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When Academic Technology Fails: Effects of Students' Attributions for Computing Difficulties on Emotions and Achievement

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Abstract: As education experiences are increasingly mediated by technology, the present research explored how causal attributions for academic computing difficulties impacted emotions and achievement in two studies conducted with post-secondary students in North America and Germany. Study 1 ($N = 1063$) found ability attributions for computer problems to be emotionally maladaptive (more guilt, helplessness, anger, shame, regret, anxiety, and boredom), with strategy attributions being more emotionally adaptive (more hope, pride, and enjoyment). Study 2 ($N = 788$) further showed ability attributions for computer problems to predict poorer academic achievement (grade percentage) over and above effects of attributions for poor academic performance. Across studies, the effects of effort attributions for computer problems were mixed in corresponding to more negative computing-related emotions despite academic achievement benefits. Implications for future research on students' academic computing attributions are discussed with respect to domain-specificity, intervention, and technical support considerations.

Keywords: academic computing; motivation; emotions; academic achievement; post-secondary education; technology; computer problems

1. Introduction

The ubiquitous use of computers in post-secondary education has prompted growing research interest in how students use technology to enhance learning experiences (e.g., accessing library services; Cassidy et al. 2014; blended learning; Castaño-Muñoz et al. 2014; for a review of mobile learning, see Pimmer et al. 2016) with research to date having principally investigated the impact of students' computer use and attitudes on learning and achievement (Hannon 2013; Littlejohn et al. 2012; Phelps et al. 2005; Prior et al. 2016). For example, large-scale research with undergraduates underscores the link between effective use of information and communication technology (ICT) and educational outcomes (Venkatesh et al. 2014), with studies also highlighting the importance of examining how students deal with technological problems (Moreno et al. 2012). However, whereas existing research has consistently examined students' general attitudes surrounding technology use in academic settings, few studies to date have adapted existing theoretical paradigms concerning achievement motivation and emotions to more specifically examine how students respond to technological challenges. Thus, even with considerable research regarding computer use and problems (Lazar et al. 2005; Levine and Donitsa-Schmidt 1998; Rosen et al. 2016), there exists a lack of research

addressing individuals' cognitive and emotional responses to difficulties encountered in academic computing contexts.

As rising technology requirements in higher education afford more opportunities for technology-related challenges for students, a greater focus on motivation constructs that address responses to such challenges in academic settings (e.g., attribution theory) is warranted. More specifically, whereas previous research underscores the psychologically intensive nature of technological difficulties experienced by post-secondary students while completing academic tasks (e.g., during summative assessments; [Deutsch et al. 2012](#)), research in this domain has to date focused more on technology implementation and integration (e.g., [Valentín et al. 2013](#); for a review, see [Kirkwood and Price 2014](#)) than students' computing-related motivation and emotions. One notable exception is a study by [Butz et al. \(2015\)](#) that found graduate students' emotions related to using technology in synchronous hybrid learning environments (anxiety, guilt, and helplessness) to partially mediate effects of control on perceived success in using technology to complete their academic program. Furthermore, rapidly expanding emotion research in general multimedia learning (emotional design; [Heidig et al. 2015](#); [Park et al. 2015](#)) and more specialized educational technology domains (e.g., engagement with artificial intelligence tutoring systems; [Harley et al. 2015](#); for a review of emotions in advanced learning technologies, see [Graesser et al. 2014](#)) highlights the importance of emotions and their determining cognitive mechanisms in exploring learning experiences mediated by technology.

Arguably, from the established importance of emotions in technology-integrated learning follows a need for understanding how technological problems specifically influence motivation and emotions when such problems are experienced in typical academic contexts. More generally, motivational variables have been regularly investigated in research pertaining to computer use in education (e.g., computer-based assessment; [Deutsch et al. 2012](#); game-based e-learning; [Martí-Parreño et al. 2018](#)), with motivation theory-driven research exploring ICT in higher education settings having focused primarily on self-efficacy beliefs (e.g., computer-based learning environments; [Moos and Azevedo 2009a](#); for a review of computer self-efficacy, see [Johnson et al. 2017](#)). Similarly, whereas emotions have often been explored in general academic computing (e.g., [MacFadden 2007](#); [Nummenmaa and Nummenmaa 2008](#)), existing studies have principally examined the role of computer anxiety ([Cooper 2006](#); [Huang et al. 2013](#); [Noteborn and García 2016](#); for a review, see [Powell 2013](#)). Given the increasing emphasis on the role of students' emotions as important consequences of motivational beliefs and predictors of learning and achievement in post-secondary education (for a review, see [Pekrun and Stephens 2010](#)), further investigation of the interplay between a wider range of theoretically-informed motivational and emotion variables within the context of educational technology is warranted. Accordingly, the present research explored the effects of students' motivational beliefs concerning technology-related challenges on emotions and achievement in post-secondary students as informed by a comprehensive theory of achievement motivation and emotions: [Weiner \(1985\)](#) attribution theory.

1.1. Motivation and Emotions in Academic Computing Contexts

In existing research on the role of student motivation in academic computing, computer self-efficacy has emerged as a specific topic of interest in studies examining student learning in technology-rich learning environments (e.g., [Cassidy and Eachus 2002](#); [Chang et al. 2014](#); [Huffman et al. 2013](#)). Self-efficacy and competence beliefs involve an individual's belief in his or her ability to successfully complete a given achievement task and represent well-established predictors of learning and achievement in educational research (for a review, see [Schunk and Pajares 2005](#)). With respect to research in academic computing contexts, there exists clear empirical support for the link between computer self-efficacy and learning processes and outcomes: students with higher computer self-efficacy consistently demonstrate greater self-regulation (e.g., self-monitoring; [Moos and Azevedo 2009b](#); [Pellas 2014](#)) and achievement in computer-mediated learning environments

as compared to students with lower computer self-efficacy (Johnson 2005; Wang et al. 2013; for reviews, see Karsten et al. 2012; Moos and Azevedo 2009a). Research with online post-secondary students has also found their self-efficacy specific to online learning to correlate with learning satisfaction (Shen et al. 2013) and to mediate the effects of various background variables (e.g., prior achievement, pre-course training, online learning anxiety) on outcome expectations, mastery perceptions, and persistence with online learning technology (Bates and Khasawneh 2007).

