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JOURNAL OF INFORMATION TECHNOLOGY THEORY AND APPLICATION

A Publication of the Association for Information Systems

The Diffusion of Second-Generation Statistical Techniques in Information Systems Research from 1990–2008

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Abstract:

Second-generation statistical techniques like Structural Equation Modeling (SEM) are being used more frequently by IS researchers to evaluate theoretical models. The purpose of this study is three-fold. First, we aim to ascertain whether there is a "fit" between IS researchers' choice of analytic method and theoretical models when they use second-generation techniques. Second, we seek to determine the degree to which IS researchers have internalized knowledge about second-generation techniques. Finally, we want to see how these factors have changed over time. Analysis of four leading IS journals between 1990 and 2008 matched the use of second-generation techniques to rational reasons for using a specific analytic technique and the degree of knowledge internalization found in 265 published empirical articles. In the early period (1990–2002), we found the use of second-generation techniques was not associated with rational choices or reasons for their use. Once researchers had ready access to Gefen et al.'s (2000) work presenting the proper use of SEM-based analytical tools (referred to as the "later period" between 2003–2008), we found their use was associated with rational choice and there was a higher degree of knowledge internalization. Our findings suggest that, over time, researchers were able to leverage their internalized knowledge of second-generation techniques when testing mediation and moderation models as indicated by the higher ratio of internal to external method citations. The paper concludes with implications for IS research.

Keywords: structural equation modeling; PLS; adoption; diffusion; collective use; knowledge dissemination

Volume 11, Issue 4, pp. 5-28, December 2010

Mark Srite acted as the Senior Editor for this paper.

JOURNAL OF INFORMATION TECHNOLOGY THEORY AND APPLICATION

INTRODUCTION

Structural equation modeling (SEM) techniques have become a mainstay of empirical work in social science research over the past three decades (Anderson and Gerbing 1988; Bagozzi and Yi 1989; Curran 2003), and their use is expected to increase dramatically in the future (Song and Lee 2008). Hereafter, we refer to PLS, maximum likelihood (ML), and other SEM techniques as second-generation techniques[1,2] (Chin 1998a; Gefen et al. 2000). In contrast to first-generation techniques (e.g., linear regression, ANOVA, MANOVA), second-generation techniques allow researchers to examine a set of research questions in a single, systematic, and comprehensive analysis (examples of first- and second-generation research articles are presented in Appendix A). Because they model relationships among multiple independent and dependent variables simultaneously, second-generation techniques are usually preferable to first-generation techniques, which can analyze only one layer of linkages between independent and dependent variables at a time. Second-generation techniques assess the structural model (the assumed causation among a set of independent and dependent constructs) and the measurement model (loadings of observed indicators on their expected latent variables) at the same time, thereby resulting in a more rigorous analysis of the proposed research model (Bollen 1989). Additionally, covariance-based second-generation techniques are useful for three reasons: (1) when theory suggests that competing models exist, researchers can model and test alternative models with the same data set; (2) modification indices can provide insight into plausible alternative explanations for relationships among constructs; and (3) second-generation technique results are readily replicable and reusable, thereby providing researchers with opportunities to independently confirm results and evaluate alternative models (Kline 2005).

Since 1990, 265 articles using first- and second-generation statistical techniques have been published in four leading IS journals (*Management Information Systems Quarterly* (MISQ), *Information Systems Research* (ISR), *Journal of Management Information Systems* (JMIS), and *Journal of the Association for Information Systems* (JAIS)[3]). Of these, 191 referenced the use of second-generation techniques as compared to seventy-four articles that referenced the use of first-generation techniques. Figure 1 compares the use of first- and second-generation techniques from 1990 to 2008 and illustrates the dramatic growth in the use of second-generation techniques in the IS field since the late 1990s and early 2000s.

Ideally, the growing use of second-generation techniques in IS research should be associated with the diffusion of knowledge in the field, with growth increasing as researchers acquire necessary knowledge and skills. However, previous research suggests IS researchers are susceptible to bandwagon effects in theories and tools used in their studies (e.g., Benbasat and Barki 2007; Fichman 2004). This susceptibility could be due to IS researchers' low production rate in elite journals when compared to other fields such as accounting, finance, management, and

CONTRIBUTION

This paper contributes to Information Systems (IS) research. Due to the growth of SEM techniques in the IS field since 1990, this paper shows the adoption of these techniques was driven by rational choice. In particular, IS researchers have correctly assessed the fit between the nature of the model and the analytic technique when they chose between first- and second-generation techniques. Our research also shows that, over time, IS researchers were more likely to choose second-generation techniques due to advances in SEM that facilitated the analysis of both mediation and moderation.

Additionally, our analysis indicates IS researchers have internalized the appropriate knowledge about the proper use and assumptions of both first and second generation technique use. In other words, IS researchers have access to relevant and legitimate information about the appropriate use of analytic techniques in research that is familiar to them and provides a similar context. Over time, this knowledge has accumulated such that second-generation techniques have become indoctrinated into the knowledge repository for IS researchers.

[1] By using the term *second-generation techniques,* we do not mean to imply first-generation techniques are being replaced by second-generation techniques. On the contrary, there are situations in which second-generation techniques are not called for (Gefen, Straub, and Boudreau 2000). Instead, we use this term to maintain a consistent use of terminology present in the literature (Chin, 1998a; Gefen, Straub, and Boudreau 2000).

[2] Additionally, we analyzed the data with the SEM and PLS articles in separate groups, since some researchers argue PLS is not SEM but rather a form of regression (Rouse and Corbitt 2008). We did not find significant differences between these two types of second-generation analyses, so grouping them together was deemed appropriate.

[3] We selected JAIS because it is considered a flagship research journal for the *Association for Information Systems* (AIS). Its recency precludes ranking, but it is perceived as a high-quality journal and has experienced a rising stature (Zhang and Li 2005) in more recent journal ranking

marketing (Dennis, Valacich, Fuller, and Schneider 2006; Swanson 2004). Bandwagon effects' influence on method-related decisions are particularly dangerous for IS research (Gregor 2006) because the field may lose legitimacy if it does not appropriately apply research techniques (Robey 2003). Therefore, the ideal is the fit between the problem and the tool (i.e., rational explanations for choice of a technique) should be independent of time or research topic.

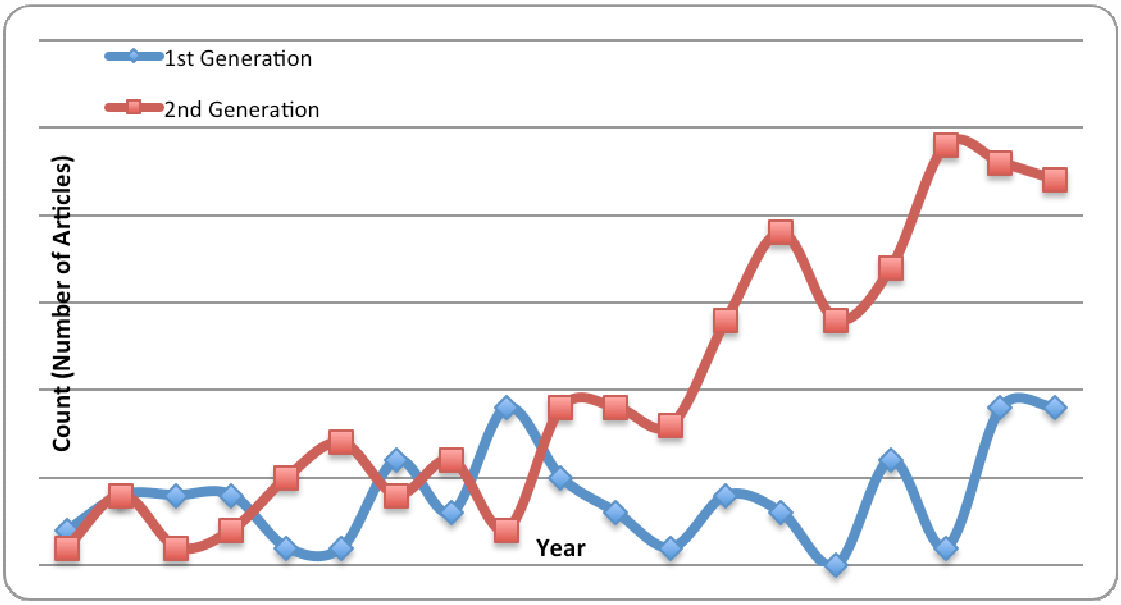

Figure 1: Analytical technique trends 1990–2008.

