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An examination of some of the cognitive and motivation variables related to gender differences in lecture note-taking

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Abstract The primary purpose of this investigation was to explore if gender is related to note-taking in a large undergraduate sample (divided relatively evenly between males and females), and if it is, to examine the cognitive (handwriting speed, working memory, language comprehension) and motivation variables (conscientiousness and goal orientation) that might explain the relationship. A second purpose was to determine if there might be gender related differences in test performance (written recall). Results indicated that females recorded significantly more information in notes and written recall than males and performed significantly better on measures of handwriting speed, working memory, language comprehension, and conscientiousness. Results also indicated that notes' quality was significantly and positively related to language comprehension, gender, and the gender × language comprehension interaction, while written recall was positively and significantly related to handwriting speed, mastery goal orientation, and the gender × conscientiousness interaction. Results imply that the female advantage typically found in language mediated tasks like reading and essay writing may extend to lecture note-taking. From a theoretical perspective, our data indicate that past research on the processes associated with note-taking, which have focused exclusively on cognitive processes, has been too narrow. Future research should attempt to replicate these findings, investigate other motivation related variables to note- and test-taking, such as openness to experience, and investigate whether females have an advantage on both functions of note-taking: encoding (taking notes), which we investigated, and review (of notes), which we did not investigate.

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Introduction

Note-taking is used to record important information presented in class. Among college students, most perceive note-taking to be an important educational activity (Van Meter, Yokoi, & Pressley, 1994), a vast majority take notes in classes (Hartley & Marshall, 1974; Nye, Crooks, Powley, & Tripp, 1984; Palmatier & Bennett, 1974), and research has shown that recording and reviewing notes from lecture is associated with good test performance (Bretzing & Kulhavy, 1981; Fisher & Harris, 1973; Kiewra, 1985; Kiewra et al., 1991; Kiewra & Fletcher, 1984; Peverly, Garner, & Vekaria, 2014; Peverly, Ramaswamy, Brown, Sumowski, & Alidoost, 2007; Peverly et al., 2013; Rickards & Friedman, 1978; Titsworth & Kiewra, 2004).

Analyses of the act of lecture note-taking suggest that it is a difficult and cognitively demanding skill (Peverly, 2006; Peverly et al., 2007; Piolat, Olive, & Kellogg, 2005). Note-takers must attend to the lecture, hold information presented in the lecture in working memory, select and or construct the information that is important to remember before the information is forgotten, transcribe the information quickly, again before it is forgotten, and maintain the continuity of what the instructor is saying.

Despite the difficulty of note-taking and its importance to academic success among college students, there is limited research on the cognitive and other individual difference variables associated with skill in lecture note-taking. The variables most consistently identified with note-taking in past research are: handwriting speed (Peverly et al., 2007, 2013, 2014), language comprehension (Peverly et al., 2013; Gleason, 2012; Vekaria, 2011) and sustained attention (Peverly et al., 2014; Gleason, 2012; Vekaria, 2011). Evidence in support of verbal working memory (VWM) is equivocal. Some have found a relationship (Bui, Myerson, & Hale, 2013; Kiewra, 1987; Kiewra & Benton, 1988; McIntyre 1992) and others have not (Cohn, Cohn, & Bradley, 1995; Peverly et al., 2007, 2013, 2014).

Evidence also suggests that females are better note-takers than males (Cohn et al., 1995; Kiewra, 1984; Maddox & Hoole, 1975; Nye, 1978; Reddington, Sumowski, Johnson, & Peverly, 2006; Williams & Eggert, 2002). Kiewra (1984) found that females recorded more important information than males and performed better on exams than males. Cohn et al. (1995) found that females took more complete notes and transcribed 5.1 more idea units than males (Cohn et al., 1995; Nye, 1978; Maddox & Hoole, 1975) and note-taking was more predictive of course performance for females than for males (Eggert, 2000; discussed in Williams & Eggert, 2002). Finally, in a reanalysis of data from Peverly et al. (2007), Reddington et al. (2006) found that females wrote faster than males (i.e., had greater handwriting speed), had higher quality notes and semantic retrieval scores and performed better on the exam. However, when all of these variables were included in a regression equation to predict test performance, only quality of notes was a significant predictor, suggesting that the effects of gender on test performance may be mediated by notes' quality.

The purpose of this investigation was to explore more systematically if females are better lecture note-takers than males, and if they are, why they are more skilled since, for all intents and purposes, the note-taking literature has not explored the reasons for gender differences in note-taking. Specifically, we explored the contributions of some of the cognitive variables thought to be associated with skill in studying (handwriting speed, working memory, and language comprehension), some of which may be related to gender (e.g., handwriting speed). In addition, we explored the contributions of two motivation variables that research suggests are significantly related to academic performance: conscientiousness and goal orientation. Conscientiousness was examined since it has been found to be related to academic success (e.g., Bidjerano & Dai, 2007; Chamorro-Premuzic & Furnham, 2003) and occasionally to gender (Vialle, Heaven, & Ciarrochi, 2005). We also explored the impact of academic goal orientation on note-taking. Although we are not aware of research on the relationship of goal orientation and note-taking, goal orientation is related to variations in academic achievement and students' reported use of study strategies (Meece, Anderman, & Anderman, 2006a). Also, although the relationship between gender and goal orientation has not typically been measured, research has occasionally found gender related differences in this construct (Elliot & Church, 1997). Thus, this study investigated if there are gender related individual differences in note-taking, and if there are, if they can be accounted for by gender related variations in handwriting speed, working memory, language comprehension, conscientiousness, and goal orientation. In addition, this study examined the extent to which these variables are related to test-taking.

Handwriting speed

Results from correlational and experimental studies with children (Berninger et al., 1997; Graham, Berninger, Abbott, Abbott, & Whitaker, 1997; Graham, Harris, & Fink, 2000; Jones & Christensen, 1999) and adults (Brown, McDonald, Brown, & Carr, 1988; Connelly, Campbell, MacLean, & Barnes, 2006; Connelly, Dockrell, & Barnett, 2005; Olive & Kellogg, 2002) have consistently established that handwriting speed is significantly and positively related to the quantity and quality of essays. These findings have been extended to note-taking, a more cryptic, less cohesive and more egocentric form of writing than essays. Peverly and colleagues found that handwriting speed was positively and significantly related to *lecture* notes, notes taken on videotaped lectures (Peverly et al., 2007 (Experiments 1 and 2); Peverly et al., 2013; Peverly et al., 2014) and *text* notes, notes taken on expository text (Peverly & Sumowski, 2012).

Cohen (1997) and Reddington et al. (2006) found that females wrote significantly faster than males. Also, females performed better than males on the Coding subtest of the Wechsler Intelligence Scales (Lyle & Johnson, 1974; Lynn, Fergusson, & Horwood 2005; Slate, 1998). The latter is a time limited task which requires copying symbols into blank boxes which correspond to symbol-number pairs displayed above the boxes. In addition, females performed better than males on tasks of speeded fine motor dexterity, such as the Grooved and Purdue Pegboards (Agnew, Bolla-Wilson, Kawas, & Bleeker, 1998; Bornstein, 1985; Ruff & Parker, 1993; Schmidt, Oliveira, Rocha, & Abreu-Villaca, 2000; Strauss, Sherman, & Spreen, 2006) both of which require placement of small objects into the appropriate places on a board.

Handwriting speed was expected to be significantly and positively related to note quality in the current study and females were expected to have significantly faster handwriting speed than males. Handwriting speed was not expected to be directly related to test performance (written recall) since notes has been found to mediate the relationship between handwriting speed and written recall (e.g., Peverly et al., 2007).

