DANEMAN, M., & HANNON, B. (in press). Using working memory theory to investigate the construct validity of multiple-choice reading comprehension tests such as the SAT. *Journal of Experimental Psychology: General*.
- DANEMAN, M., & MERIKLE, P. M. (1996). Working memory and language comprehension: A meta-analysis. *Psychonomic Bulletin & Review*, **3**, 422-433.
- ERICKSON, T. D., & MATTSON, M. E. (1981). From words to meaning: A semantic illusion. *Journal of Verbal Learning & Verbal Behavior*, **20**, 540-551.
- GARNER, R. (1980). Monitoring of understanding: An investigation of good and poor readers' awareness of induced miscomprehension of text. *Journal of Reading Behavior*, **12**, 55-64.
- GLENBERG, A. M., WILKINSON, A. C., & EPSTEIN, W. (1982). The illusion of knowing: Failure in the self-assessment of comprehension. *Memory & Cognition*, **10**, 597-602.
- HANNON, B., & DANEMAN, M. (2001). A new tool for measuring and understanding individual differences in the component processes of reading comprehension. *Journal of Educational Psychology*, **93**, 103-128.
- HOYLE, R. H., & PANTER, A. T. (1995). Writing about structural equation models. In R. H. Panter (Ed.), *Structural equation modeling: Concepts, issues, and applications* (pp. 158-176). Thousand Oaks, CA: Sage.
- JÖRESKOG, K., & SÖRBOM, D. (1993). *LISREL 8: Structural equation modeling with the SIMPLIS command language*. Hillsdale, NJ: Erlbaum.
- JUST, M. A., & CARPENTER, P. A. (1980). A theory of reading: From eye fixations to comprehension. *Psychological Review*, **87**, 329-354.
- KAMAS, E. N., REDER, L. M., & AYERS, M. S. (1996). Partial matching in the Moses illusion: Response bias not sensitivity. *Memory & Cognition*, **24**, 687-699.
- KINTSCH, W. (1988). The use of knowledge in discourse processing: A construction-integration model. *Psychological Review*, **95**, 163-182.
- KINTSCH, W., & VAN DIJK, T. A. (1978). Towards a model of text comprehension and production. *Psychological Review*, **85**, 363-394.
- MASSON, M. E., & MILLER, J. A. (1983). Working memory and individual differences in comprehension and memory of text. *Journal of Educational Psychology*, **75**, 314-318.
- REDER, L. M., & KUSBIT, G. W. (1991). Locus of the Moses illusion: Imperfect encoding, retrieval, or match? *Journal of Memory & Language*, **30**, 385-406.
- SMITH, E. E., SHOEN, E. J., & RIPS, L. J. (1974). Structure and process in semantic memory: A featural model for semantic decisions. *Psychological Review*, **81**, 214-241.
- TURNER, M. L., & ENGLE, R. W. (1989). Is working memory capacity task dependent? *Journal of Memory & Language*, **28**, 127-154.
- VAN OOSTENDORP, H., & DE MUL, S. (1990). Moses beats Adam: A semantic relatedness effect on a semantic illusion. *Acta Psychologica*, **74**, 35-46.
- VAN OOSTENDORP, H., & KOK, I. (1990). Failing to notice errors in sentences. *Language & Cognitive Processes*, **5**, 105-113.

