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Comparing Performance of Web Service Interaction Styles: SOAP vs. REST

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Abstract

This paper presents a comparative performance evaluation of two Web service implementations: one is based on SOAP and the other on Representational State Transfer (REST). Simple Object Access Protocol (SOAP) and REST-based development approaches handle service interactions quite differently. SOAP is a standardized framework for constructing and processing messages independent of the technological capabilities of the receiver and can work on top of a variety of application layer protocols such as RPC, HTTP, or SMTP, whereas, REST is a set of principles for designing Web applications (HTTP as the underlying protocol). We built SOAP and REST-based Web services that perform Create, Read, Update, and Delete (CRUD) operations on a database and retrieve local files. We utilized response time and throughput metrics to compare the performance of these Web services. We found that, on average, REST has better performance compared to SOAP, though not all results were statistically conclusive. As an ancillary outcome, we found that developing Web services using SOAP was easier, due to considerable tool support. However, developing Web services using REST was time consuming and difficult due to the necessity of in-depth knowledge of HTTP and rudimentary tool support.

Keywords: Web Service, SOAP, REST, Interaction Style, RESTful, Performance

1. INTRODUCTION

In this paper, we investigate two Web service interaction paradigms: SOAP and Representational State Transfer (REST), in order to assess effectiveness of their data transfer capabilities. These varied approaches to develop Web service solutions have attracted a lot of debate both in academic and practitioner communities. Choosing service interaction style

is a major architectural decision for designers and developers, as it influences the underlying requirements for implementing Web service solutions (Pautasso, Zimmermann, & Leymann, 2008). While the major software infrastructure providers such as Microsoft and IBM provide tool support for developing SOAP-based Web services, there have been an increasing number of advocates for the *RESTful* approach in the development of Web service solutions, where REST is used in conjunction with Universal Resource Identifier (URI) and HTTP (Note that SOAP has its own application layer protocol provisions and does not necessarily operate on top of HTTP, hence the label "SOAP-based Web services").

The SOAP-based Web service standard stack includes various standards such as WSDL, WS-BPEL, WS-Choreography, WS-Transaction, WS-Security, WS-Addressing, and many more developed by standardization organizations such as W3C and OASIS. Thus, SOAP-based Web service development essentially involves understanding relevant standards specification and using the right set of toolkits to develop solutions. This constantly increasing parade of standards and associated technologies often creates challenges for developers in terms of conceptual understanding and navigation of the standards space.

On the other hand, the RESTful approach espouses that Web service solutions can be developed by simply representing and exposing system's resources, and by transferring data over HTTP. A service is considered as a resource that can be identified and located by a URI and different operations can be performed on the resources using HTTP methods. In contrast, SOAP-based development focuses on exchange of communication and actions that occur between services. Thus, SOAP suggests a communication-oriented model (Umapathy & Purao, 2007) whereas REST suggests a resource-oriented model for designing interactions among Web services. See appendix A for overview of SOAP and REST, and a review of related work.

Although SOAP and REST are both present ways for building Web services, they differ in the manner data are processed and services offered. SOAP is XML-based message exchanging protocol for distributed computing, whereas REST is a design principle for Web-based applications that closely adheres to client-server architecture and advocates using bare minimum HTTP methods. Therefore, comparing these two technologies is not a trivial task. We developed a SOAP-based Web service and a RESTful Web service. Both services perform series of data exchange operations on a database server. In this article, we compare SOAP and REST interaction styles based on data transfer performance of two alternative Web service implementations using metrics such as response time and throughput. This article provides a neutral assessment of the performance and services offered to developers and architects by SOAP and REST methodologies for developing Web services.

The remainder of the paper proceeds as follows: first we provide a discussion of experimental methods and set up. Next, we discuss results of the experiments and statistical analysis followed by a discussion of results implications.