Working memory

Working memory is a cognitive workspace where information from the environment and long-term memory is held, manipulated and interpreted, to achieve goals such as remembering and learning (Baddeley, 2000). Individual differences in working memory have been found to be positively and significantly related to comprehension (Daneman & Merkle, 1996) and writing (Kellogg, 1996; Levy & Ransdell, 2002; Olive, 2004), both of which are related to note-taking. A good working hypothesis is that working memory capacity should be positively and significantly related to storage and processing of information from lecture, which should enable interpretation, selection and transcription of important information.

Research is mixed on the relationship between working memory and note-taking. Cohn et al. (1995), Hadwin, Kirby, and Woodhouse (1999) and Peverly and colleagues (Peverly et al., 2007 (Experiments 1 and 2); Peverly & Sumowski, 2012; Peverly et al., 2013; Peverly et al., 2014) did not find a significant relationship between the two, while Bui et al. (2013), Kiewra and Benton (1988), Kiewra, Benton, and Lewis (1987) and McIntyre (1992) did find a relationship. There may be two reasons for the discrepancies. First, Peverly et al. (2007) noted that the discrepancies in the research may be due to measures used to assess working memory. With one exception (Bui et al., 2013), significant associations between working memory and note-taking have been found in research that used atypical working memory tasks. For example, Kiewra and Benton (1988) used a task that required participants to organize words into meaningful sentences or organize sentences into meaningful paragraphs; however this information was still visible to them during the task and may not have placed as much of a strain on working memory as a task that require subjects to remember information that is no longer in sight. All of the others used a complex span task, such as Daneman and Carpenter's (1980) listening span test. This task requires participants to listen to groups of sentences that range from sets of two to six sentences. Participants have to determine whether each sentence makes sense, which then disappears from view. After all of the sentences in a set are completed, participants hear a beep and must recall the last word of all of the sentences in the set.

A second reason may have to do with the analyses used to evaluate a relationship between working memory and notes' quality. Many of the experiments that used complex span tasks found significant correlations between working memory and notes' quality. However, when notes' quality was regressed on all of the variables included in those experiments, working memory was not a significant predictor of notes' quality (Bui et al., 2013 report correlations only). These findings suggest that variables correlated with working memory are more strongly correlated with notes' quality than working memory thus eliminating working memory as a significant predictor.

Research on the relationship of gender and working memory is mixed. Men typically have the advantage on visuospatial tasks (Loring-Meier & Halpern, 1999) but verbal tasks have produced mixed results (Robert & Savoie, 2006). However, when gender related results are found with verbal tasks they typically favor females (Cochran & Davis, 1987; Duff & Hampson, 2001; Kaushanskaya, Marian, & Woo, 2011; Robert & Savoie, 2006; Speck et al., 2000), especially when the tasks are difficult (Cochran & Davis, 1987).

Even though research has been equivocal regarding the relationship of working memory to note-taking, logically speaking working memory capacity should be related to the quantity and quality of notes, given the significant relationships found between working memory and other academic skills such as reading and writing. Thus, working memory was expected to be positively and significantly related to note quality but not to gender since gender differences have not typically been found. In addition, working memory has not been shown to be significantly related to test performance as measured by written recall and multiple choice exams. Therefore we did not predict a significant association between the two.

Language comprehension

Language comprehension refers to individual differences in understanding and using language, which is based primarily in individual differences in semantics (vocabulary), and grammar (syntax and morphology; Kintsch, 1998). Conceptually speaking, higher levels of language comprehension should be associated with a better and more nuanced understanding of lectures, which in turn should be related to better notes.

Surprisingly, findings on the relationship between language comprehension and note-taking are limited and equivocal. On the one hand, research that used an experimenter constructed main idea identification task (Peverly et al., 2007) or the English and Comprehension subtests of the American College Test (ACT; Kiewra et al., 1987; Kiewra & Benton, 1988) as proxies for language comprehension, did not find a relationship between them and note-taking. On the other hand, studies which used the Nelson–Denny, a standardized reading test, as a proxy for language comprehension (text note-taking: Peverly & Sumowski, 2012; lecture note-taking: Peverly et al., 2013) found that language comprehension was significantly related to notes' quality. Also, Peverly and Sumowski (2012) found that language comprehension was significantly related to students' performance on multiple choice items that measured students' memory for information stated explicitly in text and Peverly et al. (2013) found a significant relationship between language comprehension and students' written recall of the lecture.

Although the findings are mixed and one might argue that reading comprehension measures of the kind used by Peverly and colleagues and Kiewra and colleagues are not language comprehension measures (e.g., some have argued that reading comprehension is also related to other variables such as domain-specific knowledge, e.g., Kintsch, 1998), there are two good reasons to argue that reading comprehension is a proxy for language comprehension among college students. First, reading comprehension is highly correlated with listening skill among college students (.92; Gernsbacher, Varner, & Faust, 1990), which is an excellent proxy for language comprehension (Stanovich, 1991). The reason the correlation is strong is that language comprehension accounts for most if not all of the variance of reading comprehension once word recognition is sufficiently automatized (Adlof, Catts, & Little, 2006; Chen & Vellutino, 1997; see Adlof, Perfetti, & Catts, 2011 for a review of the literature). For example, Adlof et al. (2006) found that language comprehension accounted for 100 % of the variance in reading comprehension among eighth-grade students (Adlof et al., 2006). Considered collectively, these findings suggest that reading comprehension is a strong proxy for language comprehension in these populations (Adlof et al., 2011; Perfetti, 1986). Perfetti (1986) put it succinctly: "Roughly speaking, college adults are reading as well as their verbal intelligence will allow" (p. 30). Second, Peverly and Sumowski (2012) and Peverly et al. (2013) shortened the administration time of the Nelson Denny by 5 min (20 %) to better discriminate between good and poor comprehenders (C. Perfetti, personal communication, February 3, 2003). In this investigation, we used performance on the Nelson–Denny as a proxy for language comprehension.

Regarding gender, mild to moderate effect sizes favoring females on verbal tasks have been found for decades (e.g., Maccoby & Jacklin, 1974). Although there are not a lot of data on gender differences in note-taking, as discussed previously, there are extensive data on gender differences on two other verbally mediated academic tasks: reading and writing. Data collected by the National Assessment of Educational Progress indicate that females have scored higher than males in both domains across grades (elementary, middle and high school) for decades (e.g., National Center for Education Statistics, 2012, 2013). Analyses of students' performance from other countries show the same trends (Lietz, 2006).

In summary, given decades of data from national assessments on gender-based differences on verbally mediated academic tasks we predicted that language comprehension would be significantly related to notes' quality and females would perform significantly better than males. We also predicted that language comprehension would be related to test performance (written recall) and females would perform better on the written recall than males.

Conscientiousness

Conscientious individuals tend to be meticulous, careful, thorough, and have a need for achievement (Costa and McCrae 1992a, 1992b). Given the strong association between studying and achievement, it seems reasonable to assume that individuals high in conscientiousness would have excellent study skills, including good lecture note-taking skills.

Research overwhelmingly supports a strong positive relationship between conscientiousness and academic achievement (Bidjerano & Dai, 2007; Chamorro-Premuzic & Furnham, 2003; Cheng & Ickes, 2009; Furnham, Chamorro-Premuzic, & McDougall, 2003; Kappe & van der Flier, 2010; Komarraju, Karau, Schmeck, & Avdic, 2011; Laidra, Pullmann, & Allik, 2007; Lievens, Coetsier, De Fruyt, & De Maeseneer, 2002; Poropat, 2009), even if cognitive or academic ability are controlled (Beaujean et al., 2011; Conard, 2006). Also, one study found conscientiousness to be positively and significantly related to note-taking (Nakayama, Mutsuura, & Yamamoto, 2012).

