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Differential-associative processing or example elaboration: Which strategy is best for learning the definitions of related and unrelated concepts?

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Abstract

Definitions of related concepts (e.g., *genotype–phenotype*) are prevalent in introductory classes. Consequently, it is important that educators and students know which strategy(s) work best for learning them. This study showed that a new comparative elaboration strategy, called differential-associative processing, was better for learning definitions of related concepts than was an integrative elaborative strategy, called example elaboration. This outcome occurred even though example elaboration was administered in a naturalistic way (Experiment 1) and students spent more time in the example elaboration condition learning (Experiments 1, 2, 3), and generating pieces of information about the concepts (Experiments 2 and 3). Further, with unrelated concepts (*morpheme–fluid intelligence*), performance was similar regardless if students used differential-associative processing or example elaboration (Experiment 3). Taken as a whole, these results suggest that differential-associative processing is better than example elaboration for learning definitions of related concepts and is as good as example elaboration for learning definitions of unrelated concepts.

Keywords

Elaboration strategies; Differences between definitions; Learning definitions

1. Introduction

An important question frequently asked by students is *Which strategies are best for learning and retaining information?* Unfortunately as most educators know, there are no simple answers because no one strategy is the panacea for learning problems. Rather, selecting the best strategy depends on a number of factors; such as: (i) how well it is executed (Just & Carpenter, 1988), (ii) the degree of overlap between the contents of the material being learned and the material being tested (i.e., encoding specificity; Hannon & Craik, 2001; Tulving & Thomson, 1973), and (iii) the nature of the to-be-learned material (Just & Carpenter, 1988). The nature of the to-be-learned material is particularly relevant to the present study because this study uses definitions of pairs of related concepts (e.g., *genotype–phenotype*). This type of concept was selected because although they are prevalent in introductory courses (e.g., Introduction to Psychology), students know very little about which strategy(s) work best for learning them. Indeed, re-reading, a form of rote learning, is the most common strategy that students select (Hannon, Lozano, Frias, Picallo-Hernandez,

& Fuhrman, 2010). Therefore, the present study compares two strategies for learning related concepts: (1) *example elaboration*; a well-established strategy that is considered to be one of the best, if not *the* best, strategies for learning and retaining information and (2) *differential-associative processing*; a new elaborative strategy that is suitable for learning definitions of related concepts (e.g., Hannon et al., 2010).

1.1. Background literature

Elaborations can be broadly defined as any type of enhancements that clarify the original to-be-remembered information with respect to other information (Reder, Charney, & Morgan, 1986; but see Chi, 2000, who delineates between self-explanations and elaboration). Elaborations are, for example, author-generated explanations, analogies, or examples embedded in a text. Elaborations are also learner-generated personal examples of to-be-remembered information (Hamilton, 1989; Lewalter, 2003) and they are learner-generated re-statements of important features that are included in the definitions of concepts (e.g., Reder et al., 1986). For example, Hannon et al. (2010) observed that learners re-stating the important features of pairs of definitions of concepts resulted in better learning than when learners simply re-read the definitions. Finally, elaborations are answers to *elaborative interrogation why*-questions embedded in text (e.g., Martin & Pressley, 1991; Menke & Pressley, 1994; Willoughby, Wood, McDermott, & McLaren, 2000) or they can be responses to cognitive prompts (e.g., *Which examples can you think of that illustrate, confirm your interpretations?*) (e.g., Berthold, Nückles, & Renkl, 2007).

Regardless of their form, most researchers agree that elaborations often facilitate learning of to-be-remembered information (Cherry, Park, Frieske, & Rowley, 1993; Reder et al., 1986; Simpson, Olejnik, Tarn, & Supattahurn, 1994; although see O'Reilly, Symons, & MacLachy-Gaudet, 1998, who show that self-explanations are better than elaborations). Indeed, their mnemonic benefit occurs regardless of age (e.g., Cherry et al., 1993), when the stimuli of interest are ecologically valid or when the to-be-learned information is unfamiliar to learners (e.g., Simpson et al., 1994; although see Willoughby et al., 2000 who show that elaborative interrogation is less effective when the to-be-learned information is unfamiliar to the learner).

From a theoretical perspective, researchers have proposed a number of explanations why elaborations should improve retention of to-be-remembered information (Hamilton, 1989; Reder et al., 1986). Elaborations may, for example, provide additional retrieval routes for accessing to-be-remembered information so when one route to the to-be-remembered information is forgotten, other routes are still available (Reder et al., 1986). Additionally, elaborations can be used to reconstruct information that is forgotten from a memory trace (Reder et al., 1986), they can be used to impose an organized schema on stored information (Hamilton, 1989) or they can increase the number of overlapping elements between encoding and retrieval (Craik & Tulving, 1975). Elaborations also provide a network among memory traces of the to-be-remembered information and other information in long-term memory, and elaborations are believed to increase the strength of the memory traces of the to-be-remembered information (Hamilton, 1989; see also Kalyuga, 2009).

According to Hamilton (1989), all elaborations can be classified as either learner- or author-generated. *Learner-generated elaborations* are generated by a learner; for example, when students relate to-be-learned information with prior knowledge about a similar concept (Berthold et al., 2007), when they identify differences between definitions of concepts (e.g., Hannon et al., 2010), or when they elaborate on concepts during group discussions (e.g., Kaartinen & Kumpulainen, 2002). On the other hand, *author-generated elaborations* are generated by an author; for example, author-generated explanations or examples of a concept that are embedded in the text of a paragraph (e.g., Martens, Valcke, Polemans,

&Daal,1996). Of these two types of elaboration, however, learner-generated elaborations produce more robust and consistently positive findings than do author-generated ones; see Hamilton (1989) for a discussion of this point. As noted by Reder et al. (1986), learner-generated elaborations may lead to better learning than author-generated elaborations because a student's own elaborations are probably more relevant to his or her purpose for reading.

Further, learner-generated elaborations can be classified as either integrative or comparative. *Integrative elaborations* are the products of a learner relating to-be-remembered information with pre-existing information from long-term memory; for example, when a learner generates an example for a new concept by using his/her existing schema in long-term memory. From a theoretical perspective, integrative elaborations presumably compel a learner to search their prior knowledge/previous experiences and relate this information with the to-be-remembered information (Hamilton, 1989; Mayor, 1980). The outcome of these memory searches is a larger integrated memory network which, in turn, makes the newly learned information more available during retrieval (Hamilton, 1989). In contrast, *comparative elaborations* make memory traces more distinctive from one another. They are the products of a learner comparing or consolidating different parts of to-be-remembered information; for example, when a student identifies differences between definitions of concepts (Hamilton, 1989). From a theoretical perspective, comparative elaborations increase the distinctiveness of information in two or more memory traces thereby making the retrieval of each memory trace less prone to the influences of interference.

1.1.1. Integrative elaboration—To date, only a few studies have examined the influences of integrative elaboration on learning more complex materials, such as prose or definitions of related concepts. However, the results of these studies are encouraging, especially studies where learners generate examples of to-be-remembered information. Simpson et al. (1994), for example, presented facts about fictitious islands/ animals and then asked learners to either (i) rehearse the text, (ii) answer *why* questions (i.e., elaborative interrogation), or (iii) generate examples using imagery. They observed that learners who generated examples (i.e., the example elaboration group) performed better on a subsequent memory test than did learners who either used rehearsal or answered why-questions (i.e., elaborative interrogation group). Similarly, Hamilton (1989) observed that learners who generated two personal examples for each definition of a psychological concept performed better on problem-solving questions than did learners who did not generate personal examples. Finally, a few studies underscore the importance of using examples as a medium for teaching definitions of new concepts (e.g., Park, 1984; Tennyson & Cocchiarella, 1986; Tennyson & Park, 1980).

