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ScienceDirect

Journal of Memory and Language 59 (2008) 18–35

Journal of Memory and Language

www.elsevier.com/locate/jml

Veridical and false memory for text: A multiprocess analysis ☆

Murray Singer [a,*], Gilbert Remillard [b]

[a] Department of Psychology, University of Manitoba, Winnipeg, Canada R3T 2N2
[b] Morehead State University, Morehead, KY 40351, USA

Received 14 June 2007; revision received 1 November 2007
Available online 24 March 2008

Abstract

People report recognizing discourse inferences at rates that approach target acceptance. Brainerd et al. [Brainerd, C. J., Wright, R., Reyna, V. F., & Mojardin, A. H. (2001). Conjoint recognition and phantom recollection. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *27*, 307–329] proposed that memory retrieval in contexts associated with very high levels of false memory involve a process of illusory recollection which complements the impact of recollection and familiarity [Jacoby, L. L. (1991). A process dissociation framework: Separating automatic from intentional uses of memory. *Journal of Memory and Language, 30*, 513–541]. Experiments were conducted to compare three multiprocess models of text retrieval: A three-process "phantom recollection" model; and two dual-process models, respectively lacking mechanisms of veridical recollection and phantom recollection. Participants read lists of brief texts and then evaluated explicit, implicit, and foil memory probes. Different participant groups were instructed to use verbatim, verbatim plus gist, or gist-only memory-criteria. Multinomial processing tree analysis indicated that both immediate and delayed testing require the involvement of phantom recollection (Experiments 1 and 2, respectively). When the participant's extraction of text meaning is impaired, a dual-process model is adequate to fit the data (Experiment 3).

Keywords: Text; Memory; Recognition; Inference; Representation; Process dissociation; False memory; Dual-process

Introduction

It is well-established that people report recognizing discourse inferences at rates that approach target acceptance (Johnson, Bransford, & Solomon, 1973; Singer, 1979). These observations promoted programmatic research concerning the processing and representation of inferences in language comprehension (see Singer, 2007b, for a review). Particularly striking have been findings that certain discourse inferences are, according to various measures, indistinguishable from explicit text ideas. These outcomes have characterized both coherence-preserving inferences (e.g., Keenan & Kintsch, 1974; Potts, Keenan, & Golding, 1988; Singer, 1980) and strongly constrained elaborative inferences (e.g., Garrod, O'Brien, Morris, & Rayner, 1990; McKoon & Ratcliff, 1988; O'Brien, Shank, Myers, & Rayner, 1988; Whitney, 1986).

In spite of these similar acceptance rates of explicit and implicit text ideas, there are reasons to expect repre-

☆ This research was supported by a Discovery Grant from the Natural Sciences and Engineering Research Council of Canada (NSERC) to the first author. We thank Launa Leboe for her conscientious work in collecting and tabulating the data for these experiments.
* Corresponding author.
E-mail address: m_singer@umanitoba.ca (M. Singer).

0749-596X/$ - see front matter © 2008 Elsevier Inc. All rights reserved.
doi:10.1016/j.jml.2008.01.005

sentational differences between the two. Schmalhofer, McDaniel, and Keefe (2002) proposed that whereas explicit ideas find expression at the surface, propositional ("textbase"), and situational levels of discourse representation, implicit ideas may be constructed predominantly in the situation model (see also van Dijk & Kintsch, 1983). In this regard, investigators have begun to explore the contributions of different memory processes to text retrieval. For example, McDermott and Chan (2006) had younger and older participants study sentences such as *The karate champion hit the cinder block*. The sentences were presented either once or three times. The probability of later falsely recognizing pragmatic inferences such as *The karate champion BROKE the cinder block* decreased in younger participants and increased in older participants with increased repetition of the corresponding study sentences.

McDermott and Chan (2006) interpreted these results within a dual-process framework. This framework holds that memory retrieval is supported by the *familiarity* of a test probe and by the *recollective* experience that one has previously encountered the probe (Jacoby, 1991). According to McDermott and Chan, repetition of study material increased both recollection and familiarity of the material. Thus, younger participants were better able to recollect thrice-presented than once-presented sentences upon encountering the associated test inferences, and therefore less likely to falsely recognize the former set of inferences (see also Brainerd, Reyna, & Estrada, 2006). In contrast, older participants were mainly influenced by the familiarity of the inferences, because of deficits in recollection. Familiarity was greater for inferences associated with thrice-presented than once-presented sentences, producing greater false recognition of the former set of inferences.

Thus, familiarity and recollection of studied material associated with implicit test probes appear to contribute to probe recognition. The recollection in question is *veridical*, in that it pertains to the reinstatement of studied material related to a test probe. Brainerd, Reyna, and Mojardin (1999) implemented familiarity and veridical recollection mechanisms in their conjoint recognition model. The model was able to account for people's recognition of unstudied distractors that were related to studied words.

A remember-know study, in which participants indicate whether recognized probes were distinctly remembered or more vaguely "known," suggested that another form of recollection might be involved in the recognition of inferences (Chan & McDermott, 2006). The participants studied sentences such as *The new baby stayed awake all night*, and then took a recognition test comprised of studied sentences and pragmatic inferences (e.g., *The new baby CRIED all night*). The proportion of acceptances eliciting remember responses was similar for hits (i.e., correct recognition of studied sentences) and false alarms (i.e., false recognition of inferences). Chan and McDermott suggested that remember responses accompanying false alarms could be due either to the familiarity or to the *phantom recollection* of pragmatic inferences. Phantom recollection refers to a process of illusory recollection, distinct from recollection and familiarity, that contributes to the retrieval of distractors closely related in meaning to studied stimuli (Brainerd, Wright, Reyna, and Mojardin, 2001). Chan and McDermott proposed that it was difficult to determine the relative contributions to remember responses of familiarity versus phantom recollection.

We used the extended process-dissociation model (Buchner, Erdfelder, & Vaterrodt-Plunnecke, 1995) to directly assess the contributions of familiarity and phantom recollection to the recognition of bridging inferences: that is, ones that identify the interrelations among discourse ideas (Singer & Remillard, 2004). Inference recognition was accompanied by significant levels of phantom recollection, but very low levels of familiarity. There were, however, two limitations of our approach. First, the model had zero degrees of freedom. Although it was possible to assess the magnitude of the model parameters and to test hypotheses about them, it was not possible to evaluate the fit of the full model. Second, implicit recognition probes appeared as single words rather than more meaningful phrases, potentially underestimating the influences of familiarity and phantom recollection (Singer, 2007a).

The conjoint recognition model (Brainerd et al., 1999) and the process dissociation inference model (Singer & Remillard, 2004) both implement familiarity mechanisms. However, with regard to implicit test probes, the former posits only a veridical recollection mechanism and the latter posits only a phantom recollection mechanism. In contrast, the phantom recollection model (Brainerd et al., 2001) implemented both recollection mechanisms. The phantom recollection model provided a better fit to recognition data derived using the *D*eese–*R*oediger–*M*cDermott (DRM) critical-lure paradigm (Deese, 1959; Roediger & McDermott, 1995) than did the conjoint recognition model. The DRM paradigm produced high levels of phantom recollection for critical lures and so the conjoint recognition model, lacking a phantom recollection mechanism, provided a poor fit to the data.

The present study had three goals. The first was to use the phantom recollection model to extract quantitative assessments of the contributions of recollection, familiarity, and phantom recollection to the recognition of inferences. The second goal was to compare the fits to the data of the phantom recollection model, the conjoint recognition model, and Singer and Remillard (2004) process dissociation inference model. The two limitations of Singer and Remillard (2004) that were noted earlier were overcome here. If recollection is an important process in inference recognition, then the process dissociation inference model should provide a poor fit to the data, because it lacks that mechanism. Analogously, if phantom recollection is an important process in inference recognition, then conjoint recognition should yield inadequate fits to the data. Conversely, if conjoint recognition and/or the process dissociation model fit the data, then those models would be preferred over the more complex phantom recollection model.

The third goal was to compare the processing profiles of the retrieval of explicit versus implicit text ideas. We scrutinized inferences that bridge text sequences with reference to causal and motivational relations, such as an inference about an appointment with reference to *Terry was unhappy with his dental health. He phoned the dentist*.

The privileged status of bridging inferences was not at issue. Rather, the present focus was on subtle differences between the representational profile of explicit ideas and bridging inferences with reference to the widely-endorsed multilevel representation that results from text comprehension (Schmalhofer et al., 2002; Singer & Halldorson, 1996; van Dijk & Kintsch, 1983; Zwaan & Radvansky, 1998). As discussed earlier, Schmalhofer et al. identified reasons to expect such representational differences. We presented preliminary evidence that explicit text ideas exceed bridging inferences both in recollection and familiarity (Singer & Remillard, 2004, Experiments 2 and 3). Here, we extend that investigation, using a more sophisticated methodological and theoretical framework.

