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Abstract:

Diffusion of Innovations and the Theory of Planned Behavior provide the foundation on which a preponderance of information systems (IS) theory and research is built. IS scholars often assume that the basic factors proffered by these theories are significant determinants of innovation adoption. However, there has yet to be a meta-analytic examination of research in the IS field to validate this assumption. Herein, we use Tornatzky and Klein's seminal 1982 meta-analysis of innovation characteristics as the starting point for our meta-analytic examination of Diffusion of Innovations and Theory of Planned Behavior models in IS research. In order to focus our investigation on a common criterion variable, adoption propensity, we use antecedents from both models to develop a model of innovation adoption-behavior (IAB). After describing the relationships encompassed by the IAB model, we step through a bare-bones meta-analysis. Considering the data reported in fifty-eight empirical articles, we calculate the estimated true correlations with the criterion variable to be .53 for attitude toward behavior, .33 for subjective norm, .41 for perceived behavioral control, .42 for relative advantage, .43 for compatibility, -.28 for complexity, .32 for trialability, and .38 for observability. With the exception of complexity, all correlations generalize across studies.

Keywords: diffusion of innovations; innovation adoption-behavior; meta-analysis; theory of planned behavior

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I. INTRODUCTION

The results of Tornatzky and Klein's [1982] seminal meta-analysis of the innovation characteristics that affect adoption and implementation suggest that three innovation characteristics, relative advantage, perceived compatibility, and complexity, provide the most consistently significant associations with innovation adoption. These independent variables are three of the five perceived characteristics of the innovation that are thought to affect the decision makers' propensity to adopt, as originally proposed in Rogers' [1962, 2003] Diffusion of Innovations model. In addition to their analysis of the Diffusion of Innovations literature, Tornatzky and Klein [1982] identified key research needs to guide future innovation adoption research. Among the research needs they expressed are the following: (a) the need for more and better research, (b) the need to study other independent variables in addition to innovation characteristics, and (c) the need to reduce the number of innovation attributes to only the significant few. Many in the information systems (IS) field have answered Tornatzky and Klein's call for research over the past three decades, creating an abundance of material to consider. However, as both the IS field and the study of innovation acceptance and diffusion have evolved, one must question whether or not the relationships examined by Tornatzky and Klein have remained significant over the past thirty years of research in this area. As such, the field of information systems is overdue for a meta-analytic examination of Diffusion of Innovations and Theory of Planned Behavior characteristics. Herein, we conduct such an examination.

Although literature regarding both Diffusion of Innovations and Theory of Planned Behavior are often cited together in research articles, we found few studies in which research models are actually comprised of a combination of characteristics from both Diffusion of Innovations and Theory of Planned Behavior. These models are complementary in that they both suggest antecedents to innovation adoption; Diffusion of Innovations is concerned with perceived characteristics of the innovation, whereas Theory of Planned Behavior is concerned with variables that affect the behavior of the adoption decision maker. Thus, examining both models should provide an opportunity to better understand the decision to adopt an innovation. In this study, we blend the strengths of the Theory of Planned Behavior and Diffusion of Innovations models to develop the innovation adoption-behavior (IAB) model. Exactly what the nature and magnitude of the relationships presented in the IAB are across the IS literature published since Tornatzky and Klein's [1982] article has yet to be clearly established. In this regard, we posit that more than a narrative review is necessary; particularly, we adopt a quantitative approach—a meta-analysis.

This study provides three primary contributions to the Diffusion of Innovations and Theory of Planned Behavior literature. First, we update and extend the research of Tornatzky and Klein. By quantitatively analyzing the literature over the past thirty years, we amass the findings of many separate studies, presenting a comprehensive review of the various characteristics affecting innovation adoption found in the body of research. In this study, we step through a bare-bones meta-analysis to examine what are thought to be the most salient antecedents of innovation adoption. Second, we further extend theory. By synthesizing the Diffusion of Innovations and Theory of Planned Behavior models, we develop the IAB model, using antecedents from both models to focus on a common criterion variable—adoption propensity. Third, in our review of the IS literature, we found no meta-analytic studies that attempt to estimate the effect of the five innovation adoption characteristics of the Diffusion of Innovations model and the three antecedents of the Theory of Planned Behavior on adoption. Thus, we determine whether or not these independent–dependent variable relationships, which many contemporary scholars might take for granted, have endured. As a part of said determination, we investigate the relative efficacy and strength of the relationships.

In the remainder of this article, we briefly review the Diffusion of Innovations and Theory of Planned Behavior literature that describes the relationships between the aforementioned variables and innovation adoption propensity. We then describe our method and provide the results of the meta-analysis. We close with a discussion of our findings and recommendations for future research.

II. REVIEW OF THE LITERATURE

In this study, we draw from the Diffusion of Innovations and Theory of Planned Behavior literatures. By combining these two models, we seek not only to gain a richer understanding of adoption decisions, but to examine whether or not the relationships proposed by these foundational theories have remained significant over the past thirty years of IS research. In this section, we provide a concise review of these bodies of literature and the antecedents to innovation adoption, which we use as the basis to create the IAB.