1.1.2. Comparative elaboration—One popular comparative elaboration method is *example comparison*, an instructional method that involves reading a concept's definition and then comparing pairs of examples which vary in quality (e.g., Merrill & Tennyson, 1977, 1978; Tennyson & Park, 1980). Learners first study a concept's definition and then study a "best example" of that concept, including all of its critical features. Next they make comparisons among the best example, more newly-encountered examples, which differ in both quality and quantity of concept features, and more newly-encountered non-examples, which lack one or more of the critical features of the to-be-learned concept (e.g., Park, 1984; Tennyson & Park, 1980). These comparisons between the different types of examples help learners focus on the critical features of a concept, thereby facilitating learning of the concept (Tennyson & Park, 1980). Indeed, research suggests that example comparison is a better method for learning definitions of concepts than is a method that provides the critical features of the to-be-learned concepts to the learner in advance (e.g., Park, 1984).

More recently, Hannon et al. (2010) showed that a new comparative elaboration strategy—called *differential-associative processing*—was also an excellent strategy for learning definitions of concepts. In their study, learners used one of four strategies to learn definitions of related concepts: rehearsal, picking out keywords, text-based elaboration (i.e., elaboration of the definition of the concept), or differential-associative processing, which is described below. Hannon and colleagues observed that performance was better when learners used differential-associative processing rather than rehearsal or picking out keywords. They also observed that differential-associative processing was better for learning definitions of related pairs of concepts than was an integrative strategy, namely text-based elaboration. This latter finding is relevant to the present article because it suggests that perhaps a comparative elaboration strategy, such as differential-associative processing, might be better for learning definitions of related concepts than is an integrative elaboration strategy, such as example elaboration.

The source of the mnemonic benefit of differential-associative processing is the *differential* and *associative processing* components. During the differential processing phase, a learner identifies differences between definitions of two or more concepts; for example, the difference *you can't see a genotype but you can see a phenotype* for the concepts *genotype-phenotype*. According to Hannon et al. (2010), this identification of differences between related concepts increases the activation level of critical distinctive features in the memory trace of each concept thereby making each memory trace both more unique and complex. Consequently, when learners are retrieving definitions of related concepts, there is a high probability that they will remember the critical distinctive features of each concept rather than features from the correct answer's complement.

During the associative processing phase, a learner links or associates each part of an identified difference back to its respective concept name. For example, a learner might associate the previously identified feature *you can't see it* with its respective concept, *genotype*. This associative processing between a feature and its respective concept name increases the strength of the “link” between the feature and concept thereby providing an additional retrieval cue (Hannon et al., 2010). Consequently, when learners are retrieving definitions of related concepts based on a concept's name (e.g., define the concept *genotype*), there is a high probability that they will remember the critical features that belong to that concept rather than its complement (e.g., *phenotype*).

The differential and associative processing components of differential-associative processing capitalize on the major premises of two well-established memory models (Hannon et al., 2010), namely the *distinctiveness hypothesis* (e.g., Begg, 1978; Epstein, Phillips, & Johnson, 1975; Mantylä, 1986; Radvansky, 2006) and the *associative strength theory* (e.g., Hall, 1991; Hall, Mitchell, Graham, & Lavis, 2003). According to the distinctiveness hypothesis, memory for to-be-learned information is better if the information is more unique or distinct. For example, while encoding the definition for *genotype* the distinctive feature *can't see it* and the general feature *it is related to genetics* might be encoded. If *can't see it* is a retrieval cue than *genotype* becomes an obvious answer. However, if the retrieval cue is *it is related to genetics* than both *phenotype* and *genotype* are obvious answers. In other words, distinctive information (i.e., *can't see it*) makes the memory trace for *genotype* more distinctive from the memory traces of other related concepts (e.g., *phenotype*). According to the associative strength theory, retrieval cues are more effective if they have been repetitively paired or associated with the to-be-remembered information (Hall, 1991). For example, the word *genotype* is a better retrieval cue for the feature *you can't see it* if the label/word *genotype* has been associated with this feature than if it has not been associated with this feature.

It is important to note that although differential-associative processing and example elaboration are both comparative elaboration strategies, they are quite different from each other. In example comparison features are extracted from examples of concepts whereas in differential-associative processing they are extracted from definitions of concepts. In example comparison the critical features are identified for one concept whereas in differential-associative processing they are identified between pairs of concepts. Finally, although example comparison involves identifying critical differentiating features via comparisons of examples/ non-examples, this identification process is substantially less direct and explicit than it is in differential-associative processing.

1.2. Summary and present study

Previous research suggests that an integrative elaboration strategy such as example elaboration is better for learning definitions of concepts, than are other strategies such as rehearsal and elaborative interrogation (Simpson et al., 1994). Previous research also suggests that a comparative elaboration strategy, such as differential-associative processing, is better for learning definitions of concepts than are other strategies, such as rehearsal, picking out keywords, or text-based elaborations (e.g., Hannon et al., 2010). Yet, to date no study has directly compared example elaboration with differential-associative processing. Thus, it is unclear which strategy is best for learning definitions of concepts. Therefore, the goal of the present study is to compare the mnemonic values of example elaboration versus differential-associative processing for learning definitions of both related concepts (i.e., Experiments 1, 2, and 3) and unrelated concepts (i.e., Experiment 3). Specifically, this study addresses the following research questions: (1) Which strategy is better for learning definitions of related concepts: differential-associative processing or example elaboration? (Experiments 1, 2, and 3) and (2) What are the mnemonic benefits of differential-associative processing and example elaboration for learning definitions of related versus unrelated concepts? (Experiment 3).

Based on all the aforementioned theoretical considerations and previous research that shows differential-associative processing is a better strategy for learning definitions of related concepts than is another integrative elaborative strategy, namely text-based elaboration (e.g., Hannon et al., 2010), it was predicted that differential-associative processing would be a better strategy for learning definitions of related concepts than is example elaboration (i.e., *hypothesis 1*). For the second research question, specific hypotheses are deferred until Experiment 3.

In Experiments 1 and 2, students learned concepts using either differential-associative processing or example elaboration. In Experiment 1, differential-associative processing was compared to an example elaboration condition in which students generated both a personal example and an application for each definition in a pair of related concepts. For instance, for the concept *genotype*, depicted in Tables 1 and 2, a student might generate the personal example *Even though I don't have diabetes, I might have diabetes later in life because both my grandmother and mother have diabetes*. See Table 3 for other examples. In Experiment 2, differential-associative processing was compared to an example elaboration condition in which students generated two personal examples and two applications for each concept in a pair of concepts. Finally, in Experiment 3 differential-associative processing and example elaboration were compared using both related (e.g., *genotype-phenotype*) and unrelated pairs of concepts (e.g., *morpheme-fluid intelligence*).

2. Experiment 1

In order to compare the effectiveness of differential-associative processing with example elaboration (i.e., *hypothesis 1*), one group of students learned the definitions of pairs of

related concepts using differential-associative processing while a second group learned the same definitions using example elaboration. In the differential-associative processing condition, students identified two differences between the concepts and then associated each feature back to its respective concept. In the example elaboration condition, students generated both a personal example and an example of an application for each concept in the pair. See Table 3 for examples of learner-generated personal examples and learner-generated applications. Two examples were generated per concept because this number of examples is equivalent to the two features per concept that are identified in the differential-associative processing condition. Further, although we could have presented the definitions for each concept individually—a presentation format that is consistent with that used by students—it was decided that the presentation format of concepts in both the elaboration conditions should be identical (i.e., both definitions of concepts presented simultaneously) in order to avoid confounding presentation format. Finally, the number of times students viewed the pairs of definitions in the example elaboration condition was purposely not controlled in Experiment 1 because we wanted to compare performances between a differential-associative processing condition and a more ecologically-valid example elaboration condition. In Experiments 2 and 3, the number of times students viewed the pairs of definitions were equivalent in the differential-associative processing and example elaboration conditions.

