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Technology Clusters: Using Multidimensional Scaling to Evaluate and Structure Technology Clusters

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Empirical evidence suggests that the ownership of related products that form a technology cluster is significantly better than the attributes of an innovation at predicting adoption. The treatment of technology clusters, however, has been ad hoc and study specific: Researchers often make a priori assumptions about the relationships between technologies and measure ownership using lists of functionally related technology, without any systematic reasoning. Hence, the authors set out to examine empirically the composition of technology clusters and the differences, if any, in clusters of technologies formed by adopters and nonadopters. Using the Galileo system of multidimensional scaling and the associational diffusion framework, the dissimilarities between 30 technology concepts were scored by adopters and nonadopters. Results indicate clear differences in conceptualization of clusters: Adopters tend to relate technologies based on their functional similarity; here, innovations are perceived to be complementary, and hence, adoption of one technology spurs the adoption of related technologies. On the other hand, nonadopters tend to relate technologies using a stricter ascendancy of association where the adoption of an innovation makes subsequent innovations redundant. The results question the measurement approaches and present an alternative methodology.

The diffusion of innovations paradigm provides explanations for when and how a new idea, practice, or technique is accepted, rejected, or reevaluated over time in a given society (Rogers, 2003). The strength of the theory is in its ability to coherently structure and predict the rate of adoption of an innovation. According to Rogers (2003), the decision to adopt an innovation is predicted for the most part, by the perceived attributes of an innovation, and to a lesser extent by the personality of the potential innovator. In most research on adoption, the perceived attributes explains from around 49 to 87% of the variance in the rate of adoption (Rogers, 2003). Hence, a great deal of research attention has focused on measuring the key attributes of an innovation that influence adoption decisions.

Recent empirical evidence, however, suggests that the adoption of technological innovations is better predicted by the ownership of related innovations. This suggests that innovations are not viewed singularly, but rather as interrelated bundles of new ideas (Rogers, 2003). Following this, a number of researchers have begun including a list of related technologies in their predictive models for explaining the likelihood of adoption of a new technology. For the most part, however, the approach has been ad hoc, with lists of potential clusters or related technologies being formulated without any systematic reasoning other than some a priori assumptions about cluster relationships. This is primarily because the research investigating the boundaries between innovations, and research clearly identifying the clusters of related innovations is virtually inexistent or outdated. From a communication technology standpoint, LaRose and Atkin (1992) provide the only research to date that clearly focuses on identifying the boundaries between technologies. All subsequent research assumes a clustered relationship between technologies and implements the notion of technology clusters, rather than test for the composition of a cluster.

The current research attempts to redress this gap by systematically testing the relationship between communication technologies. To that end, the boundaries and relationships between communication technologies are evaluated and mapped using an associational–multidimensional scaling approach. This article is organized as follows: the first section presents the extant research on technology clusters followed by an overview of the multidimensional scaling approach; the second section presents the methodology; this is followed by the results, the analysis, and conclusions of the study.

Prior Research

Rogers (2003, p. 249) conceptualizes technology clusters as "one or more distinguishable elements of technology that are perceived as being interrelated." This notion of

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technology clusters was first proposed by Rogers (1986) to explain a market research study in which the adopters of consumer electronic innovations were found to be more likely to adopt newer, related consumer electronic innovations such as personal computers. These findings were later confirmed by Reagan (1987) who found that the adoption of most technologies studied was related to the adoption of another technology. This phenomenon of "related adoption" suggests that potential adopters view technologies as interrelated wholes rather than disparate technological entities (products). Hence, the adoption of any one technology from a cluster, spurs adoption of related technologies from within the same cluster.

One explanation for this behavior is the perceived attributes of innovations that constitute a cluster. According to Rogers (2003), innovations that form a cluster tend to be compatible with each other and possess similar attributes; that is, they presumably satisfy the same underlying need (LaRose & Atkin, 1992). iPods (iPod is a brand of portable digital audio and video player, which is a product of Apple Computer, Cupertino, CA.) are compatible with personal computers; hence, they are part of the same cluster, and individuals who possess personal computers are more likely to purchase iPods than individuals without personal computers. This suggests an associational process where individuals, consciously or subconsciously, relate technologies to each other.

These associational processes are fundamental to human cognition: The human mind organizes all stimuli based on their conceptual similarity with other objects, such that objects which are similar are more closely associated than those which are dissimilar. In this structural notion, concepts organized in the human mind are all related to each other through a web of coherent relations or structures. Synchronous associations between the concepts lead one from the construction of simple ideas to more complex ones.

Barnett and Siegel (1988) extended this associational view to explain the innovation diffusion process. They view diffusion as a cognitive process and the innovation as a combination of associative elements. According to Barnett and Siegel (1988), innovations provide an opportunity for new linkages or rearrangements of elements that have not been previously associated. As an innovation spreads though a social system, the conceptual configuration shared by the members change thereby altering their associative structures. The degree of reorganization of the associative elements is a function of the amount of information members of that system receive about the innovation (Woelfel & Fink, 1980). Innovations that cause a minimal change in the associational structure tend to be closely related. Hence, the resultant associations indicate the compatibility with the values, past experiences, and needs of the potential adopter.

Extent research using the associational principles is limited. For the most part, the associational model has been tested on single technologies or innovations, and the relationships between a technology and its perceived attributes. For example, Barnett and Siegel (1988) demonstrated the utility of the associational approach in explaining the diffusion of computer-assisted legal research (CALR) systems. Here, they examined the associational structures of the perceived attributes of a CALR system, among different individuals at different stages in the innovation-decision process, and found strong support for the model. As such, potential adopters and earlier adopters tended to more closely associate themselves with the relative advantages of the innovation than later adopters. The current research extends the associational model to the relationships between multiple technologies and the understanding of technology clusters.