With respect to computing emotions, computer anxiety has remained the predominant focus of hundreds of empirical articles published on the topic since the 1980s (Powell 2013), with researchers having extensively explored its varied antecedents (e.g., gender, age, level of education and major, other anxieties, personality traits) and psychosocial correlates (e.g., self-efficacy, attitudes, perceived ease of use, perceived usefulness, satisfaction). Concerning relations with motivational variables, findings also consistently reveal a negative correlation between anxiety and self-efficacy specific to academic computing in university students (e.g., Cazan et al. 2016; McIlroy et al. 2007; Scott and Walczak 2009; Srisupawong et al. 2018; Thatcher et al. 2008). Both general and application-specific computer self-efficacy has been found to correlate negatively with computer anxiety (Hasan 2006; Johnson 2005), with computer anxiety corresponding more strongly with computer self-efficacy than computer use or experience (Wilfong 2006). Overall, whereas the extensive existing literature on computer anxiety clearly indicates significant relationships with student learning experiences and achievement (Huang and Mayer 2016; Wombacher et al. 2017), there exists little research on additional academic computing emotions and importantly, how technological problems influence such emotions.

1.2. Weiner's (1985) Attribution Theory of Achievement Motivation

According to Weiner's (1985, 2000, 2010) attribution theory, individuals seek to understand the reasons for important, unexpected, and/or negative events, with the causal attributions they select to explain these events having predictable consequences for subsequent emotions and achievement. Following from Rotter (1954) concept of locus of control and a realization that "if one fails because of a perceived lack of aptitude, then the causal locus is internal yet not subject to volitional control" (Weiner 2010, p. 30), Weiner's attribution theory distinguishes locus of causality from personal control, deeming distinctions between locus and control, ability and effort, and success and failure necessary when considering causal ascriptions. For example, a student who believes he or she failed a test due to a lack of ability (where ability is believed to be unchanging; cf. incremental vs. fixed theories of intelligence; Dweck and Master 2009) will likely experience feelings of hopelessness with regards to future tests. As such, Weiner proposes that each causal attribution is characterized by three underlying dimensions that correspond to their specific effects: *locus* refers to the belief that the cause was internal or external to oneself, *controllability* is described as the extent to which the cause is perceived as under one's personal control, and *stability* represents how variable the cause is believed to be over time. Accordingly, although some emotions following a failure event may be outcome-dependent (e.g., frustration), other more specific emotional responses are proposed to be attribution-dependent, resulting from the specific combination of dimensions underlying a selected attribution. Whereas pride and self-esteem are assumed to be impacted mainly by locus of causality, feelings of hopefulness or hopelessness are proposed to follow from the stability dimension, with the emotions of anger, gratitude, guilt, and shame most strongly linked to perceptions of controllability. Given that Weiner's attribution theory can be applied to examine motivation in terms of cognitions (i.e., causal attributions) and emotions specifically following failure experiences, its application in research examining motivational factors influencing students' learning experiences with digital technology following technological problems is appropriate.

1.3. Empirical Research on Attributions for Academic Failure

Over the past 30 years, empirical research has consistently underscored the relevance of Weiner's (2010) attribution theory for explaining and predicting emotions and achievement in post-secondary students. As predicted by Weiner's model, internal attributions that are controllable or unstable in nature are typically most beneficial for student motivation, persistence, and performance in higher education, with attributions specifically to effort and strategy having been identified as particularly salient predictors of academic persistence and achievement (e.g., Dong et al. 2015; Smiley et al. 2016; Van Overwalle et al. 1995; for a review, see Dickinson 1995). Similarly, intervention research based on attribution theory further shows post-secondary students who have been encouraged to adopt personally controllable attributions for academic setbacks (e.g., low effort, poor strategy), and discouraged from personally uncontrollable attributions (e.g., bad luck, lack of ability), to consistently obtain higher grades and have lower attrition rates relative to their peers (Hall et al. 2004, 2007; Hamm et al. 2014; Haynes Stewart et al. 2011; for reviews, see Haynes et al. 2009; Wilson et al. 2002).

In addition to foundational empirical research preceding attribution theory showing emotions to be a function of causal attributions for poor academic performance (e.g., ability attributions and feelings of resignation, and unhappiness; Weiner et al. 1979), further research on causal attributions as antecedents of emotions has shown that attributions indeed account for a significant proportion of variance in emotions in academic settings (e.g., anger, guilt; Smith et al. 1993). For example, internal attributions for academic performance have been shown to correlate with higher levels of hope and pride in post-secondary students, as well as lower levels of shame, with personally controllable attributions also correlated with better emotion levels (e.g., more hope and pride, less anger and shame; Dong et al. 2015). More detailed findings from Van Overwalle et al. (1995) additionally showed that whereas internal attributions did correlate with more pride and shame, personally controllable attributions actually correspond with greater feelings of guilt, and stable attributions had mixed effects (more hope, as well as greater anxiety and despair). Intervention studies based on attribution theory have further shown at-risk students who were encouraged to make personally controllable attributions for academic failure to also experience more adaptive emotions as compared to control participants (e.g., more hope, less helplessness; Hamm et al. 2014; more happiness, pride, and hope, as well as less anger, apathy, and shame; Hall et al. 2007).

1.4. Empirical Research on Attributions for Computing Problems

Significant empirical research has investigated computing-related causal attributions in K-12 settings (e.g., Baron et al. 1996; Campbell 1990; Nelson and Cooper 1997), with research having increasingly explored the impact of computing-related attributions in higher education. For example, research with German samples has shown students' attributional style concerning hypothetical computing issues (i.e., dimensions of globality, stability, internality, controllability) to correlate significantly with their self-concept of computing ability, with females demonstrating a less favorable attributional style than males (e.g., lower controllability, higher stability; Dickhäuser and Stiensmeier-Pelster 2002). Research with German university students has also investigated the role of computing-related gender stereotypes, with females reporting lower computer self-efficacy as compared to males, as well as lower expectations concerning their own computing performance as compared to others more generally (Sieverding and Koch 2009). Exploratory qualitative research has also examined the specific types of computing-related attributions made by university students, with in-person interviews of Lebanese undergraduates regarding their performance in a computer programming course showing attributions to computing-related learning strategies to be particularly prevalent (Hawi 2010).

Research at U.S. post-secondary institutions has also explored the role of computing-related causal attributions in students' emotions and computing behavior. For example, findings with U.S. college students show attributions for hypothetical computing failures to low ability to correlate

with greater computer anxiety and lower computer course enrolment (Campbell 1992). Related findings concerning students' attributional style concerning hypothetical and actual computing challenges in an undergraduate information systems course further showed stable attributions to correlate with better exam scores, and internal attributions (combined with high performance) to predict more positive affect throughout the course, with students who reported more computing experience also reporting more external attributions for computing failures (Rozell and Gardner 2000). In addition to descriptive research with European and North American samples, a notable experimental study has also explored the role of computing-related attributions in post-secondary educational contexts. In their study examining the effects of gender stereotypes on attributions for a manipulated computer task, Koch et al. (2008) found that when primed for a negative stereotype, German undergraduate females made more internal attributions for computing failures than their male counterparts, with male students instead reporting more external attributions for computing failures. Female students were also found to report less computer use, self-efficacy, intrinsic motivation, and knowledge than males in this experimental study, highlighting gender differences in attributions for computing failures and related computing variables.