Regarding conscientiousness and gender, Feingold (1994) found seven studies on gender differences in conscientiousness. Women were found to be more conscientious than men but the effect size was extremely small ($d = -.07$). Later studies provided confirmation of this result. Vialle et al. (2005) examined gender differences on various characteristics pertaining to emotional well-being and academic outcomes in high school students. Results found that females scored significantly higher than males on conscientiousness, hope, mother's authoritative parenting and attitudes towards schooling. However, only 16 % of the variance was explained by these variables. Conscientiousness accounted for 2.8 %. Costa, Terracciano, and McCrae (2001) re-analyzed data from several countries on several personality variables, and did not find gender differences at the factor level for conscientiousness. However, in an analysis of the subcomponents of consciousness (e.g., dutifulness) they found some small but significant differences, typically in favor of women. Differences in favor of females at the subcomponent level were also found by Weisberg, DeYoung, and Hirsh (2011).

Most of the aforementioned research used the NEO Personality Inventory-Revised (NEO-PI-R; Costa and McCrae 1992a, 1992b), which measures five domains of personality and assesses 30 more specific traits, with six traits under each of the five domains. Conscientiousness was measured in this study using the NEO-PI-R. It was predicted that females would score higher on conscientiousness than males and that conscientiousness would be positively and significantly related to quality of lecture notes. Conscientiousness was also hypothesized to be directly related to written recall.

Goal orientation

Achievement goals are defined as "the purpose of task engagement, and the specific type of goal adopted is posited to create a framework for how individuals interpret and experience achievement settings" (Elliot, McGregor, & Gable, 1999). Originally learners were postulated to have two different achievement goals: performance or mastery (Ames, 1984; Dweck, 1986; Nicholls, 1984). Performance goals focus on demonstrating one's competence relative to others while mastery goals focus on increasing one's competence regardless of the accomplishment of others.

Another distinction in the literature on motivation is whether achievement goals vary on the dimension of approach versus avoidance (Elliot & Church, 1997; Elliot

& Harackiewicz, 1996; Lewin, 1935). Approach goals are related to attaining a positive or desirable event, whereas avoidance goals are related to avoiding a negative or undesirable event. Using studying as an example, those with approach motivation goals are more likely to study to learn the material to receive a high grade. Those with avoidance motivation goals are more likely to study to prevent receiving a bad grade.

Elliot and Church (1997) and Elliot and Harackiewicz (1996) combined the performance-mastery and approach-avoidance frameworks into a trichotomous achievement goal framework which consists of performance-approach, performance-avoidance and mastery goals (some previous research has found that the approach-avoidance framework does not seem to apply to mastery goals, e.g., Elliot and Harackiewicz, 1996). Performance-approach goals focus on attaining normative competence while performance-avoidance goals focus on avoiding normative incompetence (Elliot, 1999). Mastery goals focus on attaining task mastery.

Research on the trichotomous framework has found that mastery and performance approach goals are more typically associated with persistence, effort, more enjoyment of academic tasks, greater self-efficacy, study strategies that promote understanding, and better academic performance. Performance avoidance is more frequently associated with less persistence and effort, more anxiety, study strategies that focus more on memory than understanding, lower self-efficacy and poorer academic outcomes (Ablard & Lipschultz, 1998; Daniels et al., 2008; Dupeyrat & Mariné, 2005; Elliot et al., 1999; Giota, 2006; McGregor & Elliot, 2002; Meece et al., 2006a; Payne, Youngcourt, & Beaubien, 2007; Shih, 2005; Sins, van Joolingen, Savelsbergh, & van Hout-Wolters, 2008).

Research on goal orientation and academic performance has not typically focused on gender (Meece et al., 2006a). Ablard and Lipschultz (1998) studied the relationship between achievement goals and self-regulated learning (SRL) in seventh grade high achieving students. Participants filled out the Self-Regulated Learning Interview Schedule (SRLIS; Zimmerman & Maninez-Ponds, 1986), which asked about strategies used in eight contexts: remembering information from class discussions, completing a short paper, completing a difficult math homework problem, checking homework assignments, preparing for a test, taking a test, completing homework with distractions, and studying at home. Analyses indicated that there were gender differences in achievement goals. Females scored higher on mastery goals than males but not performance goals (the authors did not differentiate between performance approach and avoidance). Females also had a significantly higher SRL total than males. Females reported significantly greater use of the following strategies: organizing and transforming, goal setting and planning, keeping records and monitoring, seeking assistance from peers, and reviewing notes. Gender differences also varied depending on the learning context. Females reported greater use of SRL strategies in a number of different situations: writing a short paper, completing a math problem they did not understand, preparing for tests, and when having difficulty completing assignments because of distractions.

Elliot and colleagues (Elliot & McGregor, 2001; Elliot et al., 1999) found some significant relationships between gender and goal orientation. Elliot and McGregor (2001) found significant correlations between gender and mastery motivation (direction not specified) in Studies 1 and 2 and gender was a significant predictor of mastery-approach goals in three separate regression equations in Study 2. In all of them, women had a stronger mastery approach goals than men. Elliot et al. (1999) found significant correlations between gender and performance approach in Study 1 and between gender and mastery in Study 2, although the direction of the findings was not specified. Gender did not significantly contribute to students' study strategies or performance on exams. Finally, in a study on gender related differences in writing among middle school students, Pajares and Valiante (2001) found that females had a stronger mastery orientation and males a stronger performance-approach orientation.

Given the associations between gender and goal orientation in research by Ablard and Lipschultz (1998), Elliot and colleagues and Pajares and Valiante (2001), we predicted that mastery and performance-approach goals would be positively related to note quality and performance-avoidance goals would be negatively related to note quality. We also predicted that females would be more likely to have a mastery goal orientation than males but that there would not be gender related differences on performance approach or avoidance goals. Finally, we predicted that performance-approach and mastery goals would be positively related to written recall, and performance-avoidance goals would be negatively related.

Summary and hypotheses

The cognitive variables frequently or occasionally associated with skill in note-taking are handwriting speed, working memory, and language comprehension. The motivation variables of conscientiousness and academic goal orientation also have been shown to be related to academic success. Gender has been found to be related to each although more strongly to some (handwriting speed; language comprehension) than others (working memory; conscientiousness; goal orientation).

Females were predicted to score higher than males on handwriting speed, language comprehension, conscientiousness, notes' quality and mastery goal orientation but not the other goal orientations. No gender differences were anticipated on working memory. In addition, females were predicted to have higher written recall scores.

Gender, handwriting speed, language comprehension, conscientiousness and working memory were predicted to be significantly related to notes' quality. Mastery and performance-approach goals were predicted to be positively related to notes' quality and performance-avoidance goals were predicted to be negatively related.

Notes' quality, language comprehension, conscientiousness, and goal orientation were predicted to be positively and significantly related to written recall.

Method

Participants

Participants were undergraduate students ($N = 139$) at a large public university in the northeastern United States who were registered in two sections of an introductory level Sociology class. Seventy-six students were obtained from section 1 and 63 from section 2. Across sections, the mean age was 19.7 ($SD = 1.8$), with a range of 17–29. The mean age of females and males was 19.6 and 19.8, respectively. Fifty-five percent were female and 45 % were male. Ninety-one percent spoke English as their first language. The race/ethnicity of the sample was diverse: White (40 %; $N = 55$), Black/African American 32 %; ($N = 44$), Asian American/Pacific Islander (14 %; $N = 20$), Latina/Latino (5 % $N = 7$), Native American/Alaskan Native (4 %; $N = 5$) and Other (6 %; $N = 8$). By gender, 47 % of females were White, 26 % were Black/African American, 13 % were Asian American/Pacific Islander, 6 % were Latina/Latino, 3 % were Native American and 4 % were Other. For males, 30 % were White, 38 % were Black/African American, 16 % were Asian American/Pacific Islander, 3 % were Latina/Latino, 5 % were Native American and 8 % were Other.

Participants were compensated by extra course credit as approved by the university's IRB. The investigation took place in a large classroom with the use of an electronic overhead projector and associated speaker system.