2.1. Method

2.1.1. Participants—The 52 participants were students of the University of Texas at San Antonio who were fluent English speakers, free of any learning disability, and were tested individually in one session. Forty-six participants were paid for their participation and six received course credit. The data for four students were removed because they failed to finish the concept definition processing task in the time allotted for course credit. One participant was in the differential-associative processing condition and three were in the example elaboration condition. The average age of the remaining 48 students was 18.89 years ($SD = 1.28$) and 20 of the 48 participants were female while 28 were male.

2.1.2. Design—In the concept definition processing task, students were randomly assigned to either the differential-associative processing or the example elaboration condition; 24 students completed each condition. In each condition, they learned the definitions for pairs of related concepts and then answered multiple-choice questions that assessed their knowledge about the concepts. The total time was 1.75–2.5 h.

2.1.3. Concept definition processing task—At encoding, students learned definitions of pairs of concepts using either differential-associative processing or example elaboration. The actual procedures for differential-associative processing and example elaboration are detailed in the procedures section. After learning the definitions for a set of concept pairs, students answered multiple-choice questions that assessed their knowledge for the definitions of the concepts. The accuracy scores on these multiple-choice questions were used for analysis.

2.1.3.1. Materials: The stimuli (i.e., definitions of concepts and accompanying multiple-choice questions) were identical to those used by Hannon et al. (2010) and consequently, the following information is a description of their stimuli. Briefly, there were 18 pairs of definitions of related concepts that were taken or adapted from Introductory to Psychology, Memory, Cognitive Psychology, and Abnormal Psychology textbooks (e.g., Bernstein, Clarke-Stewart, Roy, Srull, & Wickens, 1994; Davison & Neale, 1990; Haberlandt, 1999; Matlin, 2003; Myers, 1992; Nairne, 2003; Reed, 2004). The criteria used to select these definitions included: (1) the definitions for a pair of concepts needed to be related, (2) each

concept could be defined using only a few sentences, and (3) the definitions for each pair of concepts included at least two identifiable differences, and (4) the concepts represented different content areas of Psychology (i.e., Cognition, Health, Learning, Abnormal, Personality, and Social Psychology). Examples of pairs of concepts include: *objective test-projective test*, *psychogenic fugue-multiple personality*, *anomic suicide-egoistic suicide*, *somatic weakness disorder-specific reaction disorder*, *stimulus generalization-stimulus discrimination*, and *morpheme-phoneme*. Each pair of definitions was randomly presented in the middle of the computer screen one pair at a time, similar to the first pair of definitions depicted in Table 1. Students learned each pair of definitions using either differential-associative processing or example elaboration. The exact steps for differential-associative processing and example elaboration can be found in the procedures section. The computer recorded the total presentation time.

Thirty-six four-choice multiple-choice questions accompanied each set of pairs of concepts. These questions were used to assess students' knowledge for the definitions of pairs of concepts (i.e., the outcome from learning). See Table 2 for examples. These questions were taken or adapted from Introductory Psychology textbooks. Each question was presented individually in the middle of the computer screen and it remained there until a student selected one of the four choices. The computer recorded the student's response selection and response accuracy. There were 6 questions for each pair of related concepts, 3 questions for each concept in the pair. Further, because test banks routinely include three types of multiple-choice questions for assessing knowledge about the definitions of concepts and because the present study wished to keep the stimuli as ecologically valid as possible, the three types of multiple-choice questions that are included in textbanks were included in the present study. As Table 2 shows, *feature-to-concept* questions included a question stem that was a feature of a concept and four response alternatives that were the names of concepts. *Concept-to-feature* questions included a question stem that was the name of a concept and four response alternatives that were features of concepts. Finally, *applied* questions included a scenario and four response alternatives that were names of concepts.

In order to ensure that each question had some level of difficulty, Hannon et al. (2010) normalized the stimuli by having Introductory Psychology students, who were naive to the study's purpose, answer all of the multiple-choice questions without learning the definitions of the concepts in advance. More specifically, in this normalization study the multiple-choice questions were presented one at a time in the middle of a computer screen and students answered the questions by selecting the 1, 2, 3 or 4- key. Multiple-choice questions with a high percentage of correct answers were modified to become more difficult and then another group of students completed all of the questions without learning the definitions of the concepts in advance. This procedure repeated until all of the questions were suitably difficult. The results of the final group of students revealed a mean performance of 38% ($SD = 12\%$) on the multiple-choice questions.

2.1.3.2. Procedure—In both conditions, students were first taught either differential-associative processing or example elaboration and then they practiced the appropriate strategy using four pairs of definitions of concepts. During this training phase, the research assistant provided feedback about how to execute the strategies properly and answered any questions that the students might have about the strategy they were assigned. Following the training phase, students continued to the critical portion of the task and proceeded to learn the concepts using the strategy they just learned. During this learning phase of the concept definition task, students were not provided with any instructions or feedback about their execution of the strategy.

Differential-associative processing involved four steps. First, students read aloud the definitions for a pair of concepts that were presented simultaneously in the middle of a computer screen. Next they identified two differences between the definitions of the concepts. For example, for the concepts *genotype–phenotype* students might generate the differences (i) *you can't see a genotype but you can see a phenotype* and (ii) *a genotype is based on genetic code whereas a phenotype is based on genetic code and nurture*. Students were given as much time as needed to identify the differences and all differences were recorded by the research assistant. However, students were not provided hints about differences between the concepts. Thus, there was a possibility of a student generating an incorrect difference; in total this happened less than 4% of the time. Immediately after identifying two differences for each of the six pairs of concepts in a set, students completed the association phase. During this phase, the research assistant stated a feature for a concept (e.g., *you can't see this feature*) and the student's task was to identify that feature's concept (e.g., *genotype*). Students were allowed to refer to the definitions of the relevant pair of concepts as they were completing the association. After associating the four features for the first pair of concepts, students repeated this association phase for the five remaining pairs of concepts in the set. Following the association phase students answered multiple-choice questions that assessed their knowledge of the definitions of the concepts. Finally, students learned the second set of concepts using the same four-step procedure they used on the first set of concepts.

There were three steps in the example elaboration condition. First, students read aloud the definitions of a pair of concepts and then generated one personal example and one application for the first concept in the pair and then they generated one personal example and one application for the second concept in the pair. An example of a personal example for the concept *genotype* is *because my mother and grandmother have diabetes I might have the gene for diabetes and therefore might acquire diabetes in the future*; an example of an application is *Bobby's genetic make-up means that he is susceptible to leukemia*. Students were instructed that personal examples must relate to their personal experiences, whereas applications do not relate to their personal experiences. After generating one personal example and one application for each concept in the first pair of concepts, students continued to the next pair of concepts in the set, repeating the same procedure. In total, less than 4% of the examples failed to include a critical feature or property of the definition. After learning all six pairs of concepts using this procedure, students answered multiple-choice questions that assessed their knowledge about the concepts. Finally, students learned the second set of concepts following the same procedure they used to learn the first set of concepts.

2.2. Results and discussion

The alpha level was .05 for all analysis of variance (i.e., ANOVAs) in all experiments. Eta-squared (i.e., η^2) was used to report the magnitude of each significant effect. According to Cohen (1988), an η^2 .14 is a large effect that is rare in the behavioral sciences, an η^2 between .06 and .139 is a medium effect, an η^2 between .011 and .059 is a small effect and an η^2 .01 is considered to be trivial. See Runyon, Coleman, and Pittenger (2000) for a discussion of effect sizes and Hannon and Daneman (2001, 2007) for calculations of effect sizes using eta-squared. The Newman–Keuls (i.e., q statistic) was used for all post-hoc tests (Howell, 1997).

In all experiments, total number of correct answers on the multiple-choice questions (i.e., accuracy scores) was the dependent measure. These scores were used in a preliminary ANOVA that verified that the order of the stimuli sets (described in the methods section) had no influence on the data. In Experiment 1, this ANOVA was a $2 \times 6 \times 3$ with condition

(differential-associative processing, example elaboration) and stimuli order (order 1, order 2, order 3, order 4, order 5, order 6) as between-subjects variables, and question type as a within-subjects variable (concept-to-feature, feature-to-concept, applied). There were no significant results: order, $F(5, 36) = 1.48$, order $\times$ condition, $F < 1.0$, order $\times$ type, $F < 1.0$, and order $\times$ condition $\times$ type, $F < 1.0$.