Overall, existing empirical research suggests that causal attributions specific to computer mediated learning and assessment are indeed important indicators of performance, competence beliefs, and emotions for students in post-secondary settings. However, there currently exists little research that specifically examines the effects of computing-related causal attributions in response to computing setbacks in higher education as informed by Weiner's (2010) attribution theory, and no research to date exploring the utility of this theoretical model for predicting the effects of students' causal attributions for computing failures on their emotions and performance across countries. As computing-related attributions have been shown to have significant relationships with other motivational factors in both German and North American post-secondary student samples (e.g., self-concept and emotions, respectively), an examination of attributions and emotions in relation to computer problems across the two samples would offer a more holistic perspective on academic experiences with computer technology. Accordingly, the present empirical studies aim to contribute to research on how post-secondary students in both Europe and North America respond to not only academic setbacks but also technological difficulties in exploring the influence of causal attributions for academic computing challenges on students' emotions and academic achievement outcomes. Specifically, the following studies build upon prior research by addressing limitations of attribution measurement (e.g., overall style indexes, confounded measures), objective achievement outcomes, and cross-country validity of academic computing attributions.

2. Study 1: Effects of Computing Attributions on Emotions

The first study was conducted as a preliminary cross-country investigation into how post-secondary students' causal attributions correspond with their emotional experiences with respect to academic computing. Based on the long-standing literature concerning the effects of post-secondary students' causal attributions on academic emotions and achievement (e.g., Hall et al. 2004, 2007; cf. scattered findings on computing-related attributions; e.g., Dickhäuser and Stiensmeier-Pelster 2002; Koch et al. 2008), and in direct accordance with Weiner's (1985, 2000, 2010) attribution theory, the following hypotheses were evaluated under the assumptions that: (1) attributions external in nature present limited potential for personal influence; (2) attributions with elements of personal control provide opportunities to personally change one's experience; (3) attributions that are external yet unstable in nature provide the potential for improvement over time.

2.1. Study 1 Hypotheses

Hypothesis 1 (H1). *Students' causal attributions for academic computing problems to external factors (i.e., luck, hardware quality, software difficulty) should predict lower levels of positive emotions and/or higher levels of negative emotions concerning academic computing.*

Hypothesis 2 (H2). *Concerning the effects of attributions to internal factors, personally controllable attributions for computing difficulties (i.e., effort, strategy) should predict optimal computing-related emotions, whereas personally uncontrollable attributions (e.g., ability) should correspond to poorer emotion levels.*

Hypothesis 3 (H3). *With respect to the stability dimension, causal attributions for computing problems to factors typically perceived as external to oneself and unstable over time (e.g., luck, software difficulty) were expected to more positively impact computing emotions than external yet stable attributions (e.g., hardware quality).*

2.2. Study 1 Methods

2.2.1. Participants and Procedure

The first study included 1063 undergraduates recruited from one research-intensive North American university ($n = 780$) and two research-intensive German universities ($n = 283$). The North American students were recruited by email from eight sections of an introductory psychology course to complete an online self-report questionnaire consisting of demographic and computing-related measures, and participated in exchange for course credit. The German sample was recruited by email and in-person from multiple social science departments (e.g., education, philosophy, political science, religion). A subsample of students at one German university participated in exchange for program credit (i.e., volunteer hours), with most German participants receiving no compensation. Across all studies, participants' mean age was 21.20 years ($SD = 4.86$) and 67.70% were female. German versions of all self-report measures were translated from English then iteratively backtranslated and revised by doctoral psychology candidates to ensure cross-cultural consistency across study measures.

2.2.2. Study Measures

Causal Attributions for Academic Computing Problems

Six 10-point items (1 = *not at all*, 10 = *very much so*; observed range of 1–10 for all attribution items) were used to assess students' specific causal attributions for computing problems experienced in educational settings based on Weiner's (2010) attribution theory. The items were adapted from those previously used to evaluate attributions for poor academic achievement (Hall et al. 2007) and included attributions to their natural ability to use computers ($M = 4.29$, $SD = 2.45$), not learning how to use it properly (effort; $M = 5.00$, $SD = 2.74$), using the wrong approach (strategy; $M = 5.25$, $SD = 2.46$), luck or chance ($M = 4.49$, $SD = 2.72$), the quality of the computer (hardware; $M = 6.69$, $SD = 2.52$), and the difficulty of the computer program (software; $M = 6.44$, $SD = 2.36$). Individual attribution items were not combined into composite variables (e.g., controllable attributions) based on principal components factor analyses showing a lack of empirical support for singular unifying factors based on causal dimensions.

Attribution-Dependent Computing Emotions

Eight 10-point items (1 = *not at all*, 10 = *very much so*; observed range of 1–10 for all attribution items) were used to measure students' discrete emotions concerning their experiences when using computers to complete course assignments. The items evaluated "attribution-dependent" emotions proposed in Weiner's (2010) theory to follow from causal attributions for specific experiences, with scale items adapted from a previous measure evaluating emotions concerning academic

performance outcomes (Hall et al. 2004, 2007). The attribution-dependent computing emotion items consisted of hope ($M = 6.56$, $SD = 2.35$), guilt ($M = 1.97$, $SD = 1.66$), helplessness ($M = 3.05$, $SD = 2.24$), pride ($M = 6.45$, $SD = 2.45$), anger ($M = 3.43$, $SD = 2.48$), shame ($M = 1.97$, $SD = 1.72$), regret ($M = 2.07$, $SD = 1.83$), and apathy ($M = 4.37$, $SD = 3.05$), most of which have previously been assessed in similar research by Butz et al. (2015).

Activity-Related Computing Emotions

Three multi-item, 5-point scales (1 = *not at all true*, 5 = *completely true*) were additionally used to evaluate students' emotions of enjoyment, anxiety, and boredom as experienced during academic computing activities using a modified version of the Achievement Emotions Questionnaire (AEQ; Pekrun et al. 2011). Computing-related enjoyment was assessed using eight items ($M = 25.42$, $SD = 7.00$, $\alpha = 0.89$, observed range of 8–40; e.g., "I often find using computers for class to be enjoyable"), anxiety with 12 items ($M = 20.42$, $SD = 8.61$, $\alpha = 0.93$, observed range of 12–57; e.g., "When I can't keep up with new computer programs it makes me anxious"), and boredom with 14 items ($M = 25.54$, $SD = 10.33$, $\alpha = 0.94$, observed range of 14–65; "While using the computer I seem to drift off because it's so boring").