Materials and scoring

The materials consisted of a previously recorded lecture video on the psychology of problem solving, measures of handwriting speed (alphabet task), verbal working memory (operation span task), language comprehension (The Nelson Denny), conscientiousness (NEO-PI-R) and motivational goal orientation (Achievement Goal Questionnaire). All tasks were group administered. We measured inter-rater agreement for the non-standardized measures (e.g., alphabet task) by randomly selecting ten protocols, which were scored by two different raters. For the standardized measures (e.g., Nelson–Denny) we calculated Cronbach alphas.

Lecture

The lecture was taken from Brobst (1996). The videotaped lecture, read from a prepared text by the second author at a rate of 2.04 words per second, was approximately 23 min long and summarized basic concepts and research in the psychology of problem solving. The lecture was adapted from a chapter by Voss (1989) titled "Problem Solving and the Educational Process," which was taken from a book designed for use in an undergraduate educational psychology course (Brobst, 1996). The lecture consisted of a total of six general themes and 15 content areas. Students were told to watch and take notes on the lecture. They were also told that they would have time to review their notes but would not have access to their notes during the exam.

Handwriting speed

Handwriting speed was measured using a modification of the Alphabet Task created by Berninger, Mizokawa, and Bragg (1991). Participants were asked to write the letters of the alphabet across the page, in order (A through Z), as many times as they could within a 60 s time limit. The 60-s time limit is within the range of times (45–60 s) used in previous research (e.g., Berninger et al., 1991; Peverly et al., 2007). Participants were instructed to write the letters in capital case form first, followed by lower case, and alternating between these two different forms until time was up. As long as these specific instructions were followed, all letters were considered correct if they were legible. One point was awarded for each letter written correctly and points were added to calculate the participant's total score. Interrater agreement in scoring for this task on the aforementioned random 10 protocols was 1.0.

Working memory

Working memory was measured using Turner and Engle's (1989) operation span task, a highly reliable and valid measure of individuals ability to temporarily store and process recently presented information (Conway et al., 2005).

Participants were presented with 42 equations (e.g., IS $2 + 3 = 6$?) composed of four levels of three equation sets each via CD. The first level consisted of three sets of two equations each, the next consisted of three sets of three equations, and the last consisted of three sets of five equations. After the presentation of each equation, participants were immediately presented with a word (e.g., CLOUD). During the presentation of the equations, participants were required to verify whether or not the equations were mathematically correct, by writing "Y" for "yes" or "N" for "no" in their individual packets. After each set of equations was completed, the participants were required to turn the page and write down all of the words they heard within that set, in the order in which they heard them (words not recalled in order were not counted as correct). Scoring was based on the highest level at which participants were able to remember all of the words from at least one of the three equation sets. If participants were able to remember all of the last words for two or three of the equation sets on level 5, their span level would be 5. However, if they could only remember the words for one set of equations on level 5, their span would be the number of words in that set minus 0.5 (4.5). The range of scores was 1.5–5 in increments of 0.5.[1] Interrater agreement was .98.

Language comprehension

Language comprehension was assessed using the Comprehension section of the Nelson–Denny Test, Form G (Brown, Bennett & Hanna, 1981). The Nelson Denny is a widely used assessment tool for measuring reading comprehension in individuals ranging from high school to adult. The Comprehension section of the Nelson–Denny consists of seven reading passages and 38 questions. The questions are multiple-choice with five answer options for each question. Formal test

[1] In our research, we have tried two methods of scoring working memory span, the one we just described and an alternative method that counts the total number of correct sets. The correlation between the 2 has been within the range of .78 to .85. And, regardless of the method of scoring and thus the number we've included in our regressions or path analyses, the results have never changed. So, we have stuck with the procedure most typically used in the literature, which is the scoring method we reported.

administration procedures allow 20 min for the Comprehension section; however other studies have used a 15 min limit to increase the variance in performance, allowing for better discrimination between good and poor comprehenders (Perfetti, 1986). Fifteen minutes was used in the current study. The participants' score consisted of the total number of comprehension questions answered correctly. Reliability analysis of this measure produced a Cronbach's alpha of .92.

Conscientiousness

Conscientiousness was measured by the Conscientiousness subscale of the NEO Personality Inventory-Revised (NEO-PI-R)-Form S (Costa & McCrae, 1992a, 1992b). The NEO-PI-R assesses five personality domains and 30 more specific traits (facets), six within each domain. The five domains are Neuroticism, Agreeableness, Conscientiousness, Emotional Stability, and Openness to Experience. The Conscientiousness subscale of the NEO-PI-R includes 48 Likert scale items, ranging from 1 (strongly disagree) to 5 (strongly agree). Examples include "I waste a lot of time before settling down to do work" and "My work is likely to be slow but steady". Total scores for each domain and scores for each facet are calculated. Reliabilities for the domains range from .86 to .95. Construct, convergent and divergent validity of the scales has also been demonstrated. Administration time for the Conscientiousness subscale was 6–8 min. Internal consistency for our sample was $\alpha = .89$.

Goal orientation

Participants' were administered the Achievement Goal Questionnaire (AGQ) developed by Elliot and Church (1997) to measure three achievement goals: mastery, performance-avoidance, and performance-approach. The scale consists of 18 Likert scale items, with six items for each goal. Each item ranges from 1 (not very true of me) to 7 (very true of me). The reported reliability alphas for the measures of mastery, performance-approach and performance-avoidance goals were .89, .91 and .77, respectively, based on a sample of 204 undergraduates enrolled in a psychology course at the University of Rochester (Elliot & Church, 1997). The alphas for our sample were .96, .88, and .92 for performance approach, mastery, and performance avoidance respectively. Examples include, "It is important for me to understand the content of this course as thoroughly as possible" (mastery), "I just want to avoid doing poorly in this class" (performance-avoidance) and "It is important for me to do better than the other students" (performance-approach).

Written recall

Students were instructed to write an organized summary based on the videotaped lecture without the use of their written notes. Participants were given a 15-min time limit and a two-sided blank piece of paper to write their summary.

Scoring: notes and written recall

Participants' notes and essays were scored for quality of the content using the rubric created by Brobst (1996). Given that quality and quantity are very highly correlated (.93; Peverly et al., 2007) they are essentially the same construct. We did not score written recall for cohesiveness. The quality scores range from 0 to 3 points for each of the 15 topics mentioned. If the topic was not mentioned or the information was incorrect, 0 points were awarded, if the topic was merely mentioned it received 1 point, if the topic was mentioned and included a partial explanation it received 2 points, and if the topic was mentioned and included a complete explanation it received the full 3 points. Total quality scores therefore ranged from 0 to 45. Interrater agreement for scoring of note quality was .99 and 1.0 for written recall.

Procedure

Participants were given a packet of materials including a consent form, which outlined the purpose, procedures, and time involved in the study, as well as the participants' rights. If they agreed to participate and signed the consent form, they were told to turn the page and fill out a demographics questionnaire. Once they completed it, participants were told to watch and take notes on a 20-min videotaped lecture on the psychology of problem solving. The packet they received included a two-sided blank sheet of paper they used to record their notes. They were told that later in the study they would have 10 min to look over and study their notes. They were encouraged to take very complete notes to aid in the process of review. The remaining tasks were given in the following order: alphabet task, operation span task, Nelson–Denny (a 5-min break was given after the completion of this task), the Conscientiousness scale of NEO-PI-R, notes review, Achievement Goal Questionnaire (AGQ) and written recall. Total time for the study, including the 5-min break, was approximately 90 min.