Diffusion of Innovations

According to Diffusion of Innovations theory, an innovation is an idea, practice, or object that is perceived as new by an individual or group, and diffusion is the process in which an innovation is communicated over time among the members of a social system [Rogers, 2003]. Although it can be used to explain the dispersal of any new idea, practice, or object, this theory is frequently used to explain technology diffusion (e.g., Lu, Quan, and Cao, 2009). While innovations include ideas, practices, or objects, we constrain the term to include IS artifacts for the purpose of our study. Rogers [2003], in further clarifying his model, characterizes adoption as a decision to fully use an innovation. There are several stages of processing that decision makers' progress through when evaluating whether or not to adopt an innovation. The progression from initial knowledge of an innovation to confirmation of the adoption decision is what Rogers [2003] refers to as the innovation–decision process. It is within this process that we find the five perceived characteristics of innovations, which, among other variables, Tornatzky and Klein [1982] used as the basis for their meta-analysis. These five characteristics of the innovation that are thought to affect the adoption decision are relative advantage, compatibility, complexity, trialability, and observability [Rogers, 2003]. In the remainder of this article, when we use the term *Diffusion of Innovations,* we are referring to the innovation–decision process and these characteristics.

In terms of the innovation–decision process, Diffusion of Innovations is concerned with the perceived characteristics of the innovation, whereas Theory of Planned Behavior is concerned with variables that affect the decision makers' intention and behavior. Both Diffusion of Innovations and Theory of Planned Behavior are concerned with the perceptions of the decision maker. Thus, we posit that the characteristics of Theory of Planned Behavior complement the characteristics presented in Diffusion of Innovations to offer additional explanatory power regarding the decision to adopt an innovation. A brief discussion of the variables proposed by the Theory of Planned Behavior will shed light on the complementary relationship.

Theory of Planned Behavior

Based on attitude research and expectancy value models, Fishbein and Ajzen [1975] developed the Theory of Reasoned Action [1980]. To account for the assertion that behavior is not wholly voluntary, Ajzen introduced the variable, perceived behavioral control, and developed the Theory of Planned Behavior [1991]. Using attitude toward the behavior, subjective norms, and perceived behavioral control as predictors, Theory of Planned Behavior has been shown in several studies to predict behavior [Ajzen, Joyce, Sheikh, and Cote, 2011; Chang and Zhu, 2011; Park, Younbo, and Lee, 2011]. In his essay discussing the model, Ajzen [1991] suggests that behavioral intentions drive individual behaviors, and that these behavioral intentions are a function of the decision makers' attitude toward the behavior, the referent subjective norms of the decision maker, and the decision makers' perceived control over the behavior (Figure 1).

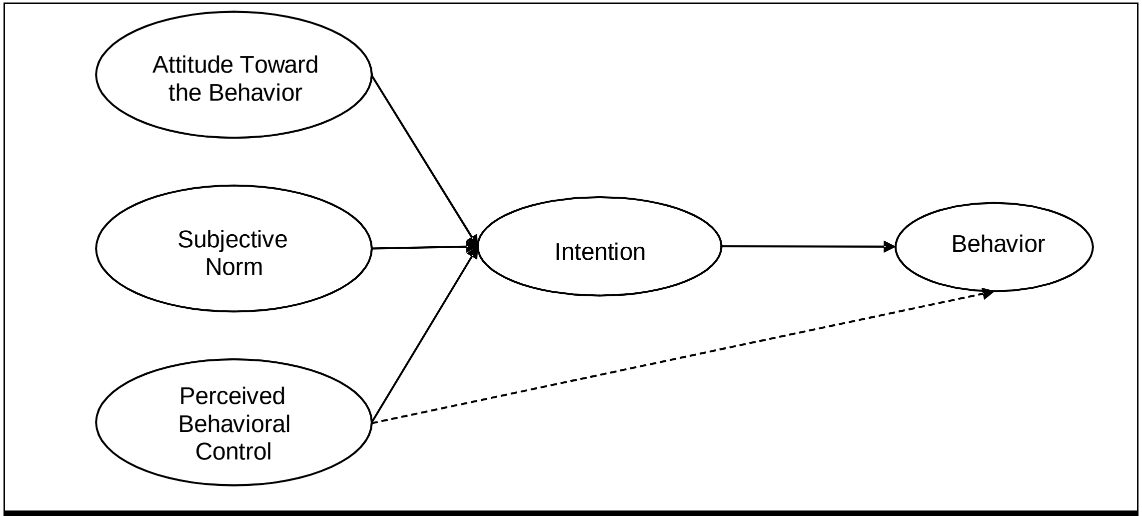

Figure 1. The Theory of Planned Behavior
Source: adapted from Ajzen, 1991

The body of Theory of Planned Behavior literature has grown steadily since Ajzen and Fishbein's [1980] seminal article [Ajzen, 2011; Chen, Razi, and Rienzo, 2011; Coombs, 2009; Ferratt, Hall, Prasad, and Wynn, 2010; Premkumar, Ramamurthy, and Liu, 2008]. The Theory of Planned Behavior is often combined with complementary models to examine adoption of information systems [Leonard, Cronan, and Kreie, 2004; Lin, Chan, and Wei, 2011; Mathieson, 1991]. To broaden the range of this study, we combine Theory of Planned Behavior characteristics with those of the Diffusion of Innovations model to develop the IAB model.

Innovation Adoption–Behavior

Using the Theory of Planned Behavior as the basis of our IAB model, we add the three perceived characteristics Tornatzky and Klein [1982] identified from the communications channels of the Diffusion of Innovations model as having significant effects on adoption: relative advantage, compatibility, and complexity. Because one of our goals is to update the Tornatzky and Klein meta-analysis using the current body of literature and using only those variables thought to provide the greatest predictive power, we include trialability and observability. As shown in Figure 2, our model differs from either of the other two models in that adoption propensity, our dependent variable, includes both intent to adopt and actual adoption.