2.3. Study 1 Results

2.3.1. Preliminary Analyses

Correlational Analyses

Correlations among causal attributions are presented in Table 1, with the correlations between the emotion variables outlined in Table 2. As expected, attributions to internal factors were positively intercorrelated (ability, effort, strategy), with the strongest correlation found between the attributions typically perceived as personally controllable (effort and strategy). Interestingly, attributions to software difficulty were significantly correlated with all other attributions, with older students being less likely to attribute computing problems to internal factors (ability, effort) and hardware quality. As for computing-related emotions, negative emotions were positively intercorrelated, as were positive emotions, with negative correlations observed between positive and negative emotions. Older students were also found to generally report lower levels of negative computing-related emotions (e.g., guilt, helplessness, shame, anxiety), and greater feelings of enjoyment, with greater academic computing experience also corresponding with more computing-related enjoyment.

Table 1. Study 1 zero-order correlations among attributions.

| | 1 | 2 | 3 | 4 | 5 | 6 |
|------------------------|----------|----------|----------|----------|----------|---|
| Attributions | | | | | | |
| 1. Ability | - | | | | | |
| 2. Effort | 0.39 *** | - | | | | |
| 3. Strategy | 0.29 *** | 0.69 *** | - | | | |
| 4. Luck | 0.06 * | -0.05 | -0.03 | - | | |
| 5. Hardware quality | 0.01 | 0.01 | 0.07 * | 0.21 *** | - | |
| 6. Software difficulty | 0.24 *** | 0.34 *** | 0.35 *** | 0.14 *** | 0.30 *** | - |

* $p \leq 0.05$. *** $p \leq 0.001$.

Initial Differences

MANOVAs were conducted to examine potential initial differences on our study measures as a function of country and gender; however, effect sizes were small ($0.01 < \eta_p^2 < 0.14$; Richardson 2011).¹

¹ Hierarchical regression analyses including gender and country as covariates were additionally performed and produced the same significant results as the main regression analyses conducted without covariates.

Table 2. Study 1 zero-order correlations among emotions.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|-----------------|-----------|----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|----------|----|
| <i>Emotions</i> | | | | | | | | | | | |
| 1. Hope | - | | | | | | | | | | |
| 2. Guilt | -0.02 | - | | | | | | | | | |
| 3. Helplessness | -0.08 ** | 0.46 *** | - | | | | | | | | |
| 4. Pride | 0.53 *** | -0.02 | -0.15 *** | - | | | | | | | |
| 5. Anger | -0.02 | 0.40 *** | 0.63 *** | -0.08 ** | - | | | | | | |
| 6. Shame | -0.11 *** | 0.75 *** | 0.51 *** | -0.07 * | 0.41 *** | - | | | | | |
| 7. Regret | -0.03 | 0.73 *** | 0.53 *** | -0.06 | 0.45 *** | 0.75 *** | - | | | | |
| 8. Apathy | -0.31 *** | 0.15 *** | 0.11 *** | -0.36 *** | 0.11 *** | 0.15 *** | 0.16 *** | - | | | |
| 9. Enjoyment | 0.34 *** | -0.06 * | -0.38 *** | 0.34 *** | -0.25 *** | -0.13 *** | -0.11 *** | -0.23 *** | - | | |
| 10. Anxiety | -0.07 * | 0.52 *** | 0.59 *** | -0.06 * | 0.45 *** | 0.57 *** | 0.58 *** | 0.11 *** | -0.19 *** | - | |
| 11. Boredom | -0.17 *** | 0.42 *** | 0.48 *** | -0.19 *** | 0.38 *** | 0.45 *** | 0.47 *** | 0.35 *** | -0.43 *** | 0.68 *** | - |

* $p \leq 0.05$. ** $p \leq 0.01$. *** $p \leq 0.001$.

2.3.2. Main Regression Analyses

The hypothesized effects of computing-related attributions on emotions were evaluated using linear regression analyses (see Table 3). As the aim of the present study was to examine hypothesized relationships generally across male and female students from North America and Europe, all data were analyzed together rather than by gender or country in light of scattered findings throughout the extant literature as well as the small effect sizes for differences between gender and country found in the preliminary analyses. As hypothesized, regression results showed attributions for academic computing problems to ability to consistently predict more negative emotions (guilt, helplessness, anger, shame, regret, anxiety, boredom), attributions to strategy to correspond with more positive emotions (hope, pride, enjoyment), and attributions to luck to predict significantly poorer levels on all emotion measures with the exceptions of hope and hardware quality. However, unexpected findings showed attributions to effort to predict poorer levels on most emotion measures (hope, helplessness, pride, anger, enjoyment, anxiety, boredom), with attributions to hardware quality instead predicting better emotion levels (guilt, helplessness, pride, shame, regret, anxiety). Attributions to software difficulty did not significantly predict any of the emotions examined. The only significant effect of attributions to software difficulty was for enjoyment, which is significant at the $p < 0.05$ level but the confidence interval for the unstandardized regression coefficient includes 0. Study 1 data is available in the supplementary materials (Data S1: Study 1).

2.4. Study 1 Discussion

2.4.1. Study Hypotheses

In support of [Weiner's \(2010\)](#) attribution theory, students' causal attributions for computing problems experienced in educational settings indeed predicted their emotions regarding academic computing, with the exception of attributions to software difficulty. Further, findings in support of both Hypotheses 1 and 2 were observed, with attributions to luck (external) and ability (personally uncontrollable) predicting poorer emotion levels, and attributions to ineffective strategies (personally controllable) predicting more positive emotions. However, despite the present attribution measures having been derived directly from parallel items concerning academic achievement ([Hall et al. 2007](#)), the remainder of effects were not consistent with findings that are typically observed for students' performance-related attributions. First, attributions for academic computing difficulties to lack of effort were found to predict lower levels of positive emotions (e.g., enjoyment) as well as higher levels of negative emotions (e.g., helplessness). This finding is directly opposite of Hypotheses 1 and 2 based on [Weiner's \(2010\)](#) theory, but is nonetheless consistent with previous findings showing internal attributions for computing failures to correspond with poorer levels on other computing-related variables for female university students (e.g., less experience, lower self-efficacy; [Koch et al. 2008](#); see also [Dickhäuser and Stiensmeier-Pelster 2002](#)). Second, the emotional benefits found for attributions to hardware quality directly contradict Hypotheses 1 and 3, instead aligning with previous studies showing external and stable attributions to correspond with greater experience and achievement, respectively (e.g., [Koch et al. 2008](#); [Rozell and Gardner 2000](#)).

