Factors Influencing Security Incidents on Personal Computing Devices

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ABSTRACT

Organizations expect their employees to connect securely to the organization's computer systems. Often these employees use their personal computers to access the organization's networks. This research explores whether these same employees apply protective security measures to their personal computers. Perhaps these employees behave riskily based on their optimistic bias. Results indicate that while cyber optimistic bias and perceived vulnerability influence individuals to apply more protective security measures, the users still experienced security incidents. Thus, organization are vulnerable to cyber-attacks if they are allowing employees to use personal computers to access these databases.

KEYWORDS

Cyber Optimistic Bias, Perceived Vulnerability, Protective Security Measures, Security Incidents, Technology Optimism

INTRODUCTION

Organizations spent over \$73.7 billion protecting their computer systems in 2016 to avoid becoming victims of security breaches with predictions that number will increase to over \$170 billion by 2020 (Freeman, 2017). Regardless of the vast amounts of money an organization spends, hackers circumvent security measures when users fail to exercise good security practices by responding to phishing emails that harvest personally identifiable information including passwords, visiting untrusted websites, downloading malicious software such as key loggers, or failing to create strong passwords or to apply updates, security patches, and virus protection software (Goel, Williams, & Dincelli, 2017; Thomas, 2004). For example, Anthem released over 83 million patient insurance records after five employees including the database administrator inadvertently responded to a phishing attack and provided their login credentials to the attackers (Huson & Hewitt, 2016; Ragan, 2015).

Many organizations allowed their employees to use personal phones (95%), tablets (67%), and laptops (93%) with slightly more than half of the devices being issued by the organization (51%, 30%, and 63% respectively) (M. A. Harris & Patten, 2015). While these organizations can enforce policies and security measures on the business owned devices, it is much harder to enforce these measures on the individual's personal devices. Over a third (35%) of the cell phone users installed third party apps, 31% of cell phone users and 52% of laptop users stored authentication credentials in apps, and 13% of cell phone users and 5% of laptop users devices were lost or stolen.

Thus, organizations must improve their users' security practices since these users are often the weakest link (Ayyagari, 2012; Bulgurcu, Cavusoglu, & Benbasat, 2010; Kirkpatrick, 2006; Lee, Lee,

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& Yoo, 2004; Mitnick, Simon, & Wozniak, 2006; Rezgui & Marks, 2008). Sometimes, attacks occur when users access their organizations' systems, databases, and confidential documents using their home computers as opposed to their work computers (Furnell, Bryant, & Phippen, 2007). Organizations must ensure users comply with information security (IS) policies to minimize incidents since roughly 70% of employees know where to find their corporate security policies and only 64% read the policy (Da Veiga, 2016). Major threats to security include employees who do not comply with policies either because they are careless (Siponen, Mahmood, & Pahlila, 2014; Siponen, Pahlila, & Mahmood, 2007) or are unaware of how to securely access the organization's systems. To improve users' compliance, IS managers have implemented IS awareness programs (Bauer, Bernroider, & Chudzikowski, 2017).

To prevent data breaches, organizations should increase the IS awareness of their employees. Subsequently, organizations attempt to increase the employee's security awareness through training and educational courses (Dodge, Carver, & Ferguson, 2007; He, Ash, et al., 2019; Schultz, 2012) in the hopes of motivating these employees to safeguard their passwords as well as the organization's computer systems and databases (Gage, 1996; Grau, 1984; Siponen, 2000). Several studies explored whether training and education influence security behavior rather than determine if it decrease the number of security incidents one experiences (Britt, 2008; Caldwell, 2016; Pollitt, 2005; Puhakainen & Siponen, 2010; Sherizen, 1984; Siponen, 2000).

However, security training and awareness programs only effect an employee's knowledge, behavior, and awareness for a short time (Hagen & Albrechtsen, 2009). White (2012, 2015) found those with more security education still reported experiencing security incidents.

Thus, the need to explore how individuals behave is important. Subsequently one must also identify factors that cause these educated individuals to experience security incidents. Perhaps, underlying perceptions such as optimistic bias, optimism and perceived invulnerability (PV) play a role in security breaches. Optimistic bias often makes a person perceive they are less vulnerable to experience a negative (or more likely to experience a positive) event than their peers (Weinstein, 1980). Trumbo, Meyer, Marlatt, Peek, and Morrissey (2014) suggest that optimism is an individuals' belief that they are less likely to experience a negative outcome than their peers. Schwarzer (1994) described PV as the individual's belief that they will be a victim.

Prior research has attempted to explain security breaches using perceptions of susceptibility, severity, and threat, as well as safeguard costs, safeguard effectiveness, self-efficacy, social norm, and cues to action ((Boysen, Hewitt, McLeod, & Gibbs, 2019; Carpenter, Young, Barrett, & McLeod, 2019; Liang & Xue, 2010; Ng, Kankanhalli, & Xu, 2009; Vance, Siponen, & Pahlila, 2012). However, the models that use these constructs do not explain the variance for security behavior (Boysen et al., 2019; Carpenter et al., 2019; Liang & Xue, 2010; Woon, Tan, & Low, 2005). While the variance for the security belief model was high, Ng et al. (2009) indicated a limitation to their study was the limited protective measure they studied (email caution). They did not explore other protective measures such as applying patches or installing malware protection. Recently, cyber optimistic bias (COB) was explored as an antecedent to protective measures (Hewitt & White, 2020), but the study focused on university students. Thus, this study will explore variables that we believe should be incorporated into those models using a general population from the United States. By exploring whether COB, technical optimism, and PV are impacted by education and subsequently impact an individual's willingness to apply protective measure, this research might explain why these individuals still experience security incidents since many of the other theories do not explain this phenomenon.