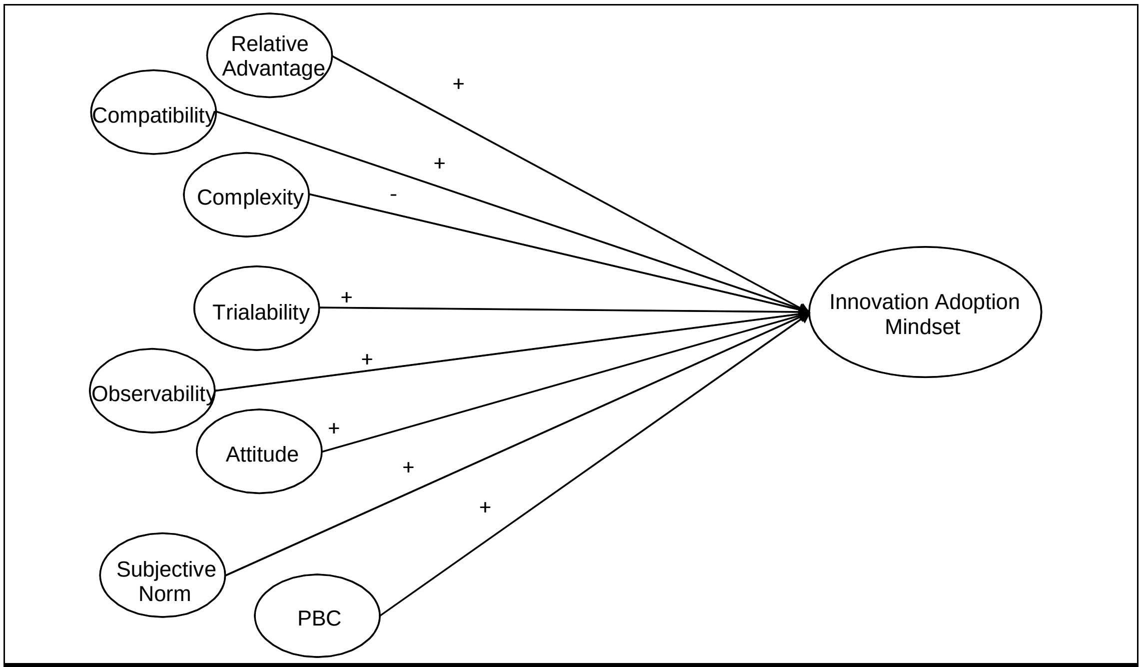

Figure 2. Innovation Adoption-Behavior (IAB) Model
Source: adapted from Ajzen, 1991 and Rogers, 2003

Considering our review of the literature and the findings presented by Tornatzky and Klein [1982], we believe that our meta-analysis of the innovation literature of the past three decades will support Tornatzky and Klein's findings—the innovation characteristics from Diffusion of Innovations will relate significantly to innovation adoption propensity. It also follows that the antecedents in the Theory of Planned Behavior model will relate significantly to innovation adoption propensity. Based on the model presented in Figure 2, we examine the degree to which the aforementioned variables relate to innovation adoption propensity. These independent variables, their definitions, and expected nature of the relationship with innovation adoption propensity are summarized in Table 1.

Table 1: Independent Variables, Definitions, and Expected Relationships

Variable	Definition	Relationship to DV
Attitude toward behavior	The degree to which a decision maker holds a positive attitude toward the adoption of the innovation	positive
Subjective norm	The degree to which a decision maker feels it necessary to behave in a manner consistent with the social environment	positive
Perceived behavioral control	The degree to which the decision maker is confident in performing the behavior	positive
Relative advantage	The degree to which an innovation is perceived as better than the idea it supersedes	positive
Compatibility	The degree to which an innovation is perceived as being consistent with the existing values, past experiences, and needs of potential adopters	positive
Complexity	The degree to which an innovation is perceived as difficult to understand and use	negative
Trialability	The degree to which an innovation may be experimented with on a limited basis	positive
Observability	The degree to which the results of an innovation are visible to others	positive

III. METHOD AND RESULTS

Meta-analysis provides a means to compare, contrast, integrate, and synthesize the results of many studies in pursuit of developing fact [Cooper, 2009; Hunter and Schmidt, 2004; Shadish, Cook, and Campbell, 2002]. Having a larger pool of data—many studies vs. one—allows for a greater body of evidence and, hence, more robust conclusions. Individual studies, in essence, become data points in the meta-analytic review of the aggregate of a collection of studies. Meta-analysis helps researchers to average studies as though they were one study; some scholars suggest that such analysis is particularly beneficial to the IS research community [King and He, 2005; Saunders, Carte, and Butler, 2003].

Hunter and Schmidt [2004], the developers of the method we use for this article, emphasize that every study has inherent in it at least two weaknesses: sampling error and measurement error. Although Hunter and Schmidt [2004] describe several more potential study artifacts, we use their bare-bones meta-analysis as the basis for this article. In a bare-bones meta-analysis, researchers correct for sampling error and combine the effect size across studies.