Table 3. Study 1 regression analyses of attribution effects on emotions.

| Predictor | Hope | Guilt | Helplessness | Pride | Anger | Shame | Regret | Apathy | Enjoyment | Anxiety | Boredom |
|---------------------|------------------------------------|-----------------------------------|----------------------------------|-------------------------------------|----------------------------------|-------------------------------------|-------------------------------------|----------------------------------|-------------------------------------|------------------------------------|-----------------------------------|
| Ability | 0.01 (0.03) [−0.06 – 0.07] | 0.16 *** (0.02) [0.12 – 0.20] | 0.13 *** (0.03) [0.07 – 0.19] | 0.07 * (0.03) [0.00 – 0.13] | 0.12 *** (0.03) [0.06 – 0.18] | 0.15 *** (0.02) [0.11 – 0.20] | 0.15 *** (0.02) [0.10 – 0.20] | 0.03 (0.04) [−0.05 – 0.11] | −0.03 (0.10) [−0.22 – 0.15] | 10.04 *** (0.11) [8.83 – 10.26] | 0.99 *** (0.14) [0.73 – 10.26] |
| Effort | −0.11 ** (0.04) [−0.18 – −0.03] | 0.00 (0.03) [−0.05 – 0.05] | 0.20 *** (0.04) [0.13 – 0.26] | −0.14 *** (0.04) [−0.21 – −0.06] | 0.12 ** (0.04) [0.04 – 0.20] | 0.03 (0.03) [−0.02 – 0.08] | 0.05 (0.03) [−0.01 – 0.11] | 0.04 (0.05) [−0.06 – 0.13] | −0.72 *** (0.11) [−0.94 – −0.50] | 0.37 * (0.13) [0.12 – 0.62] | 0.45 ** (0.16) [0.14 – 0.76] |
| Strategy | 0.12 ** (0.04) [0.04 – 0.20] | 0.03 (0.03) [−0.03 – 0.09] | −0.02 (0.04) [−0.10 – 0.05] | 0.12 ** (0.04) [0.04 – 0.20] | 0.02 (0.04) [−0.06 – 0.10] | 0.04 (0.03) [−0.02 – 0.09] | 0.06 (0.03) [0.00 – 0.12] | −0.04 (0.05) [−0.14 – 0.06] | 0.49 *** (0.12) [0.26 – 0.73] | 0.09 (0.14) [−0.18 – 0.36] | −0.14 (0.17) [−0.47 – 0.20] |
| Luck | 0.00 (0.03) [−0.06 – 0.05] | 0.07 *** (0.02) [0.03 – 0.10] | 0.11 *** (0.03) [0.06 – 0.16] | −0.09 *** (0.03) [−0.15 – −0.04] | 0.13 *** (0.03) [0.08 – 0.19] | 0.09 *** (0.02) [0.05 – 0.12] | 0.10 *** (0.02) [0.06 – 0.14] | 0.20 *** (0.04) [0.13 – 0.27] | −0.08 (0.08) [−0.24 – 0.08] | 0.58 *** (0.09) [0.40 – 0.76] | 0.84 *** (0.11) [0.61 – 10.06] |
| Hardware quality | 0.02 (0.03) [−0.04 – 0.08] | −0.05 * (0.02) [−0.09 – −0.01] | −0.06 * (0.03) [−0.11 – 0.00] | 0.13 *** (0.03) [0.07 – 0.19] | −0.03 (0.03) [−0.09 – 0.03] | −0.08 *** (0.02) [−0.12 – −0.04] | −0.08 *** (0.02) [−0.13 – −0.04] | 0.00 (0.04) [−0.07 – 0.08] | −0.01 (0.09) [−0.19 – 0.17] | −0.24 * (0.10) [−0.45 – −0.04] | −0.22 (0.13) [−0.47 – 0.03] |
| Software difficulty | 0.07 * (0.04) [0.00 – 0.14] | −0.03 (0.02) [−0.08 – 0.02] | −0.02 (0.03) [−0.08 – 0.05] | 0.00 (0.04) [−0.07 – 0.07] | 0.03 (0.04) [−0.04 – 0.10] | −0.03 (0.03) [−0.08 – 0.02] | −0.03 (0.03) [−0.08 – 0.02] | −0.01 (0.05) [−0.10 – 0.08] | 0.32 (0.10) [0.12 – 0.52] | −0.02 (0.12) [−0.25 – 0.22] | −0.21 (0.15) [−0.49 – 0.08] |
| R ² | 0.02 ** | 0.08 *** | 0.11 *** | 0.04 *** | 0.08 *** | 0.09 *** | 0.10 *** | 0.03 *** | 0.05 *** | 0.17 *** | 0.13 *** |

Notes: Unstandardized *B* coefficients are provided for regressions on all study measures, with standard errors reported in parentheses and 95% confidence intervals presented in brackets. Regression coefficient and *R*² values are for the step in which they were first entered. Significance of *R*² values indicates two-tailed significance. * $p \leq 0.05$. ** $p \leq 0.01$. *** $p \leq 0.001$.

Although unanticipated, mixed findings from the present exploratory study nonetheless align with scattered prior research on computer-related attributions and emotions, suggesting important caveats when applying Weiner's (2010) attribution theory to the academic computing domain. For example, whereas lack of effort may be perceived as personally controllable concerning typical achievement outcomes (e.g., test performance), it may instead suggest self-blame and helplessness in academic computing settings. Similarly, whereas external attributions are typically maladaptive in achievement settings in implying helplessness (e.g., Haynes et al. 2009), attributing computing failure to hardware issues instead appears to be emotionally adaptive. These findings thus suggest that attributional assumptions derived from academic achievement motivation research may not be uniformly applied to understand responses to failure across academic domains (e.g., achievement, technological course requirements, finances, extracurricular), but rather that the effects of causal attributions on emotions may be more domain-specific in nature (e.g., academic computing failures may not be perceived by students as directly equivalent to academic achievement failures). For example, previous research on how post-secondary students respond to interpersonal failures has produced findings contrary to Weiner's attribution theory (e.g., psychological risks of controllable attributions, benefits of external attributions; Dupuis and Struthers 2007; Kernis et al. 1993; Massad and Hulseley 2006; Smalley and Stake 1996; see also Graham and Williams 2009), with research on achievement goals also showing disparate theoretical effects between help-seeking behaviors for online students vs. in-person help seeking of computer science students in traditional settings (Hao et al. 2017).

Despite the unexpected and seemingly dissonant relationships presently observed between academic computing attributions and emotions, a clear pattern of effects centralize around perceptions of control following technological difficulties. More specifically, effort attributions may be perceived as less personally controllable and attributions to hardware quality perceived as more controllable following failures related to computers in comparison to academic achievement. For example, our findings could suggest that whereas strategy and effort are prototypically perceived as personally controllable in academic achievement settings, students may in fact view basic persistence as maladaptive when applied to computing failures due to a lack of perceived control over a device external to themselves. Similarly, whereas external attributions are prototypically perceived as uncontrollable with respect to learning and grades, attributions to hardware quality may be viewed as more controllable in that students are often able to change computers if they encounter hardware problems (e.g., by going to campus computer labs). Given that the present findings generate questions about perceptions of control following technological problems, a replication of the current findings via an examination of underlying causal dimensions for academic computing attributions is needed before making recommendations to post-secondary students on how best to cope with technological difficulties.