The conjoint recognition methodology

We inspected people's understanding of text sequences such as (1a) and (1b) (Singer & Remillard, 2004, Experiment 2).

(1a) Terry was unhappy with his dental health. He phoned the dentist for an appointment. (explicit)
(1b) Terry was unhappy with his dental health. He phoned the dentist. (implicit).

Test item (1c) was an explicit or implicit probe in the context of (1a) and (1b), respectively. Alternatively, it could function as a foil by appearing in the absence of any "dentist" passage.

(1c) Phoned the dentist for an appointment (test probe).

We capitalized on a *methodological development* particularly relevant to participants' evaluation of distractors that are closely related in meaning to the original stimuli: namely, the conjoint recognition procedure of Brainerd et al. (1999). The traditional process dissociation method (Jacoby, 1991) requires probe evaluation either inclusively (presence in any experimental list) or exclusively (presence in a specific list). Conjoint-recognition, in contrast, presents participants with one of *three* instructions about the criteria for evaluating memory probes: Verbatim, a typical recognition criterion; verbatim plus gist, which represents a plausibility or verification orientation; and the less usual gist-only criterion. Gist-only participants are instructed to answer "yes" if a test probe is related to an experimental stimulus but is not explicitly present. In a DRM critical-lure experiment, for example, they should reply "yes" to the critical lure *sleep* with reference to a list of *sleep* words but "no" to words that actually appeared in the list (e.g., Brainerd et al., 2001).

The application of the conjoint recognition method to the present issues is depicted in Table 1. Table 1 shows the answers that participants are instructed to give for probes of three types in relation to their antecedent messages: explicit, implicit, plus distractor probes for passages that were entirely *absent* from the stimulus list. In Table 1 and throughout, the verbatim, verbatim plus gist, and gist-only instructions are labelled "recognition," "verification," and "imply," as befits the text retrieval context.

Recognition and verification instructions are used routinely in the study of text recognition (e.g., Reder, 1982; Singer, 1979). Table 1 shows that recognition participants are of course expected to answer "yes" only for probes that exactly match an antecedent passage. Verification participants answer "yes" to all probes true of their antecedent, whether verbatim or not. The gist-only "imply" instruction is also suitable for the inspection of text retrieval (e.g., Hayes-Roth & Thorndyke, 1979). Table 1 shows that, under this instruction, readers should reply "yes" to the test probe, *phoned the dentist FOR AN APPOINTMENT* with reference to the text sequence, *Terry was unhappy with his dental health. He phoned the dentist*. However, they should reply "no" if the appointment has been mentioned in the text.

Table 1
Officially correct conjoint-recognition replies to the probe, *phoned the dentist for an appointment*, as a function of relation and instruction

Relation	Passage	Instruction		
		Recognize	Verify	Imply
Explicit	Terry was unhappy with his dental health. He phoned the dentist for an appointment.	Yes	Yes	No
Implicit	Terry was unhappy with his dental health. He phoned the dentist.	No	Yes	Yes
Absent	*Null*	No	No	No

An important impact of the conjoint recognition method is that it increases the number of observational conditions relative to the number of parameters of pertinent models. This enables the statistical evaluation of the fit of the models to the data.

Multiprocess models of text retrieval

A central goal of this study was to evaluate the process dissociation, conjoint recognition, and phantom recollection models in the context of text retrieval. In what follows, we describe the commonalities and then the distinctive features of the models.

Features common to the models

All three models make prominent reference to the contributions of familiarity and recollection ("recollection" and "veridical recollection" will be used interchangeably) to text retrieval. Yonelinas (2002) described recollection as a controlled process that depends on detecting associations between the test probe and the learning context. In contrast, he characterized familiarity as an automatic signal detection process, according to which a continuous measure of measure of strength is compared with a decision criterion.

The models specify distinct guessing parameters for the Recognize, Verify, and Imply instructions of the conjoint recognition procedure. For any fixed set of test probes, the ratio of officially correct "yes" responses relative to "no" responses is bound to differ among the conjoint recognition instruction conditions, possibly producing different likelihoods of guessing. Consistent with this observation, different rates of false alarms have been measured in the inclusion versus exclusion instructional conditions of process dissociation (Dehn & Engelkamp, 1997; Graf & Komatsu, 1994; Singer & Remillard, 2004; cf. Toth, Reingold, & Jacoby, 1994). Using the computational techniques that we will describe next, the equality of guessing parameters across conditions becomes a hypothesis to test rather than an assumption (Buchner et al., 1995).

The models were evaluated using the multinomial processing tree analysis (MPT; Buchner et al., 1995; Hu & Phillips, 1999). The trees are figures that identify all of the processing routes that result in each possible response (e.g., "yes", "no") for each type of probe. For each of the three models, the analysis specified nine processing trees, representing the 3×3 crossing of relation (explicit, implicit, absent) and conjoint recognition instruction (Recognize, Verify, Imply). However, exposition requires the detailed scrutiny of only two trees per model: namely, the implicit-probe condition (in view of the present emphasis on inference from text) under the Recognize and the Imply instructions. The MPT formulas for the full set of nine conditions appear in the Appendix. It is easiest to begin with the conjoint recognition model.

Conjoint recognition model

Conjoint recognition (Brainerd et al., 1999) applied MPT modelling and its associated statistical analysis to word recognition. In addition to the usual list-targets and foil items, it highlighted the recognition of distractors that are related to list items (cf. Underwood, 1965); such as synonyms, antonyms, and categorically related words.

Like in other process dissociation analyses, recollection and familiarity are the central mechanisms of conjoint recognition. However, Brainerd et al. (1999) characterized recollection and familiarity as being in opposition with regard to related distractors. For example, having encountered a list of dog names, the related distractor "spaniel" might appear familiar during testing. However, if "spaniel" prompted the recollection of the list item "beagle," the correct rejection of "spaniel" might result. This principle of recognizing to reject is the subject of increasing scrutiny in the analysis of memory performance (Brainerd, Reyna, Wright, & Mojardin, 2003; Brainerd et al., 2006; Lampinen, Watkins, & Odegard, 2006).

The processing of implicit probes under the Recognize instruction is addressed by Fig. 1a and Appendix formula (A4). The top branch of the figure conveys that the probe is recollected with probability R_b and that this perhaps counterintuitively results in the response "no." This signifies that the implicit probe has resulted in the recollection of the precise form of the original text. This permits the detection of a discrepancy between the (implicit) probe and the text, and therefore the rejection of the probe. This is an instance of the aforementioned recollection-to-reject.

The next branch indicates the following: Probe familiarity in the absence of recollection (probability $(1 - R_b)(F_b)$) prompts a "yes" reply. At the following branch, in the absence of both recollection and familiarity, it will be guessed with probability G_r that the probe is old; and with probability $(1 - G_r)$ that the probe is new.

Fig. 1b and Appendix formula (A6) identify the conjoint recognition processing routes for implicit probes *under the imply instruction*. According to the top branch, recollection in response to an implicit probe makes manifest that the probe is implied by the original text. The imply instructions stipulate acceptance of the probe in this circumstance. The remaining branches of Fig. 1b are identical to those of Fig. 1a.

The contribution of phantom recollection to the judgement of implicit probes will be examined with respect to the next model. It is noteworthy, however, that the conjoint recognition model lacks that mechanism.