Results

A one-way MANOVA revealed a significant main effect for gender, Wilks' $\lambda = .724$, $F(9,126) = 5.34$, $p < .001$, partial eta squared = .276. As predicted, significant main effects for gender were obtained for handwriting speed ($F = 9.50$, $p = .002$), language comprehension ($F = 9.50$, $p = .002$), conscientiousness ($F = 12.38$, $p = .001$), note quality ($F = 25.01$, $p < .001$), and written recall ($F = 8.29$, $p = .005$), with females scoring higher than males. Unexpectedly, females also had higher working memory scores than males, ($F = 9.10$, $p = .003$). The main effects for approach ($F = 1.42$, $p = .24$), mastery ($F = 2.38$, $p = .13$) and avoidance goal orientations ($F = .04$, $p = .85$) were not significant. Means and standard deviations for all of the variables, broken down by gender, are in Table 1. Correlations among the independent and dependent variables are in Table 2. Correlations, by gender, are in Tables 3 and 4.

Hierarchical regressions were used to evaluate the contributions of the independent variables to notes' quality and written recall. All of the independent variables were included in the first block and interactions between gender and the other variables in the second block (all continuous variables were centered). Given the potentially large number of interactions and the untoward effect that including all them would have on the power of the analyses, each interaction was tested separately. Only significant interactions were included in the analyses.

Notes' quality

Preliminary analyses indicated that the gender × handwriting speed ($\beta = -.25$, $p < .05$) and gender × language comprehension ($\beta = -.22$, $p < .05$) interactions were significant. In a subsequent regression, note's quality was regressed on gender, handwriting speed, working memory, language comprehension, NEO-PI-R Conscientiousness subscale, and the Achievement Goal Orientations in the first block. The significant interactions were entered in the second block. The regression equation was significant for Model 1 (tolerance and variance inflation factor values were within acceptable limits; $R = .58$, $R^2 = .34$, $R^2_{\text{adjusted}} = .30$, $p < .001$) (the effect size is large; Cohen, 1992) and Model 2 ($R = .61$, $R^2 = .37$, $R^2_{\text{adjusted}} = .32$, $p = .05$). The R^2_{change} from Model 1 to Model 2, although small, was significant ($R^2_{\text{change}} = .03$, $p = .05$).

In Model 1, as expected, gender ($\beta = -.23$, $p < .01$) and language comprehension ($\beta = .40$, $p < .001$) were significant predictors of note quality. Contrary to expectation, handwriting speed ($\beta = .03$, $p > .05$), working memory ($\beta = .12$, $p > .05$), conscientiousness ($\beta = .07$, $p > .05$), mastery orientation ($\beta = .02$, $p > .05$), approach orientation ($\beta = -.03$, $p > .05$) and avoidance orientation ($\beta = .02$, $p > .05$) were not significant predictors. In Model 2, language comprehension ($\beta = .54$, $p < .000$), gender ($\beta = -.26$, $p < .01$), and the gender × language comprehension interaction were significant ($\beta = -.23$, $p < .05$). See Table 5. To determine the source(s) of significance in the interaction, we used t-tests for independent groups to compare the means for women and men who were high and low in language comprehension on notes' quality. Results indicated that

Table 1 Means and standard deviations by gender

Variables	Females		Males		*F*
	M	*SD*	*M*	*SD*	
Notes' quality	9.34	5.65	5.27	3.00	25.01***
Written recall	3.49	3.00	2.19	1.91	8.29**
Handwriting speed	109.70	22.81	97.52	26.20	9.50**
Working memory	4.44	.67	3.96	.84	9.10***
Lang Comp	21.68	9.34	16.90	8.68	9.50**
Conscientiousness	128.57	21.03	115.40	20.59	12.38***
Approach	14.96	4.68	13.86	4.67	1.42
Mastery	17.92	3.44	16.73	4.22	2.38
Avoidance	11.75	6.15	11.87	5.17	.04

Lang Comp language comprehension

* $p < .05$; ** $p < .01$; *** $p < .001$

Table 2 Intercorrelations among the independent and dependent variables

Variables	1	2	3	4	5	6	7	8	9	10
1. Notes' quality	–									
2. Written recall	.64**	–								
3. Handwriting speed	.18**	.18*	–							
4. Working memory	.28**	.43**	.14	–						
5. Lang Comp	.48**	.36**	.21**	.17*	–					
6. Conscientiousness	.20*	.22**	.18	.20*	.07	–				
7. Approach	.13	.05	.15	.08	.20*	.31**	–			
8. Mastery	.11	.23**	−.04	.07	.03	.42**	.27**	–		
9. Avoidance	−.05	−.21**	.05	.04	−.10	−.35**	.09	−.18*	–	
10. Gender	−.40**	−.25**	−.24**	−.31**	−.26**	−.30**	−.12	−.16	.01	–

Lang Comp language comprehension

* $p < .05$; ** $p < .01$

Table 3 Intercorrelations among the independent and dependent variables for female participants

Variables	1	2	3	4	5	6	7	8	9
1. Notes' quality	–								
2. Written recall	.30**	–							
3. Handwriting speed	.21	.30**	–						
4. Working memory	.23*	.19	.16	–					
5. Lang Comp	.49**	.39**	.36**	.04	–				
6. Conscientiousness	.15	.30**	−.05	.08	.06	–			
7. Approach	.15	.09	.13	−.09	.16	.25*	–		
8. Mastery	.01	.25*	−.03	.02	.00	.32**	.06	–	
9. Avoidance	−.06	−.23*	−.02	−.16	−.12	−.53**	.00	.32**	–

Approach approach orientation, *Mastery* mastery orientation, *Avoidance* avoidance orientation

* $p < .05$; ** $p < .01$

Table 4 Intercorrelations among the independent and dependent variables for male participants

Variables	1	2	3	4	5	6	7	8	9
1. Notes' quality	–								
2. Written recall	.61**	–							
3. Handwriting speed	−.15	−.08	–						
4. Working memory	.13	−.08	.06	–					
5. Lang Comp	.32*	.19	−.06	.16	–				
6. Conscientiousness	−.04	−.09	−.07	.16	−.10	–			
7. Approach	−.03	−.11	.12	.18	.19	.34**	–		
8. Mastery	.14	.15	−.13	.04	−.02	.48**	.45**	–	
9. Avoidance	−.02	−.18	.15	.28	.02	−.13	.22	.04	–

Approach approach orientation, *Mastery* mastery orientation, *Avoidance* avoidance orientation

* $p < .05$; ** $p < .01$

differences in notes' quality among males and females who were low in language comprehension were not significant [$t(69) = 1.84$, $p > .05$]. However, among students who scored high in language comprehension, females' notes were superior to males [$t(66) = 4.335$, $p < .001$]. Also, females with high verbal scores produced significantly better notes than those with low verbal scores [$t(74) = 4.95$, $p < .001$]. However, there were no differences in notes' quality among males who were high and low in language comprehension [$t(61) = 1.44$, $p > .05$].

Written recall

Preliminary analyses indicated that the gender × handwriting speed ($\beta = -.31$, $p = .01$) and gender × conscientiousness ($\beta = -.27$, $p < .05$) interactions were

Table 5 Summary of hierarchical regression analyses predicting notes' quality with interaction terms for gender, handwriting speed, and reading comprehension

Variable	*B*	*SE B*	β	Partial *r*	Tolerance	VIF
Model 1						
Handwriting speed	.01	.84	.03	.03	.89	1.13
Working memory	.79	.50	.12	.14	.87	1.16
Lang Comp	.22	.04	.40***	.42	.86	1.16
Conscientiousness	.02	.02	.07	.07	.62	1.61
Approach orientation	−.03	.09	−.03	−.03	.79	1.27
Mastery orientation	.03	.11	.02	.02	.81	1.24
Avoidance orientation	.01	.07	.02	.02	.79	1.27
Gender	−2.34	.84	−.23**	−.24	.77	1.30
Model 2						
Handwriting speed	.01	.02	.03	.03	.40	2.52
Working memory	.90	.49	.14	.16	.85	1.17
Lang Comp	.30	.06	.54***	.42	.47	2.15
Conscientiousness	.01	.02	.06	.06	.62	1.62
Approach orientation	−.02	.09	−.02	−.02	.79	1.27
Mastery orientation	.03	.12	.02	.02	.81	1.24
Avoidance orientation	.03	.07	.03	.03	.78	1.28
Gender	−2.61	.83	−.26**	−.27	.76	1.32
Gender × Handwriting speed	−.02	.03	−.07	−.20	.51	1.96
Gender × Lang Comp	−.20	.09	−.23*	−.06	.44	2.28