2. Experimental Setup and Method

Web services are most commonly used for exposing functionalities and data to other applications. Thus, service interactions comprise of information flows into and out of a service. Complex service interactions would involve an exchange of dynamic content generated by retrieving and updating data from databases. Frequent service calls, therefore, can increase service processing time and create throughput bottlenecks. Perceived performance issues with service interactions would be response times and throughputs (Cherkasova, Fu, Tang, & Vahdat, 2003). We compare SOAP and REST using response time and throughput as performance metrics.

In order to facilitate comparison of performance of SOAP and REST interaction styles, we developed two Web services that perform– *create*, *read*, *update*, and *delete* operations on a database. However, one service, called CustomerInfoSOAP, uses SOAP technology, whereas another service, called CustomerInfoREST, takes advantage of REST principles. From here on, CustomerInfo service will be used to refer to both SOAP- and REST-based services. We created a 'Customer' table in the database (Oracle 10g) containing following attributes: First name, Last name, SSN, CustomerID (primary key), Salary, Email, Active status, Mobile, City, and Country.

A Customer program was developed (using Java) to manage the above specified customer details. This Customer program was used as the basis to develop various functionalities offered by the CustomerInfo service. The CustomerInfo service offers five functionalities: getCustomer (obtains a particular customer record from the database based on given CustomerID), addCustomer (creates a new customer record using given customer information), updateCustomer (updates an existing customer record using given information), deleteCustomer (deletes an existing customer record based on given CustomerID), and getTheFile (retrieves and returns a specified file stored locally in the server). The first four functions are used for measuring response time and the fifth function is used for measuring throughput.

Client applications were developed (using Java) to invoke and interface with the appropriate service functionalities offered by CustomerInfo service. The interaction between the client application and CustomerInfo service was used as the basis for comparing performance of SOAP and REST. The client application interacted with the CustomerInfo service using both wired and wireless connections. For this experiment, two wired client machines and two wireless client machines were used. Wired clients were connected to the service via a 10/100 Full duplex Ethernet modem. Wireless clients were connected to the service through an access point using 802.11g protocol. The server that hosts service, database server, and all clients were located in the same room. Appendix B provides hardware and software configurations and Figure C1 in appendix C depicts the experimentation setup.

Measuring Response Time

The methodology used to measure response time for each service function was same. The general scenario for measuring service response times involves a client application invoking an appropriate functionality provided by the CustomerInfo service along with relevant data at an instance of time A (measured in milliseconds). The service receives the request, processes it, connects to the database, performs the requested operation on the database, and sends an appropriate response to the client. The client receives the response completely at some time B (measured in milliseconds). The response time was measured as the difference between times A and B.

The concept of multithreading was used to simulate multiple clients accessing the service at a given time. Each service request sent from a client was a thread, and each thread had a different identification number (threadID). Each thread was initialized sequentially. To make sure each thread performs operations on the intended customer records, rather than all threads focusing on the same customer, each thread requested specific operation on the customer ID based on the thread ID.

In general, the number of service requests per client depends on the application that produces them. Since we are not modeling specific application requests, to more realistically mimic client behavior, for this experiment, we randomly allocated the number of service requests per client, namely: 1, 2, 3, 4, 10, 12, 13, 14, 15, 16, 18, 19, and 20. That sequence was produced by an on-line random number generator evaluated by (Kenny, 2005). The first experiment was conducted with one service request for each client, thus, a total of two service requests. Following that, four service requests were sent with the next experiment, i.e., two threads (service requests) on each client. Subsequent runs were conducted with 6 service requests (3 threads on each client), 8 service requests (4 threads on each client), 20 service requests (10 threads on each client), so on up to 40 service requests (20 threads on each client). Table C1 in appendix C provides a list of experiment runs along with the number of requests made by each client.

The response time was calculated for each thread separately. For every run, the arithmetic mean of the thread response times was measured and considered as the response time for that run. For example, for a run of 10 service requests, the response time for each thread was measured and the arithmetic mean of 10 response times was calculated and recorded as the response time for 10 service requests. Figure C2 in appendix C provides the skeleton of the code for measuring response time.