LITERATURE REVEIW

Education

Organizations often believe that security training will help address security issues (Ballard, 2010; Brown, 1990; Kieke, 2006; White, 2012). Organizations must make their employees more aware

of information security since the number of security incidents and the costs associated with those breaches are increasing significantly (Mensch & Wilkie, 2011; Okenyi & Owens, 2007). Employees were less likely to commit fraud after attending education and training in fraud prevention (Brown, 1990). Individuals were found to change their behavior after completing computer and security courses and training (Albrechtsen & Hovden, 2010; D'Arcy, Hovav, & Galletta, 2009; Furnell et al., 2010). For example, employees were more responsive to security incidents (Albrechtsen & Hovden, 2010), protected their environment (Greenberg, 1986; Kirkpatrick, 2006), stopped misusing an information system (D'Arcy et al., 2009), or modified their behavior (Greenberg, 1986) after attending a security workshop. Training about phishing can lead to users' heightened awareness of phishing attacks, which lowers their risk of becoming a victim (Jansson & von Solms, 2013). White (2012, 2015) found a relationship between education and security incidents but they found a negative relationship. With both computer and security education and training (CSET), users should be able to recognize security incidents. Additional factors should be considered along with awareness training to lower security incidents by motivating their employees to be security conscience (Gage, 1996; Grau, 1984; Siponen, 2000).

Perceived Vulnerability

While optimistic bias explains a significant portion of an individual's belief why they are not likely to experience negative events, perceived vulnerability measures one's likelihood of being a victim and impacts their optimistic biases (Lapsley & Hill, 2010). While vulnerability was first explored in adolescents and young adults, it later expanded to all adults (Quadrel, Fischhoff, & Davis, 1993). Along with technical optimism and optimistic bias, PV can possibly explain why individuals participate in risky behavior (Lapsley & Hill, 2010).

Cyber Optimistic Bias

Optimistic bias is an individual's perception that they are less likely to experience a negative event or more likely to experience a positive effect than others (Weinstein, 1980). Therefore, individuals often take risks regardless of their chances of experiencing a negative outcome whether its contracting a sexually transmitted disease (Chapin & Pierce, 2012; P. R. Harris, Griffin, & Murray, 2008; Li, 2008), missing a project deadlines (Korzaan & Harris, 2017), or experiencing a breach that impacts their online privacy (Cho, Lee, & Chung, 2010). When an individual perceives he or she has control over the outcomes of negative events, desired outcomes are perceived to be greater than for other subjects. Individuals who experience COB underestimate the likelihood (or probability) that they will experience a security breach, which is an error in judgment (Chapin, 2001; Harris, Griffin, & Murray, 2008; Weinstein & Klein, 1996). Weinstein (1980) explains these individuals can be defensive or simply wishful. Even in negative situations, these individuals demonstrate optimistic bias. Regardless, this error in judgment is called optimistic bias and these individuals think other are more likely to experience a bad event (Chapin, 2001; P. R. Harris et al., 2008; Weinstein & Klein, 1996).

In addition, optimistic bias decreases when fear of becoming a victim increases. For example, people who were victimized previously will exhibit less optimistic bias than people who have not experienced a security breach (Chapin & Pierce, 2012; Weinstein, 1980). Prior studies explored optimistic bias in healthcare settings or security settings. Chapin and Pierce (2012) found individuals often decide that they possess unique skills or can avoid negative situations such as sexual assault. This paper will explore COB measuring the degree of individuals' believes their chances of experiencing negative events are more (or less) than others as previously examined by Hewitt and White (2020). Individuals are also likely to feel they can circumvent security breaches by behaving differently than others. Hewitt and White (2020) determined that individuals who were cyber optimistically biased also reported that they applied more protective security measures.

Technical Optimism

Optimism is individuals' belief that they are less likely to experience a negative outcome than their peers (Trumbo, Meyer, Marlatt, Peek, & Morrissey, 2014). This optimism can result in behavior that could subsequently affect the number of security protective measures one will apply. The technology readiness index (TRI) as proposed by Parasuraman (2000) explored how individuals believe technology offers individuals more control over their lives. Basically individuals are generally optimistic about technology (Lin & Hsieh, 2012). This research will further explore how technical optimism impacts and individual's willingness to use protective security measures.

Protective Security Measures

Protective security measures (PSM) include the use of preventive measures that are utilized by the individual to defend their computer from security breaches and attacks. Computers users apply PSM as a deterrent to ensure their computers are not compromised (Claar & Johnson, 2012); however, we question whether these measures work. Herath and Rao (2009) determined that end users seldom apply PSM such as updating their antivirus software, applying operating system (OS) patches, backing up their data, or ensuring that their personal fire walls are secure. Williams, Wynn, Madupalli, Karahanna, and Duncan (2014) determined that while individuals install and run software to prevent unauthorized access to their PCs, end users don't update their OS, virus protection software, or application programs or apply patches, leave their computers unattended, and ignore their company's policies about securing sensitive information.

HYPOTHESIS

LaRose, Rifon, and Enbody (2008) recommend exploring new research to identify behaviors of individuals who use the Internet and encounter security incidents. This study examines the relationship between education, technical optimism, COB, PV, and PSM in regards to how these factors can affect the number of security incidents one experiences.