Phantom recognition model

Like other multiprocess models, phantom recollection endorses the contributions of recollection and

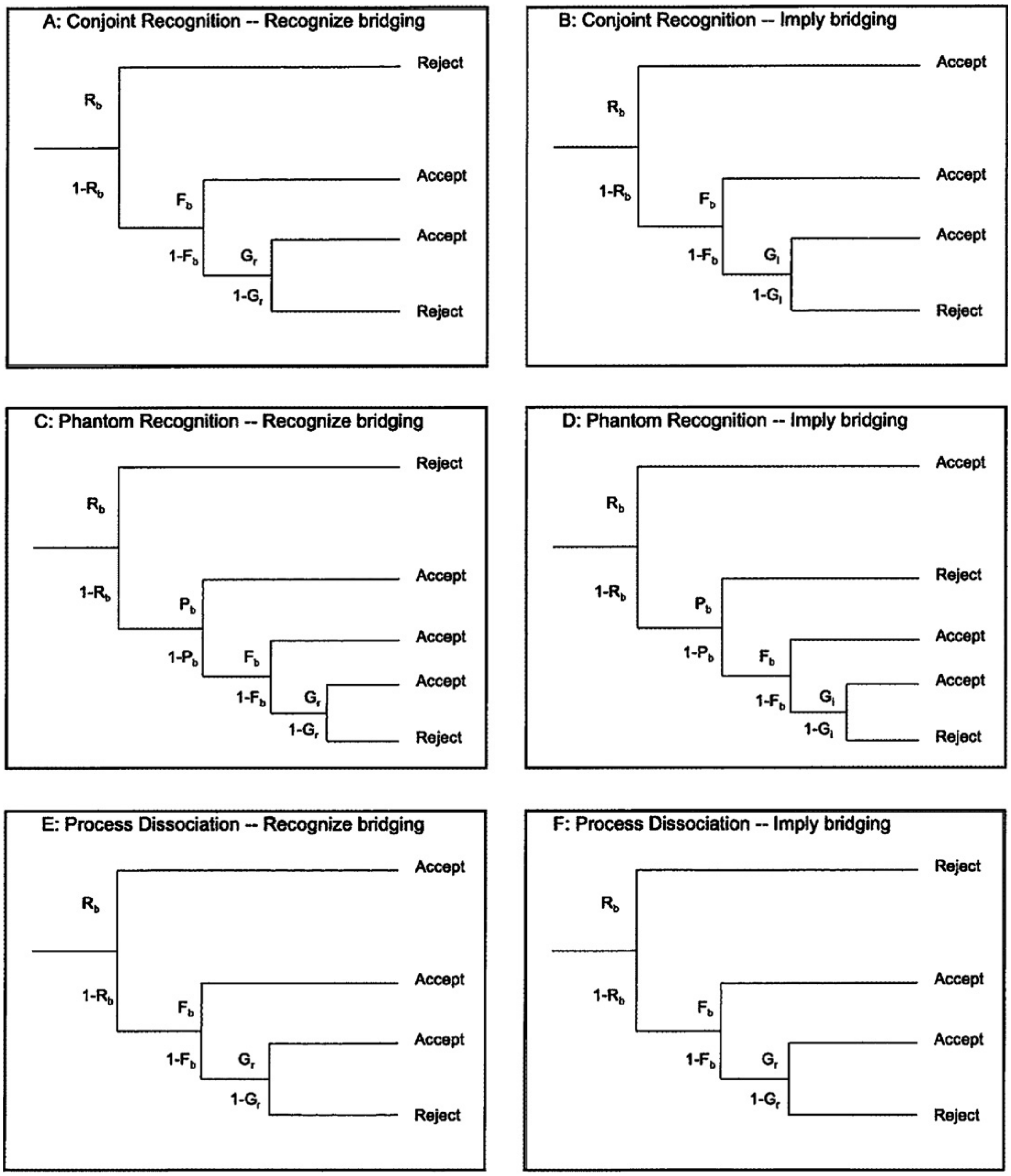

Fig. 1. Multinomial processing trees for the conjoint recognition, phantom recollection, and process dissociation models. Trees are shown only for bridging inference (implicit) probes under the Recognize and Imply instructions of the conjoint recognition procedure. The branches are labelled with the parameters R (recollection), F (familiarity), and G (guessing). The parameters P (phantom recollection) and E (erroneous recollection of related targets) are relevant only to the phantom recollection model (C and D; see text). Subscript b refers to the bridging inference probe conditions. The subscripts r and i refer to the recognize and imply instruction conditions, respectively.

familiarity to memory performance. It is novel in emphasizing those circumstances that are associated with very high rates of false memory for related distractors (Brainerd et al., 2001).

The model's central distinctive mechanism, phantom recollection, refers to the illusory vividness of nonpresented items. Phantom recollection may include spurious experiences about the physical form of the stimulus, such as its presentation font or color. However, phantom recollection is posited to accrue from gist representations (Brainerd et al., 2001, p. 315). Alone among the three models under consideration, phantom recollection addresses the contribution to the judgement of text implications of both veridical and illusory recollection mechanisms.

Recognizing implicit probes is addressed by Fig. 1c and Appendix formula (A13). The critical difference from conjoint recognition (Fig. 1a) is as follows: In the absence of recollection, the participant will, with probability $(1 - R_b)P_b$, be in a state of illusory recollection of the probe (second branch). This circumstance should, of course, lead to the acceptance of the probe. The proposal of phantom recollection is a strong claim: It adds a parameter to the model. Phantom recollection has received support from the study of memory for word lists (Brainerd et al., 2001) and text (Brainerd et al., 2006; Chan & McDermott, 2006; Singer & Remillard, 2004).

The remainder of Fig. 1c is identical to the corresponding parts of Fig. 1a. Under the imply instruction (Fig. 1d; Appendix formula (A15)), there are two differences from Fig. 1c. First, text recollection in response to an implicit probe (top branch) permits the response "yes," because the implication of the probe by the text should be manifest. Second, phantom recollection of the probe in the absence of text recollection (second branch) leads to rejection of the probe because the probe is believed to have been studied.

Process dissociation inference model (Singer & Remillard, 2004)

With hindsight, this analysis may be diagnosed to combine elements of classic process dissociation models (Buchner et al., 1995; Jacoby, 1991), on the one hand; and Brainerd et al.'s (2001) phantom recollection model, on the other. Specifically, Singer and Remillard's model included an element of misrecollection or illusory recollection. We proposed that an inference probe could be misrecollected as having been encountered in the reading of the original texts, yielding a "yes" response on a standard recognition test. This was necessary to account for people's frequent incorrect recognitions of implicit probes. However, the model was missing an element of recognizing-to-reject: It did not allow for the participant's recollection of the instantiating text of an inference probe and consequent rejection of the probe on the recognition test.

It was easy to extend the spirit of Singer and Remillard's (2004) model to the present design. Fig. 1e and Appendix formula (A22) consider implicit probes under the recognize instruction. Text recollection leads to acceptance of the probe. Comparing the top branches of Fig. 1e and 1a exposes the difference between this model and conjoint recognition for the recognize instruction. Conversely, the top branch of Fig. 1f (see also Appendix formula (A24)) shows that, on the assumption that implied probes are phantomly recollected, the participant will reply "no"; in contrast with the acceptance posited by conjoint recognition (Fig. 1b).

Conclusions

It is noteworthy that the conjoint recognition model (Brainerd et al., 1999) and the process dissociation inference model (Singer & Remillard, 2004) successfully addressed high rates of recognition of related distractors in word memory and text retrieval paradigms, respectively. Accordingly, these models comprise defensible rather than arbitrary competitors of phantom recollection in this domain.

Three experiments were conducted to permit a comparison among the competing models. Experiment 1 inspected people's evaluation of explicit, implicit, and foil test items with respect to brief texts. Experiments 2 and 3 were similar except that they imposed conditions of delayed retrieval and shallow text processing, respectively.

Experiment 1

Experiment 1 evaluated the phantom recollection, conjoint recognition, and process dissociation models with reference to people's retrieval of text statements.To accomplish this, we applied Brainerd et al.'s (1999) conjoint recognition *procedure* to the study of memory for text. Adults read brief texts and then evaluated memory probes under the recognize, verify, and imply instructions. Explicit and bridging-inference test items were the respective counterparts of the targets and related distractors of Brainerd et al.'s (2001) inspection of word memory in the DRM critical-lure paradigm.

It was noted earlier that Brainerd et al. (2001) introduced the phantom recollection model because the conjoint recognition model did not address illusory recollection. Likewise, Singer and Remillard's (2004) model lacked a recognize-to-reject mechanism, which constitutes recollection as it pertains to implicit test items. Because we considered text retrieval to involve both of these mechanisms, we anticipated that the conjoint recognition model and the process dissociation would not fit the data of Experiment 1. The phantom recollection model, in contrast, was expected to fit those data.

Method

Participants

The participants were 124 male and female native-English-speaking students of introductory psychology at the University of Manitoba. They took part in partial fulfillment of a course requirement.

Materials

The experimental materials were derived from 15 of the 16 passages of Experiment 2 of Singer and Remillard (2004). Set (1), repeated here, provides an example.

(1a) Terry was unhappy with his dental health. He phoned the dentist for an appointment. (explicit)
(1b) Terry was unhappy with his dental health. He phoned the dentist. (implicit).
(1c) phoned the dentist for an appointment (test probe).

Alternate versions of each passage were explicit and implicit with regard to a crucial idea. For example, *appointment* is explicit in (1a) and implicit in (1b). A test probe for each passage (e.g., 1c) directly mentioned the crucial idea.