Literature Search Criteria

We carefully selected studies to use for our meta-analysis based on strict inclusion and exclusion criteria. We sought to include research that not only answered the calls of Tornatzky and Klein, but also examined acceptance of an IS artifact. Therefore, the primary inclusion criterion for our sample is that the study reference Tornatzky and Klein's [1982] article. Using the primary inclusion criterion and the additional criteria (discussed below) as our guidelines, we performed a search in the online Google Scholar database. We chose Google Scholar for our database because of its demonstrated ability in indexing not just journal articles, but also conference proceedings, dissertations, and additional research [Meho and Yang, 2007]. By having access to these additional works, we sought to mitigate the file-drawer problem, a problem in which studies of non-significant results are not published in journals, thus leading to an overrepresentation of significant results in the published literature [Hunter and Schmidt, 2004; Rosenberg, 2005; Rosenthal, 1979]. To gather the first list of references, referred to as the full candidate list [DeCoster, 2009], we queried Google Scholar for articles citing Tornatzky and Klein's [1982] article. We identified our full candidate list of 964 articles, books, presentations, and reports. After a thorough table of contents, keyword, and abstract search of the 964 referenced items, we reduced the list to 477 based on our inclusion criteria (Table 2).

Table 2 : Inclusion Criteria

Criteria	Description
Cites Tornatzky and Klein, 1982	Authors cite Tornatzky and Klein's 1982 meta-analysis
TPB	Article keywords/abstract includes the Theory of Planned Behavior or any of the three TPB independent variables.
DOI	Article keywords/abstract includes Diffusion of Innovations theory or any of the five DOI independent variables.
Intent	Article keywords/abstract includes adoption intent as the dependent variable.
Adoption	Article keywords/abstract includes adoption as the dependent variable.

During the exclusion phase, we read and analyzed each of the articles remaining on the reduced list—after the inclusion phase—filtering them against our exclusion criteria in Table 3. First, because we operationalized our variables using definitions provided by Rogers [2003] and Ajzen [1991] as our foundation, we excluded references that did not hold to the original intent. For an article to be retained, the variable definitions used must be a reasonable facsimile of the definitions we developed (listed in Table 1). Then, as the next step of the exclusion phase, we chose to omit articles written in a language other than English. Based on our focus on information systems, we then excluded articles in which the artifact under investigation was not either information-systems- or information-technology-related. Because a meta-analytic method requires quantitative data, the decision to remove articles that were not empirically-based (e.g., theoretical, conceptual, etc.) was clear; more specifically, however, we also excluded those articles in which the authors did not provide the correlation values between the independent and dependent variable. Upon completion of the exclusion treatment, our efforts produced fifty-eight usable references for further analysis.

Table 3 : Exclusion Criteria	
Criteria	**Description**
Definitions	The reference must use reasonable representations of the variable definitions in Table 1.
English	We did not assess papers written in languages other than English.
Information System	The artifact of the investigation must be IS or IT related.
Empirical data	We excluded studies with no empirical data (e.g., conceptual).
States DV to IV correlations	If the article does not provide the correlation values between the independent and dependent variables, we exclude the study.

Meta-analysis Method

We performed a meta-analysis of the fifty-eight articles using the methods prescribed by Hunter and Schmidt [2004] for a bare-bones meta-analysis. Characteristics of these studies can be found in Table 4. Hunter and Schmidt assert that the two artifacts contained in every study are sampling error and measurement error [2004]. Indeed, one chief purpose of meta-analysis is to "estimate the true magnitude of correlations, as though all studies examined had been conducted without methodological flaws or limitations" [Hunter and Schmidt, 2004, p. xxv].

From the fifty-eight articles used, we collected the correlation values between each of our independent variables: attitude toward behavior, subjective norm, perceived behavioral control, relative advantage, compatibility, complexity, trialability, and observability, and our dependent variable: adoption propensity.[1] To correct for sampling error, we estimated the population correlation coefficient of the relationship between each independent variable and adoption propensity by calculating a weighted mean, where the weight is the sample size (e.g., respondents) in the study [Hunter and Schmidt, 2004] (this and subsequent meta-analysis equations can be found in the Appendix).

Additionally, we performed a frequency-weighted average squared error calculation to determine the variance across studies. To evaluate our results, we formulated 80 percent credibility intervals and 95 percent confidence intervals. Credibility intervals differ from confidence intervals in that a confidence interval provides an estimate of the variance around the estimated mean correlation and is formed using the standard error of the weighted mean, whereas the credibility interval refers to the parameter values distribution and is formed with the standard deviation of the population effect sizes [Hunter and Schmidt, 2004; Judge, Heller, and Mount, 2002]. Hunter and Schmidt [2004, p. 205] interpret the credibility interval as the percentage of the values in the parameter correlation distribution that lies in the given interval. Although Hunter and Schmidt encourage reporting the credibility intervals, others recommend reporting both credibility intervals and confidence intervals because each represent different information [Judge et al., 2002]; thus, we report both.