Despite the importance of technology clusters, research comprehensively examining the relationships between technologies or their associations is limited. The dominant theoretic framework for understanding technology clusters stems from Rogers' (1986) market research study, and empirical evidence presented by Ettema (1984), LaRose and Atkin (1992), and LaRose and Hoag (1996).

Following Rogers (1984), Ettema (1984) found a relationship between the adoption of new text services and the adoption of other innovations. The findings were attributed to the "lifestyle needs" of adopters, suggesting that technologies formed clusters because they were compatible with the adopter's beliefs and attitudes. Under this notion, individuals who possess other "high tech" products because they fulfill a need for possessing new technological innovations adopt other "high tech" innovations. Subsequent research by LaRose and Atkin (1992) provided a different explanation.

LaRose and Atkin (1992) analyzed the adopters of consumer information services and found some empirical evidence for the innovation cluster concept. They found, however, that contrary to the "lifestyle" explanation, the adoption of consumer information services was related to the other functionally similar innovations. Hence, the adoption of audio text innovation was related to the adoption of other functionally similar innovations, such as 800 numbers, videotext and automatic teller machines, which shared an "information on demand" quality. They also found a stronger relationship between innovations that were functionally dissimilar but shared the same basic network access modalities. For example, speaker phones, automatic dialers, and conference calls, though functionally dissimilar were significantly correlated.

This led LaRose and Atkin (1992) to conclude that (a) technology clusters (membership) are narrower than previously posited by Rogers (1986); and (b) innovations that constitute a cluster technology are conceptualized differently, that is, technologies might be forming a cluster not due to their perceived attributes but rather due to their shared infrastructure. LaRose and Hoag (1996) extended these findings to the organizational adoption of the internet and the clusters of related innovations, and found that technology clusters formed a distinct factor, which was separate from the conventional attributes of an innovation.

Following this, much of the research on diffusion includes technology clusters as one of the predictor variables. None of the research, however, tests for the composition of clusters. For example, Kang (2002) measured the ownership

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of five electronic devices, namely video camera, videocassette recorder (VCR), personal computer (PC), video game system, and compact disc (CD) player as a potential cluster of technologies thought to be predictors of digital cable adoption. Leung and Wei (1999) included a list of four technologies as potential predictors of cellular phone adoption, namely call transfers, caller ID, news headlines, weather updates, and paging services. The lists of technologies that form a potential cluster are drawn a priori and are neither tested for their membership nor for their appropriateness. That is, the technologies included tend to be based on the researchers' knowledge and expectations, and are assumed to be isomorphic.

In addition to a priori assumptions of cluster membership, prior research assumes that all adopter categories use the same schema to cluster technologies. The meaning of technology, however, is socially constructed and unique to consuming groups within a system (Fulk, 1993; Weick, 1990). Hence, the meaning and resultant associations between technologies within clusters, and between clusters could be distinct and different for different adopter groups.

In conclusion, extent research on technology clusters makes a number of implicit assumptions that restrict the ability to generalize the results. There is, hence, a need to clarify some of these notions and test the relationships between technologies. The current research extends the associational perspective (Barnett & Siegel, 1988) to the study of technology clusters and poses the following research questions (RQ):

RQ 1a: What is the relationship between technologies that form a cluster? How is the relationship between technological innovations represented on a multidimensional space?

RQ 1b: What is the relative distance of innovations within and between clusters? How are the boundaries of each cluster determined?

RQ 2: What are the differences in the constitution of technology clusters, among adopters and among nonadopters of technological innovations?

Methodology

The extension of the associational model to the understanding of technology clusters requires a measurement system that meets the following requirements (Barnett & Siegel, 1988): (a) the links among a set of elements must be measured in terms of the similarity (or dissimilarity) among the elements. The measurement system needs to be capable of relating technologies to each other; (b) the measurement system needs to be holistic and capable of simultaneously measuring all integrated dimensions, and produce a complete description of the relationships between technologies within and across different clusters; (c) it must involve consensual measures that allow for predictions at both the individual and the aggregated or system level; and (d) to make possible calculations of the rate of change and/or degree of differences between associations of adopters and nonadopters, the measurement scheme must ideally be at the ratio level.

About the Galileo System

The Galileo system satisfies these demands (Woelfel & Fink, 1980). The Galileo system is an integrated methodology for metric multidimensional scaling using paired distance judgment data (Barnett & Woelfel, 1988; Woelfel & Fink, 1980). Rice and Rogers (1984) suggest its use to describe the changes in conceptual structures of adopters of information technologies.

The Galileo measurement begins by measuring dissimilarities among a set of concepts describing a domain, defined by these concepts, through a mechanism called *paired comparison* (every possible pair of the concepts' dissimilarities are measured). For example, given N concepts, the dissimilarity among $N(N - 1)/2$ pairs of symbols is estimated by respondents. The estimated data collected then yields a matrix of concept dissimilarities. These estimates are averaged to represent the shared collective meanings of the concept set, and then submitted to a multidimensional scaling algorithm from which a set of coordinate axes is produced (Lee & Barnett, 1997). From these coordinates, a space in the Galileo system is displayed that describes the cognitive structure about how the respondents think of those concepts. In such a space, the concepts exist as nodes without any attributes by themselves, and their attributes are defined by their comparisons (distances) to others (Woelfel & Fink, 1980).