Three counterbalanced lists were constructed from these materials. For list 1, groups of five passages were randomly assigned to appear in the conditions "explicit," "implicit," and "absent," with each group of passages constituting a counterbalancing "verbal set." The passages were randomly assigned to a list position, subject to the restriction that at least two passages of each condition appear in each half of the list (treating the seventh passage as the end of the first half). Absent passages were simply omitted from the study list. However, their probes appeared during testing. As a result, the explicit, implicit, and foils probes served as their own controls. Following this scheme, the experimental portion of the study list comprised ten passages. Finally, the list both began and ended with three filler passages.

The test list comprised the test probes (e.g., 1c) of the 15 passages. They appeared in a fixed random order. Preceding these experimental probes were six filler probes of similar form. With reference to the filler passages from study, there were two filler probes mimicking each of the experimental conditions.

The other two study lists were constructed by cycling the experimental passages across condition, following a Latin-square pattern. There were no changes in the filler passages across study lists. The test lists for the three study lists were identical.

Procedure

The participants were randomly assigned to one of nine possible combinations of study list and test instruction. They were tested in groups of one to four in separate closed rooms. Each station consisted of a 486 personal computer,[1] monitor, and keyboard. The monitors screens were situated 22 cm from the near edge of the computer tables. All experimental events were controlled by MEL software (Schneider, 1988).

Each session consisted of a study phase and a test phase. Each study trial began with the display of "READY" in the middle of the screen. Upon the press of the ready key (the keyboard space bar), a fixation "X" appeared for 500 ms at row 10, column 1 of the screen. Then, the first sentence of the passage was displayed until the participant signalled comprehension by pressing "ready" again. The second sentence immediately replaced the first. Then, the participant rated the degree of activity conveyed by the passage on a four-point scale, using the left-most numeric keys 1–4 on the top keyboard row to, respectively, register ratings from least to most active.

After study, the participants read test instructions on printed sheets. It was explained that the participant had to judge test phrases that referred to the study passages. Recognize participants were instructed to answer "yes" only to phrases that repeated, verbatim, part of their passage. Verify participants were instructed to answer "yes" both for verbatim phrases and for phrases true with reference to their passages. Imply participants were instructed to reply "yes" only if a probe expressed an implication of its passage context but did *not* repeat the passage verbatim.

The instructions included one example representing each of the explicit, implicit, and absent conditions; along with its officially correct answer. Because the imply instructions are challenging, participants in *all three* conditions then wrote answers for three more sample items. If a participant was incorrect on any sample item, the experimenter administered another set of three items. If further errors were made, the experimenter briefly discussed these departures with the participant.

At the outset of each test trial, a fixation "X" appeared for 500 ms at row 10, column 1 of the screen. It was replaced immediately by the test probe. Guided by their instructions, the participants replied "yes" or "no" to the probe, using keyboard keys "." and "x", respectively. The test probe disappeared immediately upon the registration of a reply. One second later, the fixation point initiated the next trial. All responses were automatically recorded by the computer.

Results

Acceptance rates

The rates of responding affirmatively in each condition appear in Table 2. In participants-random (*F1*)

[1] The timing algorithms of MEL require an operating system no more recent than Windows 3.1 (or possibly Windows 95/98) run on a 486 or earlier generation PC.

Table 2
Proportion of acceptances as a function of instruction and relation

Experiment	Measure			
	Instruction	Explicit	Implicit	Absent
Experiment 1	Recognize	.744	.433	.056
	Verify	.805	.710	.130
	Imply	.439	.613	.288
Experiment 2	Recognize	.477	.450	.209
	Verify	.572	.530	.205
	Imply	.559	.441	.377
Experiment 3	Recognize	.783	.494	.117
	Verify	.833	.594	.189
	Imply	.422	.544	.267

analyses of variance (ANOVA) of these data, list (the counterbalancing variable) and instruction were between-participants variables and relation (explicit, implicit, absent) was a within-participants variable. In corresponding items-random analyses (*F2*), verbal set was a between-items variable and instruction and relation were within-items variables. The *minF'* statistic was derived from the latter ANOVAs (Clark, 1973). Effects involving the counterbalancing variables, list and verbal set, are not reported because they held no theoretical interest. The significance criterion was $\alpha = .05$ except where otherwise noted.

ANOVA revealed main effects of instruction, $minF'(2, 61) = 3.92$, and relation, $minF'(2, 91) = 88.66$. The Instruction × Relation interaction was significant, $minF'(4, 169) = 12.34$. This was appreciably because, in compliance with the imply instruction, participants accepted the explicit probes relatively less often than under the other instructions.

A test of simple main effects revealed an instruction effect in the absent condition, $minF'(2, 127) = 10.41$. In particular, the acceptance rate for these foils was lowest in the recognize condition and highest in the imply condition.

Model analyses

Modelling was performed using the General Processing Tree software of Hu and Phillips (1999).[2] The software enables parameter estimation using multinomial processing tree analysis (MPT). The fits of the competing models were assessed with G^2, a chi-square goodness-of-fit statistic. In particular, a significant G^2 conveys the lack of fit of a model. Specific null hypotheses such as $R_e = R_b$ or $R_b = 0$ (see Appendix) were evaluated by subtracting G^2 for the full model from the G^2 associated with the submodel constrained by the null hypothesis. The difference between these values is also a G^2 statistic. It has one degree of freedom because the full model and submodel differ by one free parameter.

The formulas of the conjoint recognition model and the process dissociation model (see Appendix) reveal that each model posits seven free parameters. Because the conjoint recognition procedure generates nine observations, corresponding to crossing the variables of Relation × Instruction, two degrees of freedom are associated with the G^2 statistic.

For the phantom recollection model, two additional parameters threaten to saturate the model: phantom recollection, plus the erroneous recollection of other targets that are related to the probe (Appendix of Brainerd et al., 2001: failing to recollect the target probe *collie*, but recollecting that the list did include the related item *poodle*).[3] Because the present stimulus texts were unrelated to one another, we assigned this parameter (E_e) the small, constant value 0.05 throughout modelling. This value agreed closely with that directly measured by Brainerd et al. (2006) in the immediate testing of explicit probes that refer to narratives. As a result of fixing the value of E_e, the degrees of freedom for all phantom recollection full models was 1.

The phantom recollection model satisfactorily fit the data, $G^2(1) = 1.04$. The parameters of the model appear in Table 3. Recollection and familiarity were greater for explicit than implicit items, $G^2(1) = 3.88$ and $G^2(1) = 9.11$, respectively. For implicit items, in turn, recollection, familiarity, and phantom recollection were all significantly greater than 0; $G^2(1) = 27.97$, $G^2(1) = 23.51$, and $G^2(1) = 13.76$, respectively.

As predicted, significant lacks of fit to the data were detected both for the conjoint recognition model ($G^2(2) = 16.57$) and the process dissociation model ($G^2(2) = 30.53$). The predictions were based on the absence, in those models, of different mechanisms pertinent to retrieval of implicit test items.

Discussion

A process of illusory recollection has been posited to contribute to memory performance in circumstances associated with a high degree of recognition of related distractors. In particular, Brainerd et al. (2001) provided evidence that phantom recollection collaborates with recollection and familiarity to support the acceptance of critical distractors in the DRM critical-lure paradigm. In contrast, their own dual-process conjoint recognition model did not adequately fit those data.

We proposed that text retrieval conforms with Brainerd et al. (2001) criterion of exhibiting high degrees of acceptance of related distractors: namely, the acceptance

[2] Website address: http://gpt.xiangenhu.info//.

[3] Parameter E_e in the present Appendix and parameter E_t in formula (A10) of Brainerd et al. (2001).

Table 3
Phantom recollection parameters of Experiments 1–3

Experiment	Study-test interval	Probe type	Recollection	Familiarity	Phantom recollection
1	Immediate	Explicit	.39	.65	
		Implicit	.28	.48	.23
2	2 days	Explicit	.13	.32	
		Implicit	.06[a]	.22	.19
3	Immediate	Explicit	.41	.61	
		Implicit	.06[a]	.41	.09[a]

[a] Statistically indistinguishable from 0.

of test items representing text implications. Experiment 1 supported this contention and yielded results analogous to those of Brainerd et al: The phantom recollection model adequately fit the data but two dual-process models did not.

Several features of the parameter values of the present phantom recollection analysis are noteworthy. First, and most importantly, phantom recollection contributed significantly to the acceptance of implicit probes. Second, significant recollection in the implicit condition (R_b) diagnoses accurate recollection of the text in response to an implicit probe. Such recollection permits the rejection of the probe under the recognize instruction. This outcome supports the role of a recollect-to-reject mechanism in text retrieval. It is one result that favors the phantom recollection model over Singer and Remillard's (2004) analysis.