Education

Rhee, Kim, and Ryu (2009) used number of years using a computer and the internet to measure computer and internet experience. But these are self-reported and we can't assume that number of years using is similar between different subjects. For this research, to measure experience/expertise, this research used the number of years of CSET that the individual took. PV is one's belief that they will experience an adverse event. It is widely used when exploring computer security. Thus, this research suggests that education will positively influence PV.

Hypothesis 1: CSET will have a positive effect on an individual's perceived vulnerability.

Knowledge is a predictor of optimistic bias (Li, 2008). Thus, these individuals often take more risks. These individuals often feel they have control over the outcomes. Hence, as Rhee, Ryu, and Kim (2012) suggest these individual should be exposed to more security training rather than organizations simply applying more security measures. However, organizations should be cautious about how often they require individuals attend training courses as these courses were found to lose their effect over time (Wolf, Haworth, & Pietron, 2011). This paper will determine how CSET impacts COB.

Hypothesis 2: CSET will have a positive effect on COB.

Rhee et al. (2012) suggest that organizations should provide more security awareness training to help these individuals overcome the effects of optimism bias. Optimism bias might cause a person trained in security protection to feel more confident than his or her counterparts and subsequently he or she might take more risks. Thus, this research will explore whether these individuals who are more confident experience more security breaches.

Past research has determined that individuals with more education experience more computer security incidents (White, 2012). Thus, this research posits that CSET will impact an individual's ability to recognize that they have experienced a security breach.

Hypothesis 3: CSET will have a positive effect on security incidents.

Technical optimism is defined as when individuals feel they are less likely to experience negative events (Trumbo et al., 2014). Over the years, students were more optimistic about the impact of computers on society. Males were more optimistic than females about the impact of computer technology (Walstrom, Thomas, & Weber, 2010). Having a sense of less risk, a person, most likely a male, will display riskier behavior, which can lead to security incidents.

Hypothesis 4: CSET will have a positive effect on technical optimism.

Perceived Vulnerability

Prior research suggests that education may cause individuals to feel less vulnerable and subsequently lower their guard in regard to protecting their computers against viruses and other security threats. Yoon, Hwang, and Kim's (2012) results differed from the findings of earlier studies that explored information security behaviors of working adults and professionals (Chenoweth, Minch, & Gattiker, 2009; Ng et al., 2009; Workman, Bommer, & Straub, 2008). An important reason to test this hypothesis is to ensure those who report they are less vulnerable than others (COB) still perceive security threats are real by indicating they are susceptible to breaches. Thus, the following hypothesis will be tested.

Hypothesis 5: PV will have a positive effect on COB.

Cyber Optimistic Bias

Overconfident individuals often take more risks since they possess protection confidence. They believe that they are more likely than others to experience a positive outcome. Rhee et al. (2012) suggest that organizations should provide more security awareness training to help these individuals overcome the effects of optimism bias rather than simply relying on technological security measures. However, a challenge exists since continued awareness training loses its effectiveness over time (Wolf et al., 2011). Individuals who were previously victimized were less optimistically biased than those who had not previously experienced a negative outcome (Chapin & Pierce, 2012). Wash and Rader (2015) found that individuals believed that others were at more risk for a security breach than they were.

Optimistic bias even occurs when executives believe that their business associates and other businesses are more likely to experience a security breach than their own company (Ng et al., 2009). Optimistic bias might cause a person trained in security protection to feel more confident than their counterparts and subsequently the individual might take more risks. Aytes and Connolly (2004) found that more than 40% of individuals did not conceive that they will experience a negative event. This research will explore whether these individuals who are more confident or optimistic biased that they will not experience more security breaches.

Individuals who are more educated exude protection confidence and take more risks (Li, 2008). To overcome the effects of optimistic bias, more security awareness training and a better understanding

of security threats are needed, instead of only relying on implemented security measures (Rhee et al., 2012). Wolf et al. (2011) showed that continued awareness training began to lose its effectiveness overtime. Still, the trained person may feel confident that they are more protected than others are and therefore, willing to take more risks.

Hypothesis 6: COB will have a positive effect on PSM.

Technical Optimism

When individuals believe they are less likely to be impacted by computers, they are considered to be using technical optimism to not feel threatened by computers. Since technical optimism can result in behavior that could subsequently affect whether individuals apply security measures. Hewitt and White (2020) did not find that technical optimism affected PSM ; however, they were studying students who might not have applied PSM. Students portray more technical optimism than others (Walstrom et al., 2010). Thus, we predict the following hypothesis.

Hypothesis 7: Technical optimism will have a positive effect on PSM.

Protective Security Measures

Since individuals who are more optimistic bias perceive they will experience less security incidents, they will also probably not apply as many PSM. Thus, these individuals will probably experience more security incidents. Thus, we posit the following hypothesis.

Hypothesis 8: PSM will have a positive effect on the number of security incidents an individual experience on their home computer.

Thus, this paper will explore the model as shown in Figure 1. While Hewitt and White (2020) examined a similar model, their model did not include PV and they examined the relationships between the individual variables. Furthermore, they did not examine the causal relationships between the variables.

RESEARCH METHODOLOGY

Data Collection

An online survey was used to test the proposed hypotheses. The items were entered into the online Qualtrics survey instrument. Qualtrics, Inc., an online survey company, provided 1,052 randomly selected subjects from the United States' population to respond to the survey. In order to ensure validation, an item was embedded into the survey to ensure that all respondents were reading the survey questions. To ensure that only those who were working were included, 436 respondents were not working and removed from the analysis. Thus, data for 616 valid response was analyzed.