Accuracy scores were also submitted to another ANOVA, which addressed the hypotheses. In Experiment 1 this ANOVA was a 2×3 with condition as a between-subjects variable (differential-associative processing, example elaboration) and question type as a within-subjects variable (concept-to-feature, feature-to-concept, applied). Table 4 reports the descriptive statistics.

As Table 4 shows, the results support hypothesis 1. Specifically, there was a main effect of condition such that students who learned concepts using differential-associative processing answered 79% of the multiple-choice questions correctly whereas students who learned concepts using example elaboration answered 67% of the questions correctly, $F(1, 46) = 11.24$, $MSE = 29.64$. This effect was large by Cohen's (1988) standards, $\eta^2 = .17$. There was also a small significant effect of question type, $F(2, 92) = 6.98$, $MSE = 2.59$, $\eta^2 = .02$ such that more feature-to-concept questions were answered correctly than either concept-to-feature (i.e., 76% versus 72% respectively) or applied questions (i.e., 76% versus 71% respectively), $q(3, 92) = 4.90$ and $q(2, 92) = 3.80$ respectively. However, there was no significant difference in the number of correctly answered concept-to-feature and applied questions (i.e., 72% versus 71% respectively), $q(2, 92) = 1.10$. Finally, there was a small significant interaction between condition and type of question, $F(2, 92) = 8.96$, $MSE = 2.59$, $\eta^2 = .02$, such that students in the differential-associative processing condition answered more feature-to-concept and concept-to-feature questions correctly than did students in the example elaboration condition, 83% versus 69% and 81% versus 63% respectively, $q(4, 92) = 13.70$, $p < .05$ and $q(5, 92) = 17.90$, $p < .05$ respectively. However, students in both conditions did not significantly differ in the number of correctly answered applied questions even though there was a trend toward better performance in the differential-associative processing condition, 74% versus 68%, $q(3, 92) = 6.40$, $p < .05$. Although it is not clear why performance on applied questions was not significantly poorer with example elaboration than differential-associative processing, one possibility is that perhaps in the elaboration condition, the type of processing used to learn the definitions of the concepts and answer the applied multiple-choice questions is similar. If so, then students' performance on applied questions in the example elaboration condition would be a consequence of an overlap in the types of processing at encoding and retrieval, a phenomenon known as *transfer appropriate processing* (e.g., Adams et al., 1988).

Finally, the total time to learn the concepts in the two conditions was statistically compared. On average, students took less time to learn the concepts using differential-associative processing than they did using example elaboration (174.09 s versus 234.84 s per pair respectively), $t(46) = -4.69$, $p < .0001$. Thus, the excellent performance in the differential-associative processing condition was not a consequence of students taking more time to learn the concepts.

In summary, consistent with previous research (e.g., Hannon et al., 2010), Experiment 1 suggests that differential-associative processing is an excellent strategy for learning the definitions of related concepts. Experiment 1 also extends the findings of Hannon et al. (2010) by showing that differential-associative processing is a more useful strategy than example elaboration, a strategy that is considered to be excellent for learning (e.g., Hamilton, 1989; Mayor, 1980). This outcome occurred even when the presentation format of

the pairs of concepts in the example elaboration condition was identical to that used in the differential-associative processing condition.

Of course, Experiment 1 is not without its limitations. As noted in the introduction, the application of the example elaboration strategy was kept more ecologically valid. However, this ecological validity came at the expense of experimental rigor because students viewed the concepts in the example elaboration condition less frequently than they did in the differential-associative processing condition (i.e., once versus two times). As a result, perhaps the excellent performance observed in the differential-associative processing condition was not a consequence of differential-associative processing at all but instead a consequence of the fact that these students viewed the definitions more frequently than students did in the example elaboration condition. Indeed, studies examining the positive influences of “spaced” or *distributed practice* versus “massed” practice have all shown that distributing the learning results in better retention of to-be-learned information than does learning it all at once (e.g., Baddeley, 1990; Caple, 1996). In order to eliminate this alternative explanation, in Experiments 2 and 3 the pairs of concepts were presented twice in all the conditions.

Besides eliminating an alternative explanation, Experiment 2 compared the value of differential-associative processing to two other types of example elaboration (i.e., *hypothesis 1*). Although both types of example elaboration were variants of the one tested in Experiment 1, unlike Experiment 1 the concept pairs were presented twice. As well, in both conditions students generated a personal example and an application for each concept in a pair during both the first and second presentations of the concepts. The only difference between these two new types of example elaboration was that the first one permitted re-iteration of personal examples and applications during the second presentation of concepts whereas the second one did not. The justification for permitting the re-iteration in the former condition can be found in the method section. The former example elaboration condition was called the *example elaboration-allowed* condition whereas the latter one was called the *example elaboration-no repeat* condition.

3. Experiment 2

3.1. Method

3.1.1. Participants—The 93 students were undergraduates of the University of Texas at San Antonio who were fluent English speakers, free of any learning disability, and were tested individually in one session. The data for three students were removed because two students in the example elaboration condition did not complete the task and one student did not follow the instructions in the differential-associative processing condition. Of the remaining 90 participants, 59 were paid for their participation and 31 received course credit. Fifty-five were female and 35 were male. Finally, the average age was 18.86 years ($SD = .82$).

3.1.2. Design—Ninety students were randomly assigned to one of three conditions: Differential-associative processing, example elaboration-allowed or example elaboration-no repeat (i.e., 30 students in each condition). As in Experiment 1, regardless of the condition students studied the definitions for pairs of related concepts and answered multiple-choice questions about the concepts. Students also completed two of the three sets of concepts and the three sets were counterbalanced such that each set appeared equally in each condition. Further, regardless of the condition, the presentation format of each pair of concepts was identical to the one used in Experiment 1. Finally, because the procedure for differential-associative processing was identical to the one used in Experiment 1, only the two

elaboration conditions are described below. In the differential-associative processing condition, students generated non-relevant differences <4% of the time.

3.1.3. Concept definition processing task—The example elaboration-allowed condition was identical to the one in Experiment 1 with two exceptions. The first exception was that whereas the pairs of concepts in the example elaboration condition in Experiment 1 were presented once, the pairs of concepts in the example elaboration-allowed condition in Experiment 2 were presented twice. The second exception was that during the second presentation of concepts, students were allowed to re-iterate the personal examples and applications that they generated during the first presentation of the concepts. This reiteration was permitted so that the example elaboration-allowed condition still remained somewhat equivalent to the differential-associative processing condition inasmuch as both conditions involved processing two items per concept (i.e., two examples per concept in the example elaboration condition and two features per concept in the differential-associative processing condition). However, it should be noted that students in the example elaboration-allowed condition were not explicitly told that they must generate novel examples during the second presentation of concepts. Nor were they told that they could repeat examples from the first presentation.

The example elaboration-no repeat condition was identical to the example elaboration-allowed condition with the exception that during the second presentation of concepts, students were explicitly instructed that the personal example and application must be novel. In other words, they could not re-iterate examples and applications that were previously generated. In both elaboration conditions students generated examples that were void of critical features <4% of the time.

3.2. Results and discussion

The accuracy scores on the multiple-choice questions were submitted to a preliminary ANOVA, which verified that order of stimuli set had no influence on the data, and another ANOVA, which tested hypothesis 1. The preliminary ANOVA was a $3 \times 6 \times 3$ with condition (differential-associative processing, example elaboration-allowed, example elaboration-no repeat) and order (order 1, order 2, order 3, order 4, order 5, order 6) as between-subjects variables and question type as a within-subjects variable (concept-to-feature, feature-to-concept, applied). The results revealed no main effect of order, $F(5, 72) = 1.54$, order $\times$ condition, $F < 1.0$, order $\times$ type, $F(10, 144) = 1.43$, or order $\times$ condition $\times$ type interactions, $F < 1.0$.