2.4.2. Limitations and Open Questions

Following from the exploratory nature of Study 1 are multiple limitations to be addressed. First, causal attributions and attribution-dependent emotions were assessed using face-valid single-item measures that although are readily understandable by participants (for the psychometric validity of single-item measures, see Gogol et al. 2014) are nonetheless more vulnerable to error than multi-item scales (e.g., our activity-related emotion measures). Second, whereas the attribution items were specific to computing problems, the emotion measures were somewhat more general in referring to academic computing experiences (e.g., completing course assignments)—a discrepancy in specificity that may have mitigated the magnitude of the effects observed. Similarly, it is possible that a lack of specificity concerning the type of computing problem experienced may have resulted in some attributions appearing adaptive and others not (e.g., hardware vs. software failure, data loss vs. processing delay, loss of email vs. year-end essay). Third, as the attribution measure in the present study required students to rate their endorsement of a predetermined list of specific attributions, follow-up studies with self-report measures that are open-ended or more directly assess the causal

dimensions perceived by students as underlying these attributions are also recommended (e.g., Revised Causal Dimension Scale; McAuley et al. 1992). Finally, given the extant literature highlighting the effects of post-secondary students' computing-related attributions on not only self-report psychosocial measures (e.g., emotions, attitudes) but also behavioral outcomes (e.g., course enrolment, performance), arguably the largest omission in the present study was the focus on emotions at the expense of achievement outcomes. More specifically, whereas Study 1 investigated the relationships between students' computing-related attributions and emotions as informed by multiple achievement emotion theories (e.g., Pekrun 2006; Weiner 2010), it did not explore the effects of computing attributions on more objective performance indicators that are less susceptible to response bias (e.g., course grades).

3. Study 2: Effects of Computing Attributions on Achievement

To address the aforementioned limitations of Study 1 concerning objective outcomes, Study 2 examined the effects of post-secondary students' causal attributions for computing challenges specifically on long-term academic achievement outcomes. Moreover, Study 2 further assessed the predictive utility of students' causal attributions for computing problems as compared to their attributions for academic failure experiences. As in Study 1, the following hypotheses were evaluated in direct accordance with Weiner's (1985, 2000, 2010) attribution theory under the same assumptions regarding externality, personal controllability, and stability as stated in Study 1 (i.e., external factors related to perceptions of limited opportunities for personal influence, personally controllable factors related to perceptions of capability to change one's experiences, and unstable factors related to perceived potential for improvement over time).

3.1. Study 2 Hypotheses

Hypothesis 4 (H4). *Attributions for academic computing problems were expected to positively correlate with the respective attributions for poor academic performance given domain similarity (academic context) and existing research highlighting the potential for within-individual consistency in causal attributions (e.g., explanatory style applied broadly to classroom performance; Peterson 1990; prevalent strategy attributions for academic computer programming; Hawi 2010).*

Hypothesis 5 (H5). *Students' causal attributions to external factors for both academic computing problems (i.e., luck, hardware quality, software difficulty) and poor academic performance (i.e., luck teacher quality, test difficulty) should predict lower achievement levels.*

Hypothesis 6 (H6). *Concerning the effects of attributions to internal factors, attributions for computing difficulties and poor academic performance typically perceived as personally controllable in nature (i.e., effort, strategy) should predict higher achievement. In contrast, attributions that are internal but more likely perceived as personally uncontrollable (i.e., ability) should correspond with lower achievement.*

Hypothesis 7 (H7). *With respect to the stability dimension, causal attributions for computing problems and poor academic performance to factors typically perceived as external to oneself and unstable over time (i.e., luck, software difficulty) were expected to less negatively impact achievement than external yet stable attributions (e.g., hardware quality). Due to the exploratory nature of the present study, no hypotheses were proposed as to the specific or relative magnitude of the expected directional effects of computing and performance attributions on achievement.*

3.2. Study 2 Methods

3.2.1. Participants and Procedure

Undergraduate students at a mid-western, research-intensive North American university completed an online self-report questionnaire concerning academic computing topics six months

into the academic year. Students were recruited from eight sections of Introductory Psychology and participated in exchange for experimental credit ($N = 788$). The sample was comprised of 512 females and 286 males, with a mean age of 19.91 years ($SD = 3.92$) and final course grade of 71.86% ($SD = 11.86$).

3.2.2. Study Measures

Causal Attributions for Poor Academic Performance

Six 10-point items (1 = *not at all*, 10 = *very much so*; observed range of 1–10 for all items) were used to measure students' causal attributions for poor academic performance. The achievement attribution items have been used previously in research with post-secondary students (e.g., Hall et al. 2007; Hamm et al. 2014) and consist of attributions to ability ($M = 5.43$, $SD = 2.27$), effort ($M = 8.04$, $SD = 1.92$), strategy ($M = 6.95$, $SD = 2.02$), luck ($M = 3.99$, $SD = 2.22$), teacher quality ($M = 6.86$, $SD = 2.33$), and test difficulty ($M = 7.22$, $SD = 2.08$; observed range of 1–10 for all items).

Causal Attributions for Academic Computing Problems

Identical to Study 1, a second set of attribution items paralleling that used for achievement attributions was used to assess students' causal attributions for computing problems in educational settings including ability ($M = 4.43$, $SD = 2.52$), effort ($M = 5.14$, $SD = 2.72$), strategy ($M = 5.33$, $SD = 2.48$), luck ($M = 4.17$, $SD = 2.60$), hardware quality ($M = 6.90$, $SD = 2.41$), and software difficulty ($M = 6.24$, $SD = 2.02$; observed range of 1–10 for all items).

Academic Achievement

Final grade percentages in the Introductory Psychology course from which participants were initially recruited were obtained at the end of the academic year for consenting students ($n = 644$).

3.3. Study 2 Analyses

Preliminary analyses examined effects of potential covariates (gender, age, high-school grades, English as a first language, credit hours registered for, and academic computing experience); however, effect sizes were small ($\eta_p^2 < 0.14$). A preliminary correlational analysis was also performed to evaluate Hypothesis 4 concerning the expected positive relationships between corresponding attributions for poor performance and computing problems. A hierarchical regression analysis was subsequently conducted to assess the proposed effects of attributions for academic performance and computing problems on course achievement (Hypotheses 5–7). The effects of performance attributions on achievement were evaluated in Step 1, and the effects of computing-related attributions were evaluated in Step 2 to determine their achievement effects over and above those of achievement-specific attributions.