Over half (52%) of the respondents were male. Most of the respondents were under 50. The majority of the respondents (83%) had at least some college with almost half of the respondents having a bachelor degree or higher (49%). While 12% of the respondents were computer professionals and 3% were computer security professionals, the majority (65%) indicated that they were using a computer on the job. The demographics are shown in Table 1.

Measures

The model was measured using factors for the elements identified above. Four variables that measure the number of computer classes and security classes taken at either the high school or college level

Figure 1. Proposed model

and the number of computer security training sessions were used to measure education as previously used by Hewitt and White (2020). The dependent variable (DV) measured the number of attacks reported on the home computer in the last three years as previously measured by Hewitt and White (2020) and White (2012). The protective measures were measured using measures implemented or updated in the past three years and also adapted from previous studies by Hewitt and White (2020) and White (2012). The remaining items were measured using a 7-point Likert scale. This research modified the COB scale from Chapin (2001) and Chapin and Pierce (2012) studies that examined physical abuse to measure optimistic bias experienced by those experiencing cyber-attacks. Items to measure vulnerability were adapted from the Lapsley and Hill's (2010) vulnerability scale. The variable for technical optimism items was adapted from items used by Parasuraman (2000) and Parasuraman and Colby (2015) who examined individual's readiness to adopt new technologies using the Technology Readiness Index.

Survey items were modified to fit the present environment where necessary. For example, the prior research on vulnerability and optimistic bias were studied in an automobile accidents settings (Lapsley & Hill, 2010) instead of security breaches. Thus, the items were modified accordingly. For a full copy of the survey, see Appendix B.

DATA ANALYSIS AND RESULTS

Data analysis was completed in two parts. First, the researchers ensured the validity of the model. Second, the researchers tested the model using partial least squares (PLS) - structural equation modeling (SEM). PLS is good method to use when the researcher is predicting or conducting exploratory research (Garson, 2016). Henseler, Ringle, and Sinkovics (2009) suggest that researchers should use PLS at the earlier stages of model development when testing exploratory models. PLS-SEM allows one to test the impact that variables have on each other simultaneously providing a stronger analysis than other methods such as PLS-regression (Garson, 2016; Korkmazoglu & Kemalbay, 2012). PLS works well with large or small sample sizes since it uses different methods to perform resampling (Liu & Zhang, 2014). This resampling whether conducted using bootstrapping or jackknifing provides estimates of stand error of the regression paths. Vilares, Almeida, and Coelho (2010) note that because PLS uses bootstrap resampling, skewed data does not affect the precision of the model estimates. Thus, the data was analyzed using SmartPLS 3.2, which as developed by Ringle et al. (2015). SmartPLS performs a bootstrapping function using sampling with replacement.

For this study, SmartPLS was run using the standard options. Thus, the minimum number of iterations was set to 300. To determine which items factored on variable, step-wise iterative PLS was performed until all items with factor loadings less than 0.70 were removed. Then bootstrapping was performed using 500 resamples. Each time this was run, the item with the lowest factor loading

Table 1. Demographics of the respondents

	#	%
Gender		
Male	328	53%
Female	288	37%
Age		
18-29	138	22%
30-39	171	28%
40-49	129	21%
50-59	94	15%
60-69	62	10%
70+	22	4%
Education level		
High school diploma or GED	105	17%
Some college	129	21%
Associates degree	86	14%
Bachelor's degree	190	31%
Graduate degree	90	15%
Doctorate	16	3%
Employment Type		
Employed full-time	439	71%
Employed part-time	126	20%
Unemployed looking for work	9	1%
Unemployed not looking for work	6	1%
Retired	27	4%
Student	2	0%
Disabled	7	1%
Computer Usage at Work		
Computer professional	72	12%
Computer security professional	17	3%
Computer user on the job	398	65%
Do not use a computer on the job	129	21%

was removed and the PLS calculation was run again. Once all the factor loadings for all items were greater than 0.70, the validation and reliability tests were compared to acceptable norms as described in the next section.

Measure Validation

While researchers indicate you do need to ensure goodness of fit (GOF) when studying models using covariance based (CB) -SEM, Hair Jr, Hult, Ringle, and Sarstedt (2016) suggested that users should

be cautious when reporting goodness of fit when using PLS-SEM such as when using SmartPLS to test goodness of fit in a model. Regardless, SmartPLS provides several measures for goodness of fit. Hu and Bentler (1998) suggest that standardized root mean square residual (SRMR) less than .10 can be used to determine the goodness of fit. For our model, the SRMR was 0.095 and thus, our model met this measure of goodness of fit. Another measure that can be used is Normal Fit index(NFI). Lohmöller (2013) suggests that values close to 1 are good and .9 is good. Our NFI is 0.9 and thus fit is acceptable.

For analysis purposes, all items were modeled as reflective indicators of the latent constructs. Prior to reviewing the results of the model, the model was assessed for construct reliability, convergent validity, discriminate validity (Anderson & Gerbing, 1988). To verify reliability, one can use either Composite Reliability or Cronbach's Alpha. The results for both tests must be greater than 0.70 for both tests (Chin, 2010; Fornell & Larcker, 1981). All Composite Relatability values were greater than the 0.70 threshold as shown in Table 2. The construct reliability was further confirmed since all Cronbach's Alpha were greater than 0.70 for all items. Thus, construct reliability was met.