The ANOVA testing hypothesis 1 was a 3×3 with condition (differential-associative processing, example elaboration-allowed, example elaboration-no repeat) as a between-subjects variable and type of question (concept-to-feature, feature-to-concept, applied) as a within-subjects variable.

As Table 4 shows, consistent with Experiment 1 the results support hypothesis 1. Specifically, there was a main effect of condition, $F(2, 87) = 8.46$, $MSE = 19.96$, $\eta^2 = .13$ such that students in the differential-associative processing condition answered more multiple-choice questions correctly than did students in either the example elaboration-allowed or example elaboration-no repeat conditions, 82% versus 70% and 75% respectively, $q(3, 58) = 11.40$, $p < .05$ and $q(2, 58) = 6.40$, $p < .05$ respectively. However, there was no significant difference between the example elaboration-allowed and example elaboration-no repeat conditions, $q(2, 58) = 5.00$, $p < .05$. Although the η^2 of .13 is somewhat smaller than the η^2 of .17 that was observed in Experiment 1, there is no significant difference between the magnitudes of these two effects, $z = .32$, $p < .05$.

There was also a main effect of question type, $F(2, 174) = 10.02$, $MSE = 2.84$, $\eta^2 = .02$, such that more feature-to-concept questions were answered correctly than concept-to-feature and applied questions (i.e., 78% versus 73% and 76% respectively), $q(3, 174) = 4.70$, $p < .05$ and $q(2, 174) = 2.50$, $p < .05$ respectively, but there was no significant difference in the number of concept-to-feature and applied questions that were answered correctly, (i.e., 73% versus 76% respectively), $q(2, 174) = 2.20$, $p < .05$. Finally, there was no interaction between condition and type of question, $F(4, 174) = 1.44$, $MSE = 2.84$. In fact, the effect was trivial by Cohen's (1988) standards, $\eta^2 = .006$. Although, this finding is different from that observed in Experiment 1, the only real difference between Experiments 1 and 2 is that whereas there was no significant difference in the number of correctly answered applied questions in the differential-associative processing versus the example elaboration conditions in Experiment 1 (i.e., differential-associative processing = example elaboration), in the present experiment more questions were answered correctly in the differential-associative processing condition than in the two example elaboration conditions (i.e., differential-associative processing < example elaboration).

The total time to learn the concepts was also compared among the conditions. The results revealed that students spent significantly less time learning concepts in the differential-associative processing condition than in either the example-elaboration-allowed or example-elaboration-no repeat conditions (169 s versus 384.62 s and 406.36 s per pair respectively), $t(58) = -9.92$, $p < .0001$ and $t(58) = -10.12$, $p < .0001$ respectively. However, there was no difference in the amount of time spent learning concepts in the two elaboration conditions (384.62 s versus 406.36 s), $t < 1.0$.

In summary, Experiment 2 replicates the findings of Experiment 1 inasmuch as performance was better when students used differential-associative processing than when they used either type of example elaboration (i.e., *hypothesis 1*). This outcome occurred even though students in the example elaboration conditions viewed the pairs of concepts two times and students in the example elaboration-no repeat condition actually generated more information per concept (i.e., four unique examples per concept) than did students in the differential-associative processing condition (i.e., two features per concept). Thus, the mnemonic benefit of differential-associative processing over example elaborations is not simply a consequence of distributed practice.

4. Experiment 3

So far, the results of Experiments 1 and 2 provide strong support for differential-associative processing over example elaboration as a learning strategy. However, one could argue that this outcome is simply the product of using related pairs of concepts as a medium for comparing differential-associative processing with example elaboration. In other words, the previous experiments were somewhat unfair tests of example elaboration because differential-associative processing was designed to be an effective strategy for learning related concepts whereas example elaboration was not. Indeed, consistent with the encoding specificity principle (e.g., Hannon & Craik, 2001; Tulving & Thomson, 1973), the amount of overlap between the content of the material being learned and the cues given at retrieval is greater for the differential-associative processing condition than it is for the example elaboration condition.

Perhaps a fairer test of example elaboration might be to use concept definitions that are more neutral or unrelated (e.g., *morpheme-fluid intelligence*). The use of unrelated pairs will eliminate the advantage that differential-associative processing had with related concept pairs because the degree of overlap between encoding and retrieval will be greatly reduced. Indeed, previous research examining the mnemonic value of generating differences for

unrelated versus related word pairs (e.g., *train – bowl* versus *train – caboose*) suggests that memory is poorer for unrelated versus related word pairs when differences are generated (e.g., Begg, 1978; Epstein et al., 1975). As a result, based on these findings it was hypothesized that performance in the differential-associative processing condition will be better when the pairs of concepts are related (e.g., *genotype–phenotype*) than when they are unrelated (e.g., *morpheme–fluid intelligence*) (i.e., *hypothesis 2a*).

Additionally, previous research suggests that when students use example elaboration to learn unknown concepts, performance in this integrative elaboration condition is greater than performance in a comparative elaboration condition, namely elaborative interrogation (Simpson et al., 1994). Therefore, based on these findings it was hypothesized that performance in the example elaboration condition will be better when the pairs of concepts are unrelated (e.g., *morpheme–fluid intelligence*) than when they are related (e.g., *genotype–phenotype*) (i.e., *hypothesis 2b*).

4.1. Method

4.1.1. Participants—The 48 participants were students from the University of Texas at San Antonio who were fluent English speakers, free of any learning disability, and were tested individually in one session. Forty participants were paid for their participation and eight received course credit. All participants completed their sessions. Twenty-nine were female and 19 were male and the average age was 19.06 ($SD = 1.47$).

4.1.2. Design—Twenty-four students were randomly assigned to each of the two conditions: Differential-associative processing or example elaboration-no repeat. Example elaboration-no repeat was selected because it had the best performance in Experiment 2 and thus served as a stringent comparison condition. As in Experiments 1 and 2, the presentation of the concept definitions was similar to the pairs depicted in Table 1, the students learned definitions for two sets of pairs of concepts, and answered multiple-choice questions about the concepts. However, unlike Experiments 1 and 2, half the pairs of concepts were related pairs (e.g., the *genotype–phenotype* example in Table 1), while the other half were unrelated pairs (e.g., the *morpheme–fluid intelligence* example in Table 1). The procedures for differential-associative processing and example elaboration-no repeat were identical to those used in Experiment 2. Thus, only the stimuli changes are described below. For both the differential-associative processing and example elaboration-no repeat conditions students generated irrelevant differences/examples <1.5% of the time.

4.1.3. Materials—The stimuli were 16 pairs of concepts and their respective multiple-choice questions. These 16 pairs of concepts were divided into two sets of 8 unique pairs each.

Each set included four related and four unrelated pairs of concepts, see Table 1 for examples. Students completed both sets of concepts. Consequently, they learned the definitions for eight pairs of related and eight pairs of unrelated concepts. The unrelated pairs were created by re-pairing one concept from one related pair of concepts within a set with one concept from another related pair of concepts within that same set. For example, the concept *morpheme* was taken from the related pair of concepts, *morpheme–phoneme*, and paired with the concept *fluid intelligence*, which was taken from the related pair of concepts, *crystallized intelligence–fluid intelligence*.

In order to fully counterbalance the stimuli, two additional sets of stimuli were created that were complementary of the first two sets. That is, concepts that were used in related pairs of concepts became concepts used in unrelated pairs of concepts and concepts used in unrelated

pairs of concepts became concepts used in related pairs of concepts. For example, whereas *genotype-phenotype* was a related pair of concepts in one of the first two sets of pairs of concepts, in one of the latter two additional sets *genotype* and *phenotype* were re-paired with other concepts in order to form unrelated pairs. On the other hand, whereas *morpheme* and *phoneme* were used in unrelated pairs in one of the first two sets of pairs of concepts, in one of these two additional sets *morpheme* and *phoneme* were paired together, thus forming the related pair *morpheme-phoneme*. The sets of concepts were completely counterbalanced such that an equal number of students in the differential-associative processing and example elaboration-no repeat conditions completed each set.