NOTES

1. Of course, Reder and Kusbit's (1991) high-context sentences contained more words than did their low-context sentences, so it is unclear whether it was the number of semantically related words or the sheer number of words that produced the effect. Moreover, there was also a context-strength/materials confound (i.e., the acorn question was always a high-context question, and the Juneau question was always a low-context question). In the present study, we avoided both these confounds.
2. These knowledge access statements are called *high-knowledge access statements* in Hannon and Daneman (2001). One might wonder how university students can get such items as *A jet has a pilot whereas a car doesn't* or *A robin lives in Canada whereas a penguin typically doesn't* wrong, given that these items were designed to test facts that are part of a Canadian university student's world knowledge. However, embedded in the complex paragraph-learning task, the high-knowledge access component has been shown to produce a good range of scores and to correlate with global reading comprehension ability and with specific reading tasks that load heavily on knowledge access (see Hannon & Daneman, 2001). These findings suggest that it is not simply how much relevant prior knowledge the reader has that is related to reading success; equally important is the ability to have ready access to that long-term memory knowledge.
3. Time-out failures accounted for fewer than 1% of the trials for knowledge access statements.
4. Because a "don't know" response is ambiguous with respect to whether the participant was tricked by the anomaly, we did not include "don't know" responses in the analyses of correct detections reported in the paper. However, exploratory analyses showed that even if the "don't know" responses were classified as correct detections along with the correct "wrong" responses, the pattern of results remained the same.
5. Impostor strength was calculated with the following formula: $[(WI/LC + WI/HC) - (SI/LC + SI/HC)]/2$. Context strength was calculated as $[(SI/LC + SI/HC) - (WI/LC + WI/HC)]/2$.

culated with the following formula: $[(WI/LC + SI/LC) - (WI/HC + SI/HC)]/2$.

6. It is often tricky to compare the relative predictive powers of two measures, because such factors as the range and reliability of the measures will affect how well they correlate with the criterion task. Because

we show that the relative predictive powers of the two measures can be switched, depending on the nature of the criterion task, this provides strong evidence that it is the degree to which the individual-differences measures are related to the criterion task, rather than range and reliability differences, that accounts for the pattern of results found here.

APPENDIX

Anomalous Questions Used in Experiments 1 and 2

The first question is the strong-impostor/high-context question. The second question is the strong-impostor/low-context question. The strong-impostor word is in italics and the weak-impostor word is in italics and parentheses.