Table 4 : Characteristics of Studies used in Meta-analysis

			Correlations with Innovation Adoption							
Studies	Description of Innovation	Study Sample Size	Attitude Toward Behavior	Subjective Norm	Perceived Behavioral Control	Relative Advantage	Compatibility	Complexity	Trialability	Observability
Agarwal, R., & Prasad, J. (1997a).	C-based environment	71				,52	,51	-,43		
Agarwal, R., & Prasad, J. (1997b).	World Wide Web	73				,58	,58	-,49	,32	,14
Al-Gahtani, S. (2003).	Computer use	1 190				,27	,34	-,31	,26	,43
Basaglia, S., Caporarello, L., Magni, M., & Pennarola, F. (2009).	Convergent mobile phones	103	,61	,43		,78		-,45		
Calantone, R., Griffith, D., & Yalcinkaya, G. (2006).	Manufacturing technology	506	,44				,25			
Chau, P., & Hu, P. (2001).	Telemedicine	408	,54	,01	,38		,49	-,09		
Chen, C., Huang, E., & Taiwan, R. (2006).	Online taxation system	359	,82				,55	-,76		
Cheung, C. (2001).	Internet banking services	147		,58				-,37		,60
Chin, W., & Gopal, A. (1995).	Group support systems	64				,45	,59	-,12		
Cho, I., & Kim, Y. (2002).	O-O technology as a software process	220				,14	-,07	-,09		

[1] In our literature review, we found the variable "ease of use" used as an alternative to complexity in some studies. It has been argued that ease of use and complexity are parallel, while opposite, constructs (Igbaria and Iivari, 1995). Thus, if an ease of use variable matched the definition of complexity by exchanging "difficult" with "easy," we retained the study, multiplied the ease of use value by -1 to correct for the relationship of the constructs, and included the value in our analysis.

Table 5: Characteristics of Studies used in Meta-analysis – Continued

Cruz, P., Neto, L., Muñoz-Gallego, P., & Laukkanen, T. (2010).	Mobile banking	666	,61	,41	,44	,49	,56	-,33	,70	,60
Damanpour, F., & Schneider, M. (2008).	Various innovations	633						-,05		
Davis, F. (1989).	Application programs; PROFS e-mail	264						-,38		
Flanagin, J. (2000).	Organizational website	288				,64		-,21		
Fu, Z., Yue, J., Li, D., Zhang, X., Zhang, L., & Gao, Y. (2007).	e-learning	134				,41	,39	-,03	,27	,40
Giovanis, A., Binioris, S., Tsiridani, M., & Novas, D. (2009).	Internet banking	137					,50	-,40		
Grover, V. (1993).	Customer based interorganizational systems	216				-,36	,41	-,29		
Gwayi, S. (2009).	Instructional Innovation (TALULAR)	265				,28	,13	-,14	,20	
Hardgrave, B., Davis, F., & Riemenschneider, C. (2003).	Structured life-cycle development method	128		,63			,73	-,56		
Hashem, G., & Tann, J. (2007).	ISO 9000 standards	239				,67	,58	-,61		,34
Holak, S., & Lehmann, D. (1990).	Consumer durable innovations	130				,47	,56	-,01	,04	
Hung, S., Chang, S., & Lee, P. (2004).	Enterprise Resource Planning (ERP) system	139				,10	,33	,46		
Igbaria, J. and Iivari, J. (1995).	general IT	450						-,27		
Joo, Y., & Kim, Y. (2004).	e-marketplace	39				,01				
Karahanna, E., Agarwal, R., & Angst, C. (2006).	Shopping on the world wide web	216					,30	-,42		
Klein, R. (2007).	Internet-Based Patient- Physician Comm.	143						-,21		
Lai, V., Liu, C., Lai, F., & Wang, J. (2008).	Enterprise Resource Planning	208				,44	,36	-,37		
Lee, S., Kim, I., Rhee, S., & Trimi, S. (2006).	Object-oriented technology	154						-,07		
Linjun, H. (2003).	e-mail	302		,49				-,78		
Lu, J., Liu, C., Yu, C., & Yao, J. (2003).	Wireless internet and Mobile technology	128						-,32		
Luo, X., Gurung, A., & Shim, J. P. (2010).	Enterprise internet messaging	140					,73	-,43		
Manns, M. (2002).	Software patterns	130				,44	,35	-,27	,20	,40
Maruf, A., Sirion, C., & Howard, C.	e-bay	385				,18	,20	,20		
Ndubisi, N., & Chukwunonso, N. (2005).	Landscaping	94				,50	,94	-,27		
Ojha, A., Sahu, G., & Gupta, M. (2009).	Paperless tax return	310				,51	,50	-,51		
Pahnila, S. (2006).	Web information systems	197	,29					-,24		
Parthasarathy, M., & Bhattacherjee, A. (1998).	Online information services	443					,53	-,47		
Plouffe, C., Vandenbosch, M., & Hulland, J. (2001).	Smart card-based electronic payment system	604				,63	,58	-,30	,29	,02
Premkumar, G., & Potter, M. (1995).	Computer aided software engineering	90				,66	,08	-,21		
Premkumar, G., & Roberts, M. (1999).	Online data access	78				,47	-,09	-,10		
Premkumar, G., Ramamurthy, K., & Liu, H. (2008).	Instant messaging	309		,27				,03		
Purvis, R., Sambamurthy, V., & Zmud, R. (2001).	CASE technologies as knowledge platforms	124					,22			
Ramamurthy, K., Premkumar, G., & Crum, M. (1999).	Electronic Data Interchange	181					,19			
Ramamurthy, K., Sen, A., & Sinha, A. (2008).	Data warehousing	117					,43	-,29		
Ramayah, T., Dahlan, N., & Karia, N. (2006).	Personal digital assistant	70				,26	,36	-,42	,39	,48
Schultze, U., & Carte, T. (2007).	e-sales of cars	137	,32					-,21		
Shih, H. (2008).	Chinese web portal (Yahoo-Kimo)	279				,54	,56			
Teo, H., Wei, K., & Benbasat, I. (2003).	FEDI	548						-,26		
Thompson, R., Higgins, C., & Howell, J. (1991).	PC	212	,32	,19				,28		
Thong, J. (1999).	Information system (in general)	166						,21		
Truman, G., Sandoe, K., & Rifkin, T. (2003).	Smart card technology in banking	168				,38	,12	,29		
Udeh, E. (2008).	Wi-fi hotspot	129				,49		-,42		
Van Slyke, C., Belanger, F., & Hightower, R. (2005).	Consumer-oriented electronic commerce	507				,68	,72	-,66		,62
Völlink, T., Meertens, R., & Midden, C. (2002).	Energy conservation interventions	99				,38	,51	-,23	,20	
Wang, S., & Cheung, W. (2004).	e-business approach	137				,34				
Yoon, T. (2009).	Virtual Worlds	130				,54	,30			
Zheng, K., Padman, R., Johnson, M., & Diamond, H. (2007).	Customer relationship management	48				,47	,79	-,68		
Zolait, S., Hussein, A., & Sulaiman, A. (2008).	Internet banking	369						-,69	,17	,00