The Galileo system's multidimensional scaling method is more precise when compared to traditional scale measurements. Gillham and Woelfel (1977) experimentally measured the precision of a Galileo type paired-comparison instrument against other scaling methods. They found that even in extreme cases when the Galileo ratio procedures might be only 50% reliable, it still generated about 2.70 times more reliable information when compared to a 10-point semantic differential scale, even if the semantic differential scales contained no random error (Woelfel & Fink, 1980). A vast body of communication, linguistic, and cross-cultural research has demonstrated the reliability and theoretical validity of the Galileo system (Barnett, 1977a, 1977b, 1980; Barnett & McPhail, 1980; Barnett, et al., 1981; Kincaid, Yum, Woelfel, & Barnett, 1983).

Procedures

To ascertain the products which constitute a technology cluster, it was first necessary to derive a list of typical telecommunication products. A list of 29 technologies was drawn from an extensive search of the diffusion literature. The research guiding the choice included research by Atkin (1993), Jeffers and Atkin (1996), Kang (2002), LaRose and Atkin (1992), Leung and Wei (1999), Vishwanath and Goldhaber (2003), and Vishwanath (2005). Table 1 presents the list of technologies.

Each technology represents a concept in the Galileo system; with 29 technologies, there are 29 concepts. Galileo also allows for the inclusion of the "self" as a concept; therefore, including this, there were a 30 concepts. Each concept was

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TABLE 1. Concepts tested in the study.

No.	Technology or Galileo concept name
1	PDA
2	TV
3	Laptop computer
4	YOURSELF
5	Cell phone - Blue Tooth enabled
6	Cable TV
7	Video camera
8	Cellular phone
9	Cellular phone with camera
10	Digital camera
11	Digital video camera
12	DVD player
13	Fax machine
14	Laptop compute with wireless
15	LCD flat panel display
16	MP3 player
17	Personal computer
18	High-speed Internet service
19	Plasma or flat screen TV
20	High-Definition TV
21	Satellite TV
22	Satellite radio
23	Cable subscription
24	Land line telephone
25	TIVO or DVR
26	VCR
27	Video game console
28	Wireless-enabled PDA
29	GPS system
30	Portable CD player or disk-man

Note. YOURSELF = self, i.e., person's own rating of him/herself.

included in a Web-based, paired-comparison questionnaire that asked respondents to report the differences between all possible pairs of concepts on an open-ended metric scale. An example criterion pair was presented: Computers and telephones are 50 units apart. The criterion pair was selected because the two concepts were fairly well known.

Respondents were instructed to report a number less than 50, if they perceived any two concept pairs to be more or less similar than computers and telephones; if they perceived the concepts to be less similar, a larger number was to be entered; if concepts were perceived to be identical, they were instructed to enter zero. No upper limit was set. Hence, respondents could, in theory, choose any number from zero to infinity, to indicate the differences between technologies.

An introductory communication class at the State University of New York at Buffalo completed the Galileo survey online, in the first 3 weeks of February 2005. College students were thought to provide a sound profile because students are often the most likely adopters of emerging technology innovations (Atkin, 1993).

Because 30 concepts results in 435 pair-comparisons and respondent fatigue is a concern, the Galileo system allows for a random number of pairs to be assigned to respondents. The algorithm performs the following functions: It assigns random pairs of concepts to respondents; it ensures that each pair is only assigned once to a respondent; and it ensures that the entire data matrix is populated. Seventy-five pairs of concepts were randomly assigned to each respondent.

Subjects were given the Web site address in class, and asked to login into the system to complete the Web survey. Students received a small amount of research credit for their participation. In all, the survey netted 338 completed surveys. After removing outlier entries (paired dissimilarities in excess of 1,000), the final dataset included responses from 332 subjects for 24,961 paired-comparisons. Lastly, to measure innovativeness, two measures were used: Respondents were asked to indicate their ownership (1 = *own*, 0 = *do not own*) of a series of 18 technology products; respondent innovativeness was also measured using the six-item Domain-Specific Innovativeness Scale (Goldsmith & Hofacker, 1991).

Results

Innovativeness was measured on two separate levels: the variables measuring current technology ownership (Range = 0–18, $M = 8.03$, $SD = 3.15$, $\alpha = 0.82$), provided a behavioral measure of innovativeness; and the Domain-Specific Innovativeness Scale (Range = 0–23, $M = 10.40$, $SD = 3.53$, $\alpha = 0.77$) provided a trait-level measure. The two measures were significantly correlated ($r = 0.32$, $p < .01$). Because of its higher reliability, the behavioral (technology ownership) variable was used to segment the dataset into adopters and nonadopters. Using the mean to parse the dataset, resulted in 52% adopters ($N = 173$), and 48% ($N = 159$) nonadopters or late-adopters. The slight overestimation of adopters in the dataset is consistent with the use of student populations who tend to be earlier adopters of many technological innovations (Atkin, 1993; Goldsmith & Hofacker, 1991).

Next, t tests were performed on the mean differences between the concept pairs. Table 2 presents the means, standard deviations, and t-values for the significantly different concept pairs. Overall, the two groups significantly differ ($t = 4.0$, $p < .05$) on their perceived relationships between technologies: The combined means distance across all concepts for adopters ($N = 13{,}215$) was 167.4 ($SD = 167.3$), and the combined means distance for nonadopters ($N = 11{,}746$) was 159.4 ($SD = 145.4$). The t-test result comparing the self (individual) with all 29 technologies was significantly different for only one concept: high-definition television (HDTV; $t = 3.02$, $p < .001$); that is, this concept was viewed as most dissimilar from themselves, by adopters and nonadopters.