$\Delta R^2_{change} = .34$, $R = 0.58$, $R^2 = 0.34$, $R^2_{adjusted} = 0.30$ for Model 1. $\Delta R^2_{\text{change}} = .03$, $R = 0.61$, $R^2 = 0.37$, $R^2_{\text{adjusted}} = 0.32$ for Model 2

VIF variance inflation factor

* $p < .05$; ** $p < .01$; ***$p < .00$

significant. In a subsequent regression, written recall was regressed on all of the aforementioned variables, including note quality, in the first block and the significant interactions were included in the second block. The regression equation for Model 1 was significant (tolerance and variance inflation factor values were within acceptable limits; $R = .69$, $R^2 = .47$, $R^2_{adjusted} = .43$), $F(9,\ 135) = 12.44$, $p < .001$ (the effect size, with R^2used as an estimate of effect size, was large; Cohen, 1992). The regression equation for Model 2 was also significant ($R = .70$, $R^2 = .50$, $R^2_{\text{adjusted}} = .45$, $p = .05$). The R^2_{change} from Model 1 to Model 2, although small, was significant ($R^2_{change} = .03$, $p = .05$).

In Model 1, consistent with expectations, note quality ($\beta = .58$, $p < .001$) was a significant predictor of written recall. In addition, handwriting speed ($\beta = .14$, $p = .05$) and mastery goal orientation ($\beta = .15$, $p < .05$) were also significant predictors of written recall. Gender ($\beta = .05$, $p > .05$), language comprehension ($\beta = .12$, $p > .05$), and conscientiousness ($\beta = .03$, $p > .05$) were not found to be significant predictors of written recall, which was unexpected. In Model 2, note quality ($\beta = .56$, $p < .001$), handwriting speed ($\beta = .23$, $p < .05$), mastery orientation ($\beta = .17$, $p < .05$) and the gender × conscientiousness interaction were found to be significant ($\beta = -.20$, $p < .05$). See Table 6. To determine the source(s) of significance in the interaction, we used t-tests for independent groups to compare the means for women and men who were high and low in conscientiousness on written recall. Differences in written recall among males and females who were low in conscientiousness were not significant [$t(69) = 1.70$, $p > .05$]. However, among students who were high in conscientiousness, females' written recall was superior to males [$t(66) = 2.07$, $p < .05$]. High conscientiousness females did not score significantly better on written recall than low conscientiousness females [$t(74) = 1.21$, $p > .05$]. Similarly, there were no significant differences in written recall among males who were high and low conscientiousness [$t(61) = .321$, $p > .05$].

Table 6 Summary of hierarchical regression analyses predicting written recall with interaction terms for gender, handwriting speed, and conscientiousness

Variable	*B*	*SE B*	β	Partial *r*	Tolerance	VIF
Model 1						
Notes' quality	.30	.04	.60***	.55	.66	1.51
Handwriting speed	.01	.01	.14*	.17	.89	1.13
Working memory	−.14	.24	−.04	−.05	.85	1.18
Lang Comp	.02	.02	.08	.09	.71	1.41
Conscientiousness	.00	.01	.03	.03	.62	1.61
Approach orientation	−.06	.04	−.10	−.12	.79	1.27
Mastery orientation	.11	.05	.15*	.18	.81	1.24
Avoidance orientation	−.06	.03	−.13	−.16	.79	1.28
Gender	.28	.40	.05	.06	.73	1.38
Model 2						
Notes' quality	.29	.04	.56***	.53	.65	1.54
Handwriting speed	.02	.01	.23*	.21	.42	2.38
Working memory	−.11	.23	−.03	−.04	.85	1.18
Lang Comp	.02	.02	.06	.07	.68	1.46
Conscientiousness	.02	.01	.18	.15	.38	2.65
Approach orientation	−.06	.04	−.10	−.12	.79	1.27
Mastery orientation	.12	.05	.17*	.21	.79	1.27
Avoidance orientation	−.04	.03	−.09	−.11	.74	1.35
Gender	.19	.40	.04	.04	.72	1.39
Gender × handwriting speed	−.02	.02	−.13	−.12	.44	2.28
Gender × conscientiousness	−.04	.02	−.20*	−.19	.49	2.06

$\Delta R^2_{change} = .47$, $R = 0.69$, $R^2 = 0.47$, $R^2_{adjusted} = 0.43$ for Model 1. $\Delta R^2_{\text{change}} = .03$, $R = 0.70$, $R^2 = 0.50$, $R^2_{\text{adjusted}} = 0.45$ for Model 2

VIF variance inflation factor

*$p < .05$; ** $p < .01$; ***$p < .001$

To further explore the relationship of gender to note quality and written recall, regressions were run independently for females and males. First, note quality was regressed on all of the independent variables, for females. The regression equation was significant [$F(7, 74) = 4.48$, $p < .001$]. Only working memory ($\beta = .22$, $p = .04$) and language comprehension ($\beta = .50$, $p < .001$) significantly predicted females' note quality. Next, note quality was regressed on all of the independent variables, for males. The regression equation was not significant [$F(7, 60) = 1.6$, $p > .05$]. See Table 7. Additionally, written recall was regressed on all of the independent variables, including note quality, for females. The regression equation was significant [$F(8, 74) = 7.78$, $p < .001$]. Note quality ($\beta = .50$, $p < .001$) and mastery goal orientation ($\beta = .19$, $p < .001$) were the only significant predictors of written recall. Written recall was then regressed on all of the same variables for males. The regression equation was significant [$F(8, 60) = 5.00$, $p < .001$]. Note quality was the only significant predictor of written recall for male participants ($\beta = .57$, $p < .001$). See Table 8.

Discussion

Research suggests that females are better note-takers (Cohn et al., 1995; Maddox & Hoole, 1975; Nye, 1978;) and test takers (Kiewra, 1984) than males. However, research on lecture note-taking has only examined gender differences, or used gender as an anecdotal variable, in post hoc analyses. The primary purpose of this study was to further investigate the relationship of gender to lecture note-taking, and if there was a significant relationship, to examine the cognitive and motivation variables that might explain it. A second purpose was to determine if there might be gender related differences in written recall.

Table 7 Summary of the regression analyses predicting notes' quality by gender

Variable	*Females*			*Males*		
	B	*SE B*	*β*	*B*	*SE B*	*β*
Handwriting speed	.00	.03	.00	−.01	.02	−.06
Working memory	1.86	.88	.22*	.50	.48	.14
Lang Comp	.30	.07	.50***	.11	.05	.32
Conscientiousness	.05	.03	.17	−.02	.02	−.11
Approach orientation	.05	.13	.04	−.12	.10	−.19
Mastery orientation	.01	.18	.00	.16	.11	.22
Avoidance orientation	.14	.12	.15	−.02	.08	−.03

$R = 0.57$, $R^2 = 0.32$, $R^2_{adjusted} = 0.25$ for females. $R = 0.42$, $R^2 = 0.18$, $R^2_{adjusted} = 0.07$ for males

* $p < .01$; ** $p < .05$; *** $p < .001$

Table 8 Summary of the regression analyses predicting written recall by gender

Variable	*Females*			*Males*		
	B	*SE B*	*β*	*B*	*SE B*	*β*
Notes' quality	.26	.06	.50***	.37	.07	.57***
Handwriting speed	.02	.01	.18	.01	.01	.08
Working memory	.07	.42	.02	−.22	.26	−.10
Lang Comp	.03	.04	.08	.01	.03	.05
Conscientiousness	.02	.02	.16	−.01	.01	−.12
Approach orientation	−.05	.06	−.07	−.04	.05	−.11
Mastery orientation	.16	.08	.19*	.07	.06	.15
Avoidance orientation	−.02	.05	−.04	−.05	.04	−.15

Note quality

As we hypothesized, females took better notes than males and students with higher language comprehension took better notes than students with lower language comprehension. However, the analyses also indicated that low verbal males and females took notes of comparable quality and high verbal females took better notes than high verbal males. There were no significant differences between high and low verbal males in the quality of their notes. Although these data are consistent with prior research which suggests that females are better note-takers than males (Kiewra, 1984; Cohn et al., 1995; Nye, 1978; Maddox & Hoole, 1975; Peverly et al., 2007) and that language comprehension is related to note-taking (Peverly & Sumowski, 2012; Peverly et al., 2013) they are also more nuanced in suggesting that the variables that predict females skills in note-taking may be different from those of males. Subsequent regression analyses by gender found language comprehension and working memory to be significant predictors of note quality for females (also, the MANOVA indicated that females had significantly higher working memory scores than males). In contrast, none of the independent variables were significant predictors of notes' quality for males. Future research needs to focus more on differences between males and females in note-taking.