Third, unlike Chan and McDermott (2006), Brainerd et al. (2001) were able to estimate the proportion of false recognitions attributable to phantom recollection as opposed to familiarity. The respective formulas are derived by decomposing formula (A13) (Appendix) into a phantom recollection component ($(1 - R\text{b})P\text{b}$) and a familiarity component ($(1 - R\text{b})(1 - P\text{b})F\text{b}$) and dividing each one by the proportion of acceptances of implicit probes under the recognize instruction. This yielded values of 0.38 and .60, respectively.[4] Thus, incorrect recognitions of the implicit probes received strong support from familiarity but also accrued appreciably from phantom recollection.

Fourth, the false alarm rates differed significantly among instruction conditions, an outcome that is consistent with other observations (Dehn & Engelkamp, 1997; Graf & Komatsu, 1994; Singer & Remillard, 2004). This result violates an assumption of the original process dissociation formulation (Jacoby, 1991) but is accommodated by the extended process dissociation framework (Buchner et al., 1995).

The false alarm rate of .288 in the Imply condition was high. It reflects that it is difficult for a participant to decide that an arbitrary foil is not implied by any one of numerous texts. A comparable rate of .237 was reported by Brainerd et al. (2006) for the second of pairs of texts. In the extreme, the difficulty of this judgement could interfere with the fitting of the phantom recollection model but there is little indication that it has done so here.

The contribution of familiarity to inference retrieval was appreciable in Experiment 1 but modest to negligible in our process dissociation investigation of these issues (Singer & Remillard, 2004). It is possible that this disparity reflects that the test probes were phrases in Experiment 1 (e.g., *phoned the dentist for an appointment*) whereas Singer and Remillard used word probes (*appointment*). A single *implied* word would minimize the recapitulation of antecedent processes of perception (Yonelinas, 2002) and propositional construction (Masson, 1993) that accompanied prior reading. Evidence based on the embedding of phrase-probes in Singer and Remillard's procedure supported this interpretation (Singer, 2007a).

The possibility that illusory recollection reflects accurate memory for the surrounding encoding context rather than vivid recollection of the related distractor was raised by Geraci and McCabe (2006). They conducted DRM experiments in which they either included or excluded the typical instruction to interpret recollection of adjacent words as partial evidence of having encountered the probe. Consistent with their hypothesis, excluding that instruction reduced false-remember responses to critical lures but not to list targets. In Experiment 1 of our study, the instructions in no way encouraged the participants evaluate the probe with reference to recollection of either the discourse context or related texts in the study list. Therefore, it is unlikely that our measurement of phantom recollection resulted from the recollection of context.

We next considered the impact of a testing delay on the processing profile of text retrieval. Phantom recollection has been proposed to reflect the illusory vividness associated with strong gist memories (Brainerd et al.,

[4] The values of 0.38 and 0.60 would seem to suggest that few false alarms were due to guessing. However, an analogous guessing formula (Brainerd et al., 2001) yielded a value of 0.04 in Experiment 1. That the sum of the three values slightly exceeds 1.00 probably reflects rounding errors.

2001, 2006). Such memories are more resistant to decline with delay than surface representations (e.g., Kintsch, Welsch, Schmalhofer, & Zimny, 1990). Therefore, the phantom recollection model ought to satisfactorily characterize delayed text retrieval.

Experiment 2

Experiment 2 examined the impact of a two-day study-test delay on processing profiles of text retrieval. Two days is a typical interval in delayed text-retrieval research (Kintsch & van Dijk, 1978; Kintsch et al., 1990; Reder, 1982; Singer, Gagnon, & Richards, 2002). Understanders exhibit surface memory that exceeds chance for a period of days after processing (Anderson & Paulson, 1977; Bates, Masling, & Kintsch, 1978; Brainerd et al., 2001; Keenan, MacWhinney, & Mayhew, 1977). Within two to four days of comprehension, however, readers have difficulty distinguishing text sentences from their paraphrases (Kintsch et al., 1990). Memory for propositional content likewise declines appreciably with delay (Kintsch & van Dijk, 1978; Kintsch et al., 1990). In contrast, inferential memories decline relatively little with delay, as indicated by signal detection analyses (Kintsch et al., 1990; Singer et al., 2002). Such inferences are posited to reflect gist representations, particularly situation models (Schmalhofer et al., 2002). Thus, we predicted that phantom recollection would decline little with test delay. On the basis of previous findings, however, it was anticipated that recollection and familiarity would diminish with greater study-test intervals (Yonelinas, 2002).

Method

The method differed from that of Experiment 1 only in that, after study, the participants were reminded to return to continue the experiment two days later. The participants were 131 naive individuals drawn from the same population that had been sampled in Experiment 1.

Results

Acceptance rates

The mean acceptance rates appear in Table 2. ANOVA was applied to these data, the designs being identical to those of Experiment 1. There was a relation main effect, $minF'(2,61) = 15.91$ and an Instruction × Relation interaction, $minF'(4,208) = 2.52$. The instruction main effect was not significant, $minF'(2,57) = 1.13$; although it did reach significance in the participants-random analysis, $F1(2,122) = 3.01$, $MSE = 1.38$. Like in Experiment 1, acceptance rates among the foils varied significantly across the instruction conditions, $minF'(2,75) = 4.30$.

Model analyses

The phantom recollection model satisfactorily fit the data, $G^2(1) = 0.56$. The values of the model parameters appear in Table 3. Neither recollection nor familiarity was statistically greater in the explicit condition than the implicit condition; $G^2(1) = 1.64$ and 2.17, $G^2(1) =$ respectively. For implicit items, both familiarity ($G^2(1) = 7.96$) and phantom recollection ($G^2(1) = 13.16$) significantly exceeded 0. Implicit recollection was not significantly greater than 0, $G^2(1) = 1.41$.

Evaluations of the other models were likewise performed. The conjoint recognition exhibited significant lack of fit to the data, $G^2(2) = 15.11$. However, there was satisfactory fit of the process dissociation model to the data, $G^2(2) = 3.44$.

The phantom recollection model specifies identical processing routes in immediate and delayed testing. Therefore, we were able to perform a joint analysis of the results of Experiments 1 and 2, positing distinct parameter values for the two delays. In both the explicit and implicit conditions, immediate recollection and familiarity were greater than their delayed counterparts, $G^2(1) > 9.11$. Phantom recollection, in contrast, did not decline with delay, $G^2(1) = 0.18$.

Discussion

Several substantive features of the phantom recollection solution merit consideration. First, in contrast with Experiment 1, recollection rejection ($R = 0.06$) was not significant for implicit probes. Brainerd et al. (2006, Table 6) reported a comparable recollection value of 0.14 across several types of implied probe, although they did not report whether this value differed significantly from 0. Recollection reflects both the strength of the supporting representations and the capacity of a retrieval cue to access those representations (Brainerd et al., 2006). Negligible recollection-rejection in Experiment 2 might diagnose that the verbatim representations (Brainerd et al., 1999) or the conceptual representations (Yonelinas, 2002) that support recollection and that permit readers to correctly reject an implicit probe have sufficiently declined after two days to have minimal impact. However, recollection significantly exceeded 0 in the explicit condition. That suggests that the absence of a recollective contribution in the implicit condition resulted partly from the decreased capacity of implicit probes to access their instantiating texts' representations.

Second, the joint analysis of Experiments 1 and 2 revealed that recollection and familiarity declined with delay in all conditions, but that the phantom recollection of implicit probes did not. The decline of recollection and familiarity is consistent with prior findings in the process dissociation literature (see Yonelinas, 2002, p. 463 for a review). This pattern has been attributed to the dependence both of recollection and familiarity on conceptual representations (Yonelinas, 2002). Certain conceptual representations, such as the propositional textbase (Kintsch & van Dijk, 1978; Kintsch et al., 1990; Singer, 1982), are likely to weaken with delay. The decline with delay in familiarity might also reflect the weakening of perceptual representations, which have been hypothesized to support familiarity (Yonelinas, 2002).

The parametric patterns are reflected in certain intriguing patterns in the acceptance rates. In the Imply instruction condition, for example, the explicit acceptance rate was lower than the implicit rate of Experiment 1, but exceeded it in Experiment 2 (.559 versus .441; see Table 2). In the delayed testing of Experiment 2, the high acceptance of explicit probes in the Imply condition reflects the loss of their verbatim representations. Under the Imply instruction, the consistency of the explicit probe with the gist representation of a passage should, in the absence of a verbatim trace, of course result in acceptance.