The other concepts that were viewed significantly different by adopters and nonadopters were: the personal data assistant (PDA) and VCR ($t = 3.86$, $p < .05$); PDA and video game console ($t = 3.86$, $p < .05$); TV and cellular phones ($t = 2.26$, $p < .05$); TV and PC ($t = 2.27$, $p < .05$); laptop computer and digital video display (DVD) players ($t = 2.24$, $p < .05$); laptop computer and HDTV ($t = 2.45$, $p < .05$); laptop computer and TIVO (TV video recorder) ($t = 2.35$, $p < .05$); cable TV and Fax machines ($t = 2.72$, $p < .05$); cable TV and high-speed Internet ($t = 2.70$, $p < .05$);

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TABLE 2. Means, standard deviations, and significant *t*-values for concept pairs.

Concept pairs	Adopters *M* (*SD*)	Nonadopters *M* (*SD*)	*t*	Significance
PDA—VCR	236.89 (171.5)	164.76 (132.6)	2.02	$p < .05$
PDA—Video game console	330.48 (251.2)	140.97 (117.9)	3.86	$p < .001$
TV—Cellular phone	228.56 (169.9)	154.30 (83.9)	2.26	$p < .05$
TV—Personal computer	193.86 (162.8)	95.96 (125.1)	2.27	$p < .05$
Laptop computer—DVD player	101.24 (112.8)	181.00 (126.2)	2.24	$p < .05$
Laptop computer—High-definition TV	229.55 (174.3)	124.35 (107.2)	2.45	$p < .05$
Laptop computer—TIVO or DVR	130.03 (96.1)	211.50 (154.5)	2.35	$p < .05$
Yourself—High-definition TV	161.12 (144.2)	345.67 (368.2)	3.02	$p < .001$
Cable TV—Fax machine	295.36 (231.3)	161.72 (120.0)	2.72	$p < .05$
Cable TV—High-speed Internet	86.47 (85.4)	154.19 (119.4)	2.70	$p < .05$
Video camera—High-speed Internet	123.15 (131.4)	201.35 (132.6)	−2.08	$p < .05$
Video camera—Satellite TV	274.09 (195.8)	153.47 (105.3)	2.86	$p < .05$
Cellular phone with Camera—Plasma or flat screen TV	266.07 (217.4)	157.21 (128.1)	2.31	$p < .05$
Digital camera—Digital video camera	51.97 (61.4)	158.42 (168.2)	−3.12	$p < .05$
Digital camera—Landline telephone	233.07 (139.4)	148.59 (133.8)	2.41	$p < .05$
Digital video camera—VCR	202.28 (189.264)	101.11 (68.254)	2.19	$p < .05$
DVD player—Satellite Radio	107.96 (78.208)	177.71 (138.5)	2.29	$p < .05$
Fax machine—Satellite TV	182.03 (179.3)	290.52 (187.1)	2.31	$p < .05$
Fax machine—Wireless-enabled PDA	194.17 (151.2)	121.00 (92.4)	2.14	$p < .05$
Fax machine—GPS system	162.28 (133.5)	242.97 (149.2)	2.10	$p < .05$
LCD flat panel display—Video game console	245.00 (143.8)	149.59 (99.0)	2.87	$p < .05$
MP3 Player—High-definition TV	272.29 (258.8)	148.97 (117.8)	2.37	$p < .05$
Plasma or flat screen TV—Video game console	243.48 (227.8)	120.82 (88.3)	2.87	$p < .05$
Satellite TV—TIVO or DVR	157.73 (147.6)	86.03 (77.8)	2.42	$p < .05$
Satellite radio—Cable subscription	86.21 (66.4)	153.62 (121.9)	−2.55	$p < .05$

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video camera and high-speed Internet ($t = -2.08$, $p < .05$); video camera and satellite TV ($t = 2.86$, $p < .05$); cellular phone with cameras and plasma TV ($t = 2.31$, $p < .05$); digital camera and digital video camera ($t = -3.12$, $p < .05$); digital camera and landline telephones ($t = 2.41$, $p < .05$); digital video camera and VCR ($t = 2.19$, $p < .05$); DVD player and satellite radio ($t = 2.29$, $p < .05$); fax machines and satellite TV ($t = -2.31$, $p < .05$); fax machines and wireless PDAs ($t = 2.14$, $p < .05$); fax machines and global positioning systems (GPS) systems ($t = 2.10$, $p < .05$); MP3 players (portable digital audio players) and HDTV ($t = 2.37$, $p < .05$); LCD (liquid crystal display) flat panel and video game console $t = 2.87$, $p < .05$; plasma TV and video game console ($t = 2.87$, $p < .05$); satellite TV and TIVO ($t = 2.42$, $p < .05$); satellite radio and cable subscription ($t = -2.55$, $p < .05$). LaRose and Atkin (1992) concluded that technology clusters were more narrowly defined than theorized by Rogers (1986); consistent with their findings, the current results indicate fewer technologies, only 25 pairs against 435 tested pairs, differed between adopters and nonadopters.

The mean values for each group were converted into Cartesian coordinates and plotted across two dimensions. The difference among groups (a = adopters, b = nonadopters) in that space, are presented in Figure 1. The figure reveals the associative structures of adopters and nonadopters; adopters are closer to new technologies such as plasma TV, HDTV, satellite TV, TIVO, and cable TV. Interestingly, it is the TV and related technologies that adopters clearly identify with.

To identify clearly the clusters of related technologies, a hierarchical cluster analysis was performed on the Galileo pairs for adopters and nonadopters. Tables 3 and 4 present the cluster analysis results. Using 100 as the agglomeration cut-off resulted in 8 clusters accounting for 23 concepts in the adopter group, and 24 concepts in the nonadopter group. This was not considered problematic because the list of technologies used in the study, include a greater number of older technologies than innovations. For ease of presentation, the clusters of technologies are marked on a two-dimensional Galileo space and shown in Figures 2 and 3.