Although working memory has been hypothesized to be related to note-taking (Peverly et al., 2007; Piolat et al., 2005), previous research using complex span tasks of the type used in this study have not substantiated this. Explanations of our results are not straightforward. On the one hand, research has not typically found differences between males and females on verbal working memory tasks, which suggests that our results could be due to error. On the other hand, research that found an advantage for females (Cochran & Davis, 1987; Duff & Hampson, 2001; Kaushanskaya et al. 2011; Robert & Savoie, 2006; Speck et al., 2000) used more difficult tasks, like the one used in this investigation. However, why females might perform better on more difficult tasks is not clear. There are many working memory theories, each of which has a different explanation for individual differences. It could be that females (a) are better at switching between the processing and storage components of working memory (Towse, Hitch, & Hutton, 2000), (b) more efficiently process information and thus have more resources to devote to storage (Daneman & Hannon, 2001), or (c) are better able to attend to a task and inhibit distractions than males (Engle, 2002), among many other explanations. Also, some research has found gender-related differences in brain activation patterns during working memory tasks, which may indicate that males and females use different strategies (Shaywitz et al., 1995; Speck et al., 2000). Future research on the relationship of cognitive variables to gender-related differences in note-taking should attempt to replicate these findings, and if they are found, the reasons for them.

The most surprising inconsistency in our results compared to prior research was the non-significant relationship between handwriting speed and notes' quality. Several previous studies on lecture note-taking (Peverly et al., 2007, 2013, 2014) and text note-taking (Peverly & Sumowski, 2012) found handwriting speed to be related to notes' quality. One possible hypothesis is that handwriting speed was acting as a proxy for gender in previous research since gender was not a variable these studies. However, we evaluated the hypothesis by rerunning the regression equation with all of the independent variables but gender. Handwriting speed was still not significantly related to notes' quality. Further, although handwriting speed was significantly but weakly correlated with notes' quality in the overall sample, it was not correlated with notes' quality for either males or females, and the sign of the coefficient was the opposite for males and females, negative for the former (−.15) and positive for the latter (.21). Negative coefficients have not been reported previously in the literature. Thus, we are not sure why handwriting speed was not related to note-taking.

Conscientiousness was predicted to be significantly and positively related to the quality of notes since conscientiousness has consistently been found to be strongly related to academic outcomes. Although conscientiousness was significantly but weakly correlated to note-taking, which confirms the findings of Nakayama et al. (2012), as well as the relationship between it and other academic outcomes found in the literature (e.g., Lievens et al., 2002; Vialle et al., 2005), it was not significantly related to note-taking in the regression equation. Since conscientiousness was significantly correlated with gender and working memory, both of which were more strongly related to note-taking than conscientiousness, one or both of these variables may have mediated the relationship between conscientiousness and note-taking.

Mastery and performance-approach goals also were predicted to be significantly related to notes' quality and performance-avoidance goals were predicted to be negatively related. None of these predictions were upheld. One possible explanation is related to the functions of note-taking. Note-taking has two functions: encoding (recording) information and review (DiVesta & Gray, 1972). The review function is much more strongly related to test performance (Kobayashi, 2006), for obvious reasons. Students have very little time to process information during encoding, but they can choose to spend a great deal of time and use a variety of strategies during review to prepare for exams. Future research should evaluate the relationship of goal orientation to encoding and review to evaluate whether goal orientation is related to the latter but not the former. Another possible explanation is the ecological validity of our experiment. Replicating the experiment in an actual class, where notes and exams are more goal oriented, may yield a different pattern of outcomes between notes, exams and goal orientation.

Written recall

We also sought to examine the relationship of gender to test performance, as measured by written recall. As predicted, the results of the MANOVA indicated that females wrote significantly more than males. These data, along with the data on note-taking discussed previously, indicate that females are superior to males on writing tasks, no matter what their nature. Notes, for example, are writer-based prose. Because lecturers typically speak quickly, notes are often cryptic, list like representations of continuous speech, produced without substantial regard for grammar and the conventions of punctuation. Their primary purpose is to capture important concepts for later review by the note-taker. An essay in contrast, is reader based prose. It is meant to convey meaning to someone other than the writer via coherent and cohesive text. In other words, regardless of the goal of the writing product, reader-based or writer-based, females consistently outperform males.

This finding corresponds to females' consistently superior performance on the writing portions of the NAEP, as well as on standardized assessments of writing in other countries (Lietz, 2006). In addition, the hierarchical regression found significant main effects for notes' quality, handwriting speed, and mastery goal orientation and a significant gender × conscientiousness interaction. The interaction indicated that the differences in written recall among females and males with low conscientiousness were not significant. However, among students who scored high on conscientiousness, females were superior to males.

Note quality was the strongest predictor of written recall, which supports the findings of previous research (Fisher & Harris, 1973; Kiewra et al., 1991; Peverly et al., 2007, 2013, 2014; Peverly & Sumowski, 2012). Furthermore, subsequent regression analyses also found note quality to be the best predictor of written recall for females and males, independently. This result is not surprising, given that participants were allowed to study their lecture notes before the test. Research has also indicated that students are much more likely to include information from notes in recall than information that was not included in notes (Rickards & Friedman, 1978).

The significant relationship between handwriting speed and written recall was a surprising result. In previous research on note-taking, handwriting speed has been significantly related to notes' quality, not written recall (Peverly et al., 2007, 2013, 2014; Peverly & Sumowski, 2012). However, this finding is consistent with research by Connelly et al. (2005, 2006) who found undergraduates' handwriting speed was related to both essay writing quality and quantity under realistic testing conditions. Similarly, research on writing among elementary and middle school students has found a strong relationship between handwriting speed and the quality of their written compositions (Graham et al., 1997, 2000; Jones & Christensen, 1999). In elementary students especially, handwriting speed is the strongest predictor of students' essay quality and quantity. Therefore handwriting speed appears to be an essential component of essay writing in both children and adults alike.

As discussed in the introduction, research overwhelmingly supports a strong positive relationship between conscientiousness and academic achievement, even if cognitive or academic ability are controlled (Beaujean et al., 2011; Conard, 2006). Also some research has found that women are more conscientiousness than men although the effect size is small (Costa et al., 2001; Feingold, 1994; Vialle et al., 2005; Weisberg et al., 2011). Our data indicate that at higher and comparable levels of conscientiousness women write more than men. One possible explanation, discussed earlier, is the ecological validity of our experiment. Women high in conscientiousness may choose to actively and purposively participate regardless of the relationship of the situation (experiment; class) to a grade. Men high in conscientiousness may make a different choice. They may choose to participate actively and purposively only if the situation is grade-relevant, or meaningful in some other way. Indeed, men may be more 'situational' in general. Johnson (2012) found that men given a performance approach goal generated more idea units in an essay than men given either a mastery or avoidance goal, whereas situational goal orientation had no effect on women's performance. They performed equally well in all conditions. Again, replicating our experiment in an actual class will help clarify the relationship of gender and conscientiousness to note-taking and test-taking. Although there is very little research on interventions to increase conscientiousness (Magidson, Roberts, Collado-Rodriguez, & Lejuez, 2014), Krasner et al. (2009) found that mindfulness training increased conscientiousness in primary care physicians.