In the context of those results, it is especially important that phantom recollection did not significantly decline over two days. Likewise, for texts tested both immediately and one week after reading, Brainerd et al. (2006) detected similar levels of phantom recollection. As discussed earlier, Brainerd et al. (2001) proposed that phantom recollection reflects illusory vividness that is associated with strong gist memories. In the realm of text retrieval, situational representations would exemplify such gist memories. Situation models are resistant to decline with test delay. In this regard, Kintsch et al. (1990) showed that people's ability to discriminate true and false text probes diminished little with across appreciable test delays: A quantitative index of situation model strength that Kintsch et al. derived from the participants' performance showed little variation with delay (see also van Dijk & Kintsch, 1983; Zwaan & Radvansky, 1998). In contrast, comparable indices of the strength of the surface and propositional representations declined dramatically with test delay.

Because phantom recollection carries the illusion of verbatim reappearance and verbatim representations decline with delay, one might conclude that phantom recollection likewise ought to decline with delay. The problem with this proposal is that the illusory vividness associated with phantom recollection reflects gist rather than verbatim memories (Brainerd et al., 2001). However, we note that thematically incidental ideas are not robustly captured in text representations (Kintsch, Kozminsky, Streby, McKoon, & Keenan, 1975). Therefore, it is possible that the phantom recollection associated with minor text details might diminish with test delay. The present data do not bear on this issue. In general, the association of phantom recollection with gist representations and numerous findings of the relative permanence of gist-preserving situation models are consistent with the stability, across test delay, of phantom recollection in Experiment 2.

The relative contribution of familiarity versus phantom recollection to the false recognition of implicit probes dropped from over 1.50 in immediate testing (Experiment 1) to approximately 0.85 ($0.34 \div 0.40$) in delayed testing.This change provides another index of the different rates of loss of representations supporting the familiarity and phantom recollection processes.

Recollection and familiarity were numerically larger in the explicit condition than the implicit condition of Experiment 2; but, unlike Experiment 1, these differences were not significant. The nonsignificant *recollection* result may reflect that recollection at least partly taps verbatim representations (Brainerd et al., 2001) which decline rapidly with delay. Explicit familiarity did exceed implicit familiarity by 0.10 in Experiment 2, and the nonsignificance of this difference may constitute a Type II error.

We measured a significant lack of fit to the data of the conjoint recognition model, like in Experiment 1; but not of the process dissociation inference model. The process dissociation model instantiates a phantom recollection mechanism at the cost of the (veridical) recollection of the instantiating texts of the implicit probes. However, the phantom recollection analysis indicated that implicit recollection was indistinguishable from 0. As a result the process dissociation adequately fit the data of Experiment 2.

Experiment 3

The next experiment further contrasted the competing models. There is considerable evidence that the derivation of situational representations is limited in shallow orienting-tasks in reading (Mayer & Cook, 1981; Schallert, 1976; Singer & Halldorson, 1996; Till & Walsh, 1980). In Experiment 3, therefore, the readers were constrained to adopt a proofreading orientation: They were instructed to monitor texts for spelling errors. Two main predictions were made. First, because phantom recollection is posited to reflect situational representations, it was anticipated that phantom recollection would be negligible. Second, because the phantom recollection model with a phantom parameter of 0 is identical to the conjoint recognition model (with the exception of the phantom recollection model parameter E_e, which was set at the near-zero value of .05), the conjoint recognition model was predicted to adequately fit the data, unlike in Experiments 1 and 2.

Method

Participants

The participants were 108 naive individuals from the same population that was accessed for Experiment 1.

Materials

The materials were identical to those of Experiment 1, but spelling errors were introduced to some of the passages. The experimental passages were randomly assigned in equal numbers to exhibit either 0 or 1 spelling errors and the practice and filler passages were randomly assigned to have either 2 or 3 spelling errors. The spelling errors in the experimental passages always appeared in the first sentence, rather than the manipulated second sentence. For those filler passages with three spelling errors, either sentence 1 or 2 was randomly selected to bear two errors. The spelling errors were created by selecting a random content word in the designated sentence. A random consonant in this word was replaced by another random consonant, subject to the restrictions that the new string be pronounceable but not form an English word and that the spelling error be conspicuous (e.g., *restaugant*).

Procedure

Each participant was randomly assigned to one of the nine conditions representing the crossing of List × conjoint-recognition Instruction. The participants were instructed to monitor the passages for spelling errors, in preparation for reporting the number of such errors. Apart from that, they read the passages following a procedure identical to that of Experiment 1. After reading the first sentence, they pressed "ready" to view the second sentence. After reading the second sentence, they reported the number of spelling errors they had detected. The replies 0–3 were mapped onto the numerical keys 1–4 that had been used for the activity ratings of Experiment 1, except that the keys were given the appropriate labels 0–3. In all other respects, the procedure was identical to that of Experiment 1.

Results

Acceptance rates

ANOVA was applied to the mean acceptance rates (Table 2). There were main effects both of relation, $minF(2,50) = 44.52$, and instruction, $minF(2,76) = 5.00$. In addition, the Relation × Instruction interaction was significant, $minF(4,152) = 2.52$. The interaction reflected smaller acceptance-rate differences among the probe types under the imply instruction than the other instructions. There was a marginally significant effect of instruction in the absent condition ($minF(2,102) = 2.73$, $p = .07$): Acceptance rate was once again lowest under the recognize instruction and highest under the imply instruction.

Model analyses

In contrast with the other experiments, satisfactory fits were observed for all three models: phantom recollection, $G^2(1) = 0.02$, conjoint recognition, $G^2(2) = 3.13$, and process dissociation, $G^2(2) = 1.69$. Thus, data from a shallow orienting task were fit by dual-process models as well as by the three-process phantom recollection model.

It is instructive, nevertheless, to inspect the parameters derived from the phantom recollection analysis (see Table 3). Both recollection and familiarity were significantly greater in the explicit condition than the implicit condition, $G^2(1) = 27.34$ and $G^2(1) = 13.87$, respectively. Implicit familiarity statistically exceeded 0, $G^2(1) = 31.98$. However, implicit recollection, the index of recognizing-to-reject, was indistinguishable from 0, $G^2(1) = 1.16$. Perhaps most importantly, phantom recollection was statistically indistinguishable from 0, $G^2(1) = 2.60$. The proportions of false recognition of implicit probes resulting from phantom recollection and familiarity were 0.17 and 0.72, respectively.

Discussion

The main rationale of Experiment 3 was that a shallow orienting task would prevent the extraction of rich, gist representations, thereby rendering phantom recollection irrelevant. Three features of the data supported this analysis: First, phantom recollection did not significantly exceed 0. Second, as predicted, the conjoint recognition model adequately fit the data. Conjoint recognition lacks a phantom recollection mechanism. In the absence of a phantom recollective contribution, there is no reason for the conjoint recognition model to misfit the data. Third, and consistent with the other features, whereas the contribution of familiarity to the false recognition of implicit probes was 1.50 times that of phantom recollection in normal reading (Experiment 1), the comparable ratio for the spelling orientation was over 4.00 (0.72 ÷ 0.17).

An unpredicted outcome was that the process dissociation inference model (Singer & Remillard, 2004) likewise adequately fit the data. The weakness of that model is that, for the judgement of implicit probes, it substituted a phantom recollective process for veridical recollection. However, because veridical recollection did not significantly contribute to inference recognition in Experiment 3, as indicated by the phantom recollection model analysis, the process dissociation model adequately fit the data.

The nonsignificance of implicit recollection meant that, like in Experiment 2, there was no basis for recognizing-to-reject the implicit probes. Both delayed testing (Experiment 2) and shallow processing (Experiment 3) precluded the rejection of inferences on the basis of noticing their surface discrepancies from their texts.

Considering Experiment 3 in isolation, the dual-process models would be preferred to the three-process phantom recollection model, on the basis of parsimony: They accounted for the data pattern in terms of fewer parameters. Across the composite results of Experiments 1–3, however, the phantom recollection model was clearly superior.

The results of these experiments also bolster a principle evident in this research domain. In the comparison of competing models, simpler models may appear superior in limited circumstances. In this regard, the conjoint recognition adequately addresses many phenomena of list recognition (Brainerd et al., 1999), but falls short when extended to the DRM critical-lure paradigm (Brainerd et al., 2001). Likewise, whereas a one-process signal detection analysis may adequately address some data patterns, dual-process solutions may be demanded for many others (Yonelinas, 2002).