Table 5 presents the cluster memberships for adopters and nonadopters. The table shows the differences between adopters and nonadopters in their conceptualization of technology and the relationships between technologies. Adopters seem to be grouping technology by using the mode of the technology or shared infrastructures; on the other hand, nonadopters seem to be grouping technologies using functional similarity or dissimilarity. For example, TIVO, satellite TV, DVD, and VCR form a cluster of related technologies among nonadopters while for adopters TIVO clusters with cable TV and cable subscription; satellite TV clusters with satellite radio; DVD clusters with video game consoles and TV; and VCR is an outlier. This is an interesting finding as it points to differences in the conceptualization of relationships between technologies. Likewise, digital video cameras cluster with video cameras and digital cameras among adopters, whereas digital video camera is still considered a new innovation that does not fit and is not associated with any other current or related technology. Again, adopters

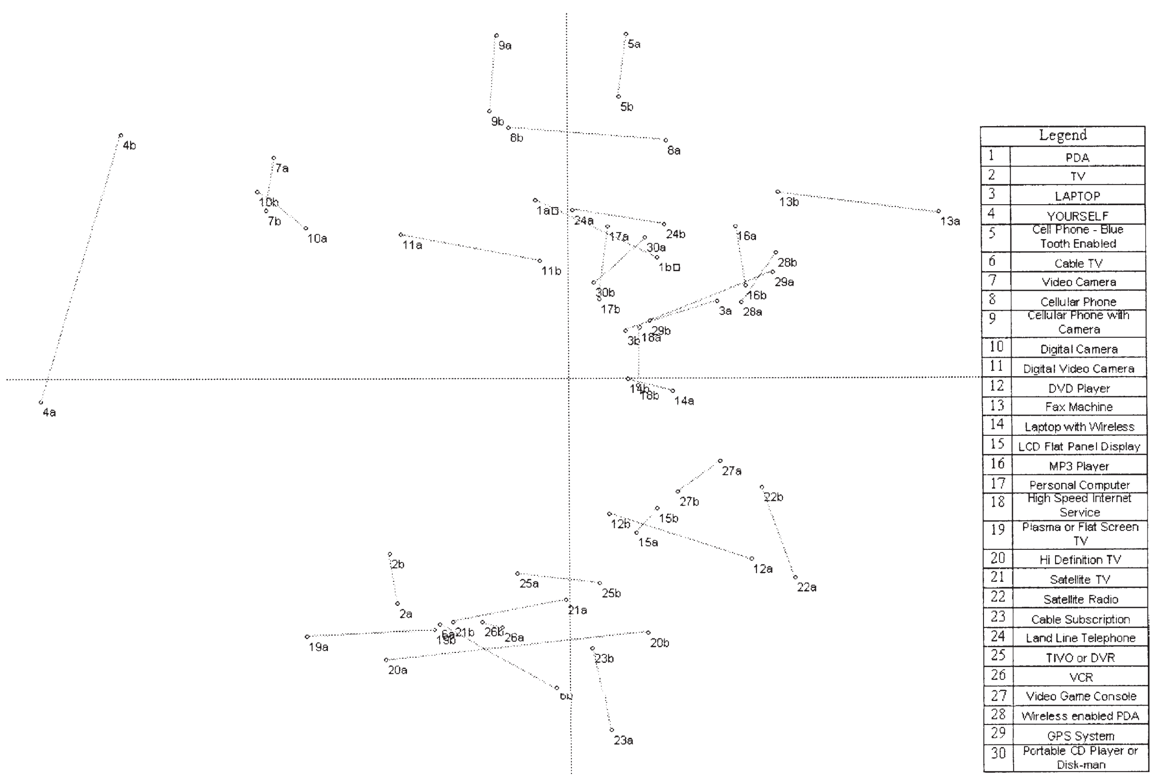

FIG. 1. The mean values for each group (a = adopters, b = nonadopters) have been converted into Cartesian coordinates and plotted across two dimensions.

TABLE 3. Cluster analysis results: Dendograms for adopters or innovating segment.

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HIERARCHICAL CLUSTERING

          5 5 5 5 5 5 5 5 5 5 4 5 5 4 5 5 5 4 5 5 5 5 5 5 5 5 5 5 5 5
          0 0 2 1 1 1 0 1 2 2 9 0 2 9 1 1 1 9 2 1 1 2 0 0 0 0 0 0 1 2
          0 9 0 1 5 6 2 9 1 2 5 8 3 8 3 0 4 3 4 7 8 5 1 4 5 3 6 7 2 6