Several test were performed in SmartPLS to confirm convergent and divergent validity (Gefen & Straub, 2005). First, the average variance extracted (AVE) must be greater than 0.5 in support of discriminant validity. As shown in Table 2, all AVE are greater than 0.5. Another comparison used to confirm discriminant validity determines whether the square root of the AVE for a given construct is greater than the correlations of all other constructs both diagonally and horizontally (Fornell & Larcker, 1981). As shown in Table 3, the diagonal terms represent the square root of the AVE and are greater than the correlations between constructs.

The latent variable factor loadings were computed according to Gefen and Straub (2005). The convergent validity of individual items was determined by verifying all loadings greater than .70 as shown in Appendix A. All items loaded "on-factor" with values greater than .70. All indicators loaded greater "on-factor" than "off-factor" also demonstrating good discriminant validity. These results demonstrated good convergent and discriminant validity.

Another issue that can exist when using surveys is common method bias (CMB). CMB occurs when the survey instrument causes the variation in the responses rather than the actual respondents' beliefs and character (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003). For example, our survey included subheadings for some of the variables, which could have introduced CMB. Thus, to ensure the survey did not compound any measurement error, several tests can be used to test for CMB. When using PLS-SEM, Kock (2015) suggests one should test for vertical and lateral collinearity. In SmartPLS, the variance inflation factors (VIF) automates these tests for both vertical and lateral collinearity. While Kock (2015) indicates that VIF should be less than 3.3 and any values over 3.3 imply pathological collinearity, Hair, Ringle, and Sarstedt (2013) recommend that the VIF less than 5 is acceptable. As shown in Table 2, the VIF is less than 4 for all items.

RESULTS

Figure 2 depicts the results of the PLS model testing. The proposed COB model accounts for 42% of the security incidents that the respondents experience. The results show that CSET positively impacted the individual's PV with a beta coefficient equal to .14 and a p-value of less than .001 ($b=.14$, $p<0.001$), technical optimism ($b=.17$, $p<0.001$), COB ($b=.10$, $p<0.01$), and security incidents ($b=.31$, $p<0.001$) providing support for hypotheses 1, 2, 3, and 4. PV positively impacted COB with a beta coefficient of .52 and a p-value less than .001 supporting hypothesis 5. Hypothesis 6 that explored the relationship between COB and PSM was significant. Technical optimism impacted PSM (H7). PSM positively impacted security incidents (H8). The results of the hypotheses tests are presented in Tables 4 and 5.

To further explore the results, responses were analyzed for select variables. For example, one may question whether the individuals actually installed PSM. The majority changed their passwords,

Table 2. Construct Reliability Results

Construct	Items	Loadings	VIF	Alpha	CR	AVE
Computer/ Security Education	CompSecurityUniv	0.90	3.28	0.87	0.90	0.65
	compSecTrain	0.77	1.62			
	compUnivCrs	0.86	2.46			
	comphscourse	0.69	2.14			
	compsechscourse	0.77	2.84			
Cyber optimistic Bias	CybOptBias1	0.91	2.66	0.89	0.93	0.82
	CybOptBias2	0.91	2.90			
	CybOptBias3	0.90	2.51			
Security Incidents	Incident1	0.73	2.11	0.94	0.95	0.62
	Incident10	0.77	2.27			
	Incident11	0.81	2.43			
	Incident12	0.79	2.43			
	Incident3	0.81	2.85			
	Incident4	0.83	3.10			
	Incident5	0.80	2.50			
	Incident6	0.79	2.58			
	Incident7	0.81	2.80			
	Incident8	0.78	2.66			
	Incident9	0.72	1.91			
Technical Optimism	TechOpt1	0.84	2.34	0.86	0.93	0.76
	TechOpt2	0.88	2.50			
	TechOpt3	0.91	3.01			
	TechOpt4	0.86	2.38			
Protective Security Measures	Protect2	0.80	1.89	0.92	0.90	0.70
	Protect4	0.81	1.82			
	Protect5	0.86	2.23			
	Protect6	0.88	2.56			
Perceived Vulnerability	Vuln2	0.91	3.34	0.90	0.94	0.80
	Vuln1	0.87	2.63			
	vuln3	0.89	3.55			
	vuln4	0.91	3.96			

update their malware/virus protection software, web browser security, privacy setting on web browser and social media accounts as shown in Table 6. Fewer individuals updated their operating system, configured their firewall, or encrypted data on their computer. These findings suggest that these individuals focus on the security features that are less technical.

Table 3. AVE - Correlation Table

	Mean	SD	1	2	3	4	5	6
Computer & Sec Education (1)	2.61	1.54	0.81					
Perceived Vulnerability (2)	4.00	1.45	0.12	0.89				
Cyber Optimistic Bias (3)	4.22	1.49	0.15	0.53	0.91			
Technical Optimism (4)	5.18	1.32	0.12	0.15	0.26	0.87		
Protect Measures (5)	2.64	1.61	0.43	0.05	0.11	0.12	0.84	
Security Incidents (6)	1.87	1.45	0.51	0.00	0.53	0.04	0.57	0.79

Figure 2. Resulting Model

Table 4. Results

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (IO/STDEV)	P Values
Comp & Sec Ed -> Cyber Optimistic Bias	0.12	0.12	0.04	3.10	0.002
Comp & Sec Ed -> Perceived Vulnerable	0.1	0.27	0.04	6.25	0.000
Comp & Sec Ed -> Technical Optimism	0.13	0.13	0.05	2.82	0.005
Cyber Optimistic Bias -> Protective Measures	0.18	0.18	0.04	4.62	0.000
Perceived Vulnerable -> Cyber Optimistic Bias	0.10	0.10	0.04	2.39	0.017
Protective Measures -> Security Incidents	0.52	0.52	0.04	12.66	0.000
Technical Optimism -> Protective Measures	0.47	0.48	0.04	11.53	0.000

These individuals were also asked how many times they experienced a security breach. Overall, only 20% of the individuals indicated that they never experienced a security breach. The remaining 80% of the respondents experienced at least one breach as indicated in Table 7.