Rational explanations refer to technical reasons tied to the fit between the technique and the nature of the problem at hand. If such technical reasons explain the use of second-generation techniques, one might infer the IS field is appropriately applying rigorous techniques (Boudreau, Gefen, and Straub 2001) and could be maturing as an academic discipline (Palvia, Mao, Salam, and Soliman 2003). To effectively employ an innovation such as SEM, researchers must possess the theoretical and technical knowledge required to use the analytic technique (Fichman and Kemerer 1999).

When users lack theoretical or technical understanding, knowledge barriers may constrain researchers' ability to use an analytic technique. Knowledge barriers arise because the expertise required to leverage complex techniques requires more than simple awareness of their existence and potential benefits (Attewell 1992). To overcome such barriers, IS researchers tap into pools of knowledge about how and when to appropriately employ a methodological innovation. Understanding knowledge barriers' influence is important because they may influence scholars' choices of method. If alternative reasons such as knowledge barriers are associated with the use of second-generation techniques, one might glean deeper insight into bandwagon effects and the social context's influence on IS research (Meyer and Rowan 1977; Tolbert and Zucker 1983).

Hence, to understand factors associated with analytic techniques employed in IS research, this study evaluates how rational explanations (e.g., choice based on the fit between the nature of the model and the analytic technique) and knowledge barriers (e.g., the number of internal versus external method citations referenced) influence the appearance of first- and second-generation techniques in leading IS journals. Specifically, we ask: *Are IS researchers using second-generation techniques in their research for the appropriate technical reasons, or are they burdened by knowledge barriers? Do these reasons change over time?*

By reflecting on factors associated with the use of analytic techniques, we believe our work has the potential to help the IS field understand the sources of, as well as establish more meaningful, research traditions (Hamilton and Ives 1982; McFarlan 1986; Straub 1989). Therefore, our goal is three-fold. First, we seek to determine the drivers of second-generation technique use when researchers are testing more complex models. Second, we want to establish if researchers are relying on internal- or external-method citations to justify their choice of analytic technique (e.g., the degree of knowledge internalization). Finally, we want to see how these factors are changing over time.

studies (e.g., Lowry, Romans and Curtis 2004; Willcocks, Whitley and Avgerou 2008). Additionally, JAIS is included as the fourth journal in the AIS Senior Scholar's "Basket of 6" journals that represent the top journals in the field.

The paper unfolds as follows. First, we review the relationship between the use of second-generation techniques and rational choice and degree of knowledge internalization. Next, we develop a research model and articulate specific hypotheses. Then, we review our methodology and explain how we operationalize key constructs. In the following section, we present our results. The paper concludes with implications for future research.

WHY USE SECOND-GENERATION TECHNIQUES?

Many books (e.g., Duncan 1975; Hoyle 1995; Marcoulides and Schumacker 1996), book chapters (e.g., Chin 1998b; Rigdon 1998; Ullman 2007), and journal articles (e.g., Anderson et al. 1988; Chin 1998a; Gefen et al. 2000) explain how to use first- and second-generation techniques. In this section, we focus our review on explanations for their use.

Rational Choice

As IS researchers have developed more sophisticated and complex theories, there has been a corresponding increase in studies that hypothesize and test for moderation and mediation (Carte and Russell 2003). Specifically, researchers have added third variables to study the relationship between predictor and criterion variables. A moderating variable is defined as "a third variable that affects the zero-order correlations between two other variables," whereas, "a given variable may be said to function as a mediator to the extent that it accounts for the relation between the predictor and the criterion" (Baron and Kenny 1986, pp. 1174 and 1176). To select appropriate tools for testing these complex models, researchers often consider the assumptions and estimation approaches of analytic techniques. First-generation techniques include principal components analysis, factor analysis, discriminant analysis, and multiple regression. Typically, first-generation techniques are used to either evaluate the properties of measures of constructs or relationships among constructs. For example, principal components analysis is used to establish the discriminant and convergent validity of construct measures (Harman 1976). Having established construct validity, researchers often use tools such as linear regression to estimate the relationships among constructs. For example, regression estimates the relationship between a set of data points, which allows researchers to explain variance and assists in rejection of relationship or path-specific null hypotheses (Gefen et al. 2000). To use regression, researchers must collapse the indicators of a variable into an index.

Executing tests of relationships using collapsed measures and linear analysis renders results prone to measurement error (Anderson and Gerbing 1982; Cohen, Cohen, West, and Aiken 2003). Further, if a theory suggests that a mediating or moderating variable exists, the researcher must run multiple models and significance tests to examine construct interrelationships as well as control for error's influence (Tabachnick and Fidell 2007). This requires individually testing each set of relationships between independent variables (IVs) and dependent variables (DVs) (Gefen et al. 2000; Gerbing and Anderson 1988; Tabachnick et al. 2007). Many researchers consider first-generation techniques cumbersome because they require multiple steps to evaluate measurement models, test relationships among variables, and control for error. On the other hand, first-generation techniques are well-suited to testing for moderation and are, therefore, often a more rational choice over second-generation techniques in MIS research (Carte et al. 2003).

In contrast to first-generation techniques, second-generation techniques allow researchers to more readily estimate sophisticated measurement and structural models. Second-generation techniques, such as covariance- or components-based SEM, simultaneously estimate the measurement of constructs, as well as the relationships between IVs and DVs (Aaker and Bagozzi 1979; Rigdon 1998; Ullman 2007). Because second-generation techniques simultaneously estimate relationships, they allow researchers to examine theoretical models that incorporate mediating variables in fewer steps than first-generation techniques (Iacobuuci, Saldanha, and Deng 2007). For example, SEM allows researchers to estimate all relevant paths, including mediators and moderators that may occur in parallel or in sequence in one set of analyses (Iacobuuci et al. 2007; Kenny and Judd 1984; McClelland and Judd 1993). Further, rather than separately estimating many different relationships to compare theoretical models, second-generation techniques more readily permit estimating alternative models and comparing their results (Aaker et al. 1979; Gefen et al. 2000; Marsh, Hau, Balla, and Grayson 1998; Rigdon 1998; Tabachnick et al. 2007). In addition, unlike first-generation techniques, second-generation techniques account for measurement error when estimating structural models (Aaker et al. 1979; Gefen et al. 2000; Rigdon 1998; Ullman 2007). In the case of mediating variables, SEM automatically corrects for problems created by measurement error and feedback (Baron et al. 1986; Joreskog and Sorbom 1982; Ullman 2007). By doing so, second-generation techniques avoid underestimating mediation effects or the influence of error that may be symptomatic of first-generation techniques such as regression analysis (Cheung and Lau 2008). Additionally, in recent years, the introduction of more sophisticated second-generation techniques like Chi-square difference tests and PLS allows researchers to perform moderation tests (Carte et al. 2003). Hence, second-generation techniques are a more rational choice if researchers are seeking means to estimate complex models and correct for measurement error (Iacobuuci et al. 2007).

Degree of Knowledge Internalization

Knowledge barriers may limit use of second-generation techniques. A knowledge barrier exists when adoption is hindered by an individual's lack of knowledge or skills required to use an innovation (Attewell 1992). When considering an innovative statistical technique, scholars evaluate the time and difficulty associated with learning to conduct the analysis (Fichman et al. 1999; Rogers 1995), particularly for more complex tools like second-generation techniques. For example, SEM requires that researchers possess a sound understanding about intricate causal networks (e.g., direct effects, mediation, or moderation) rather than simple correlation-based models, knowledge of measurement (in particular, formative constructs are not supported by regression), and the ability to interpret complex statistics (Gefen et al. 2000; Rigdon 1998; Ullman 2007). In other words, using second-generation techniques requires more than simply learning to use a computer program (Rigdon 1998); instead, researchers must acquire a deep understanding of abstract theoretical and statistical concepts.