The accompanying multiple-choice questions were the same ones used in Experiments 1 and 2 and consequently, most of them included the correct answer's complement; for examples, see Table 2. However, because unrelated pairs of concepts do *not* include any information about a concept's complement, it is expected that students will commit more errors when answering multiple-choice questions assessing unrelated concepts. For example, the definitions for the unrelated pair of concepts *genotype- fluid intelligence* provide no information about the definitions for *phenotype* and *crystallized intelligence* and consequently, students might experience more difficulty when answering questions assessing knowledge about the definitions for *genotype* and *fluid intelligence*.

4.2. Results and discussion

Accuracy scores were submitted to a $2 \times 8 \times 2 \times 3$ ANOVA that assessed whether stimuli set order influenced the data: condition (differential-associative processing, example elaboration-no repeat), and order were between-subjects variables (order 1, order 2, order 3, order 4, order 5, order 6, order 7, order 8), while type of concept pairs (related, unrelated) and question type (concept-to-feature, feature-to- concept, applied) were within-subjects variables. There were no significant results: (i) order, $F < 1.0$, (ii) two-way interactions, such as order $\times$ condition, order $\times$ question type, order $\times$ pair type, *all* $F's < 1.0$, (iii) three-way interactions, such as order $\times$ condition $\times$ pair type, $F < 1.0$, order $\times$ condition $\times$ question type, $F < 1.0$, order $\times$ question type $\times$ passage type, $F(2, 88) = 1.32$, or (iv) order $\times$ condition $\times$ question type $\times$ passage type interaction, $F < 1.0$.

The accuracy scores were also submitted to another $2 \times 2 \times 3$ ANOVA which include condition (differential-associative processing, example elaboration-no repeat) as a between-subjects variable, and type of concept pairs (related, unrelated) and type of question (concept-to-feature, feature-to-concept, applied) as within-subjects variables.

As Table 4 shows, consistent with the findings of Experiments 1 and 2, hypothesis 1 was supported. More specifically, differential-associative processing was a better strategy than example elaboration for learning pairs of concepts, 76% versus 68% respectively, $F(1, 46) = 7.61$, $MSE = 15.11$, $\eta^2 = .07$. The main effect for type of concept pairs was also significant, $F(1, 46) = 16.49$, $MSE = 4.86$, $\eta^2 = .05$, such that more questions about related pairs of concepts were answered correctly than were questions about unrelated pairs, 76% versus 69% respectively.

The two-way interaction between condition and type of concept pair was also significant, $F(1, 46) = 6.86$, $MSE = 4.86$, $\eta^2 = .02$. In order to test hypotheses 2a and 2b, two subsequent post-hoc tests were completed. For hypothesis 2a, which asserts that the mnemonic benefit of differential-associative processing is greater when the pairs of concepts are related than when they are unrelated, one post-hoc test compared performance on questions assessing related versus unrelated pairs of concepts in the differential-associative processing condition. The results revealed that students answered correctly more questions assessing related than unrelated pairs when the definitions were learned using differential-associative

processing (i.e., 82% versus 71% respectively), $q(2, 46) = 10.90$. These results support hypothesis 2a as well as previous research, which suggests that the mnemonic benefit of differences is greater for related word pairs than unrelated ones (e.g., Begg, 1978; Epstein et al., 1975). For hypothesis 2b, which asserts that the mnemonic benefit of example elaboration is better when the pairs of concepts are unrelated than when they are related, another post-hoc test compared performance on questions assessing related versus unrelated pairs of concepts in the example elaboration condition. The results revealed no significant difference in the number of correctly answered questions assessing related versus unrelated pairs when the definitions were learned using example elaboration (i.e., 70% versus 67% respectively), $q(2, 46) = 2.30$, $p < .05$. These results do not support hypothesis 2b.

In addition, to testing hypotheses 2a and 2b, further analyses revealed that there was no significant difference between performance on the unrelated pairs in the differential-associative processing condition and performance in both related and unrelated pairs in the example elaboration condition (i.e., 71% versus 67% and 70% respectively), $q(3, 46) = 3.60$, $p < .05$ and $q(2, 46) = 1.30$, $p < .05$ respectively. These two findings suggest that regardless of the type of pair of concepts (i.e., unrelated or related), a comparative elaborative strategy (e.g., differential-associative processing) is as good as, and in some instances better than, an integrative elaborative strategy (e.g., example elaboration). These findings also suggest that while a high degree of overlap between the materials being encoded and retrieved might be why performance in the differential-associative processing is greater than example elaboration for related concepts, it cannot explain why performance in the differential-associative processing-unrelated concepts condition is not significantly better than performances in the example elaboration-related and example elaboration-unrelated concepts conditions.

The two-way interaction between type of concept pair and question type, was also significant, $F(1, 46) = 6.77$, $MSE = 2.39$, $\eta^2 = .02$. Post-hoc tests revealed that significantly more feature-to concept and concept-to-feature questions were answered when the concept pairs were related than when they were unrelated (i.e., 77% versus 71% respectively and 77% versus 65% respectively), $q(3, 46) = 5.70$, $p < .05$ and $q(4, 47) = 12.35$, $p < .05$ respectively. On the other hand, regardless of type of concept pair, there was no significant difference in the number of applied questions that were answered (i.e., 73% versus 71% respectively), $q(2, 47) = 1.95$, $p < .05$. Taken as a whole, these findings suggest that the type of concept pair (i.e., related, unrelated) influences some of the question types (i.e., concept-to-feature and feature-to-concept). One possible explanation for this finding is that perhaps concept-to-feature and feature-to-concept questions have a greater reliance on distinguishing features between concepts that are easier to identify when the concepts are related than when they are unrelated.

The remaining effects—the main effect for type of question, the two-way interaction between condition and type of question (i.e., condition $\times$ type of question), and the three-way interaction among condition, type of question and type of concept pair (i.e., condition $\times$ type of question $\times$ concept pair type)—were not significant, $F(2, 92) = 2.70$, $F(2, 92) = 2.35$, and $F < 1.0$. This lack of significant findings was not a consequence of lack of power. Rather, the effect size calculations revealed that the sizes of these three effects were less than the smallest acceptable effect size (i.e., $\eta^2 < .01$); a finding that suggests that they are trivial by Cohen's standards (1988) and are of no psychological relevance. Finally, the non-significant condition $\times$ question type interaction is consistent with the results of Experiment 2.

As a final check, the total time spent learning the concepts in the two conditions was statistically compared. The analysis revealed that students spent less time learning the

concepts using differential-associate processing than they did when they used example elaboration (190.08 *s* versus 335.80 *s* per pair respectively), $t(23) = -9.27$, $p < .0001$.

5. Discussion

Definitions of related concepts are prevalent in introductory courses. Consequently, it is very important that both educators and students know which strategy(s) work best for learning these definitions. The goal of the present study was to test which of two strategies—differential-associative processing and example elaboration—might be best for learning definitions of related concepts (i.e., *hypothesis 1*). All three experiments showed the same pattern of results; specifically a medium-large main effect for condition (i.e., strategy choice) such that differential-associative processing, a comparative elaborative strategy, was better for promoting the learning of definitions of pairs of concepts than was example elaboration, an integrative elaborative strategy. This main effect was prevalent even when students in both conditions viewed the definitions twice (i.e., Experiments 2 and 3) (i.e., *hypothesis 1*), and even when the pairs of definitions were unrelated (i.e., Experiment 3), which was an unexpected finding.