Table 5.Results

Hypothesis	Sign	Hypothesis
Hypothesis 1: CSET will have a positive effect on an individual's perceived vulnerability.	.14, $p < .001$	Supported
Hypothesis 2: CSET will have a positive effect on COB.	.10, $p < .05$	Supported
Hypothesis 3: CSET will have a positive effect on security incidents.	.31, $p < .001$	Supported
Hypothesis 4: CSET will have a positive effect on technical optimism.	.17, $p < .001$	Supported
Hypothesis 5: PV will have a positive effect on COB.	.52, $p < .001$	Supported
Hypothesis 6: COB will have a positive effect on protective security measures.	.10, $p < .01$	Supported
Hypothesis 7: Technical optimism will have a positive effect on PSM.	.17, $p < .001$	Supported
Hypothesis 8: PSM will have a positive effect on the number of security incidents that occur on an individual home computer	.44, $P < .001$	Supported

Table 6. Percentage of protective security measures applied

	Percentage who applied the security measure a certain number of times						
	0	1	2	3	4	5	6 or more
Updated malware /antivirus	19%	22%	17%	17%	6%	4%	16%
Updated web browser security	27%	22%	16%	15%	7%	5%	9%
Updated privacy settings on web browser	26%	21%	15%	15%	7%	5%	11%
Reconfigured privacy settings on social media	31%	21%	15%	12%	6%	5%	10%
Encrypted data	56%	15%	10%	6%	4%	2%	7%
Configured firewall	44%	20%	11%	11%	5%	2%	7%
Upgrade operating system	44%	12%	11%	9%	5%	4%	15%
Changed passwords	11%	12%	18%	17%	9%	7%	26%

Sixteen percent indicated that they had not had any CSET. Thirty-three percent indicated that they had not received any computer security training even though they worked for a company. The results for the computer security and training are shown in Table 8.

DISCUSSION

CSET impacts one's PV, technical optimism, COB, and the number of security incidents that they experience. Our questions for vulnerability asked whether the individual perceived they were susceptible to security breaches. Thus, this research indicates that the more education these individuals had, they feel less vulnerable to security breaches and less vulnerable than their peers since they also indicated they were less likely to experience a breach than their counterparts. These results support the findings of Hewitt and White (2020) who also found that those who were more COB had more education. CSET impacted their technical optimism as well but the more CSET a person received,

Table 7. Percentage of individuals experiencing each type of security breach

Number of times	0	1	2	3	4	5	6+
Victim of ID theft	72%	13%	5%	4%	2%	2%	2%
Computer performance due to Virus/malware	27%	23%	20%	11%	7%	3%	8%
Data corruption or loss due to virus/malware	55%	16%	11%	8%	4%	2%	4%
PC controlled by hacker	78%	7%	5%	3%	1%	3%	2%
Unauthorized access of computer	65%	14%	9%	5%	2%	2%	3%
Internet inaccessible due to virus/malware	54%	18%	10%	7%	4%	3%	4%
Download virus/malware via internet	58%	19%	9%	4%	4%	3%	4%
Download virus/malware via email	50%	20%	12%	7%	3%	3%	4%
Victim of phishing attack	72%	10%	5%	5%	3%	2%	4%
Fallen to a hoax email	73%	9%	6%	5%	3%	1%	3%
Privacy problem via social media	66%	12%	8%	5%	4%	3%	3%
Denial of service attack	79%	7%	4%	3%	3%	2%	2%

Table 8. Amount of training or course a respondent received

		High school		College/University	
	Computer Security Training	Computer	Security	Computer	Security
None	33%	56%	34%	53%	45%
At least 1 course	67%	44%	66%	47%	55%

the more they perceive the less technical optimism they had. These results can possibly be explained as those individuals who are more aware of computers and the security issues through CSET are also more cognizant of the threats exist but feel less vulnerable because they most likely feel confident that they can install mechanisms to prevent any threats. These individuals also indicated that they experienced more security breaches as supported by CSET was also seen to impact the number of security incidents as suggested by Hewitt and White (2020). Perhaps, this is due to the fact that these individuals recognize that security incidents are most likely going to happen.

Those who perceive they are not vulnerable to security incidents are more cyber optimistically biased that they won't experience an attack. Subsequently, those that perceive low vulnerability also perceive they are less vulnerable to cyber-attacks than their peers.

The same individuals who feel cyber optimistically biased perceive they will not experience a security breach, but they still apply more protective measures than their counterparts. As previously determined by Chapin (2001), Weinstein (1980), and Weinstein and Klein (1996), those who feel more at risk than others (optimistic biased) are more likely to behave less risky. Subsequently, as the belief of being a cyber-victim increased (COB, Hypothesis 6), the individual applied more protective behavior.