3.4. Study 2 Results

Correlational analyses showed computing-related attributions to ability, effort, strategy, luck, hardware quality, and software difficulty to consistently demonstrate among the strongest positive relationships with their corresponding achievement attributions (see Table 4, bolded diagonal values). Although most of the correlations between computing attributions and achievement attributions were statistically significant (30 of 36, $p \leq 0.05$), the significant inter-domain correlations observed were weak in magnitude ($|0.07| < r < |0.32|$). Concerning our regression analyses (see Table 5), Step 1 results showed attributions for poor achievement to ability, effort, and strategy to predict course grades in the expected directions, with these effects retaining similar magnitudes after controlling for the effects of computing attributions in Step 2. Results from Step 2 additionally showed multiple attributions for computing problems to predict significant additional variance in course grades in the expected directions. Similar to the achievement attributions, attributions for computing difficulties to ability predicted lower grades, with attributions to effort predicting higher grades. However, contrary to

expectations and the results for achievement attributions, causal attributions for computing problems to strategy were not significant, with attributions to luck found to predict higher course grades. Study 2 data is available in the supplementary materials (Data S2: Study 2).

Table 4. Study 2 zero-order correlations between achievement attributions, computing attributions, and course grades.

| <i>Achievement attributions</i> | Computing Attributions | | | | | | Course Grades |
|---------------------------------|------------------------|-------------|-------------|-------------|-------------|-------------|---------------|
| | Ability | Effort | Strategy | Luck | Hardware | Software | |
| Ability | 0.32 | 0.11 | 0.07 | 0.16 | 0.09 | 0.18 | −0.10 |
| Effort | −0.14 | 0.13 | 0.08 | −0.03 | 0.17 | 0.06 | 0.22 |
| Strategy | 0.02 | 0.15 | 0.11 | 0.02 | 0.15 | 0.16 | 0.15 |
| Luck | 0.28 | 0.08 | 0.11 | 0.31 | 0.04 | 0.16 | −0.12 |
| Teaching quality | 0.10 | 0.16 | 0.11 | 0.06 | 0.15 | 0.20 | −0.02 |
| Test difficulty | 0.18 | 0.09 | 0.08 | 0.12 | 0.17 | 0.27 | −0.01 |
| Course grades | −0.12 | 0.13 | 0.09 | 0.03 | 0.06 | 0.04 | |

Note: Bolded values on diagonal indicate correlations between parallel measures of performance and computing attributions. For example, the bolded coefficient in the column labeled ability is the correlation between computing attributions to ability and academic achievement attributions to ability, while all other coefficients in that column are correlations between computing attributions to ability and all other achievement attributions (as indicated by row). Hardware = hardware quality; software = software difficulty. Significance levels: $0.07 \leq r \leq 0.08 = p \leq 0.05$; $0.09 \leq r \leq 0.11 = p \leq 0.01$; $r \geq 0.12 = p \leq 0.001$.

Table 5. Study 2 hierarchical regression analyses of attribution effects on achievement.

| | Step 1 | Step 2 |
|--------------------------|------------------------------------|------------------------------------|
| R^2 | 0.07 *** | 0.10 *** |
| ΔR^2 | | 0.03 *** |
| Achievement attributions | | |
| Ability | −0.52 ** (0.21) [−0.94 – −0.11] | −0.44 * (0.22) [−0.87 – −0.01] |
| Effort | 0.99 *** (0.27) [0.45 – 1.52] | 0.77 ** (0.27) [0.23 – 1.31] |
| Strategy | 0.61 * (0.26) [0.11 – 1.11] | 0.08 * (0.25) [0.07 – 1.06] |
| Luck | −0.31 (0.23) [−0.75 – 0.14] | −0.46 (0.24) [−0.93 – 0.01] |
| Teaching quality | −0.07 (0.22) [−0.51 – 0.37] | −0.15 (0.22) [−0.59 – 0.29] |
| Test difficulty | 0.03 (0.26) [−0.49 – 0.54] | 0.03 (0.26) [−0.49 – 0.54] |
| Computing attributions | | |
| Ability | | −0.56 ** (0.21) [−0.97 – −0.15] |
| Effort | | 0.65 ** (0.25) [0.15 – 1.15] |
| Strategy | | 0.08 (0.27) [−0.46 – 0.61] |
| Luck | | 0.52 ** (0.19) [0.14 – 0.89] |
| Hardware quality | | −0.01 (0.21) [−0.42 – 0.41] |
| Software difficulty | | 0.06 (0.23) [−0.40 – 0.52] |

Note: Unstandardized *B* coefficients are provided for regressions on all study measures, with standard errors reported in parentheses and 95% confidence intervals presented in brackets. Significance of R^2 values indicates two-tailed significance. * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$.

3.5. Study 2 Discussion

3.5.1. Study Hypotheses

In accordance with Hypothesis 4, findings showed attributions for academic computing problems to correlate significantly with equivalent attributions for poor course performance. However, as these cross-domain correlations were weak in magnitude, these results thus suggest that despite some conceptual overlap, the types of attributions reported by students for achievement vs. computing challenges were largely orthogonal in nature. Nevertheless, Study 2 findings revealed computing-related attributions to significantly predict year-end academic achievement over and above the effects of achievement attributions. Consistent with [Weiner's \(2010\)](#) attribution theory, attributions to ability for both poor performance and computing problems predicted poorer final course grades, whereas attributions to effort concerning achievement and computing challenges were found to positively predict course performance. These findings thus provide partial empirical support for Hypothesis 6 in showing that although computing attributions to strategy did not predict better grades as did achievement attributions to strategy, attributions for computing problems to insufficient effort (learning) did predict better course performance likely due to the motivational benefits of a perceived potential to overcome computing problems. Finally, these results also provided intriguing results concerning achievement benefits of causal attributions for computing challenges to luck. Although this effect is consistent with Hypothesis 7 in showing attributions to luck to be less detrimental than those to other external factors typically perceived as less likely to change over time (hardware issues), it is nonetheless contrary to Hypothesis 5 in showing external attributions to in fact *benefit* course performance. Overall, these findings demonstrate significant effects of attributions for academic computing problems on subsequent academic achievement even after controlling for the effects of more domain-specific attributions for poor academic performance.

3.5.2. Limitations and Open Questions

Despite the improvements upon Study 1 (e.g., longitudinal design, objective achievement outcomes), Study 2 presents a few limitations to be noted. First, although face-valid, single-item measures have been recently demonstrated to have comparable psychometric validity as compared to corresponding multi-item measures ([Gogol et al. 2014](#)), they are nevertheless more vulnerable to error warranting replication with more intensive, multi-item attribution measures that provide greater specificity (e.g., networking vs. hardware problems) and internal validity information. Second, future research utilizing self-report methods that minimize response bias and provide greater ecological validity are encouraged (e.g., experience sampling methods during computing activities). Finally, as the attribution measure in both Studies 1 and 2 required students to rate their endorsement of a predetermined list of attributions, follow-up studies with self-report measures that are open-ended or more directly assess the causal dimensions perceived by students as underlying these attributions are also recommended (e.g., Revised Causal Dimension Scale; [McAuley et al. 1992](#)).