- 1a. Regina is the capital of what Canadian prairie *city (town)*?
- 1b. Regina is the capital of what well-known *city (town)*?
- 2a. What country includes the *Congo (Thames)* River, sphinxes, pyramids, mummies, pharaohs, and Cleopatra?
- 2b. What is the name of the country known for the *Congo (Thames)* River, sphinxes, and Cleopatra?
- 3a. What short *year (hour)* has only 28 days except during leap years?
- 3b. What very short *year (hour)* has only 28 days in it?
- 4a. Snoopy is a black and white *cat (mouse)* in what famous Charles Schulz comic strip?
- 4b. Snoopy is a *cat (mouse)* in what famous comic strip?
- 5a. Who starred in "Philadelphia," "Apollo 11 (9)," "Forrest Gump," and "Sleepless in Seattle"?
- 5b. Who is known for being in "Apollo 11 (9)" and the very popular "Forrest Gump"?
- 6a. What was discovered when the apple fell on the head of the sitting scientist *Galileo (Aristotle)*?
- 6b. What was discovered when the apple fell on *Galileo (Aristotle)*?
- 7a. What caped crusader has a sidekick "Robin" and protects *Metropolis (Atlantis)*?
- 7b. What hero has a sidekick "Robin" and is associated with *Metropolis (Atlantis)*?
- 8a. Besides high-jump, what other *eight (six)* track and field events are in an Olympic decathlon?
- 8b. Besides high-jump, what are the other *eight (six)* events in a decathlon?
- 9a. What country includes the Great Lakes, Rockies, Yukon, Northwest Territories, and ten *states (cities)*?
- 9b. What includes the Yukon, Northwest Territories, and ten other *states (cities)*?
- 10a. What patriotic American holiday is celebrated with fireworks on the fourth of *June (November)*?
- 10b. What is the name of the American holiday that occurs on the fourth of *June (November)*?
- 11a. How many *letters (words)* are there in a Canadian social insurance number?
- 11b. How many *letters (words)* are there in a social insurance number?
- 12a. During the Biblical flood, how many animals of each kind did *Moses (Adam)* take on the ark?
- 12b. How many animals of each kind did *Moses (Adam)* take on the ark?
- 13a. What does *Dasher's (Frosty's)* nose do to guide Santa's sleigh on foggy Christmas eves?
- 13b. What does *Dasher's (Frosty's)* nose do to help with Santa's sleigh?
- 14a. When did the *Germans (Italians)* bomb the American naval base "Pearl Harbor"?
- 14b. When did the *Germans (Italians)* attack Pearl Harbor?
- 15a. By flying a kite and key during a lightning storm, what did *Edison (Einstein)* discover?
- 15b. By flying a kite what is *Edison (Einstein)* known for discovering?
- 16a. What board game includes *cardinals (monks)*, rooks, pawns, knights, kings, and queens?
- 16b. What game includes such common things as *cardinals (monks)*, rooks, and pawns?
- 17a. What famous, 1960s British rock group did Paul McCartney sing and play *drums (flute)* with?
- 17b. What is the name of the British group that McCartney played *drums (flute)* with?
- 18a. In what ancient Mediterranean mythology is Venus the goddess of *war (wine)*?
- 18b. In what mythology is Venus known as the goddess of *war (wine)*?
- 19a. What large brown animal has *three (five)* humps and is desert transportation?
- 19b. What is the name of the animal that has *three (five)* humps?
- 20a. What are the scary carved pumpkins displayed in windows at *Thanksgiving (Christmas)*?
- 20b. What is the name of the carved pumpkin displayed at *Thanksgiving (Christmas)*?
- 21a. When did the Toronto *Argonauts (Raptors)* win the World Series championship?
- 21b. When did the *Argonauts (Raptors)* win the World Series?
- 22a. How many partridges in a pear tree in "The *Ten (Seven)* Days of Christmas"?
- 22b. There are how many partridges in "The *Ten (Seven)* Days of Christmas"?
- 23a. On what holiday do children go door-to-door, dressed in costume, *giving out (buying)* candy?
- 23b. On what occasion do children go door-to-door *giving out (buying)* candy?
- 24a. Who created Mickey Mouse, Goofy, *Tweety (Big Bird)*, Minnie Mouse, and Uncle Scrooge?
- 24b. What is the name of the person who created Mickey Mouse, *Tweety (Big Bird)*, and Goofy?
- 25a. What sport uses a black, *five-holed (one-holed)* ball for knocking down ten white pins?
- 25b. What is the name of the sport that includes a *five-holed (one-holed)* ball and pins?
- 26a. What *card (marble)* game scores points by horizontally and vertically laying out beige tiles to form words?
- 26b. What is the name of the *card (marble)* game that involves using tiles to form words?
- 27a. What black and white Chinese bear is nearly extinct because it eats only *palm (olive)* shoots?
- 27b. What is the name of the Chinese bear that eats only *palm (olive)* shoots?

APPENDIX (Continued)