To overcome knowledge barriers associated with second-generation techniques, researchers can seek help either external or internal to their field of study (Nambisan and Wang 2000). External to their field, researchers seek assistance when they draw on knowledge found in a different domain of inquiry. When they pattern their work after external experts, researchers tie their work to relevant sources of information (George, Chattopadhyay, Sitkin, and Barden 2006), substantiate the legitimacy of their efforts (Dacin, Goodstein, and Scott 2002; George et al. 2006; Hargadon and Douglas 2001), and enhance successful adoption by following best practices (Dacin et al. 2002; Ravichandran 2005) instead of attempting to create a new practice within their field (Selznick 1996). If researchers seek help internal to their field, they will often experience the same benefits of relevancy and legitimacy with an added benefit of finding this information in readily available and familiar sources that explain the technique. In addition, these internal sources contextualize techniques for the field and provide references for further information. Researchers utilizing internal sources can also observe the benefits prior researchers have experienced by using these techniques, e.g., publication success in top IS journals (Best 2006; Rao, Greve, and Davis 2001; Van den Bulte and Lilien 2001).

Time

Diffusion refers to the process by which an innovation is communicated through certain channels among members of a social system over time (Rogers 1995). Typically, diffusion begins slowly, increases dramatically as many individuals adopt, peaks, and then levels off over time (Rogers 1995). Early adopters are often responsible for establishing the legitimacy of the technique (Tolbert et al. 1983) and offer advice to new users about how to successfully implement the technique (Best 2006). As IS researchers accumulate information about second-generation techniques from mentors, external sources, or peers, they may become better equipped to weigh the merits of adoption (Burns and Wholey 1993; Burt 1987). This is likely because they possess better information (Saloner and Shepard 1995) to help determine how the technique fits their data analysis needs (Pare and Trudel 2007). By using the technique, IS researchers absorb knowledge (Robey, Ross, and Boudreau 2002) and should become less dependent on mentors and external experts. The cumulative absorption of knowledge among IS researchers leads to the field encapsulating the information necessary to use second-generation techniques, which leads to future research relying on IS citations to support use of an analytic technique (Grover, Ayyagari, Gokhale, Lim, and Coffey 2006). In summary, time increases researchers' exposure to a technique and decreases their reliance on mentors and external experts, thereby reducing knowledge barriers to using second-generation techniques.

VARIABLES, CONCEPTUAL MODEL, AND HYPOTHESES

Based on this review, we turn to developing hypotheses tying rational choice, degree of knowledge internalization, and time to the use of first- and second-generation techniques. Figure 2 presents our research model. Table 1 presents construct definitions.

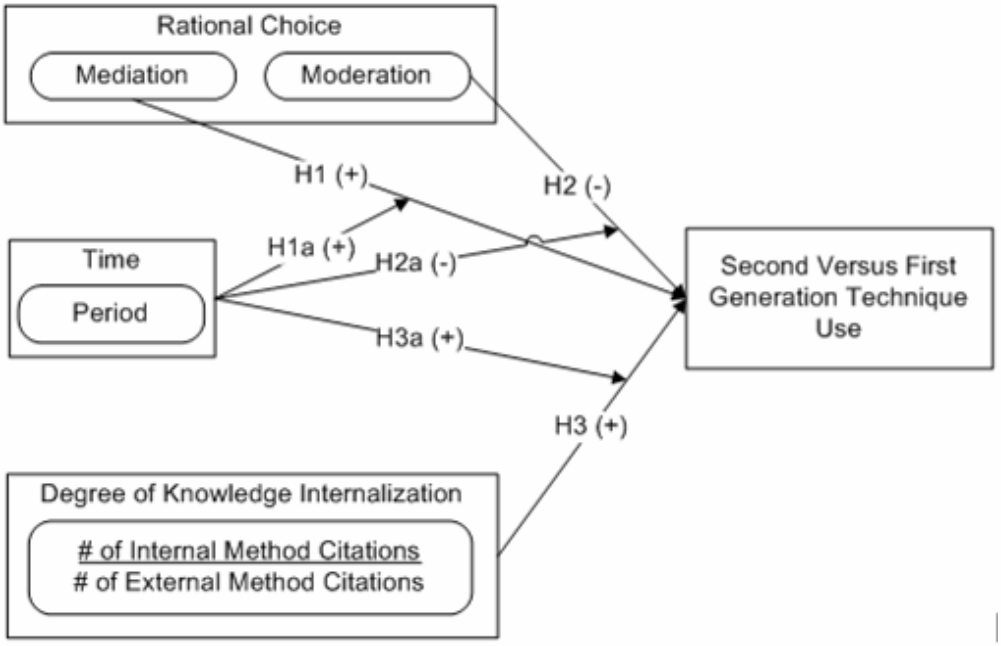

Figure 2: Research model for choosing second- versus first-generation techniques.

Table 1: Construct Definitions

Construct	Definition
Second- Versus First-Generation Technique Use	The use of first- or second-generation techniques for empirical research
Rational Choice	The fit between the nature of the model and the analytic technique
Degree of Knowledge Internalization	The extent to which knowledge and skills about the merits of a technique are gained from within the field
Time	The impact of time on the complexity of the model and the degree of knowledge internalization associated with second- vs. first-generation techniques

Rational Choice

Second-generation techniques offer researchers the opportunity to test more sophisticated theoretical models. Since second-generation techniques automatically incorporate all the relevant paths between IVs, mediating variables (MVs), and DVs, we anticipate researchers will use these techniques to estimate models including mediators. They also address complications that exist in regression due to measurement error and feedback. Second-generation techniques are also not restricted by mediating variables that are latent or occur in parallel (Baron et al. 1986; Joreskog et al. 1982) or moderators that form product variables (Kenny et al. 1984; McClelland et al. 1993). Since using second-generation techniques is a more rational choice when the model contains mediating variables (Iacobuuci et al. 2007), often reflective of more complex theoretical models, we expect researchers to use second-generation techniques as opposed to first-generation techniques when assessing mediation. On the other hand, even though more sophisticated second-generation techniques like Chi-square difference tests and PLS allow researchers to perform moderation tests, researchers are still more likely to use first-generation techniques for testing moderation since those techniques are more established and are often considered more appropriate (Baron et al. 1986; Carte et al. 2003). Hence:

> *H1: IS researchers are more likely to use second-generation techniques versus first-generation techniques when they are testing mediation.*
>
> *H2: IS researchers are more likely to use first-generation techniques versus second-generation techniques when they are testing moderation.*

Over time, MIS theory and research increased in sophistication and complexity (Carte et al. 2003). With this, researchers are now hypothesizing and testing both mediation and moderation effects (Carte et al. 2003).