Those who believe that computers are a positive part of their life (technical optimism) also apply more security protective measures. This maybe in part due to the fact that they simply recognize that along with the computers being good for them, anything related to computers is good and thus, PSM are good. Thus, they apply more protective measures further supporting the results by Hewitt and White (2020).

PSM include virus and malware protection software, firewalls, and other security measures. Researcher have previously determined that users do not apply PSM to their home computers properly (Aytes & Connolly, 2004; Bryant, Furnell, & Phippen, 2008). The majority of researchers explored PSM using a single protective measure such as virus protection software (Liang & Xue, 2010) or applying security patches (Ng & Rahim, 2005). White (2012, 2015) also determined that, regardless of whether users installed protective measures, they reported experiencing significant numbers of security incidents. This research supported these prior claims that PSM has a positive impact on the number of security incidents that occur on individuals' home computers.

CONCLUSION

Security efforts should be focused on people as well as technology, since security is also a people issue (Rezgui & Marks, 2008). Therefore, we support prior research that suggested the more educated an individual is and the more PSM taken, they are more capable of detecting security incidents. Based on the results of this study, individuals must recognize that they are just as likely to experience a security breach or are not any less than others are regardless of what protective measures they take or how much CSET they possess. Thus, individuals are susceptible to security breaches and should implement security countermeasures to mitigate these risks. In other words, a user's optimism can lead to a false sense of security even when an individual takes protective measures causing them to take risky behavior such as visiting less untrusted websites.

This paper shows that protection/prevention alone is not sufficient. Individuals still experience security incidents. Hence, this paper supports the need for users to be educated in detection and responses to security incidents. Users are going to experience security incidents no matter how much protection they have on their computer. In other words, this study, along with others, shows protection is not an absolute.

As suggested by Hewitt and White (2020), organizations should focus their security efforts on people in addition to security technology. Organizations spend vast amounts of their security budget on technological solutions such as intrusion prevention systems and security professionals; however, they fail to see security as a people issue (Ayyagari, 2012; Bulgurcu et al., 2010; Kirkpatrick, 2006; Mitnick et al., 2006; Neumann, 1999; Rezgui & Marks, 2008; Thomas, 2004). Organizations must educate their employees to ensure those employees recognize they are part of the issue, and help these employees understand how they can become part of the solution. Designing effective training programs need to follow the suggestions by scientific literature (Bauer et al., 2017) especially since Hagen and Albrechtsen (2009) indicated that employees don't always retain the training. The incorporation of a comprehensive mix of security awareness interventions in training programs is likely to lead to improved levels of behavioral security compliance (Bauer et al., 2017; He, Anwar, et al., 2019; He, Ash, et al., 2019).

This paper contributes to the prior research in several ways. First, it introduces a way to measure multiple PSM that were significant and factored together. Second, it shows that optimistic bias plays a significant role in the reason individuals apply or fail to apply protective measures. It also adds to the literature that explored the role that CSET also play a role in many of the factors that influence one's behaviors such as applying PSM.

Limitations

While we obtained a large sample size, general population to gather data for this research, this study still has limitations. For example, we only included vulnerability as a variable from past research that have studied protecting oneself from security. This was in large part due to two reasons. First, we were worried about survey fatigue. Second, we wanted to ensure that those who indicated that they were less likely to experience a security breach still believed that they were vulnerable. A larger sample may show better reliability and/or detect significant smaller negative relationships. Exploring how exposure to the internet during the week and weekend could also have influence on protective measures taken as shown by the relationship between exposure as measured by time on the internet on the weekend and protective measures.

Future Research

Future research should incorporate cyber optimism bias into the previously studied models such as protection motivation theory or technology threat avoidance theory. This would allow us to see whether COB plays a role in these theories and possibly improves the variance these models explain.

While other research often uses only one protective measure, this study included multiple items to examine different protective measures. Using protective measures as prescribed here would also add to the literature and determine which protective measures influence security behavior. Additionally, this model could be explored in specific settings such as healthcare where the stakes to keep patient data confidential is high.

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APPENDIX A

Table 9. Factor Analysis

	CompSec Edu	CybOpt Bias	Incidents	Invuln	Prevent	TechOpt	VIF
CompSecuni	0.78	0.17	0.38	0.12	0.41	0.18	1.79
compSecTrain	0.77	0.08	0.38	0.08	0.39	0.09	2.21
compUnivCrs	0.90	0.19	0.46	0.12	0.43	0.17	3.97
comphscourse	0.86	0.13	0.52	0.09	0.44	0.09	3.09
compsechscourse	0.82	0.18	0.33	0.11	0.34	0.21	2.79
Incident1	0.50	0.14	0.80	0.07	0.47	0.08	2.52
Incident10	0.42	0.06	0.84	0.00	0.49	0.10	3.14
Incident11	0.47	0.09	0.86	0.02	0.56	0.10	3.34
Incident12	0.47	0.16	0.84	0.08	0.51	0.09	3.25
Incident3	0.43	0.04	0.86	0.00	0.51	0.07	3.61
Incident5	0.41	0.07	0.86	-0.01	0.52	0.07	3.32
Incident6	0.34	0.03	0.82	-0.02	0.48	0.08	2.90
Incident7	0.38	0.06	0.85	-0.01	0.49	0.07	3.48
Incident8	0.37	0.05	0.82	-0.02	0.54	0.07	3.09
Incident9	0.38	0.09	0.76	0.03	0.45	0.10	2.12
Opt1	0.13	0.29	0.07	0.14	0.13	0.87	2.56
Opt2	0.14	0.23	0.07	0.09	0.13	0.88	2.70
Opt3	0.18	0.29	0.12	0.14	0.13	0.91	3.09
Opt4	0.17	0.29	0.09	0.16	0.13	0.86	2.21
OptbiasTech1	0.14	0.91	0.02	0.52	0.08	0.33	2.83
OptbiasTech2	0.19	0.93	0.09	0.48	0.15	0.24	3.17
OptbiasTech4	0.17	0.90	0.15	0.47	0.16	0.29	2.61
Prevent2	0.37	0.08	0.48	0.02	0.85	0.11	2.31
Prevent4	0.37	0.12	0.50	0.03	0.84	0.14	2.16
Prevent5	0.51	0.15	0.57	0.08	0.88	0.13	2.50
Prevent6	0.42	0.14	0.52	0.04	0.88	0.13	2.66
Vuln2	0.08	0.49	-0.04	0.91	0.03	0.16	3.56
Vuln1	0.08	0.50	-0.04	0.88	0.06	0.14	3.01
vuln3	0.17	0.46	0.10	0.88	0.05	0.12	2.98
vuln5	0.14	0.46	0.05	0.90	0.05	0.13	3.14