Meta-analysis Results

Table 5 includes the results of the meta-analyses of the relationships between each of the eight IAB antecedents and adoption propensity. Attitude toward behavior, one of the three Theory of Planned Behavior variables, was the strongest correlate of adoption propensity, yielding a "large" effect size (ρ = .53) [Cohen, 1992]. Following are the correlates with "medium" effects: compatibility (ρ = .43), relative advantage (ρ = .42), perceived behavioral control (ρ = .41), observability (ρ = .38), subjective norm (ρ = .33), and trialability (ρ = .32). None of the confidence intervals for the relationships noted above include zero. With the exception of complexity, all of the proposed antecedents were found to have a positive and significant correlation with adoption propensity.

Table 5: Results

	Current Meta-analysis									Tornatzky and Klein	
Characteristic	k	N	r	ρ	SDρ	95% CI LL	95% CI UL	80% CV LL	80% CV UL	k	p-value
Attitude toward behavior	8	2,588	.49	.53	.15	.37	.69	.33	.73	-	-
Subjective norm	8	2,275	.38	.33	.18	.15	.52	.10	.57	-	-
Perceived behavioral control	2	1,074	.41	.41	.00	.39	.44	.41	.41	-	-
Relative advantage	32	7,303	.42	.42	.21	.20	.63	.15	.69	5	.031
Compatibility	38	9,366	.42	.43	.19	.24	.62	.19	.66	13	.046
Complexity	51	12,825	-.27	-.28	.25	-.54	-.03	-.60	.04	7	.062
Trialability	11	3,730	.28	.32	.18	.14	.50	.09	.55	*	*
Observability	11	4,129	.37	.38	.22	.16	.60	.09	.66	*	*

Note: * = unable to calculate because of lack of data
k = number of correlations
N = combined sample size
ρ = weighted mean corrected correlation
SDρ= standard deviation of the estimated true score correlation
CI = confidence interval
CV = credibility interval

Complexity yielded the smallest effect size (ρ = -.28). While the confidence interval for complexity indicates that it has a negative association with adoption propensity, the credibility interval for complexity contained zero, indicating that the correlation between complexity and adoption propensity is not consistent across all studies.[2] For no other antecedent did the credibility interval include zero, which indicates that 80 percent of the values in each of the other antecedents' ρ distributions lie within their respective intervals (e.g., 80 percent of values in the distribution for attitude toward behavior lie between .33 and .73). Of note is the standard deviation of the estimated true score correlation of perceived behavior control (SDρ = .00). This value is calculated from the variance of the estimated true score correlation of perceived behavior control, in this case, -0.0006. We have a negative variance because the variance is not calculated using normal conventions. Instead, it is derived as the difference between the observed correlations' variances and the sampling error variance that is computed statistically (formula 4, Appendix). We set the SDρ to zero when the variance is zero or less than zero [Hunter and Schmidt, 2004]. Because the variance of observed correlations is a sample estimate and, therefore, subject to some error in the empirical estimate unless the sample size is infinite, we caution against generalizing these results across studies because only two studies presented perceived behavior control correlations [Cohen, 1992; Davis, 1986].

For comparison to our results, in Table 5 we included Tornatzky and Klein's results for the Diffusion of Innovations variables. Although Tornatzky and Klein performed their study meta-analytically, readers should note that meta-analysis methods have matured greatly since Tornatzky and Klein performed their study. In their approach,

[2] For example, in about 90 percent of the studies, complexity is negatively related to adoption propensity; in the other ~10 percent of the studies, the relationship between complexity and adoption propensity was either zero or positively related to adoption propensity.

Tornatzky and Klein determined the positive or negative correlation for each independent–dependent variable relationship and "… calculated the binomial probability of obtaining the given ration of positive to negative correlations under the null hypothesis of a 50–50 split between negative and positive findings" [Tornatzky and Klein, 1982, p. 31]. While their approach is valid, current meta-analytic methods encourage calculating independent–dependent variable relationships to compensate for sampling error and evaluating the body of studies as an aggregate study [Hunter and Schmidt, 2004]. In other words, we look at the body of studies as though they are one and with the sampling error for each study corrected.