As per HTTP specification, GET, PUT, and DELETE methods have idempotence property (HTTP, 1999). The idempotent methods produce same results, whether it is executed once or multiple times (Wikipedia-Idempotence, 2011). GET method is idempotent safe, as it is typically used for retrieving a resource without resulting in any side-effects (HTTP, 1999). In the context of HTTP PUT method, modifying a resource state

(for e.g., updating a customer name from "Smith" to "Jones") is considered idempotent; because the final resource state will be same no matter how many times the operation is performed. Similar, argument can be made for the HTTP DELETE method. Thus, according to HTTP specification, multiple HTTP PUT and DELETE requests are not allowed. This has implications for CustomerInfoREST service as updateCustomer and deleteCustomer functionalities rely on HTTP PUT and DELETE methods correspondingly. We were able to make multiple service requests using multithreading for getCustomer and addCustomer functionalities for both services, however, were not able to make multiple requests for updateCustomer and deleteCustomer functionalities for CustomerInfoREST service.

Using HTTP PUT and DELETE methods as a part of a sequential request, however, is considered to be non-idempotent (HTTP, 1999). We created a client application that invokes addCustomer, getCustomer, updateCustomer, and deleteCustomer service functions in a sequential order. The client application first invoked addCustomer service function with relevant data, upon receiving a response, invoked getCustomer function, upon receiving a response, invoked updateCustomer function, upon receiving a response, finally invoked deleteCustomer function. Similar to other service functions, response times for composition of all four functions were measured for multiple service requests using multithreading. Figure C3 in appendix C provides the skeleton of the code for measuring response time for composition of all four service functions. Therefore, we use response time measures for getCustomer, addCustomer, and composition of all four functionalities as the basis to compare performance of the service.

Measuring Throughput

Throughput is, typically, defined as the data processed per second. We measure throughput as the number of application bytes per second and the number of clients per second. Throughput was measured using getTheFile function, which retrieves a specified file. Ten different image files ranging in size from 76 KiloBytes (KB) to 5 MegaBytes (MB) were used for measuring throughput. Files of type .png were stored in the local directory of the server in which CustomerInfo services were hosted. The client invokes getTheFile function and sends a service request for a file with the filename. The service processes the request, retrieves the file from the local drive, and sends the file to the client. System time stamp was recorded by using the getTime() Java method before invoking getTheFile and another timestamp of the system clock was recorded again after receiving the requested file. The difference between the two times was considered as the response time. Throughput in KB per second was calculated by dividing the file size in KB by the response time in seconds. Throughput in clients per second was calculated by dividing the number of clients by the response time in seconds. Figure C4 in appendix C provides the skeleton of the code used for measuring throughput.

Since there are multiple requests to the same files (including both accesses to the database table and image files), the effects of caching needed to be considered. We anticipated that physical memory caching of retrieved from the server's hard drive files (including database Table files) would have the largest effect on response times. Most of the accesses to cached files were following the exact same pattern for both the REST-based and SOAP-based implementations. The only difference in caching for the two implementations resulted from the fact that REST based experiments were conducted first, that is, the very first accesses to each file took longer to retrieve by the REST implementation. That is, we are taking a pessimistic approach in estimating response times, where our reported REST based implementation response times, would have been even faster if files were located in physical memory before the experiments were conducted. We must also note that we did not implement Web caching, as our Web server was attached to the same LAN as the clients for all experiments.

3. Results

Response times for multiple service requests were gathered for getCustomer, addCustomer, and all four functions. Throughputs were gathered for multiple service requests accessing image files using getTheFile function.

Response times for getCustomer function

The getCustomer function enables a client to request for information about a customer by providing customer ID. The service gets the

specified customer details from the database and sends the response to the client. Multithreading was used to depict multiple clients requesting the service at the same time. Figure C5 in appendix C depicts SOAP vs. REST comparative chart of the response time in milliseconds against the number of simultaneous service requests for wired clients. Figure C6 in appendix C depicts the same for service requests from wireless clients. From the graphs, it can be observed that for the getCustomer function, REST had better response times than SOAP as the number of simultaneous requests increased. Graphs also indicate that response times for wireless clients were better than for wired clients. Links were underutilized for this experiment (i.e. are not bottleneck and carry little amount of traffic as compared to the next experiment). These results are not surprising since difference in network speeds between Fast Ethernet and 802.11g had little effect on performance. The effect of link speed differences is overshadowed by the effects of the performance capabilities client computers. This happened because the wireless clients were running on computers that had a newer configuration (dual and virtual cores) compared to those where the wired clients executed. From figure C6, it can be noted that SOAP was competitive until the number of simultaneous service requests gets greater than 30.