APPENDIX B

Survey

Please complete the following questions.

Demographic

1. Age _____ years old
2. Gender 1. M 2. F

Comp/Sec Education

3. Please indicate how many courses you have taken for each category.

Number of semester courses in computers while in high school (1 year = 2 semesters)

0 1 2 3 4 5 6+

Number of semester courses in computer/information security while in high school (1 year = 2 semesters) 0 1 2 3 4 5 6+

Number of semester courses in computers at a college or university 0 1 2 3 4 5 6+

Number of semester courses in computer/information security at a college or university

0 1 2 3 4 5 6+

Non-academic presentations/training on computer/information security 0 1 2 3 4 5 6+

For the past 3 years, how many times occurred on your personal computer or laptop? (White, 2012, 2015)

Personal/Home Incidents --

Inc1. Victim from ID theft 0 1 2 3 4 5 6+

Inc2*. Computer "performance" problems due to viruses 0 1 2 3 4 5 6+

Inc3. Data corruption or loss due to viruses 0 1 2 3 4 5 6+

Inc4. PC controlled by hacker 0 1 2 3 4 5 6+

Inc5. Number of unauthorized access to your data 0 1 2 3 4 5 6+

Inc6. Internet became inaccessible due to virus/malware 0 1 2 3 4 5 6+

Inc7. Downloaded a virus via email attachment 0 1 2 3 4 5 6+

Inc8. Downloaded a file off the Internet that contained a virus 0 1 2 3 4 5 6+

Inc9. Victim of phishing 0 1 2 3 4 5 6+

Inc10. Fallen to a hoax email 0 1 2 3 4 5 6+

Inc11. Experienced a privacy problem of social networks 0 1 2 3 4 5 6+

Inc12. Victim of denial of service attack 0 1 2 3 4 5 6+

* Item removed from analysis due to poor factor analysis loadings.

Protective Security Measures

Pro1. upgrade my anti-virus software? 0 1 2 3 4 5 6+

Pro2. increase my security settings of your web browser? 0 1 2 3 4 5 6+

Pro3. increase my privacy settings on my web browser? 0 1 2 3 4 5 6+

Pro4. re-configured my privacy settings on a social network like Facebook?

0 1 2 3 4 5 6+

Pre5*. encrypt data on my computers? 0 1 2 3 4 5 6+

Pre6. configured my firewall? 0 1 2 3 4 5 6+
Pre7*. upgraded my OS with patches? 0 1 2 3 4 5 6+
Pre8*. changed my password? 0 1 2 3 4 5 6+

* Item removed from analysis due to poor factor analysis loadings.

For the following items, indicate 1. Strongly disagree, 2. Disagree, 3. Somewhat disagree, 4. Neither agree nor disagree, 5. Somewhat agree, 6. Agree, 7. Strongly agree.

OPTIMISM (about Technology) (Parasuraman, 2000; Parasuraman & Colby, 2014)

Please indicate your optimism on the following topics.

OptTec01. New technologies contribute to a better quality of life. 1 2 3 4 5 6 7

OptTec02. Technology give me more freedom of mobility. 1 2 3 4 5 6 7

OptTec03. Technology gives people more control over their daily lives. 1 2 3 4 5 6 7

OptTec04. Technology makes me more productive in my personal life. 1 2 3 4 5 6 7

Cyber Optimistic Bias (not happened to me - cyber); item was modified from “abused by an intimate partner” to “cyber-attack.” (Chapin, 2001; Chapin & Pierce, 2012)

Compared to others the U.S. that are similar age as you, answer the following questions. I am less likely to be a:

CyberOptBias1. victim of a cyber-attack 1 2 3 4 5 6 7

CyberOptBias2. victim of a virus/malware 1 2 3 4 5 6 7

CyberOptBias3. victim of security breach 1 2 3 4 5 6 7

CyberOptBias4. victim of identity theft 1 2 3 4 5 6 7

Perceived vulnerability (Lapsley & Hill, 2010)

Vul1*. I am less likely to experience a computer virus than others. 1 2 3 4 5 6 7

Vul2. I am unlikely to experience identity theft than others. 1 2 3 4 5 6 7

Vul3. A security breach will not happen to me. 1 2 3 4 5 6 7

Vul4. Security problems such as identity theft or viruses are not likely to happen to me. 1 2 3 4 5 6 7

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