            1 2 1 1 2   2 2 2   1 2   1 1 1   2 2 2 2         1 1 1 3
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 43.22    . . . . . . . . . . . . . XXX . . . . . . . . . . . . . . .
 44.63    . . . . . . . . . . . . . XXX . . . . . . . . XXX . . . . .
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 51.97    . . . XXX . . . . . . . . XXX . . . . . . . . XXX . XXX . .
 55.60    . . . XXX . . . . . . . . XXX . . . . . . . . XXX XXXXX . .
 56.48    . . . XXXXX . . . . . . . XXX . . . . . . . . XXX XXXXX . .
 59.89    . . . XXXXX XXX . . . . . XXX . . . . . . . . XXX XXXXX . .
 64.70    . . . XXXXX XXX . . . . . XXX . . XXX . . . . XXX XXXXX . .
 72.29    . . . XXXXX XXX . . . . . XXX XXX XXX . . . . XXX XXXXX . .
 73.33    . . . XXXXX XXX . . . . . XXX XXX XXX . . . . XXX XXXXX XXX
 73.84    . . . XXXXX XXX . . . . . XXX XXX XXX XXX . . XXX XXXXX XXX
 76.69    . . . XXXXX XXX . . XXX . XXX XXX XXX XXX . . XXX XXXXX XXX
 89.72    . . . XXXXX XXX . . XXX . XXXXXXX XXX XXX . . XXX XXXXX XXX
 95.38    . . . XXXXX XXX . . XXX . XXXXXXX XXX XXX . XXXXX XXXXX XXX
 95.53    . . . XXXXX XXX . . XXXXX XXXXXXX XXX XXX . XXXXX XXXXX XXX
 99.97    . . . XXXXX XXXXX . XXXXX XXXXXXX XXX XXX . XXXXX XXXXX XXX
115.00    . XXX XXXXX XXXXX . XXXXX XXXXXXX XXX XXX . XXXXX XXXXX XXX
121.08    . XXX XXXXX XXXXX . XXXXX XXXXXXXXXXX XXX . XXXXX XXXXX XXX
127.85    . XXX XXXXXXXXXXX . XXXXX XXXXXXXXXXX XXX . XXXXX XXXXX XXX
129.75    . XXX XXXXXXXXXXX . XXXXX XXXXXXXXXXX XXXXX XXXXX XXXXX XXX
131.38    . XXX XXXXXXXXXXX . XXXXX XXXXXXXXXXX XXXXX XXXXXXXXXXX XXX
141.61    . XXX XXXXXXXXXXXXX XXXXX XXXXXXXXXXX XXXXX XXXXXXXXXXX XXX
156.00    . XXX XXXXXXXXXXXXX XXXXX XXXXXXXXXXXXXXXXX XXXXXXXXXXX XXX
156.98    . XXX XXXXXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXXX XXXXXXXXXXX XXX
158.66    . XXX XXXXXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXXX XXXXXXXXXXXXXXX
178.62    . XXX XXXXXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
185.49    . XXX XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
202.71    . XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
254.64    XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
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TABLE 4. Cluster analysis results: Dendograms for nonadopters or noninnovating segment.

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HIERARCHICAL CLUSTERING

          5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4 5 5 4 5 5 5 4 5 5 5 5 5 5
          0 0 0 2 0 0 0 0 0 1 0 1 1 1 0 2 9 1 2 9 1 1 1 9 2 2 2 1 1 2
          0 6 9 0 1 4 5 7 3 1 2 5 6 9 8 1 5 7 2 8 3 0 4 3 4 5 3 2 8 6

            1 1 2       1   1   1 2 2 1 2   2 2   1 1 1   2 2 2 1 2 3
 Level    4 0 3 4 5 8 9 1 7 5 6 9 0 3 2 5 2 1 6 3 7 4 8 1 8 9 7 6 2 0
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 36.63    . . . . . . . XXX . . . . . . . . . . . . . . . . . . . . .
 36.92    . . . . . XXX XXX . . . . . . . . . . . . . . . . . . . . .
 41.24    . . . . . XXX XXX . . . . . . . . . . XXX . . . . . . . . .
 45.29    . . . . . XXX XXX . . . . . . . . . . XXX . . XXX . . . . .
 50.68    . . . . . XXX XXX . . XXX . . . . . . XXX . . XXX . . . . .
 66.93    . . . . . XXX XXX . . XXX . . . . . . XXX XXX XXX . . . . .
 73.48    . . . . . XXX XXX . . XXX . . . XXX . XXX XXX XXX . . . . .
 75.31    . . . . . XXX XXX . XXXXX . . . XXX . XXX XXX XXX . . . . .
 76.56    . . . . XXXXX XXX . XXXXX . . . XXX . XXX XXX XXX . . . . .
 82.46    . . . . XXXXX XXX . XXXXX . . . XXX . XXXXXXX XXX . . . . .
 83.10    . . . . XXXXX XXX . XXXXX . . . XXX . XXXXXXX XXX . . XXX .
 84.88    . . . . XXXXX XXX . XXXXX . . . XXXXX XXXXXXX XXX . . XXX .
 87.14    . . . . XXXXX XXX . XXXXX . XXX XXXXX XXXXXXX XXX . . XXX .
 92.79    . . . . XXXXX XXX . XXXXX . XXXXXXXXX XXXXXXX XXX . . XXX .
 93.71    . . XXX XXXXX XXX . XXXXX . XXXXXXXXX XXXXXXX XXX . . XXX .
100.20    . . XXX XXXXX XXX XXXXXXX . XXXXXXXXX XXXXXXX XXX . . XXX .
105.09    . . XXX XXXXX XXX XXXXXXX XXXXXXXXXXX XXXXXXX XXX . . XXX .
105.65    . . XXX XXXXX XXX XXXXXXX XXXXXXXXXXX XXXXXXXXXXX . . XXX .
107.92    XXX XXX XXXXX XXX XXXXXXX XXXXXXXXXXX XXXXXXXXXXX . . XXX .
114.24    XXX XXX XXXXX XXX XXXXXXX XXXXXXXXXXX XXXXXXXXXXX . . XXXXX
115.02    XXX XXX XXXXXXXXX XXXXXXX XXXXXXXXXXX XXXXXXXXXXX . . XXXXX
122.04    XXX XXX XXXXXXXXX XXXXXXXXXXXXXXXXXXX XXXXXXXXXXX . . XXXXX
127.76    XXX XXX XXXXXXXXX XXXXXXXXXXXXXXXXXXX XXXXXXXXXXXXX . XXXXX
151.06    XXX XXX XXXXXXXXX XXXXXXXXXXXXXXXXXXX XXXXXXXXXXXXX XXXXXXX
159.58    XXX XXX XXXXXXXXX XXXXXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXXXXXXX
163.26    XXX XXX XXXXXXXXXXXXXXXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXXXXXXX
171.57    XXX XXX XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
193.63    XXX XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
196.89    XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
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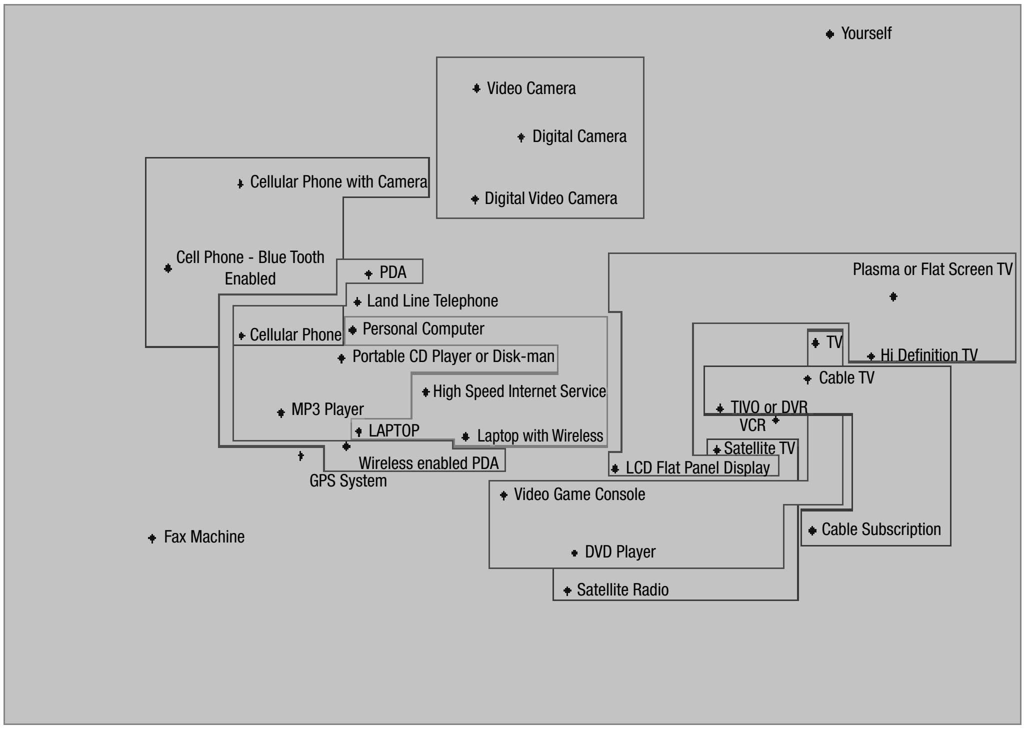