Furthermore, recent conceptual and analytical advances in SEM (in addition to the ability to use PLS to test moderation) provide opportunities for IS researchers to effectively apply second-generation techniques to models that include moderation (Carte et al. 2003; Marsh, Wen, and Hau 2004). At the same time, the contemporary review process at the top journals demands an increasing level of rigor for positivist, quantitative research (Boudreau et al. 2001). This suggests newer research must reflect a tighter match between the theoretical model and the analytic technique. Since second-generation techniques have become more capable of handling both mediation and moderation over time, we hypothesize:

> *H1a: Time strengthens (moderates) the association between testing mediation and the use of second generation techniques versus first generation techniques.*

> *H2a: Time weakens (moderates) the association between testing moderation and the use of first generation techniques versus second generation techniques.*

Degree of Knowledge Internalization

When researchers cite references for their choice of methodological technique, they can draw on codified information internal or external to their field (i.e., articles or textbooks) (George et al. 2006; Wade, Biehl, and Kim 2006). Researchers will frequently rely on internal citations because they are perceived as readily available, familiar, and legitimate thereby requiring less explanation for why and how to use a specific technique. Beyond legitimacy, using and referencing specific techniques could be the result of researchers observing positive implications of prior use of a technique (Best 2006; Rao et al. 2001; Van den Bulte et al. 2001). Since 70 percent of the empirical articles in the top IS journals have used second-generation techniques in the method section, one might infer using these techniques is necessary for publication success. Therefore, researchers may imitate prior work (Haveman 1993) to establish credibility (Staw and Epstein 2000) or project the perception they use contemporary methods (DiMaggio and Powell 1983). From a more positive point of view, one could argue a growing number of internal citations reflects the growth of norms and knowledge about appropriate tools for analyzing sophisticated theoretical models. Whether for negative or positive reasons, one could argue IS researchers signal their compliance to norms by citing a high number of method citations internal to their field. By doing so, researchers signal they are adhering to established IS norms for conducting rigorous research.

On the other hand, if there are limited internal citations, IS researchers may turn to original resources (i.e., citing method papers external to IS) as a means to overcome knowledge barriers, avoid compounding citation errors, establish credibility (Partington and Jenkins 2007), gain legitimacy (Dacin et al. 2002; Hargadon et al. 2001), and ensure their application is consistent with guidelines for use of the technique (George et al. 2006). However, over a large period of time, we believe the internalization argument dominates; therefore:

> *H3: IS researchers are more likely to use second-generation techniques versus first-generation techniques when there is a high degree of knowledge internalization.*

As researchers grow more familiar with techniques, they may bundle knowledge found in external material and internalize or encapsulate their knowledge within their own field (Grover et al. 2006). Hence, instead of relying upon external literatures (Rao et al. 2001), IS researchers should increasingly turn to the IS field's maturing internal knowledge base (Grover et al. 2006) for guidance on when to use different techniques (Hamilton et al. 1982). Hence:

> *H3a: Time strengthens (moderates) the association between the degree of knowledge internalization and the use of second-generation techniques versus first-generation techniques.*

METHOD

Consistent with previous studies (Palvia et al. 2003; Zhang et al. 2005), we selected articles published in four leading, peer-reviewed academic journals to assess the use of first- and second-generation techniques in the IS discipline: *Management Information Systems Quarterly* (MISQ), *Information Systems Research* (ISR), *Journal of Management Information Systems* (JMIS), and *Journal of the Association for Information Systems* (JAIS). These journals are commonly considered top journals in IS research (Hardgrave and Walstrom 1997; Lowry et al. 2004; Zhang et al. 2005).

Our unit of analysis is a research article—as these reflect the behavioral choices made by the researchers. We restricted our search to articles published from January 1990, the year during which SEM was first introduced into mainstream IS research (Gefen et al. 2000; Straub 1990), through December 2008. Since we were interested in the

use of either first-generation or second-generation techniques, we manually screened for regression or structural equation modeling (including partial least squares) in the method section. The article was coded if either of these analytic techniques was used for primary statistical analysis (Gefen et al. 2000). We excluded articles that employed a research design which was not conducive to either regression or SEM. For example, we did not code articles that used ANOVA to test an experimental design. We also excluded studies using archival data (e.g., citation analysis) or unobtrusive measures (e.g., computer system productivity measures). For each article, we recorded the journal name, publication year, analytic technique used, whether or not mediators were included in the model, whether or not moderators were included in the model, and the number of methodological citations. The number of methodological citations was categorized as either internal or external. Citations were recorded as internal if the article was published in IS journals such as the four used for this study or journals like *Communications of the ACM*, *Information & Management*, and *Communications of the Association for Information Systems*. Citations were recorded as external if the original article was published in multidisciplinary journals like the *Academy of Management Journal,* or journals in disciplines such as marketing, psychology, or sociology. Our review of the literature yielded 265 usable articles.

Measurement

Our dependent construct, "First- Versus Second-Generation Technique Use," was operationalized as the IS researchers' choice of analytic technique. We considered this a discrete, binary choice between forms of SEM (e.g. maximum likelihood, expectation-maximation, Bayesian, PLS) and regression. We assigned a "1" when SEM was used in the methodology section of the paper under analysis and "0" when regression was used. Papers that included both SEM and regression techniques were excluded from our study.

"Rational choice" was operationalized using a discrete binary choice of mediators and moderators. We assigned a "1" when mediators were used in the theoretical model and "0" when they were not. We also assigned a "1" when moderators were used in the theoretical model and "0" when they were not. Papers that included both mediators and moderators in the same theoretical model were excluded from our study.

To measure our second exogenous construct, "Degree of Knowledge Internalization," we used two variables: number of external method citations and number of internal method citations. The number of internal method citations, on the other hand, captures the researchers' interaction with prior research efforts (Hamilton et al. 1982) and is an acknowledgement of previous IS researchers who have successfully implemented second-generation techniques in published articles. We then calculated the degree of knowledge internalization by dividing the number of internal citations by the number of external citations to get a ratio of internal to external citations.

To estimate the influence of time, we considered two options. The first option was to consider time as a continuous variable. Using this approach, we could compare the overall trend toward an analytic technique. The second option, on the other hand, was to consider time as a dichotomous variable. With this approach, we would be able to compare two distinct time periods. Since this second option is more consistent with diffusion research (e.g., Rogers 2004), we chose to split the data into two periods to capture different diffusion stages of these techniques in the literature. The first period, 1990–2002, will be referred to as the "early period" hereafter. The second period, 2003–2008, will be referred to as the "later period." While this may appear to be an arbitrary year for splitting our sample, our decision was based on the publication of Gefen et al.'s 2000 article in CAIS's October issue ("Structural Equation Modeling and Regression: Guidelines for Research Practice"). Gefen et al.'s work presented heuristics and rules-of-thumb for proper use of SEM-based analytical tools in clear language and an easily followed tutorial. Therefore, we believe researchers publishing after this article had ready access to information on first- and second-generation techniques and their proper use. We chose 2002 to represent the delay in publication time since Gefen et al.'s 2000 article.

Finally, we coded two other variables to rule out confounding factors: research topic and research type. The research topic consisted of five different categories based on Sidorova et al.'s (2008) five core research areas. Each study was evaluated and placed into the following categories: IS Development, IT and Groups, IT and Individuals, IT and Markets, and IT and Organizations. IS Development studies included topics such as risk management, training, and prototyping. These studies were coded as a "0." The category "IT and Groups" included studies on teams and groups, both virtual and physical; these were coded as a "1." The research area "IT and Individuals" consisted of all studies on individual-level topics such as individual technology acceptance, trust, and satisfaction. These studies were coded as a "2." All marketing and e-commerce studies were included in the "IT and Markets" category; these studies were coded with a "3." Finally, studies on supply chain management, ERP implementations, knowledge management, and industry-level topics were categorized under "IT and Organizations" and were coded as a "4."

The research type was operationalized as the confirmatory or exploratory nature of the study. We considered this a discrete, binary choice between exploratory studies and confirmatory studies. We assigned a "1" when the study was confirmatory (i.e., research that confirmed previously tested models) and "0" when it was exploratory (i.e., studies generating new models or adding new variables or new relationships). The results for the confounding factors analyses are presented in Appendix B.

RESULTS

Our dependent variable is dichotomous ("0" for first-generation techniques and "1" for second-generation techniques). Since ordinary least squares (OLS) regression assumes the residuals from an analysis will be normally distributed (Cohen et al. 2003), we used logistic regression (Peng and So 2002), which assumes a binomial probability distribution. We estimated our model in SPSSv15.[4] The equation for the logistic regression is

$$Equation\ 1: \text{logit}(p) = \ln\left(\frac{p}{1-p}\right) = \beta_0 - \beta_1 \text{ x TIME} + \beta_2 \text{ x MED} + \beta_3 \text{ x MOD} + \beta_4 \text{ x INT}$$

where ln is the natural logarithm, p = Pr(SGTA=1) is the probability of second-generation technique adoption, $p/(1-p)$ is the "odds ratio—the probability of the event divided by the probability of the nonevent" (Soares-Aguiar et al. 2008, p. 127), SGTA is the second-generation technique adoption, TIME is the time period of publication, MED is the use of mediators in the model, MOD is the use of moderators in the model, and INT is the number of internal method citations divided by the number of external ones.