-
- 28a. What *country (island)* includes Argentina, Bolivia, Peru, and Brazil?
- 28b. What is the name of the *country (island)* that includes Argentina and Brazil?
- 29a. What sci-fi series features Kirk, Scotty, Sulu, and a logical, pointed-eared *Klingon (Gemhidar)*?
- 29b. What is the name of the show that includes Kirk and a pointed-eared *Klingon (Gemhidar)*?
- 30a. What leafy, green vegetable, high in iron, makes Popeye *weak (cringe)*?
- 30b. What is the name of the vegetable that makes Popeye *weak (cringe)*?
- 31a. What vital, “beating” organ pumps blood and has *two (seven)* chambers?
- 31b. What is the name of the “beating” organ that has *two (seven)* chambers?
- 32a. What hot southern country has wild *cats (horses)* called “dingoes” roaming its deserts?
- 32b. What country is known for its wild *cats (horses)* that are called “dingoes”?
- 33a. Clark Kent becomes what blue-tighted hero when he changes in a *toll (kissing)* booth?
- 33b. What well-known hero is always associated with changing in a *toll (kissing)* booth?
- 34a. What passenger liner was tragically sunk by an iceberg in the *Pacific (Indian)* Ocean?
- 34b. What is the name of the ship that encountered an iceberg in the *Pacific (Indian)* Ocean?
- 35a. Who has a red suit, long white beard, and *birthday (anniversary)* presents on his sleigh?
- 35b. What is the name of the man who gives out *birthday (anniversary)* presents from his sleigh?
- 36a. What water bird is on the *two-dollar (five-dollar)* Canadian coin?
- 36b. What is the name of the bird found on the *two-dollar (five-dollar)* coin?
- 37a. What teddy-like bear eats eucalyptus leaves, represents Qantas airlines, and lives in *Africa (Europe)*?
- 37b. What is the name of the eucalyptus-eating bear that only lives in *Africa (Europe)*?
- 38a. What creature is known for disliking crosses, *hating (donating)* blood, and sleeping in coffins?
- 38b. What is associated with disliking crosses and *hating (donating)* blood?
- 39a. Who found the glass slipper left at the ball by *Snow White (Goldilocks)*?
- 39b. What person found the slipper left behind by *Snow White (Goldilocks)*?
- 40a. What smiling “Mona” portrait, hanging in the Louvre, did the Italian *Rembrandt (Mozart)* paint?
- 40b. What is the complete name of the “Mona” that *Rembrandt (Mozart)* is known for painting?
- 41a. What sci-fi movie features Luke Skywalker, the robot R2D3 (7), Solo, Chewbacca, and Darth Vader?
- 41b. What is the name of the movie that includes Skywalker, R2D3 (7), and Chewbacca?
- 42a. In Charles Dickens’s “A Christmas *Song (Harmony)*” how many ghosts visited miserly Scrooge?
- 42b. In “A Christmas *Song (Harmony)*” how many ghosts visited Scrooge?
- 43a. Who lives in Sherwood Forest, has merry men, and *steals (buys)* from the poor?
- 43b. Who lives in Sherwood Forest and *steals (buys)* from the poor?
- 44a. What ice sport includes camel spins, double *anvils (hammers)*, and triple lutzers?
- 44b. What is the name of the sport that involves double *anvils (hammers)* and lutzers?
- 45a. What mythical kingdom includes Arthur, Lancelot, and *princes (peasants)* of the round table?
- 45b. What is the name of the kingdom that has *princes (peasants)* of the round table?
- 46a. What dinosaur movie, starring raptors and T-Rexes, was directed by Steven *King (Hawking)*?
- 46b. What is the name of the very popular dinosaur movie directed by Steven *King (Hawking)*?
- 47a. What winter weather phenomenon is very dangerous for growers of Sunkist *pineapples (apples)*?
- 47b. What is the name of the phenomenon that is very dangerous for Sunkist *pineapples (apples)*?
- 48a. What movie includes a *brainless (wicked)* tinman, Dorothy, a cowardly lion, and munchkins?
- 48b. What is the name of the movie that includes a *brainless (wicked)* tinman and Dorothy?
- 49a. What famous black singer started as a child in the Jackson *Four (Three)*?
- 49b. What is the name of the singer who first started with the Jackson *Four (Three)*?
- 50a. What large, ferocious, white bear lives near the icy *South (West)* Pole?
- 50b. What is the name of the white bear that lives near the *South (West)* Pole?
- 51a. What small animal hides acorns from *pine (elm)* trees for his winter food supply?
- 51b. What is the name of the animal that hides the acorns from *pine (elm)* trees?
- 52a. What ancient *Grecian (French)* city was destroyed when Mount Vesuvius erupted in 79 AD?
- 52b. What is the name of the *Grecian (French)* city that was destroyed by Vesuvius?
- 53a. What blonde, sex symbol named “Marilyn” had an affair with *premier (prince)* Kennedy?
- 53b. What well-known “Marilyn” is known for having an affair with *premier (prince)* Kennedy?
- 54a. In the 1950s sci-fi movies, what *Chinese (Cambodian)* city was terrorized by the giant lizard “Godzilla”?
- 54b. What is the name of the *Chinese (Cambodian)* city that “Godzilla” constantly terrorizes?
- 55a. When did the Apollo 11 astronaut *Louie (Dennis)* Armstrong walk on the moon?
- 55b. When did *Louie (Dennis)* Armstrong walk on the moon?
- 56a. What board game features Park *Avenue (Gardens)*, Boardwalk, hotels, houses, and Community Chest?
- 56b. What is the name of the game that includes Park *Avenue (Gardens)* and Boardwalk?
-