Further, differential-associative processing promoted learning of the definitions when students in the example elaboration condition spent significantly more time and they generated more pieces of information per concept (i.e., example elaboration-no repeat condition involved four pieces of information per concept versus two pieces of information per concept in the differential-associative processing condition). This latter finding is particularly interesting because it suggests that additional processing of information does not necessarily produce better learning. Rather, consistent with previous research (e.g., Hannon et al., 2010) it appears that an important aspect of learning definitions of concepts is to identify features that are unique for each concept. Presumably the explicit identification of unique distinguishing features makes these features more salient in the memory trace of a concept. This increase in salience makes it easier to select appropriate answers on subsequent multiple-choice tests because it reduces interference from other similar information, such as the type of information that is found in the memory trace of the correct answer's complement. This finding is also consistent with Renkl and Atkinson's (2007) idea of *focused processing*. According to these authors, it is not sufficient for students to just actively process the to-be-learned material (Robins & Mayer, 1993). Rather it is important that they process information with a focus on central ideas and principles in the concepts (Renkl & Atkinson, 2007; see also Atkinson & Renkl, 2007).

In addition, the results of Experiment 3 reveal a significant main effect of strategy such that regardless of the type of pair of concepts (i.e., related or unrelated), differential-associative processing is a significantly better strategy than is example elaboration. Indeed, students answered correctly 76% of the questions when they used differential-associative processing but only 68% of the questions when they used example elaboration. Thus, the take home message from this significant main effect is that regardless of the types of pairs of concepts (e.g., related or unrelated) when students have a choice between differential-associative processing and example elaboration as a strategy for learning concepts, they should select differential-associative processing. Of course, this main effect was qualified by an interaction between condition and type of concept. However, this interaction again supported the idea that when given a choice between differential-associative processing and example elaboration, students should select differential-associative processing. Specifically, it showed that differential-associative processing was a significantly better strategy than example elaboration for learning related concepts (e.g., genotype, phenotype) (i.e., *hypothesis 1*) but differential-associative processing and example elaboration were both effective strategies when the pairs of concepts are unrelated (e.g., *morpheme-fluid*

intelligence). On the one hand, this latter finding is quite surprising because previous research examining related and unrelated word pairs (e.g., *beer-wine* versus *beer-donkey*) suggests that generating differences between unrelated word pairs (such as those differences generated with differential-associative processing) does not facilitate learning as well as generating similarities (e.g., Begg, 1978; Epstein et al., 1975). In other words, one might expect differential-associative processing to be a significantly poorer strategy than example elaboration for learning definitions of unrelated pairs of concepts. On the other hand, the comparison condition used here was example elaboration and not similarities, which was the comparison condition that was used in the original word pair studies. Thus, when considering unrelated pairs of concepts, perhaps the lack of a significant difference between differential-associative processing and example elaboration might be because generating similarities would have been a better comparison strategy than example elaboration.

The findings of Experiment 3 also provide some theoretical insight as to why differential-associative processing is an effective strategy for learning definitions of concepts. Specifically, differential-associative processing was a better strategy when the critical stimuli were related definitions of concepts with a high degree of overlap of information between encoding and retrieval (i.e., encoding: pairs of definitions of related concepts; retrieval: assess differences between definitions of related concepts) than when the critical stimuli were unrelated definitions of concepts with a low degree of overlap of information between encoding and retrieval (i.e., encoding: pairs of definitions of unrelated concepts; retrieval: assess differences between definitions of related concepts). In other words, the encoding specificity principle (e.g., Hannon & Craik, 2001; Tulving & Thomson, 1973), which states that better learning occurs when there is a greater overlap in the material at learning and test, explains why differential-associative processing is a better strategy for learning definitions of related concepts versus definitions of unrelated concepts.

The findings of the present study also extend the earlier findings of Hannon et al. (2010). In their study, Hannon and colleagues showed that differential-associative processing was a better strategy for learning related pairs of concepts than were three other learning strategies, namely (i) a strategy in which students identified important features for each concept in a pair of concepts, (ii) a strategy in which students identified both similarities and differences between a pair of concepts, and (iii) a strategy chosen by a student. The present study expands this research by showing that differential-associative processing is a better strategy than example elaboration, a well-established integrative strategy that is considered to be one of the best strategies for learning definitions of concepts (e.g., Hamilton, 1989; Mayor, 1980). It also expands this research by showing that one reason why differential-associative processing is a better strategy for learning definitions of related concepts is because it focuses students on the information that is important for subsequent testing. In other words, because differential-associative processing focuses on differences between the definitions of the concepts and these differences are needed when answering multiple-choice questions, students are likely to perform better on subsequent multiple-choice questions (i.e., encoding specificity).

The positive findings for differential-associative processing add to a growing literature that assesses the efficacies of learning strategies/methods. One such method, called worked-out examples, include a statement about a problem, steps for solving the problem, and the problem's final solution (Atkinson & Renkl, 2007). Research suggests that worked-out examples are an effective instructional method, especially when they include interactivity, such as prompts that focus a learner on critical to-be-learned information (e.g., Berthold et al., 2007). Consistent with this latter research, the present study showed better performance when students focused on the critical to-be-learned information (i.e., the differences between the concept definitions).

There are also other strategies that could and perhaps should be compared to differential-associative processing. Recently, researchers have suggested that repeated testing of to-be-remembered information enhances performance on the final test (e.g., Roediger & Karpicke, 2006a; see also Roediger & Karpicke, 2006b). In this research, students study two short passages and then either re-read the passages or complete multiple recalls of the passages before the final test. The general findings are that repeated recall/testing of the to-be-remembered information enhances final testing in comparison to repeated reading/studying. Further, the value of repeated testing exists even when the final testing is delayed by one week. Given these findings and those of the present study, it would be interesting to compare repeated testing with differential-associative-processing. Such a comparison would help determine whether repeated testing is better than, the same as, or poorer than differential-associative processing for learning definitions of concepts.

It would also be interesting to compare the mnemonic value of differential-associative processing with example comparison; another comparative strategy that involves comparisons between pairs of examples for the same concept (e.g., Merrill & Tennyson, 1977, 1978; Park, 1984) rather than pairs of concept definitions. Indeed, experimentally testing these two strategies might reveal that one or both of these strategies are suitable for learning definitions of related concepts.

Of course, the present study also has some limitations. One limitation is that only one type of example elaboration was tested in the present study, namely subject-generated examples. However, it is quite possible that other types of example elaborations might be better for learning definitions of related pairs of concepts and/or definitions of unrelated pairs of concepts. For example, Chi, Bassok, Lewis, Reimann, and Glaser (1989) have found that when students generate many self-explanations while studying detailed examples, they learn with greater understanding than do students generating a few self-explanations. A second limitation is that the present and past studies (i.e., Hannon et al., 2010) have examined the efficacy of differential-associative processing with only pairs of concepts rather than examining the efficacy of differential-associative processing with three, four, or five concepts simultaneously. Although, given the value of differential-associative processing for pairs of concepts there is no reason to believe that differential-associative processing would not be suitable for groups of three or more concepts. A third related limitation is that the stimuli used in the present and previous research (i.e., Hannon et al., 2010) were definitions of concepts and multiple-choice questions taken from test banks of Introductory Psychology textbooks. Although these stimuli are ecologically valid and important, especially to students, it would be interesting to see whether the value of differential-associative processing can be transferred to prose passages or even whole chapters of textbooks as well as recall or short answer questions. A fourth limitation is the small inconsistency in significance across the three experiments for the condition $\times$ question type interaction. Specifically, whereas the condition $\times$ question type interaction was significant in Experiment 1, it was non-significant in Experiments 2 and 3. While the results of Experiment 1 seem to suggest that differential-associative processing may not be a superior learning strategy for questions that require the learner to understand and use the concept, such interpretations should be made with caution because Experiment 1 was also confounded. Nevertheless, perhaps future research might ask the very important question: *Is differential-associative processing a superior strategy for questions that require the learner to understand and use the concept?* Finally, the present research was conducted individually in the lab. It would be interesting to see whether the value of differential-associative processing can be generalized to a classroom setting. For example, perhaps differential-associative processing could be used as an instructional strategy where students are asked to explicitly identify critical differences between related concepts. Once, the critical differences are

identified the instructor could quiz students as to which concept belongs to which part of the difference (i.e., feature).