The next two sections present the results of our analyses. The first section describes the results of the general use of first- and second-generation techniques over the entire period 1990–2008. The second section reports hypothesis test results for rational choice, degree of knowledge internalization, and the moderating influence of time on use of first- and second-generation analytic techniques.

Descriptive Use of Analytical Techniques

Our review of the literature suggests second-generation techniques have become one of the dominant methods across leading IS journals (see Table 2). Second-generation techniques were used in 77 percent of the empirical papers published in ISR from 1990–2008. The lowest incidence was in JMIS, which used second-generation techniques in 62 percent of articles.

Table 2: Use of First- vs. Second-Generation Techniques 1990–2008

Data Analysis Technique	MISQ (n = 74)	ISR (n = 70)	JMIS (n = 101)	JAIS (n = 20)
First Generation	16	16	38	4
Second Generation	58	54	63	16
1st and 2nd Generation[5]	4	11	5	0

Table 3 presents the number of articles published by each journal containing a first- or second-generation technique and the percentage of the analyses used per journal for 1990–2002 and 2003–2008. In the early period in MISQ, 76 percent of the empirical articles used some form of SEM; this increased to 80 percent in the later period. Similarly, second-generation techniques were used in 74 percent of the articles in the early period in ISR, but increased to 81 percent in the later period. Growth in second-generation techniques doubled in percentage terms in JMIS. In the early period, researchers used some form of SEM in 43 percent of their published articles. In the later period, however, they used second-generation techniques in forty-one out of fifty articles; this is a total of 82 percent of the articles published in 2003–2008. Finally, growth for second-generation techniques in JAIS went from 50 percent to 88 percent. We interpret this increase in JAIS with caution since the early period percentage was based on small numbers (i.e., 2 second-generation articles out of 4 total articles).

[4] As noted by an anonymous reviewer, we chose a first generation technique for our analysis. While structural modeling techniques provide some significant advantages for mediation (Baron and Kenny 1986), these advantages do not apply to moderation tests such as the one included in our model (e.g., a simple many-to-one relationship where the DV is a dichotomous variable). Even though more sophisticated second-generation techniques like χ^2 difference tests and PLS allow researchers to perform moderation tests (Carte and Russell 2003), we chose to use a more traditional approach in line with other similar research models (Soares-Aguiar and Palma-dos-Reis 2008).

[5] These papers were removed from the analysis so are not included in the sample size totals.

Table 3: Use of First- vs. Second-Generation Techniques Early vs. Later Periods					
Data Analysis Technique		MISQ (n = 74)	ISR (n = 70)	JMIS (n = 101)	JAIS (n = 20)
Regression First Generation	1990–2002	7	9	29	2
	2003–2008	9	7	9	2
SEM or PLS Second Generation	1990–2002	23	25	22	2
	2001–2007	35	29	41	14

Table 4 presents the number of articles that used first- or second-generation techniques in the method section of the paper. For MISQ, articles citing second-generation techniques were published as much as, or more frequently than, first-generation techniques in every year except 1992 and 1996. Similarly, ISR published an equal amount or more articles using second-generation techniques in every year except 1992, 1993, and 1998. In contrast to MISQ and ISR, JMIS published an equal number or more articles using first-generation techniques from 1990 until 1998 (the single exception was 1995). From 1999 through 2008, JMIS followed the same trend as MISQ and ISR and published more articles using second-generation techniques. Finally, articles published in JAIS have used second-generation techniques more than first-generation techniques in every year except 2000, the year JAIS was introduced, and 2008.

Table 4: Analytical Technique Article Counts by Journal and Year											
Journal	Generation	Year									
		'90	'91	'92	'93	'94	'95	'96	'97	'98	'99
MISQ	First	0	1	1	0	0	0	2	0	2	0
	Second	0	1	0	1	2	2	0	3	2	1
ISR	First	0	1	2	1	0	0	0	2	1	1
	Second	1	2	0	0	2	3	2	3	0	3
JMIS	First	2	2	1	3	1	1	4	1	6	4
	Second	0	1	1	1	1	2	2	0	0	5
JAIS	First	0	0	0	0	0	0	0	0	0	0
	Second	0	0	0	0	0	0	0	0	0	0
Overall	First	2	4	4	4	1	1	6	3	9	5
	Second	1	4	1	2	5	7	4	6	2	9
Absolute Comparison of Use of Techniques		-1	0	-3	-2	4	6	-2	3	-7	4
Percentage of Second Generation Used		33	50	20	33	83	88	40	67	18	64

Table 4 (cont): Analytical Technique Article Counts by Journal and Year										
Journal	Generation	Year								
		'00	'01	'02	'03	'04	'05	'06	'07	'08
MISQ	First	0	0	1	0	0	3	1	4	1
	Second	6	3	2	6	3	6	9	4	7
ISR	First	1	0	0	1	0	0	0	0	6
	Second	2	1	6	3	4	5	5	6	6
JMIS	First	0	1	3	1	0	3	0	4	1
	Second	1	3	5	6	6	5	6	9	9
JAIS	First	2	0	0	1	0	0	0	0	1

Table 4 (cont): Analytical Technique Article Counts by Journal and Year										
Journal	Generation	Year								
	Second	0	1	1	4	1	1	4	4	0
Overall	First	3	1	4	2	0	6	1	9	9
	Second	9	8	14	19	14	17	24	23	22
Absolute Comparison of Use of Techniques		-1	6	7	10	16	14	11	23	15
Percentage of Second Generation Used		33	75	89	78	86	100	74	96	74

Correlation and Convergent Validity

Table 5 provides variable correlations. All of our exogenous variables are significantly correlated with the dependent variable. Most of the independent variables are significantly correlated with each other less mediation with time and mediation with moderation. The largest correlation among all the variables is between the technique chosen and "internal/external" at 0.3. However, even this value is not large enough to suggest issues with multicollinearity (Tabachnick et al. 2007).

Table 5: Pearson Correlations				
	1st- vs. 2nd-Generation Technique	Time	Mediation	Moderation
1st- vs. 2nd- Generation Technique	--			
Time	0.23**	--		
Mediation	0.29**	0.11	--	
Moderation	–0.12*	0.19**	-0.08	--
Internal/External	0.30**	0.27**	0.13*	0.16*
** Correlation is significant at the 0.01 level (2-tailed) * Correlation is significant at the 0.05 level (2-tailed)				

Hypotheses: Rational Choice and Degree of Knowledge Internalization

Logistic regression uses maximum likelihood estimations to test the differences in the deviances of two different models. These differences are referred to as "fit" functions. R_L^2 is one common measure of "fit" that employs deviance measures based on measures of likelihood following the form of R^2 from ordinary least squares regression (Cohen et al. 2003). It is defined as the difference between the deviance measures (e.g., –2 log-likelihood statistics) of the null (or initial) model (D_{null}) and the model with all the predictors (D_k) divided by the deviance measure of the null model (Cohen et al. 2003; Peng et al. 2002). This is expressed in the following equation:

$$Equation\ 2: R_L^2 = \frac{D_{null} - D_k}{D_{null}}$$

Individual statistics are then measured by removing the predictor being tested and calculating the R_L^2. The R_L^2 for these statistics is computed by subtracting the deviance with all the predictors in the model, except the predictor in question, from the deviance with all the predictors in the model and then dividing by the deviance measure of the null model (Peng et al. 2002). The significance of an effect size is determined by the χ^2 difference test. This test is calculated by subtracting the deviance with all the predictors in the model from the deviance of the null model (without any predictors). If this results in a zero fit function, it would indicate the model is a perfect fit (Cohen et al. 2003; Peng et al. 2002). For the full research model, the test statistic is distributed as a χ^2 with the degrees of freedom equaling the number of predictors in the model. For the unique effect sizes, the test statistic is distributed as a χ^2 with the degrees of freedom equaling one (Cohen et al. 2003). The calculations for the model and unique effect sizes are displayed in Table 6.