FIG. 2. Cluster memberships: Adopters or innovating segment (presented in a two-dimensional space).

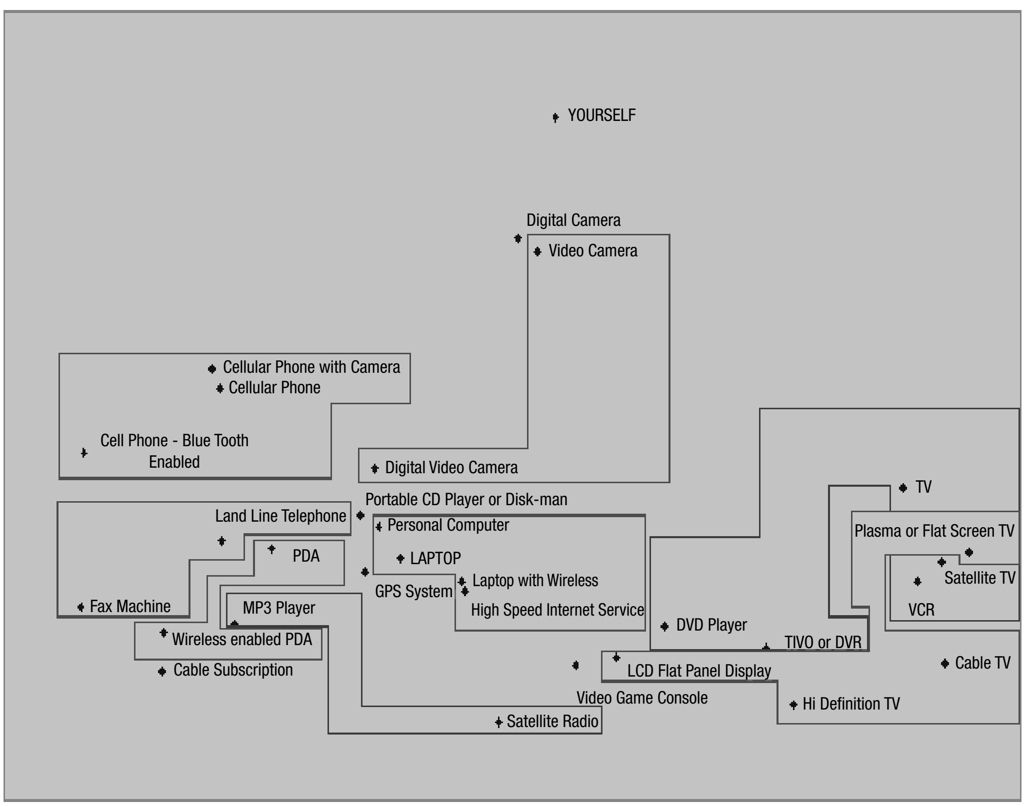

FIG. 3. Cluster memberships: Nonadopters or noninnovating segment (presented in a two-dimensional space).