IV. DISCUSSION

The results of our examination of the relationships in the IAB model support Tornatzky and Klein's [1982] findings and provide a foundation for further examining adoption propensity. Attitude toward behavior indicated the largest correlation with adoption propensity and all the remaining antecedents, except complexity, fit within the "medium" effect size category [Cohen, 1992].

Tornatzky and Klein [1982] found that the three innovation characteristics, relative advantage, compatibility, and complexity, provided the most consistently significant associations with innovation adoption. However, Tornatzky and Klein's [1982, p. 40, Table 4] results suggest that complexity is negatively associated with adoption at a near-acceptable level of significance ($p = 0.062$). Therefore, we were not surprised that our results also suggest a weak correlation regarding complexity. Tornatzky and Klein uncovered twenty-one studies that investigated complexity, of which seven provided sufficient data for them to extract. In six of the seven studies from which Tornatzky and Klein were able to extract correlations, negative correlations between complexity and adoption were indicated. In our study, our k was 51 and our calculated effect size was only marginally greater than that of Tornatzky and Klein, thus providing further empirical support that complexity may be the least significant antecedent of the eight that we tested.

We were not surprised that relative advantage and compatibility were found to have medium effect sizes, as was the case with Tornatzky and Klein's [1982] study. All of the studies analyzed by Tornatzky and Klein in regard to relative advantage indicated a positive correlation between relative advantage and adoption. Likewise, all thirty-two relative advantage studies we evaluated indicated a positive relationship between relative advantage and adoption propensity. As in the case with complexity, our results regarding relative advantage mirror the findings of the Tornatzky and Klein [1982] study. Likewise, our results regarding compatibility also coincide with the results of Tornatzky and Klein's study. A mean corrected ρ of .43 over an aggregate N of 9,366 suggests an effect size just slightly greater than what Tornatzky and Klein found. In contrast to Tornatzky and Klein's lack of sufficient studies for analysis, we were able to find enough studies to analyze trialability and observability. With Ks of 11 each, our results suggest that both trialability and observability are positively related to adoption propensity. Overall, our findings suggest that all of the relationships from Diffusion of Innovations encompassed in the IAB model are significant, with the caveat that because the credibility interval for complexity contained zero, the correlation between complexity and adoption propensity does not generalize completely across all studies.

In addition to our goal of updating Tornatzky and Klein's [1982] study, we also examined independent variables from the Theory of Planned Behavior. The largest correlation in our study was found to be between attitude toward behavior and adoption propensity, and both social norms and perceived behavior control were found to have medium effect sizes. These findings are similar to those from other meta-analyses of the Theory of Planned Behavior constructs from areas outside of IS [Armitage and Conner, 2001; Topa and Moriano, 2010]. This suggests that the tenets of the theory adequately transcend IS applications and have proven useful for explaining behavior in IS research.

Implications for Research and Practice

Hunter and Schmidt [2004] suggest two necessary steps for the accumulation of knowledge: the accumulation of results across studies and the formation of theories to organize the results into a useful form. Meta-analytic, quantitative analysis of extant literature affords a means by which both of these steps are possible. It is via this quantitative analysis of the extant literature that we show the relationship between each of the IAB antecedents and adoption propensity. Our findings strengthen extant theory and suggest that the use of the Theory of Planned Behavior and Diffusion of Innovations in information systems research is useful and appropriate. In answer to the first Hunter and Schmidt knowledge growth step—accumulation of results across studies—our meta-analysis impacts the IS research community through a synthesized body of literature that corroborates and confirms the general efficacy and relevance of these foundational theories in the context of IS. Indeed, our findings can be used by scholars to support the enduring relevance of these theories when using them in the design of their own research. As shown in this study, the variables addressed herein are powerful predictors of adoption propensity, which should motivate their continued use and give confidence to scholars who choose to use them.

For practitioners, our findings offer similar implications. Again, the relationships examined herein are not new. However, the understanding that these relationships have remained significant over the decades and across a variety of studies suggests that practitioners can have confidence when relying on the constructs suggested by the Theory of Planned Behavior and Diffusion of Innovations to predict adoption behavior. For instance, sales and marketing professionals can use these results to help influence consumers of IS products. Likewise, our findings might be useful when deploying new information systems or changing current information systems. To positively affect employee adoption, CEOs and CIOs can focus their efforts toward influencing those Innovation Adoption Behavior antecedents we found to have stronger relationships to adoption propensity. For instance, although CIOs may find little improvement in employee intent to adopt by exerting effort to reduce the complexity of an information system, it is likely that their work to improve the attitude of employees toward the adoption of the system—perhaps, by more clearly explaining the value of the information system—will yield an increase in adoption rates.

In light of this study, future research might also focus on developing further refinements of the IAB framework by exploring additional antecedents to the decision-makers' innovation adoption propensity that may elucidate the relationships within the model. For instance, we found over 7,000 studies catalogued on Google Scholar as citing the Technology Acceptance Model (TAM) [Davis, 1986, 1989; Davis, Bagozzi, and Warshaw, 1989], which may have also used Tornatzky and Klein's [1982] study as the basis of investigation. Although the TAM has been modified, critiqued, and updated several times [Legris, Ingham, and Collerette, 2003; Venkatesh, 2000; Venkatesh and Bala, 2008; Venkatesh and Davis, 2000; Venkatesh, Morris, Davis, and Davis, 2003] and meta-analyses have been done [King and He, 2006; Schepers and Wetzels, 2007], the TAM and its core constructs may provide a different lens in which to view our research objectives, thus providing an opportunity for future study.