Table 6: R_L^2 Change from 1990-2002 to 2003-2008[6]					
	Full Research Model	Year	Mediation	Moderation	Internal/ External
Overall	24.50%**	2.32%*	3.15%**	2.03%*	23.60%**
1990-2002	9.28%**	n/a	0.25%	2.42%*	12.58%**
2003-2008	45.34%**	n/a	14.80%**	1.65%	43.00%**
** R_L^2 is significant at the 0.01 level (2-tailed) * R_L^2 is significant at the 0.05 level (2-tailed)					

Binary logistic regression is used to predict the logit (log of the odds) of an outcome by a set of predictors (Peng et al. 2002; Tabachnick et al. 2007). We need an odds "ratio" in order to calculate the probability researchers will be in one group versus another. By converting the regression coefficient (which is used to predict the logit) into an exponential, we get this odds ratio (Cohen et al. 2003; Peng et al. 2002). This exponential is expressed as Exp(β) in Tables 8 and 9.

The Exp(β) can be used to calculate the likelihood (or probability) a researcher will use first- versus second-generation techniques (Soares-Aguiar et al. 2008). The regression coefficients (β) express the direction of the relationship, where a positive number means the researcher is more likely to use second-generation techniques and a negative number means the researcher is more likely to use first-generation techniques. For example, Table 7 shows researchers were almost three times more likely to use second-generation techniques than first-generation techniques when mediators were included in the model (β = 1.014). On the other hand, the odd ratio is 1 to 3 (Exp(β) = 0.331) researchers will choose second-generation techniques over first-generation techniques (see Equation 3). This means there is a 25 percent probability researchers will choose second-generation techniques when they include moderators in their theoretical model (see Equation 4).

$$\textit{Equation 3: Odds Ratio} = 1 \text{ to } \frac{1}{\text{Exp}(\beta)}$$

$$\textit{Equation 4: Probability} = \frac{\text{Exp}(\beta)}{\text{Exp}(\beta) + 1} \text{ x } 100$$

Table 7: Logistic Regression Coefficients and Their Significance Levels for the Model				
	Independent Variables on the Logistic Regression	Regression Coefficients (β)	Sig.	Exp(β)
H1 and H2: Rational Choice	Mediation	1.014	0.003**	2.756
	Moderation	-1.107	0.018*	0.331
H3: Degree of Knowledge Internalization	Internal/External	3.491	0.000**	32.830
Control	Binary Variable—Year	0.911	0.013*	2.487
** significant at 0.01 * significant at 0.05				

Hypothesis 1 suggests researchers will be more likely to use second-generation techniques when they are testing mediation in their models. As shown in Table 6, the significant R_L^2 values reported for the entire period from 1990–2008 indicate researchers used mediation (R_L^2 = 3.15%) as a reason for choosing an appropriate analytic technique. Table 7 confirms researchers are almost three times more likely to use second-generation techniques in lieu of first-generation techniques when they have included mediators in their theoretical model. This is expected since, in general, theoretical models containing mediators are considered more complex and require the choice of second-generation techniques (Iacobuuci et al. 2007). Therefore, Hypothesis 1 is supported.

[6] This index is not a goodness of fit index with an interpretation as "proportion of variance accounted for, as in OLS regression" (Cohen, Cohen, West, and Aiken 2003) due to the inherent heteroscedasticity (i.e. every value of the criterion does not have the same error variance) (Cohen, Cohen, West, and Aiken 2003). Since these R_L^2 analogs are not as well-behaved as the R^2 from OLS regression and tend to be smaller than R^2 for good models in OLS regression, we rely on the odds ratios reported in Tables 8 and 9 for the majority of our interpretations (Cohen, Cohen, West, and Aiken 2003).

Hypothesis 2 indicates researchers will be more likely to use first-generation techniques when they are testing moderation in their models. Table 6 shows the significant R_L^2 values reported for the entire period from 1990–2008 indicate researchers used moderation (R_L^2 = 2.03%) as a reason for choosing an appropriate analytic technique. Table 7 confirms researchers are three times more likely to use first-generation techniques as opposed to second-generation techniques when they have included moderators in their model (the odds are 1 to 3 for choosing second-generation techniques when moderators are included in the model). Therefore, Hypothesis 2 is supported.

Hypothesis 1a states researchers are more likely to use second- versus first-generation techniques in the later period as opposed to the earlier period due to the inclusion of mediators. Table 6 indicates the inclusion of mediators in the theoretical model was not a reason researchers chose to use second-generation techniques (as indicated by the insignificant R_L^2 value of 0.25%) in the early period. In the later period, researchers were much more likely to choose second-generation techniques when they included mediators in their theoretical models. The R_L^2 value is 14.80%. Table 8 provides further information about the likelihood researchers will use second-generation techniques due to mediation. In the early period, researchers were not significantly more likely to choose second-generation techniques when including mediators in their models. In the later period, on the other hand, researchers were over twelve times more likely to use second- vs. first-generation techniques when they included mediators in their models. This difference is significant with a χ^2 difference of 15.853 (significant at 0.01). Since researchers' use of second-generation techniques was associated with rational choice more in the later period, we found support for Hypothesis 1a.

Table 8: Logistic Regression Coefficients and Their Significance Levels per Period

	Independent Variables on the Logistic Regression	Early Period			Later Period		
		Regression Coefficients (β)	Sig.	Exp(β)	Regression Coefficients (β)	Sig.	Exp(β)
H1a and H2a: Rational Choice	Mediation	0.258	0.537	1.295	2.511	0.000**	12.320
	Moderation	–1.253	0.066*	0.286	–1.019	0.176	0.361
H3a: Degree of Knowledge Internalization	Internal/ External	2.166	0.015**	8.724	6.633	0.002**	759.699

** significant at 0.05
* significant at 0.1

Hypothesis 2a states researchers are less likely to use first- versus second-generation techniques in the later period as opposed to the earlier period due to the inclusion of moderators. Table 6 indicates the inclusion of moderators in the theoretical model was a reason researchers chose to use first-generation techniques (as indicated by the significant R_L^2 value of 2.42%). In the later period, researchers were not any more likely to choose first- or second-generation techniques when they included moderators in their theoretical models as indicated by the insignificant R_L^2 value of 1.65%. Table 8 provides further information about the likelihood researchers will use first-generation techniques due to moderation. In the early period, researchers were three and a half times more likely to use first-generation techniques when they included moderators in their models (the odds are 0.286; the odds ratio is 1 to 3.5 for choosing second-generation techniques when moderators are included in the model). In the later period, on the other hand, researchers were just as likely to use second- vs. first-generation techniques when they included moderators in their models. However, this difference is insignificant with a χ^2 difference of 1.832. Since researchers' use of first-generation techniques was not associated with the inclusion of moderators in the later period, we found moderate support for Hypothesis 2a.

Hypothesis 3 indicates researchers are more likely to use second-generation techniques versus first-generation techniques when they reference more internal method citations as compared to external method citations. Table 6 indicates the degree of knowledge internalization does have a significant unique effect size at 23.60 percent. Table 7 confirms this by showing the Exp(β) is significant, so researchers were almost 33 times more likely to use second-generation techniques over first-generation techniques when the ratio of internal to external citations was high. Therefore, we find support for this hypothesis.