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TABLE 5. Cluster membership for adopters and nonadopters.

Technology name	Adopter cluster		Nonadopter cluster
Video camera	1	Video camera	1
Digital camera	1	Digital camera	1
Digital video camera	1	TIVO or DVR	2
LCD flat panel display	2	Satellite TV	2
Plasma or flat screen TV	2	TV	2
High-definition TV	2	DVD player	2
Cable TV	3	VCR	2
Cable subscription	3	LCD flat panel display	3
TIVO or DVR	3	Plasma or flat screen TV	3
Satellite TV	4	High-definition TV	3
Satellite radio	4	Cable TV	3
Laptop computer	5	Satellite radio	4
Laptop with wireless	5	MP3 player	4
Personal computer	5	PDA	5
High-speed Internet service	5	Wireless-enabled PDA	5
Cell phone—Blue Tooth enabled	6	Fax machine	6
Cellular phone	6	Landline telephone	6
Cellular phone with camera	6	Cell phone—Blue Tooth enabled	7
PDA	7	Cellular phone	7
Wireless-enabled PDA	7	Cellular phone with camera	7
TV	8	Laptop computer	8
DVD Player	8	Laptop compurter with Wireless	8
Video Game Console	8	Personal computer	8
YOURSELF	0	High-speed Internet service	8
Fax machine	0	Digital video camera	0
MP3 player	0	Cable subscription	0
Landline telephone	0	Video game console	0
VCR	0	YOURSELF	0
GPS system	0	GPS system	0
Portable CD player or Disk-man	0	Portable CD player or Disk-man	0

Note. The numbers assigned, between and within clusters, are in no particular order.

relate video game console with TV, and DVD players, while nonadopters consider videogame consoles as a separate technology.

Discussion

In this article we have demonstrated the utility of the Galileo system in defining technology clusters. In addition to validating the use of this system, the research also extends Barnett and Siegel's (1988) associational model to the study of technology clusters.

The results indicate significant differences in the association between technology among earlier adopters and nonadopters. These differences in association, point to differences in conceptualization. Earlier adopters seem to associate or relate technologies on functional interdependence and shared infrastructure. For example, DVD players and video game consoles cluster along with TV; likewise, satellite TV clusters with satellite radio. Hence, adopters perceive technologies as being complementary, where one technology is necessary for another thereby promoting the ownership and adoption of related technologies.

In contrast, nonadopters or late-adopters relate technologies based on their functional merits. Here, functionally similar technologies are perceived as redundant thereby inhibiting the adoption of a number of new and related innovations. For example, late adopters relate TV, satellite TV, DVD player, and VCR. Likewise, they relate video cameras and digital cameras, but not digital video cameras; the latter is probably still considered similar to video cameras and thereby redundant. Also, there seems to be an ascendancy of association: newer technologies form clusters with older technologies as and when the newer technology is introduced, and when the newer technology has a clear functional merit over another competing technology; and clusters once formed are then used to judge the merits of subsequent innovations. This ascendancy of association is a stricter criterion that results in far few innovations being perceived as clear advantages. Hence, digital cameras, when introduced, formed a cluster with video cameras; digital video cameras, however, now competes with both these products for adoption.

The key finding, of differences in conceptualization of technology among adopters and nonadopters, questions the current methodological treatment of technology clusters. Currently, some researchers measure a potential adopter's innovativeness or likelihood to adopt an innovation by measuring his or her ownership of related technologies that form a cluster (e.g., Kang, 2002; Leung & Wei, 1999;); the lists of technologies that form a potential cluster are drawn a priori and are neither tested for their membership nor for their appropriateness; the technologies included tend to be based on the researchers knowledge and expectations, and the technologies are assumed to be isomorphic. Usually in these approaches, clusters are formed based on the functional similarity between technologies which, based on the current research findings, represents only the conceptualization of earlier adopters.

Hence, the following methodological approach is suggested: Researchers interested in evaluating innovativeness based on the potential adopters prior ownership of technology products should include a large list of products that may or may not be functionally similar or even related, and then have respondents score the ownership from among all of these products. The aim of the researcher should be to include a large enough list to account for the variations in the social construction of technology between differing adopting segments. This strategy would accurately measure ownership behavior, while at the same time account for the different styles of conceptualization.

A shortcoming of the current research is its sample: The student sample used seemed to have a slightly larger number of innovators or earlier adopters to nonadopters that might have overestimated the cluster solutions. Next, the research

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uses the terms innovator and earlier adopter and late or later adopters and nonadopters synonymously, as if the marketplace consists of any one classification or the other. The terms are connotatively used to signify intent, rather than classify behavior; of course, subcategories and classifications within categories and their cluster conceptualizations is an exercise for future research. The study also used a limited list of technologies and tried to balance the number of newer and old innovations. Lastly, the research did not include the commonly used attributes of innovations, but rather focused solely on the interpretations of technologies (as concepts) by themselves and the relationships between these concepts.

Future research should extend these findings by testing a larger set of technologies or innovations, by using heterogeneous adult samples, and by including the measures of the perceived attributes of innovations. Additionally, future research should explore the associations between groupings of newer technologies against a separate grouping of older technologies. Such a mapping process would be instructive, as it would further clarify the differences in associations between adopters and nonadopters.

The current research, however, is noteworthy: it clearly validates the associational model, and demonstrates the utility and applicability of the Galileo system for evaluating complex relationships. The current research also presents a first attempt at a multidimensional mapping of the cognitive associations of a number of innovations between adopter groups. The research identifies differences in the associational structure employed by adopters and non-adopters, in classifying the interrelationships between technologies. Diffusion researchers need to be cognizant of these differences and account for these differences when measuring adoption.

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