Response times for addCustomer function

The addCustomer function enables a client to add new customer data to the database. The service adds the new customer details to the database and sends a response to the client to inform successful completion of the process. Figure C7 depicts SOAP vs. REST comparative chart for wired clients and figure C8 depicts for wireless clients. From the graphs, it can be observed that for the addCustomer function, REST had better response times than SOAP as the number of simultaneous requests increased. Similar to getCustomer function, SOAP had better response times for wireless clients than for wired clients.

Response times for all four functions

The all four functions involved invocation of addCustomer, getCustomer, updateCustomer, and deleteCustomer functions in a sequential order. Thus, the client makes service requests in a sequential order, and service fulfills each request and sends a response after completion of the request. Response time was calculated for completion of all four functions. Similar to other functions, multithreading was used to make multiple simultaneous service requests. Figure C9 and C10 depicts SOAP vs. REST comparative chart for response times against the number of multiple service requests for wired clients and wireless clients, correspondingly. Similar to other getCustomer and addCustomer results, REST had better response times than SOAP as the number of simultaneous requests increased. Among the four functions, the getCustomer function constituted the majority of the response time, affecting the overall functionality and response time, accounting for the major performance difference. Similar to getCustomer and addCustomer functions, SOAP had better response times for wireless clients than for wired clients.

Response times for getTheFile function

The getTheFile function enables a client to retrieve a file stored locally in the server that hosts the CustomerInfo service. When the client makes the request for the file, the service retrieves and responds with the requested the file. Figure C11 depicts SOAP vs. REST comparative chart for response times against the file sizes in KB for wired clients and figure C12 depicts the same for wireless clients. From the graphs, it can be observed that response times for REST were comparatively better than SOAP response times, which is in keeping with the general trend observed with response times with other functions discussed before. However, as a departure to observed trend, wireless clients had higher response times than wired clients. Previously discussed functions requested text data, whereas the getTheFile requested image files (*.png). Thus, as the payload size of service response increases wireless clients may incur higher response times than that of wired clients for same service requests.

Throughput in KiloBytes per Second

Throughput can be defined as the average rate of successful data transmission over a channel. Throughput for CustomerInfo service was measured using the getTheFile function by requesting image files of sizes ranging from 76 KiloBytes to 5083 KiloBytes. Throughput for each file was calculated using the following formula: Throughput (bytes per second) = file size/response time in seconds. Figure C13 and C14 depicts SOAP vs. REST comparative chart

for throughputs in KB per second against to varying file sizes for wired and wireless clients, respectively. From below two figures, it can be observed that as the file size increased, REST has a higher throughput than SOAP. Figures also indicate that throughput for service requests for wired clients were higher than from wireless clients as it is expected because of link speed differences.

Throughput in Clients per Second

The following formula was used for calculating throughput expressed as clients per second: Throughput (clients per second) equals number of clients/response time in seconds. Similar to throughput in KB per second, getTheFile function was used for measuring throughput in clients per second and multiple service requests of files of varying sizes was made using multithreading. Figure C15 depicts SOAP vs. REST comparative chart for throughputs in clients per second against to varying file sizes for wired and wireless clients and figure C16 depicts the same for wireless clients. It can be observed that as the number of simultaneous service requests increased, REST has a higher throughput than SOAP. Similar to throughput in KB per second, throughput in clients per second was higher for wired clients than wireless clients.