As predicted, mastery goal orientation was also found to be significantly and positively related to written recall. Contrary to our predictions performance approach and avoidance were not related to written recall. These outcomes are partially congruent with those found in the literature. Mastery and performance approach goal orientations are typically related to better academic performance while performance avoidance is typically negatively or not significantly related to academic performance (e.g., Ablard & Lipschultz, 1998; Daniels et al., 2008; Dupeyrat & Mariné, 2005; Elliot et al., 1999). Also, it should be noted that our experiment was lab-based, where there really is no "performance" to be approached because the situation was inconsequential. Thus, only those who were truly motivated by mastery may have been motivated to perform well on the written recall measure, since this was not truly an academic performance situation.

Although mastery goals were related to test performance (written recall) we do not know whether mastery is related to preparations to take the test (taking; and reviewing notes), taking the test, or both. Relative to the former, mastery was not correlated with note-taking. However, as discussed earlier, we did not separately measure encoding and review. It could be that mastery is strongly associated with the strategies used during review, which then leads to better test performance. Alternatively, mastery goals may have their effects only at the time of test. Future research on note-taking should evaluate the relationship of mastery to both encoding and review as well as test performance.

Independent variables: gender differences

We predicted that females would be superior to males on notes' quality, essay, handwriting speed, language comprehension, conscientiousness, and mastery goal orientation but not the other goal orientations. No gender differences were anticipated on the working memory task. We discussed some of these differences in previous sections of the *Discussion*. The variables that were not discussed are presented here.

As predicted, females scored higher than males on our measure of handwriting speed, which is consistent with previous research on handwriting speed (Cohen, 1997; Lyle & Johnson, 1974; Lynn et al., 2005; Reddington et al., 2006; Slate, 1998) and with the female advantage found in fine motor fluency, which is a component of handwriting speed (authors, in preparation), as measured by performance on the Perdue Pegboard task (Agnew et al., 1998; Strauss et al., 2006) and the Grooved Pegboard task (Bornstein, 1985; Ruff & Parker, 1993; Schmidt et al., 2000).

As predicted, females scored higher on our measure of language comprehension than males. This is consistent with prior research indicating females' advantage over males in language comprehension (Halpern, 2000; Hayes & Waller, 1994; Martin & Hoover, 1987) and on language mediated academic tasks like reading and writing (National Center for Education Statistics, 2012, 2013). Martin and Hoover (1987), for example, explored gender differences in language comprehension in grades 3–8; overall females' outperformed males' on measures of spelling, capitalization, punctuation, language usage, and reading comprehension. In studies of college students, Hayes and Waller (1994) found females had higher scores on the Nelson Denny Reading Comprehension subtest (Brown et al., 1981) as well as on tasks of basic processing involving words or knowledge of words and the identification of letters.

Females were predicted to have more of a mastery goal orientation than males. The MANOVA did not find gender-related differences on any of the motivational variables and there were no significant gender $\times$ goal orientation interactions in the regression analyses. These results are inconsistent the findings of Ablard and Lipschultz (1998) who found that females scored significantly higher on mastery goals than males, and Elliot and McGregor (2001) who also found that females had significantly greater mastery goals orientations than men in some of their regression analyses (Study 2). However, our results are consistent with others studies that did not find differences (Meece, Glienke, & Burg, 2006b; Pajares & Valiante, 2001).

Theoretical implications

Previous research investigating processes related to effective lecture note-taking focused exclusively on cognitive variables. They found lecture notes to be related to: handwriting speed (Gleason, 2012; Peverly et al., 2007; Peverly & Sumowski, 2012; this study), language comprehension (Gleason, 2012; Vekaria, 2011; Peverly et al., 2013) and sustained attention (Gleason, 2012; Vekaria, 2011; this study). Similar results were found in an investigation on text note-taking (Peverly &

Sumowski, 2012). These studies also found that notes predict performance on tests that assess students' memory (Kintsch, 1998; e.g., written recall; multiple choice items) but not understanding, as measured with inference items. This investigation did not include a measure of sustained attention or background knowledge but did include gender and the non-cognitive variables of goal orientation and conscientiousness. The results of this study suggest note-taking and test performance related to notes are not purely a cognitive phenomenon and that any ultimate theory of note-taking must include gender, cognitive, and non-cognitive variables.

Limitations and future research

As is true of almost every existing investigation of note-taking, ours suffers from an insufficient degree of external validity. Students did not take notes in a real class, the test (written recall) did not count toward a class grade, the lecture was shorter than a typical lecture, the lecture was presented via video rather than in person, we asked students to take very complete notes which instructors do not typically do, and the content of the lecture did not match the content of the class in which the data were collected, thus mitigating the effect of background knowledge on note-taking and test-taking. All of these issues could have had an untoward effect on the relationship of the independent variables, especially setting goals (goal orientation) and the willingness to persist (conscientiousness), to the dependent variables. This study should be replicated in a real class setting to see if the relationships found here generalize to one where the content and consequences are more pronounced.

Note-taking consists of two functions (DiVesta & Gray, 1972); the act of taking notes (encoding), and the processing of notes for a test (review). We measured the quality of notes but we did not measure the quality of review, although we provided time for review. According to Kobayashi (2006) when considering the effect of taking notes versus reviewing notes on test performance, the effect size for review is more than twice the effect size for taking notes. This suggests that future research should evaluate the cognitive processes related to review as well as to note-taking.

Technology use is now ubiquitous in classrooms. Many students use laptops, note-pads, note-taking pens and other devices to take notes. We have very little idea how efficacious these devices are in comparison to taking notes with paper and pen and whether the cognitive processes that underlie the use of these are different than those that underlie the use of paper and pen. For example, one study found that students took more notes with a computer than with paper and pencil (Bui et al., 2013; Mueller & Oppenheimer, 2014) while another found that notes taken by hand, as compared to notes taken by computer, increased depth of processing and improved performance on application exam questions (Mueller & Oppenheimer, 2014). Also, instructors use software (e.g., PowerPoint) and technology (e.g., Smart Boards), that may have a strong impact on note-taking and should be systematically investigated for their impact on note-taking and students' performance in school. Future research should focus on the effects of technology on note-taking and test-taking.

Finally, our data indicate that note-taking is not purely a cognitive exercise. Future research should focus on the cognitive processes found to be related to note-taking so far (handwriting speed, sustained attention, language ability), replicate the contributions of gender, goal orientation and conscientiousness found in this study, and investigate other non-cognitive variables as well. One possible variable is one of other the Big-Five personality variables (Costa & McCrae, 1992a, 1992b): openness to experience. Openness has been found to be related to academic achievement in the primary and secondary grades (Laidra et al., 2007) and college (O'Conner & Paunonen, 2007).

Conclusion

Lecture note-taking is an important study strategy. The primary goal of this study was to explore possible gender differences in the variables which underlie note-taking skill and test performance (written recall). Significant gender differences were observed on both of the dependent variables, note quality and written recall in favor of females. Females also performed significantly better on measures of handwriting speed, working memory, language comprehension, and conscientiousness. Note quality was significantly predicted by language comprehension, gender, and the gender $\times$ language comprehension interaction, while written recall was significantly predicted by notes' quality, handwriting speed, mastery goal orientation, and the gender $\times$ conscientiousness interaction. Future research should continue to focus on examining potential gender differences on cognitive and non-cognitive variables that may be associated with note-taking and test performance.

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