Limitations

Meta-analysis is generally accepted as a viable and valid research method. However, use of secondary data derived from the research published by a variety of authors in a number of journals over a wide range of years may pose a validity threat. To reduce this threat, we carefully selected empirical studies using strict criteria. We also used meta-analytic techniques that have been demonstrated to mitigate such validity threats [Hunter and Schmidt, 2004]. In addition, it is reasonable to assume that studies exist in which the authors did not cite Tornatzky and Klein, yet still used the same principles to examine relationships between Diffusion of Innovations and Theory of Planned Behavior constructs and innovation adoption. However, our results are shown to be robust to the omission of such studies [Rosenberg, 2005; Rosenthal, 1979].

V. CONCLUSION

"The goal of any science is the production of cumulative knowledge" [Hunter and Schmidt, 2004, p. 17]. In the past three decades, the volume of research on IS innovations has grown and many researchers have responded to Tornatzky and Klein's [1982] call for research focusing on IS and the organization. Just as Tornatzky and Klein quantitatively analyzed the literature available to them, it is through the strengths of meta-analysis that we produce additional cumulative knowledge about IS innovations. The individual studies Tornatzky and Klein evaluated provided seemingly contradictory results about perceived innovation adoption characteristics. They performed a quantitative review of the extant literature regarding various innovation characteristics and their relation to innovation adoption and implementation. Although they contended that some of the literature at the time lacked conceptual and theoretical rigor, by meta-analyzing the studies in aggregate, they were able to discern that characteristics found in the Diffusion of Innovations model provide the most consistently significant relationships with innovation adoption [Tornatzky and Klein, 1982]. Using the same rationale and similar methods, we provide a timely update and extension to their study.

Responding to Tornatzky and Klein's call [1982], we answered their identified research needs: (a) for more and better research, (b) to study other independent variables in addition to innovation characteristics, and (c) to reduce the number of innovation attributes to only the significant few. To respond to their first call—more and better research—we evaluated the past thirty years of the IS research community's accumulated literature that empirically examines the effect of these variables on innovation adoption. Through the IAB model, we have satisfied the other two calls. Combining variables from the Theory of Planned Behavior and the Diffusion of Innovations model, we included eight predictor variables—answering Tornatzky and Klein's call to study other independent variables. Finally, through our meta-analytic approach, we responded to the third call and focused on those explanatory variables of significance to better understand the nature and magnitude of the relationships between each of the eight variables and adoption propensity.

In summary, we found that the five characteristics of an innovation set forth in Diffusion of Innovations and the three antecedents to behavior in Theory of Planned Behavior are significantly and positively related to adoption propensity. The results of our meta-analytic assessment of the relationships in the IAB model provide a solid foundation for future examination of the source of innovation adoption propensity.

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Editor's Note: The following reference list contains hyperlinks to World Wide Web pages. Readers who have the ability to access the Web directly from their word processor or are reading the article on the Web, can gain direct access to these linked references. Readers are warned, however, that:

1. These links existed as of the date of publication but are not guaranteed to be working thereafter.
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APPENDIX A: META-ANALYSIS FORMULAE

To correct for sampling error, we estimated the population correlation coefficient of the relationship between each independent variable and adoption propensity by calculating a weighted mean ($\bar{\rho}$) where the weight is the sample size, *n*, (e.g., respondents) in the study [Hunter and Schmidt, 2004]:

$$\bar{\rho} = \frac{\sum_{i=1}^{k} n_i r_i}{\sum_{i=1}^{k} n_i} \quad (1)$$

where *k* is the number of studies, r_i is the correlation in study *i*, n_i is the sample size for study *i*, and $\bar{\rho}$ is the weighted mean correlation across all studies. Additionally, we performed a frequency-weighted average squared error calculation to determine the variance across studies:

$$s_{\rho}^2 = \frac{\sum_{i=1}^{k} n_i (r_i - \bar{\rho})^2}{\sum_{i=1}^{k} n_i} \quad (2)$$

where s_{ρ}^2 is the variance of sample effect sizes (i.e., frequency-weighted average squared error). To evaluate our results, we formulated 80% credibility intervals and 95% confidence intervals. The intermediate formulas necessary to calculate the credibility intervals include the sampling error variance and the estimated variance of population effect size:

$$\sigma_e^2 = \frac{(1-\bar{\rho}^2)^2}{N-1} \quad (3)$$

Where σ_e^2 is the sampling error variance and *N* is the total sample size.

$$\hat{\sigma}_{\rho}^2 = \sigma_r^2 - \sigma_e^2 \quad (4)$$

Where $\hat{\sigma}_{\rho}^2$ is the estimated variance of the population effect size. The calculations required for the upper and lower 80% credibility intervals (CV) are as follows:

$$CV_{Upper} = \bar{\rho} + 1.28\sqrt{\hat{\sigma}_{\rho}^2} \quad (5)$$

$$CV_{Lower} = \bar{\rho} - 1.28\sqrt{\hat{\sigma}_{\rho}^2} \quad (6)$$

The calculations required for the upper and lower 95% confidence intervals (CI) are as follows:

$$CI_{Upper} = \bar{\rho} + 1.96\sqrt{\frac{s_r^2}{4}} \quad (7)$$

$$CI_{Lower} = \bar{\rho} - 1.96\sqrt{\frac{s_r^2}{4}} \quad (8)$$

ABOUT THE AUTHORS

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