General discussion

It has long been apparent that understanders frequently incorrectly recognize the plausible pragmatic implications of discourse (Johnson et al., 1973). Intensive investigation revealed that those inferences which augment coherence by bridging discourse ideas are reliably encoded during comprehension (Haviland & Clark, 1974; Keenan & Kintsch, 1974). On some behavioral measures, bridging inferences are indistinguishable from explicit discourse ideas (Potts et al., 1988; Singer, 1980; Singer & Ferreira, 1983).

Theoretical analysis suggests, however, that explicit text ideas may be encoded at all levels of representation but that encoded inferences should be relatively restricted to situation model representations (Schmalhofer et al., 2002). This ought to result in different retrieval profiles for these idea categories. The process dissociation investigation of Singer and Remillard (2004) tended to support that proposal: Explicit memory probes exceeded corresponding bridging-inference probes both in recollection and familiarity.

The phantom recollection proposal of Brainerd et al. (2001) offered the opportunity to refine Singer and Remillard's (2004) multiprocess analysis of text retrieval. Brainerd et al. posited that designs associated with very high levels of false memory (e.g., the DRM critical-lure paradigm, Roediger et al., 1995) require that recollection and familiarity be complemented by a process of phantom recollection. This is because these designs give rise to strongly instantiated gist representations that have unusual vividness when they are accessed during memory performance. Brainerd et al.'s joint methodology and theoretical analysis mapped strikingly well onto the domain of text retrieval. First, readers incorrectly recognize the pragmatic implications of text at a very high rate (Johnson et al., 1973; Singer, 1979). Second, the three instructional conditions of the conjoint recognition method are very suitable in the text domain. In particular, it makes considerable sense to apply judgements of recognition, verification, and implication to text-relevant memory probes (Brainerd et al., 2006; Hayes-Roth & Thorndyke, 1979; Reder, 1982).

Three experiments yielded results that are very consistent with the phantom recollection model. In both immediate and delayed text retrieval, the three-process phantom recollection model was superior to two competing dual-process models. However, in a shallow-encoding condition posited to impede the construction of the sort of strong gist representations that support illusory recognition, the phantom recollection model offered no better a fit to the data than the conjoint recognition model. In addition, because implicit recollection was negligible, the data of Experiment 3 were also fit by the process dissociation model.

The phantom recollection model therefore deserves careful consideration in the analysis of text retrieval. Furthermore, there are at least two reasons to propose that phantom recollection is a model that generalizes to a wide variety of circumstances. First, as evident both in this study and that of Brainerd et al. (2001), phantom recollection offers satisfactory fits to data stemming from designs associated both with high and low degrees of false memory. When false memory is not very high, the phantom recollection parameter simply approximates 0 (Experiment 3 of this study; Brainerd et al., 1999). Second, it is likely that many human endeavours are associated with the derivation of situation models and mental models (Johnson-Laird, 1983; van Dijk & Kintsch, 1983). This would suggest that the need to invoke a process of phantom recollection is the rule rather than the exception.

We note that the algebraic modelling underlying the present approach may be contrasted with simulation modelling techniques. Several influential simulation models in the domain of reading, comprehension, and text retrieval have been hybrids of symbolic processing (e.g., Newell, 1973) and the connectionist analysis (e.g., Rumelhart & McClelland, 1986). In Kintsch's (1988) construction-integration model, for example, preliminary representations are constructed according to symbolic rules, such as syntactic rules about the usual form of phrases and sentences. Then, activation is settled in the representation according to connectionist principles of constraint satisfaction. Elements that receive negligible activation are effectively excluded from the representation (see also Just & Carpenter, 1987).

The present multinomial tree processing modelling is well-defined in terms of the formulas that guide the parametric estimation. In contrast with some simulation models, however, the form of the underlying text representations is not specified (Lamberts, 2004). A general strategy for combining the two techniques is outlined in Singer and Kintsch's (2001) analysis of text retrieval. In that study, well-defined construction-integration representations provided the basis for estimating the activation of explicit, paraphrased, and implicit memory probes. Activation was calculated on the basis of the global match (e.g., Hintzman, 1988; Murdock, 1982) between the probe and the corresponding representation. In terms of the present analysis, probe activation constituted an index of familiarity. As such, Singer and Kintsch advanced a single-process model. Combining the multiprocess mathematical modelling of this study with the simulation techniques of Singer and Kintsch remains a challenge for the future.

Relation between retrieval processes and underlying representations

In the framework of multiprocess analyses of memory retrieval, relating the different processes to their supporting representations has been a continual and sometimes controversial endeavour. These analyses have predominantly distinguished between the representational bases of recollection versus familiarity. Accumulating evidence of a process of phantom recollection makes it useful to review and refine these treatments. Here, it is convenient to address recollection last.

Familiarity

Familiarity has long been characterized as a relatively fast process that reflects item-specific information (Humphreys, 1978) resulting from the *perceptual integration* of the stimulus (Mandler, 1972, 1980). In this framework, familiarity is interpreted to assess the degree of similarity between the memory probe and the stored trace.

The latter analysis has been augmented by the contemporary understanding that familiarity reflects conceptual as well as perceptual representations. Numerous process dissociation investigations have converged on the generalization that familiarity responds to conceptual manipulations such as full versus divided attention (Jacoby, Lindsay, & Toth, 1992; Jacoby, Toth, & Yonelinas, 1993) and deep versus shallow semantic processing (Dehn & Engelkamp, 1997; Komatsu, Graf, & Uttl, 1995; Toth, 1996). In the latter regard, Yonelinas (2002) proposed that familiarity shares characteristics with conceptual implicit memory. Conceptual implicit memory, as measured in tasks such as exemplar generation (Roediger & McDermott, 1993), responds to manipulations such as divided attention (Mulligan & Stone, 1999) and study duration (Challis & Sidhu, 1993) in the same manner as does familiarity.

These observations mesh with the comprehension-domain evidence that text rereading time is less than that of the original reading (Carr, Brown, & Charalambous, 1989; Levy et al., 1995). Rereading is not an intentional memory task so it does not entail recollection. This suggests that rereading benefits are attributable to familiarity. However, rereading benefits have been analyzed to reflect semantic rather than verbatim influences (Levy et al., 1995; Masson, 1993). These findings are consistent with Yonelinas's (2002) aforementioned proposal that familiarity is supported at least in part by conceptual implicit memory. On the basis of such evidence, Yonelinas concluded that familiarity reacts both to perceptual (e.g., Gardiner, Gawlick, & Richardson-Klavehn, 1994) and conceptual (e.g., Jacoby, 1991; Jacoby et al., 1992) manipulations.

Phantom recollection

As discussed throughout, existing evidence suggests that phantom recollection is supported by gist representations. The processing of stimuli that promote strong gist memories, such as the thematic lists of the DRM paradigm and ordinary inference-bearing texts, result in the measurement of phantom recollection (Brainerd et al., 2001, 2003, 2006; Chan & McDermott, 2006; present Experiments 1 and 2).

In the domain of text comprehension, the representational level viewed as best capturing gist is the situation model. Situation models serve to integrate text information and relevant world knowledge (Halldorson & Singer, 2002; van Dijk & Kintsch, 1983; Zwaan & Radvansky, 1998). They are relatively immune to decline with increasing test delay (Kintsch et al., 1975; Kintsch et al., 1990). Congruent with this observation, phantom recollection diminishes either modestly or negligibly with increasing test delay (Brainerd et al., 2001a; present Experiments 1 and 2).

Recollection

Recollection has traditionally been described as a relatively slow process (Atkinson & Juola, 1973) that is supported by the sort of relational and contextual information that results from elaborative processing (Mandler, 1972, 1980). Such relational and contextual information captures the gist rather than the superficial form of the stimulus. Indeed, Yonelinas (2002) characterized recollection as reflecting *only* conceptual factors, and as being more sensitive to them than is familiarity.

It is possible, however, that a somewhat different understanding of recollection may emerge from the application of the phantom recollection model. Consider the analysis of a dataset using a somewhat deficient model, such as analyzing DRM recognition data using the conjoint recognition model (cf. Brainerd et al., 2001). The analysis would produce parameters estimates (recollection and familiarity) for the different experimental conditions; but, to the extent that the model was inadequate, the parameter values might be misleading.

In this regard, the association of recollection with the elaborative and inferential aspects of stimulus encoding (Long, Wilson, Hurley, & Prat, 2006; Mandler, 1980; Yonelinas, 2002) has stemmed from the application of dual-process analyses. However, the phantom recollection process is itself strongly associated with highly inferential representations, such as situation models. Therefore, phantom recollection analyses may depict recollection somewhat differently than do dual-process analyses.