4. General Discussion

As the use of computing technologies in higher education continues to grow, so does the need for research that evaluates not only students' use and the effectiveness of such technologies for learning and performance (e.g., online course requirements, wikis, social learning environments), but also how they respond when technology fails. Although students have consistently identified technological problems as a barrier to learning with digital technology, motivational processes that follow such problems in academic contexts remain largely under-examined. As such, the present examination of relationships between students' causal attributions, emotions, and academic achievement following computer problems was theoretically grounded in [Weiner's \(2010\)](#) attribution theory of achievement motivation. The present multi-study investigation provides novel empirical evidence of significant effects of students' causal attributions for academic computing problems on computing-related emotions

and academic performance while allowing for a cross-country examination of such attributions and emotions than previously available (i.e., by employing an international sampling method in attempting to reconcile scattered findings throughout the extant literature between German and North American students).

Although previous research has provided support for the application of [Weiner's \(2010\)](#) attribution theory to the domain of academic computing in higher education, the present study extends upon existing work through the use of specific as opposed to composite, global measures of causal attributions and in employing multiple assessment methods (e.g., single-item vs. multi-item emotion scales; self-report vs. objective outcome measures). Additionally, the present research provides longitudinal as well as cross-sectional findings concerning the effects of students' causal attributions for actual computing difficulties on discrete emotions and objective academic performance, as compared to existing studies reporting the effects of students' attributions as assessed via scenarios or experimental methods having lower ecological validity. Furthermore, the parallel assessment of students' causal attributions for both grades and computing challenges allowed us to directly evaluate the generalizability of achievement effects between attributions for academic performance and academic computing problems. As such, the present study contributes to the academic computing literature in expanding theoretical concepts (i.e., potentially domain-specific relationships between attributions and emotions, particularly those involving personal control) as well as empirical evidence for significant effects of academic computing attributions on emotions and academic achievement internationally. Nevertheless, future research is needed to more specifically evaluate post-secondary students' computing-related attributions (e.g., effort attributions, underlying dimensions, specific computing tasks) and emotions (e.g., observation, facial recognition).

Consistent with [Weiner's \(2010\)](#) attribution theory, findings across Studies 1 and 2 consistently showed attributions to ability (for both poor performance and computing-related problems) to be consistently maladaptive for both students' emotions and achievement. However, the effects observed for effort attributions were mixed, with effort attributions for computing difficulties predicting better course grades as well as more negative computing-related emotions. Although these maladaptive emotional consequences of computing-related attributions to effort contradict attribution theory, it is important to note that our computing attributions item pertaining to persistence (i.e., learning) did not exactly parallel the corresponding achievement attribution item (i.e., effort), and our study did not evaluate the perceived causal dimensions underlying this prototypic causal attribution.

More specifically, whereas lack of effort is typically perceived by students as personally controllable in nature, it may in an academic computing context instead be perceived as reflecting uncontrollable factors such as insufficient computing abilities (cf. findings for children interpreting effort feedback after persistence as reflecting low ability in a computing context; [Dresel and Haugwitz 2008](#)). Alternatively, it is also possible that as our attribution measure did not specifically mention insufficient effort but rather *learning*, students may have interpreted the item as also suggesting an uncontrollable lack of computing-related *teaching* or IT support that may have contributed to their technological learning deficits. As such, future research employing more specific measures of both discrete attributions (e.g., effort vs. learning) and the perceived dimensions underlying an expressed attribution (e.g., perceived personal controllability) is needed to further elucidate the present ambivalent findings for effort-related attributions in academic computing contexts. Given the observed effect size of computing attributions on grade percentage, longitudinal research allowing for the exploration of potential moderating factors influencing effects of computing-related attributions on emotions and achievement outcomes would greatly contribute to understanding unique effects of computing attributions (e.g., personality traits, computing self-efficacy). Nevertheless, it is also possible that effort attributions in academic computing contexts may indeed have opposite effects on achievement and emotions similar to findings based on achievement goal theory showing performance-approach goals reflecting unmitigated effort to predict both higher grades (e.g., [Pekrun et al. 2009](#)) and anxiety ([Daniels et al. 2009](#)).

Another surprising set of findings of the present research were the beneficial effects of external attributions for academic computing failures. More specifically, whereas external attributions to luck were found to predict poorer emotion levels as expected, external attributions to hardware quality predicted significantly *better* computing-related emotions across eight of the 11 discrete emotions assessed. With respect to course performance, anticipated negative effects of external attributions to hardware or software issues were also not observed, with external attributions to luck actually predicting *better* year-end grades. Although contrary to our study hypotheses and Weiner's (2010) attribution theory, these findings are nonetheless consistent with existing findings in the academic computing literature showing external attributions to correspond with greater experience and achievement (e.g., Koch et al. 2008; Rozell and Gardner 2000) and warrant further study as to the veridicality of students' attributions for computing challenges given the likely emotional and performance benefits of accurately diagnosing technology failures as due to external hardware issues that do not implicate personal capabilities (e.g., processor speed). Overall, the present empirical research contributes to the academic computing literature in showing the types of causal attributions made by post-secondary students internationally for academic technology failures to have both concurrent effects on their emotions concerning academic computing, as well as long-term effects on objective achievement outcomes over and above the effects of attributions for poor performance. Nevertheless, future research is needed to more specifically evaluate post-secondary students' computing-related attributions (e.g., effort attributions, underlying dimensions, specific computing tasks), emotions (e.g., observation, facial recognition), and performance across academic contexts (e.g., performance on computing tasks, in different subject areas).

It is anticipated that continued research on how higher education students attribute and respond emotionally to academic technology challenges will serve to inform future educational technology development, classroom instructional support, IT support services, and intervention efforts (e.g., attributional retraining; Hall et al. 2004, 2007), and provide a useful framework for applying Weiner's (2010) attribution theory to understanding how technological challenges are experienced in other academic settings (e.g., students in asynchronous online learning environments, secondary and post-secondary instructors). For example, further research examining attributions and emotions following technological problems could help students in online distance education programs in light of research showing online students to have overall higher emotion ratings compared to traditional students (e.g., anger, anxiety, helplessness; Butz et al. 2015) and to consistently identify technological difficulties as a source of frustration or stress (Hara 2000), with some citing "computer problems" specifically in qualitative studies (Safford and Stinton 2016). More recent research has also found significant relationships between attributions and emotions following computer problems to differ between traditional and online students (Maymon et al. 2018), highlighting the relevance of attribution theory in examining motivational processes following technological difficulties. Furthermore, research on motivation following technological failure experiences of students who will soon enter the workforce could serve to improve training and support programs for newly hired employees working closely with computer technology given similarities previously found between student and workplace computer user frustration (Lazar et al. 2005). Generally, research programs that identify cognitive and emotional coping strategies following technological problems may prove important in creating more positive, effective learning environments.

Supplementary Materials: The following are available online at <http://www.mdpi.com/2076-0760/7/11/223/s1>, Data S1: Study 1; Data S2: Study 2.

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