Statistical Analysis

In order to assess whether there is a statistically significant difference between SOAP and REST in terms of their population means, for each conducted experiment we performed an independent samples t-test using SPSS software (SPSS, 2011). Due to space limitation, we have provided details of the statistical analysis, descriptive statistics, t-test results, effect size analysis and power size analysis in appendix E (see appendix D for tables).

Independent samples t-tests were conducted for each response time and throughput experiment groups. At the 5% level of significance, only addCustomer response time experiment with wired clients, and throughput in KB per second experiment with wireless clients were significantly different (i.e., $p < 0.05$). Difference between REST and SOAP groups for other experiments were not statistically significant at the 5% level of significance. The comparison of means reveals that REST had a lower response times and higher throughput than SOAP for all experimental groups.

Results of experiments with an insignificant difference, smaller than typical effect size and low power (less than 0.5) should be considered as inconclusive (Onwuegbuzie & Leech, 2004). Therefore, an insignificant difference cannot be interpreted as there is no statistical difference between REST and SOAP. Rather it indicates changes in experimental design and conditions may be necessary to reach conclusive results. Thus, regarding experiments with insignificant findings, future experiments should consider using either sample size larger than 13 per group or different experimental set up to observe a significant difference between REST and SOAP groups. We conclude that service developed using RESTful interaction style performed better than service developed using SOAP interaction style for addCustomer function with wired clients and throughput in KB per second with wireless clients.

4. Discussion

The results of the experiments indicate that REST has better response times and throughput than SOAP. However, the difference between REST and SOAP were statistically and practically significant only for addCustomer (wired) and throughtput in KB per second (wireless) experiments. Response times can be affected by server processing capabilities and network bandwidth (Cherkasova, et al., 2003). Throughput can be affected by a number of parameters, including network capability, transmission channel, network congestion (number of shared applications), distance between computers, payload size, and processing technique to handle a payload (Choudhury & Gibson, 2006; Zhu, Davis, Chan, & Perreau, 2011). In our experimental setup, both services were tested using the same set of payload sizes, client and server machine configurations, number of clients, and number of service requests. All clients and server machines were located in the same room. Both services used HTTP as the underlying protocol for exchanging messages and files. To ensure that services have same processing capabilities, both SOAP-based and REST-based services were hosted in the same server machine. Services were tested in varied network environments (wired and wireless). Thus, experiment set up ensured that only difference is the technique used by services to process and respond to messages, i.e., service interaction techniques.

Regarding response time experiments, for all wired clients, REST consistently had lower response times than SOAP. In regard to wireless clients, SOAP and REST were competitive, however, on average REST had a better response time. Newer network configuration of the wireless clients helped SOAP to be competitive in comparison to REST. Apart from network bandwidth, response time would be affected by the processing time at the service-side. One of the main difference between REST and SOAP style interactions is that, for SOAP messages, the actual payload is included inside the envelope element, whereas, for REST entire message is the payload. Thus, SOAP service would have to perform additional processing to extract the payload information. Similarly, when sending a response message, SOAP service would have to perform additional processing to construct a SOAP formatted message. The SOAP client machines also would have to perform additional processing to create and to read the message. This additional processing time incurred towards retrieving information from the message and embedding response into the message, may explain higher response times for SOAP service.

Similar to response time experiments, REST on average performed better than SOAP for throughput experiments for both wired and wireless clients. Throughput experiments were conducted using image files of various sizes. There are considerable differences among REST and SOAP on handling messages with image files. REST considers the image file as a resource and includes the URL of the resource in the response message. Client machines can access the resource via URL and download the file. SOAP standard has an attachment feature that allows transmission of attachments along with a SOAP message. The SOAP attachment feature allows creation of a compound message structure consisting of a primary SOAP envelope part and secondary parts for including attachments (SOAP-Attachment, 2004). A compound structured SOAP message must contain one and only one primary part and zero or more secondary parts. Thus, every SOAP message with an attachment would contain a primary part regardless of whether an XML encoded message is included along with the attachment. Therefore, in comparison to REST service, SOAP service would have to perform additional processing to encode the image file as an attachment into a SOAP message. The SOAP client machines would have to perform additional processing to decode the message and access the image file. This additional processing time for encoding/decoding attachments from a message along with larger payload size due to compound structure could possibly explain lower throughput for SOAP service.