Hypothesis 3a addresses the temporal aspect of the degree of knowledge internalization: in the later period, researchers will be more likely to use second-generation techniques when they cite internal resources. Table 6 shows the degree of knowledge internalization is significant in both the early and later periods but is much higher in the later period (respective R_L^2 values of 12.58% and 43.00%). This difference is significant with a χ^2 difference of

28.287 (significant at 0.01). Table 8 confirms this by showing the Exp(β) is significant in both the early (p = 0.015) and the later period (p = 0.002). However, the Exp(β) values show the true difference between these two periods. In the early period, researchers were almost nine times more likely to use second- versus first-generation techniques when they referenced internal citations. In the later period, researchers' likelihood of using second-generation techniques increases to almost 760 times that of using first-generation techniques. This difference is significant with a χ^2 difference of 28.287 (significant at 0.01). Since researchers are more likely to use second- vs. first-generation techniques when a higher number of internal citations are referenced in the later period, we find support for this hypothesis.

In summary, the logit analysis yielded significant estimates of model fit for the entire model (24.50% at a 0.01 significance level), for the early period (9.28% at a 0.01 significance level), and for the later period (45.34% at a 0.01 significance level). We found rational choice explained second-generation technique usage (H1 and H2), but it provided a stronger explanation in the later period as opposed to the early period (in support of H1a and H2a). We also found the degree of knowledge internalization significantly explained the use of second-generation techniques overall (23.60% at a 0.01 significance level) in support of H3 and that time significantly strengthened this relationship (H3a).

Since reliance on external citations decreased dramatically in the later period, we believe our analysis provides useful insight into the degree of knowledge internalization of second-generation techniques that has occurred in IS. First, reliance on external references signals that IS applications of second-generation techniques were both technically sound and legitimate tools for conducting empirical analysis (Partington et al. 2007; Pederson 2006; Westenholz, Pederson, and Dobbin 2006). Second, our analysis indicates as use of second-generation techniques became more legitimate and diffuse in IS, researchers increasingly turned to internal sources of information on second-generation techniques to justify their work. Hypothesis test results are summarized in Table 9.

Table 9: Hypothesis Results

	Independent Variables on the Logistic Regression	Result
Hypothesis 1	IS researchers are more likely to use second-generation techniques versus first-generation techniques when they are testing mediation.	Supported
Hypothesis 1a	Time strengthens (moderates) the association between mediation and the use of second-generation techniques versus first-generation techniques.	Supported
Hypothesis 2	IS researchers are more likely to use first-generation techniques versus second-generation techniques when they are testing moderation.	Supported
Hypothesis 2a	Time weakens (moderates) the association between moderation and the use of first-generation techniques versus second-generation techniques.	Moderately Supported
Hypothesis 3	IS researchers are more likely to use second-generation techniques versus first-generation techniques when there is a high degree of knowledge internalization.	Supported
Hypothesis 3a	Time strengthens (moderates) the association between the degree of knowledge internalization and the use of second-generation techniques versus first-generation techniques.	Supported

IMPLICATIONS

The call for methodological rigor in IS has been prominent since the late 1980s (Straub 1989). In response, we have seen a growth in the use of SEM techniques in the IS field since 1990. In this study, we examined whether the adoption of these techniques by IS researchers was driven by rational choice of a specific analytic technique and knowledge internalization of second-generation techniques. A synopsis of our implications is presented in Table 10.

Table 10: Research Implications

	Implications
Hypotheses 1 and 2	Overall, IS researchers use analytic tools consistent with their theoretical models and their fit with the analytic technique. This suggests researchers on aggregate are correctly assessing the fit between the nature of the model and the analytic technique when they choose a method.

Table 10: Research Implications

	Implications
Hypotheses 1a and 2a	Over time, IS researchers were more likely to choose second generation techniques when testing mediation and moderation. This suggests the following: • IS researchers need to take particular care during the early stages of adoption of a research method. In particular, they need to make sure they understand the reasons for adopting new methodologies and ensure they employ those methodologies appropriately. • IS researchers are getting better at assessing the fit between increasingly sophisticated and complex theoretical models (e.g. the addition of mediation and moderation variables) and the analytic technique. • Recent methodological advances surrounding the inclusion of latent interaction (moderation) variables in SEM techniques hold promise for strengthening the rigor of second generation techniques (Marsh et al. 2004). Therefore, IS researchers should assess the effectiveness of these advances and, where appropriate, apply them in their own methodologies.
Hypothesis 3	Overall, our analysis suggests IS researchers have internalized the appropriate knowledge about the proper use and assumptions of first and second generation techniques. This means we have access to relevant and legitimate information about the appropriate use of analytic techniques in readily available and familiar sources that explain the technique in a way that contextualizes the technique for the field and potentially provides references to other similar research for additional information or examples.
Hypothesis 3a	Over time, we have witnessed an accumulation of knowledge in the field where second generation techniques became indoctrinated into the knowledge repository for IS researchers. This suggests the following: • IS Researchers are getting better at codifying and contextualizing the use of second generation techniques in IS research. • Method use in the early periods contributes to richer discourse in later periods. • IS Researchers are positioned to make an impact on the use of methodological tools in other fields.

Our analysis of empirical research in top IS journals from 1990–2008 indicates IS researchers have used analytic tools in a manner that is consistent with the nature of their theoretical models and the assumptions of the analytic technique they chose. In addition, we found researchers in this time period had access to and referenced internal knowledge repositories about the proper use of first- and second-generation techniques. Taken together, this suggests IS researchers were able to appropriately assess the fit between the nature of the model and the analytic technique by relying on methodological information provided by other IS researchers. This implies the information available in familiar IS resources provides the same level of relevance and legitimacy found in external sources. Our research shows IS researchers are looking at both methodological articles (e.g., Boudreau et al. 2001; Carte et al. 2003; Chin 1998a; Gefen et al. 2000; Moore and Benbasat 1991; Straub 1989) as well as other empirical research articles (e.g. Compeau and Higgins 1995; Segars and Grover 1993; Teo, Wei, and Benbasat 2003) to legitimize their work. Armed with information that is both detailed in an IS context and contextualized in other studies, IS researchers can confidently reference the analytic techniques employed in previous IS studies.

In addition to the overall effects of knowledge internalization on IS researchers' ability to assess the fit between the nature of the model and the analytic technique, we also found an effect of time. We found, over time, the rational choice associated with using second-generation techniques changed. While IS researchers did not originally leverage second-generation techniques to test complex structural models (i.e., mediation), IS researchers in the later period were more likely to use second-generation techniques than first-generation techniques to test mediation and just as likely to use either technique for moderation. This suggests later use of second-generation techniques was driven more by the sophistication of the theoretical model (i.e., the inclusion of both mediators and moderators). In other words, the use of second-generation techniques was increasingly guided by the features of theory over time. Given that theoretical models involving mediation and moderation require richer explanations, our analysis suggests IS researchers are appropriately assessing the fit between increasingly sophisticated and complex theoretical models (e.g., the addition of mediation and moderation variables) and the analytic technique. On the other hand, the lack of support for rational choice in the early period when mediation is included in the theoretical model indicates IS researchers need to take particular care during the early stages of adoption of a research method. In particular, they need to make sure they understand the reasons for adopting new methodologies and ensure they employ those methodologies appropriately.

To determine the degree of knowledge internalization in our field, we chose Gefen et al. (2000) as an inflection point. We felt this article clearly codified knowledge about both first- and second-generation techniques for our field. Our analysis shows the point of inflection was appropriate: since Gefen et al.'s (2000) article, there has been an accumulation of knowledge in the field where second-generation techniques became indoctrinated into the knowledge repository for IS researchers. In the early period, IS researchers' use of second-generation techniques was associated with citing some method papers found in journals external to the IS field and some internal to the IS field, yet researchers still relied more heavily on internal citations (they were eight times more likely to use second-generation techniques with a high degree of knowledge internalization). However, over time, our analysis suggests external method papers were cited less frequently in papers published in core IS journals. After 2002, IS researchers turned from citing some external references to referencing mostly domain-specific papers for justifying their use of second-generation techniques. This suggests we are getting better at codifying and contextualizing the use of second-generation techniques in IS research. This, in turn, has fostered an environment that encourages a mature and encapsulated knowledge of second-generation techniques within the IS domain (Grover et al. 2006). IS researchers are able to turn to internal, familiar sources of knowledge and legitimacy for their use of statistical tools.