Brainerd et al. (2001, Experiment 2) provided some evidence of such a trend. They presented either forward-order DRM lists, which show the strongest theme-relevant words first; or backward-order lists. Toglia, Neuschatz, and Goodwin (1999) proposed that the strong cuing of the theme in the forward order promotes very strong gist memories. According to that analysis, list order comprises a conceptual manipulation in this context. Brainerd et al. reported that, in immediate testing, phantom recollection was appreciably higher in the forward than backward order (Brainerd et al., 2001, Table 4). Recollection, however, did not respond to this conceptual manipulation: There was no order effect in the recollection parameter.

Indeed, Brainerd et al. (2003) characterized recollection as being strongly influenced by verbatim memories but only slightly by gist memories. They proposed that target recollection might, to a small degree, actually result from phantom recollective influences. This is a sensible possibility—forgotten targets ought to be phantomly recollectible, just as are strongly related distractors. However, it is premature to offer firm conclusions on this issue.

Relation among the processes

An ostensive incongruity between the phantom recollection analysis and the nature of recollection and familiarity merits comment. Recollection is widely regarded as a slower process than familiarity (Mandler, 1980; Yonelinas, 2002), but the phantom recollection processing trees (Fig. 1c and d) and formulas (Appendix) imply that recollection has priority over the other two processes. Brainerd et al. (2001, Footnote 3), however, noted that the form of the phantom recollection formulas is not intended to carry implications about the relative speed of the processes. Indeed, those formulas could be rewritten to assign priority to any of the processes (see also Buchner et al., 1995). Brainerd et al. wrote the phantom recollection formulas to reflect the intuition that, given adequate processing time, recollection overrules familiarity and phantom recollection. Thus, Brainerd et al. tacitly assumed that the judgements in question are not speeded, as indeed was the case in our experiments.

However, this raises the legitimate point that competing models in this domain might be usefully informed by response latency data. The statistical procedures for accommodating conjoint recognition latency data have been described (Hu, 2001). We intend to apply those algorithms to these issues.

Conclusion

The tenets of Brainerd et al.'s (2001) phantom recollection model suggested that the model could be fruitfully applied to text retrieval. Data stemming from (a) immediate and delayed retrieval after normal reading and (b) immediate retrieval after a shallow-processing reading task converged to support this suggestion. This indicates that the phantom recollection model has the capacity to clarify many subtle issues pertinent to text comprehension and retrieval.

Appendix A

The subscripts e, b, and d in the formulas below refer to the explicit, *b*ridging inference, and distractor items, respectively. The subscripts r, v, and i refer to the recognize, verify, and imply instructions, respectively. The quantity p on the left side of the formulas is the probability of accepting an item belonging to the subscripted conditions. Finally, the parameters R (recollection), F (familiarity), P (phantom recollection), G (guessing), and E (erroneous recollection of related targets) appear on the right side of the formulas and are described below with each model.

Conjoint recognition model

Formulas

$$P_{\mathrm{er}} = (R_{\mathrm{e}}) + (1 - R_{\mathrm{e}})(F_{\mathrm{e}}) + (1 - R_{\mathrm{e}})(1 - F_{\mathrm{e}})(G_{\mathrm{r}}) \tag{A1}$$
$$p_{\mathrm{ev}} = (R_{\mathrm{e}}) + (1 - R_{\mathrm{e}})(F_{\mathrm{e}}) + (1 - R_{\mathrm{e}})(1 - F_{\mathrm{e}})(G_{v}) \tag{A2}$$
$$p_{\mathrm{ei}} = (1 - R_{\mathrm{e}})(F_{\mathrm{e}}) + (1 - R_{\mathrm{e}})(1 - F_{\mathrm{e}})(G_{i}) \tag{A3}$$
$$p_{\mathrm{br}} = (1 - R_{\mathrm{b}})(F_{\mathrm{b}}) + (1 - R_{\mathrm{b}})(1 - F_{\mathrm{b}})(G_{\mathrm{r}}) \tag{A4}$$
$$p_{\mathrm{bv}} = (R_{\mathrm{b}}) + (1 - R_{\mathrm{b}})(F_{\mathrm{b}}) + (1 - R_{\mathrm{b}})(1 - F_{\mathrm{b}})(G_{v}) \tag{A5}$$
$$p_{\mathrm{bi}} = (R_{\mathrm{b}}) + (1 - R_{\mathrm{b}})(F_{\mathrm{b}}) + (1 - R_{\mathrm{b}})(1 - F_{\mathrm{b}})(G_{\mathrm{i}}) \tag{A6}$$
$$p_{\mathrm{dr}} = G_{\mathrm{r}} \tag{A7}$$
$$p_{\mathrm{dv}} = G_{\mathrm{v}} \tag{A8}$$
$$p_{\mathrm{di}} = G_{\mathrm{i}} \tag{A9}$$

Notes

For both explicit and bridging inference items, R is the probability that an item produces recollection of its instantiating text, and F is the probability that an item produces a sense of familiarity that exceeds the acceptance threshold given that the item does not produce recollection of its instantiating text. The parameter G is the probability of accepting an item given that the item fails to elicit recollection or sufficient familiarity.

Phantom recollection model

Formulas

$$p_{er} = (R_e) + (1 - R_e)(1 - E_e)(F_e) + (1 - R_e)(1 - E_e)(1 - F_e)(G_r) \quad (A10)$$
$$p_{ev} = (R_e) + (1 - R_e)(E_e) + (1 - R_e)(1 - E_e)(F_e) + (1 - R_e)(1 - E_e)(1 - F_e)(G_v) \quad (A11)$$
$$p_{ei} = (1 - R_e)(E_e) + (1 - R_e)(1 - E_e)(F_e) + (1 - R_e)(1 - E_e)(1 - F_e)(G_i) \quad (A12)$$
$$p_{br} = (1 - R_b)(P_b) + (1 - R_b)(1 - P_b)(F_b) + (1 - R_b)(1 - P_b)(1 - F_b)(G_r) \quad (A13)$$
$$p_{bv} = (R_b) + (1 - R_b)(P_b) + (1 - R_b)(1 - P_b)(F_b) + (1 - R_b)(1 - P_b)(1 - F_b)(G_v) \quad (A14)$$
$$p_{bi} = (R_b) + (1 - R_b)(1 - P_b)(F_b) + (1 - R_b)(1 - P_b)(1 - F_b)(G_i) \quad (A15)$$
$$p_{dr} = G_r \quad (A16)$$
$$p_{dv} = G_v \quad (A17)$$
$$p_{di} = G_i \quad (A18)$$

Notes

For explicit items, R is the probability that an item produces recollection of its instantiating text, E is the probability that an item produces recollection of related studied material given that it does not produce recollection of its instantiating text, and F is the probability that an item produces a sense of familiarity that exceeds the acceptance threshold given that the item does not produce recollection of its instantiating text and that it does not produce recollection of related studied material. In the present study, the value of E was set to the small value of .05 because the passages in the study phase were minimally related to one another.

For bridging inference items, R is the probability that an item produces recollection of its instantiating text, P is the probability that an item is recollected as having been studied given that it does not produce recollection of its instantiating text, and F is the probability that an item produces a sense of familiarity that exceeds the acceptance threshold given that the item does not produce recollection of its instantiating text and that it is not recollected as having been studied.

Finally, the parameter G is the probability of accepting an item given that the item fails to elicit any type of recollection or sufficient familiarity.

Process dissociation model

Formulas

$$P_{er} = (R_e) + (1 - R_e)(F_e) + (1 - R_e)(1 - F_e)(G_r) \quad (A19)$$
$$p_{ev} = (R_e) + (1 - R_e)(F_e) + (1 - R_e)(1 - F_e)(G_v) \quad (A20)$$
$$p_{ei} = (1 - R_e)(F_e) + (1 - R_e)(1 - F_e)(G_i) \quad (A21)$$
$$p_{br} = (R_b) + (1 - R_b)(F_b) + (1 - R_b)(1 - F_b)(G_r) \quad (A22)$$
$$p_{bv} = (R_b) + (1 - R_b)(F_b) + (1 - R_b)(1 - F_b)(G_v) \quad (A23)$$
$$p_{bi} = (1 - R_b)(F_b) + (1 - R_b)(1 - F_b)(G_i) \quad (A24)$$
$$p_{dr} = G_r \quad (A25)$$
$$p_{dv} = G_v \quad (A26)$$
$$p_{di} = G_i \quad (A27)$$

Notes

For both explicit and bridging inference items, R is the probability that an item will be recollected as having been studied, and F is the probability that the familiarity of an item will exceed the acceptance threshold given that the item is not recollected as having been studied. The parameter G is the probability of accepting an item given that the item is not recollected as having been studied and its familiarity does not exceed the acceptance threshold.

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