The sophistication of SOAP standard is contributing towards higher processing time and larger payload, which subsequently affects response time and throughput of the service. The simplicity and light-weight approach can be attributed to RESTful services better performance than SOAP-based services. However, there is another important side to this comparison, which should not be ignored before selecting a particular interaction style for designing services. As SOAP is a well-accepted industry standard, there are numerous specialized tool support provided by software vendors. Software vendors provide "out of the box" products to allow anyone with basic understanding of web services to develop SOAP-based services. These tools help developers with developing services easier and faster, thereby increasing productivity. Tool support available for RESTful approach is rudimentary and not as matured as the SOAP-based approach. Developers need to have basic understanding of HTTP, REST principles, and web services to develop RESTful service. The lack of tool support means developers would have to spend a considerable amount of time towards developing RESTful services, thereby reducing productivity.

Taking results of the experiments and practical implications into consideration, we provide recommendations for selecting REST and SOAP based interaction styles. The RESTful approach would be appropriate when the bandwidth needs to be limited as it does not utilize any headers along with the payload. The RESTful approach espouses stateless service by maintaining resource state information at server-side and application state information at the client-side. The RESTful approach would be recommended when the service needs to be stateless, i.e., each service interaction is independent of other interactions. The RESTful approach would be a good choice when service needs to be developed with minimal vendor-based products, whereas, developing SOAP-based service without relying on tool support would be very difficult, due to complex associations between standards.

SOAP-based interaction style would be appropriate when the service must address complex non-functional and QoS requirements, including security, reliability, and routing. There are many standards developed on top of SOAP to support those requirements. As RESTful approach supports only service interaction (Issarny et al., 2011), thus, developers would have to hard code these requirements into their applications (Tyagi, 2006). SOAP-based services would be recommended when existing services needs to be aggregated into a composed service. Standards such as WS-BPEL (WS-BPEL, 2007) allow developers to specify a sequence of service invocations and exchange of input and output data between services. SOAP-based services are a good choice when the service needs to maintain contextual information and conversation state with partnering services. These requirements are supported by standards such as coordination (WS-Coordination, 2009) and choreography (WS-CDL, 2005).

One of the limitations of this study is that only two out of twelve experimental groups were revealed to be statistically different and rest of the groups were inconclusive. This limitation can be attributed to smaller sample size that is affecting effect size and statistical power. Another limitation related to inconclusive result and experiment design is the focus on CRUD operations. Payload (customer data and image files) used for CRUD operations may not have been sufficient to create substantial differences between REST and SOAP interaction styles. CRUD scenarios used in this study did not necessitate usage of other additional standards. Usage of additional standards can create a considerable difference in payload size between SOAP and REST interaction styles. Database and CRUD scenarios are conceptually closer to RESTful as it considers these operations as resources and exposes them as a service. SOAP-based approach could have a conceptual advantage over enterprise application integration scenarios which involves complex business transactions, maintaining conversation states, and conducting secured and reliable message exchanges. Thus, as a part of future work, we intend to compare REST and SOAP interaction styles in both CRUD and enterprise application integration scenarios using a larger sample size.

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Editor's Note:

This paper was selected for inclusion in the journal as the CONISAR 2012 Best Paper. The acceptance rate is typically 2% for this category of paper based on blind reviews from six or more peers including three or more former best papers authors who did not submit a paper in 2012.

Appendix A. Background

Overview of SOAP

SOAP is a communication protocol for exchanging messages among distributed applications regardless of their implementation specific semantics and programming platform. SOAP specifies XML-based framework to construct messages that can be transmitted over a variety of transportation protocols such as HTTP and FTP (SOAP-Primer, 2007). A SOAP message must have an envelope as its root element (SOAP-Primer, 2007). An envelope element can contain two sub-elements: header and body. The body is a mandatory element used for encoding information being conveyed. The information can be encoded either using document-style or RPC-style (Alonso, Casati, Kuno, & Machiraju, 2004). The header is an optional element used for providing contextual information related to processing the message. Thus, the body element is used for specifying actual payload and header element is used for specifying the value-added services such as security and transactional context (Alonso, et al., 2004). For more information about SOAP, refer to (SOAP-Primer, 2007).