In addition to the benefits for internal researchers, these sources also position the IS field to make contributions to other fields. For example, Gefen et al.'s (2000) article has been cited over 799 times[7] and has been referenced by other management disciplines (Ferris et al. 2005; Paul and Anantharaman 2003); Chin et al.'s (1998a) article has been cited almost 858 times,[7] including in the fields of psychology (Huey, Henggeler, Brondino, and Pickrel 2000), economics (Becker and Clement 2006), and agriculture (Tenenhaus, Pages, Ambroisine, and Guinot 2004); and Moore and Benbasat's (1991) paper has been cited over 1948 times[7] in IS as well as in the medical field (Lorenzi, Riley, Blyth, Southon, and Dixon 1997), public administration (Nedovic-Budic and Godschalk 1996), psychology and marketing (Yoh, Damhorst, Sapp, and Laczniak 2003), and travel research (Yuan, Gretzel, and Fesenmaier 2003). In summary, this reinforces the contention of some that other fields are paying attention to our research (Grover et al. 2006).

LIMITATIONS AND FUTURE RESEARCH

Prior to considering directions for future research, it is important to consider the limitations of our study. First, we reviewed second-generation technique use in four journals in the IS field. While many IS researchers publish their work in these journals, there are other journals like *Decision Sciences* and *Management Science* that have been classified as top journals in IS research (Hardgrave et al. 1997; Zhang et al. 2005). Further, because we focused on a small set of well-regarded journals, it is less clear whether a broader set of journals may have yielded different results. Thus, we acknowledge our discussion should be extended to the full body of IS research with caution.

Second, our constructs only offer a limited model complexity based perspective for the rational choice of first- or second-generation techniques. The two items representative of rational choice, mediation and moderation, are not comprehensive but consistently appear in papers as reasons to use the different analytic techniques.

Third, the available data restricted our operationalization of the variables (less Degree of Knowledge Internalization) to discrete, binary choices. In particular, this limited our analysis of model complexity in that a model with one moderator or mediator was considered as complex as a model with multiple moderators and mediators. Despite this limitation, our results indicated complexity at any level impacts the researchers' choice of second-generation techniques.

Fourth, we acknowledge additional explanations may exist for the use of second- versus first-generation techniques in the IS field (Straub, Boudreau, and Gefen 2004; Straub 1989). For example, we suspect the IS disciplines' use of second-generation techniques differs from referent fields. In our review of second-generation technique use, we found the PLS approach was widely used in IS research. However, if one reads extensively in disciplines such as Organizational Behavior or Marketing, PLS rarely appears in top journals. A plausible explanation for PLS's extensive diffusion in IS research is the widespread availability of tools such as PLSGraph (Chin 1998b) that were created by members of the IS community. Unfortunately, we lack data on the level of awareness of statistical tools or creators of tools found in different fields. Therefore, future research on the use of analytic techniques could investigate whether the diffusion of factors external to the field, such as software packages required for their application, drives their adoption in the IS field.
Finally, this study focused on the degree of knowledge internalization within a single academic field. Our research provides evidence that researchers are more likely to use second-generation techniques when they reference other IS researchers who use the same techniques. While we assumed the degree of knowledge internalization would be

[7] Per Harzing's Publish or Perish (http://www.harzing.com/pop.htm) as of January 23, 2010.

a positive or healthy trend in that knowledge is codified and contextualized within our field, we also acknowledge the degree of knowledge internalization could be negative or unhealthy. For example, a higher degree of knowledge internalization could reflect a social effect where researchers only choose a technique because other IS researchers are using the chosen analytic technique. We don't subscribe to this cynical view and are more upbeat about the field (Grover, Straub, and Galluch 2009). Any social contagion effect, however, is mitigated by the fact that our method pieces are indeed impacting other fields as described earlier (e.g., general management, psychology, economics, medicine, and public administration as illustrated earlier). Second, the significance of the rational choice effect in our data indicates contagion might be limited in our field. Finally, we are optimistic about the efficacy of review processes where reviewers and editors can assess the merits of each paper and ensure a specific analytic technique is being used for a good reason.

To further emphasize the impact of degree of knowledge internalization, we recommend one logical extension of our work: to examine whether the use of second-generation techniques in different academic fields was a function of the similar drivers of change or whether there is interplay of drivers of adoption across fields. For example, do some academic fields have the ability to persuade, induce, or coerce the IS field to adopt new methodological techniques? Is there a level of homogeneity between the fields that encourages use of a specific methodology? Did the IS field truly gain an enhanced efficiency due to the adoption of second-generation techniques relative to other fields? Are IS researchers subject to bandwagon effects across fields in their decision to use analytic techniques? These are just a few interesting questions that could be pursued in future studies focused at the “field” level of analysis.

CONCLUSION

It is important for IS researchers to make methodological choices that are consistent with the overarching theory and features of the data. This study offers a modest effort at exploring rational explanations and knowledge barriers associated with choice of analytic technique in IS research. Our examination of first- and second-generation techniques from 1990–2008 provides evidence that, on aggregate, IS researchers rationally use second-generation techniques while attempting to use knowledge codified and contextualized in IS research. Also, our results suggest that over time the major driver for second-generation use became the researchers' understanding of the fit between the nature of the model and the analytic technique. Further, there is evidence of knowledge internalization changing over time. Researchers' reliance on internal over external knowledge changes as knowledge about second-generation techniques is encapsulated within the IS field. The increased use of internal citations reflects the quality of the internal knowledge, reducing the need for IS researchers to rely on intense external literature reviews. This is emphasized by the strengthening of rational choice over time. Overall, the diffusion of this “innovation” provides an interesting examination of a variety of forces at play and suggests IS research assimilates these methods into the field as it gets to a point where the methods are normatively adopted and used. Further research can examine the tipping point at which such normative influences might stagnate learning or be unproductive for the field.

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APPENDIX A: EXAMPLES OF FIRST- AND SECOND-GENERATION TECHNIQUES

Technique	Example Article
First Generation	
Linear Regression	(Agerfalk and Fitzgerald 2008)
ANOVA	(Gopal and Sivaramakrishnan 2008)
MANOVA	(Storey, Burton-Jones, Sugumaran, and Purao 2008)
Second Generation	
PLS	(Venkatesh, Brown, Maruping, and Bala 2008)
Maximum Likelihood	(Rutner, Hardgrave, and McKnight 2008)
SEM	(Son and Kim 2008)

APPENDIX B: RESEARCH TOPIC AND TYPE ANALYSIS

Logistic Regression Coefficients and Their Significance Levels for the Topic and Type Analysis

Independent Variables on the Logistic Regression	Regression Coefficients (β)	Sig.	Exp(β)
IS Development		**0.001**	
IT and Groups	-0.732	0.394	0.481
IT and Individuals	1.113	0.135	3.043
IT and Markets	2.132	0.085	8.436
IT and Organizations	-0.586	0.414	8.436
Exploratory vs. Confirmatory Research	0.536	0.051	1.710

Logistic Regression Coefficients and Their Significance Levels per Period for the Topic and Type Analysis

Independent Variables on the Logistic Regression	Early Period			Later Period		
	Regression Coefficients (β)	Sig.	Exp(β)	Regression Coefficients (β)	Sig.	Exp(β)
Adoption/Use		0.121			0.912	
Individual Differences	1.818	0.108	6.161	18.158	0.999	8.00E+07
Individual Impact	0.467	0.609	1.596	19.756	0.998	4.00E+08
IT Value	-0.992	0.088	0.371	0.143	0.867	1.154
Organizational Interaction	-0.622	0.334	0.537	0.58	0.606	1.787
Organizational-Level	-0.538	0.413	0.584	-0.707	0.427	0.493
Exploratory vs. Confirmatory Research	0.550	0.146	1.733	0.500	0.237	1.648

JOURNAL OF INFORMATION TECHNOLOGY THEORY AND APPLICATION

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