In conclusion, this study suggests that differential-associative processing is a good strategy for learning related and unrelated pairs of concepts. This outcome occurred even when students using example elaboration generated more information and spent more time learning the concepts. These findings should be of interest to educators and students because of the prevalence of related definitions of concepts and multiple-choice questions that assess differences between the concepts in introductory classes. Further, based on these favorable results as well as those of earlier research (e.g., Hannon et al., 2010), I believe the time is ripe to examine thoroughly the mnemonic benefits of differential-associative processing using other stimuli in other settings, such as classrooms.

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Appendix A

Results of ANOVAs for Experiments 1, 2, and 3.

	<u>Experiment</u>		
	Experiment 1	Experiment 2	Experiment 3
<i>Effect</i>			
condition	yes, $\eta^2 = .17$	yes, $\eta^2 = .13$	yes, $\eta^2 = .07$
question type	yes, $\eta^2 = .02$	yes, $\eta^2 = .02$	no, $\eta^2 = .007$
condition $\times$ question type	yes, $\eta^2 = .02$	no, $\eta^2 = .006$	no, $\eta^2 = .006$
concept pair type			yes, $\eta^2 = .05$
condition $\times$ concept pair type			yes, $\eta^2 = .02$
concept pair type $\times$ question type			yes, $\eta^2 = .02$
condition $\times$ concept pair $\times$ question type			no, $\eta^2 = .0001$

Note. The main effect for condition varies from experiment to experiment inasmuch as it includes a combination of the following conditions: Example elaboration, differential-associative processing, example elaboration-allowed, example elaboration-no repeat. Question type includes: feature-to-concept, concept-to-feature, and applied. Concept pair type includes: related pairs, unrelated pairs. As noted earlier, $\eta^2 < .01$ are considered trivial by Cohen's standards as they: (i) have no psychological relevance and (ii) represent less than 1% of the total variance.

Table 1

A sample pair of related concepts used in Experiments 1, 2, and 3 and a sample pair of unrelated concepts used in Experiment 3.

(i) Sample pair of related concepts

Genotype

You cannot see a person's genotype. It is the actual genetic information inherited from one's parents. A genotype will tell you what type of genes someone has. For example, although a woman may not have breast cancer, she could potentially develop breast cancer because she carries the genotype for breast cancer that she inherited from her mother.

Phenotype

It is the expression or behavioral manifestation of the genotype. It results from the interaction between a person's genotype (nature) and the environment (nurture). You can see a person's phenotype. For example, a child may have brown eyes that he inherited from his father or he may demonstrate artistic qualities that he has inherited from his mother.

(ii) Sample pair of unrelated concepts

Morpheme

A morpheme is the smallest unit of language that carries meaning. Some morphemes such as word stems like DOG and RUN can stand alone as words, while other morphemes such as the prefixes PRE- and UN- and the suffixes -ED and -S cannot stand alone. The English language has more than 40 morphemes.

Fluid intelligence

It is the natural ability to solve problems, reason, and remember. Fluid intelligence is thought to be relatively uninfluenced by experience. It's the type of intelligence that is probably determined by biological or genetic factors. It tends to decrease in late adulthood.

Table 2

Examples of multiple-choice questions used in Experiments 1, 2, and 3.

Genotype		Phenotype	
<i>Concept-to-feature</i>			
A person's genotype is:		A person's phenotype is their:	
a. never observable	c. often goes unobserved	a. actual genetic message	c. inherited genetic code
b. always observable	d. often observed	b. behavioral manifestations	d. unobservable genetic code
<i>Feature-to-Concept</i>			
An inherited trait is:		The outward physical manifestations of a person are called;	
a. a phenotype	c. a person's genetic code	a. genotypes	c. phenotypes
b. an inherited behavior	d. a genotype	b. dispositions	d. traits
<i>Applied</i>			
Although Jesse doesn't show signs of rheumatoid arthritis, he could eventually develop rheumatoid arthritis because he inherited it from his father. This is because of a:		Jeremy inherited his mother's double-jointed thumbs and his father's basketball skills. How Jeremy looks and acts is a result of:	
a. phenotype	c. genotype	a. phenotype	c. genotype
b. trait	d. gene	b. behavior	d. mannerisms

Table 3

Examples of student responses for differential-associative processing and example elaboration conditions.

Differences for differential-associative processing

- 1 can't see a genotype, can see a phenotype
- 2 genotype is related to heritability, phenotype is related to heritability and environment
- 3 a genotype does not manifest from anything, a phenotype manifests from a genotype

Example elaboration – personal

- 1 I can have the genotype for skin cancer but I can't see it. Everyone knows I am good at math because I inherited this ability from my dad.
- 2 I don't have liver cancer but my mom did, so I might have the genotype for it. I am good at biology and I inherited that skill from my mom.
- 3 My dad has high cholesterol, which I may have one day too. My dad has blond hair, which is the hair color of my sister too.

Example elaboration – applied

- 1 Someone born with HIV may not show the symptoms but a gene test would show it. Some people inherited brown hair from their parents and you can see it.
 - 2 A person's ancestors may have the genotype leukemia, which may be passed down. A son can appear to be tall because he inherited height from his dad.
 - 3 A girl, who's mom had problems with child bearing, may also have problems having children. A person may have big hands that he/she inherited from one of his/her parents.
-

Table 4

Percentage of correct responses to multiple-choice questions in Experiments 1, 2, and 3.

	Type of question			
	Feature-to-concept	Concept-to-feature	Applied	Overall average
<i>Experiment 1</i>				
Example elaboration	68.9 (3.08)	63.0 (3.37)	67.7 (3.32)	66.6 (3.00)
Differential-associative	82.6 (2.70)	80.9 (2.27)	74.1 (2.47)	79.2 (2.31)
average:	75.8 (2.26)	72.0 (2.39)	70.9 (2.10)	72.9 (2.95)
<i>Experiment 2</i>				
Example elaboration – allowed	73.9 (2.74)	67.2 (3.33)	69.3 (2.26)	70.1 (2.63)
Example elaboration – no repeat	77.1 (1.78)	71.9 (2.11)	76.4 (2.08)	75.1 (1.64)
Differential-associative	83.1 (1.57)	80.8 (1.61)	80.7 (1.92)	81.5 (1.40)
average:	78.0 (1.26)	73.3 (1.53)	75.5 (1.29)	75.6 (1.22)
<i>Experiment 3</i>				
Example elab – no repeat – related pairs	69.8 (3.74)	70.3 (2.97)	68.5 (3.58)	69.5 (3.14)
Example elab – no repeat – unrelated pairs	68.5 (2.75)	62.8 (3.14)	70.3 (2.41)	67.2 (2.19)
example elab average:	69.1 (2.83)	66.5 (2.60)	69.4 (2.27)	68.4 (2.33)
Differential-associative – related pairs	84.1 (2.06)	84.1 (1.88)	76.8 (2.14)	81.7 (1.42)
Differential-associative – unrelated pairs	74.0 (2.62)	67.5 (2.94)	71.1 (2.88)	70.8 (2.23)
differential-associative average:	79.0 (1.85)	75.8 (2.00)	74.0 (2.12)	76.3 (1.66)
average for Expt. 3:	74.1 (1.82)	71.2 (1.76)	71.7 (1.57)	72.3 (1.53)

Note. Standard errors are in brackets. Extreme caution should be exercised when comparing percentages across experiments because data collection for each experiment took place at different points in time and so, the expected variations in numbers exist. What is most important is: (i) that data for conditions within the same experiment were collected simultaneously and (ii) the patterns of results among the conditions within the same experiment.