Overview of REST

REST is an architecture style for designing and developing Web-based applications. The concept and architectural principles of REST were outlined by Roy Fielding in his Ph.D. dissertation. As per REST design principles, Web-based applications are built on top of stateless client-server architecture, where in, services offered by the server are considered as resources that can be identified by their URL (Tyagi, 2006). For example, if a client requests access to a resource (ex.: a Web page) using a URL, the server transmits the resource to the client along with links for accessing other relevant resources. If the client navigates to one of those links, then a transfer from one state to another has occurred, thus, the name REpresentational State Transfer (REST). Following the above argument, Web services can be considered as resources. Web service clients can access these resources through particular representations (URLs), and transfer data and other application content that describe the action to be performed on the resource (Tyagi, 2006). Web services developed following REST principles are called *RESTful services*. For more information about REST, refer to (Fielding, 2000).

Related Work

The debate between SOAP-based Web service development and taking a RESTful approach in the development of Web service solutions has been extensively argued among the practitioner community. In the academic community, recently few studies have focused on this important design choice. Pautasso et. al (Pautasso, et al., 2008) provide a conceptual comparison of SOAP- vs. RESTful web services based on technical differences. Their analysis indicates that in comparison to REST, SOAP-based development involves fewer design decisions but there are many alternatives to consider for each decision due to standardization and tool support availability. They also suggest that choosing a RESTful approach would eliminate series of decisions and alternatives to consider for supporting advanced functionality such as choreography, and QoS. However, providing such functionality support using REST would incur significant technical risk and development effort. Zur Muehlen et. al. (zur Muehlen, Nickerson, & Swenson, 2005) provide a comparison of SOAP and REST from the context of cross-organizational workflows and conclude that both provide different but technically valid ways to solve the problem. Mulligan and Gracanin (Mulligan & Gracanin, 2009) compared SOAP and REST-based implementations to support interactions between a middleware application and its peripheral devices. Their test results indicate that REST implementations are more efficient in terms of network bandwidth utilization and latency. However, their investigation was based on the context of supporting a specific middleware application; thus, their findings cannot be generalized for the context of designing and developing Web service solutions.

While there has been some discussions comparing SOAP- and REST-based approaches for supporting interactions among Web services, there is a lack of empirical studies that compare these technologies based on performance metrics. We intend to address this gap, in this paper.

Appendix B. Hardware and Software Configurations

Following is the hardware and software configurations used for both service and client applications:

- Service configurations
  - Hardware configurations of the hosting server
    - Processor: Intel ® Pentium ® 4 CPU 3.00 GHZ 2.99 GHz
    - RAM: 0.99 GB
    - Operating System: Microsoft XP Professional Version 2002 Service Pack 3
    - Hard Drive: Maxtor 6Y080M0
    - Network Adapter: Broadcom NetXtreme 57xx Gigabit Controller
  - Software configurations
    - Integrated Development Environment (IDE) used for developing services: Netbeans version 6.7
    - Application server used for hosting services: GlassFish 3 Prelude
    - Programming platform used for developing services: Java, Java Development Toolkit (JDK) 1.6
    - Application programming interface (API) for SOAP: Java API For XML-based Web Services (JAX-WS) 2.0
    - Application programming interface (API) for REST: Java API for XML RESTful Services (JAX-RS) 1.1
    - Database: Oracle 10g
- Client configurations
  - Hardware configurations of wired clients
    - Same as the hardware configurations for the hosting server
  - Hardware configurations of the first wireless client
    - Processor: Intel ® Dual Core CPU T2050 @ 1.73 GHz
    - RAM: 1.99 GB
    - Operating System: Microsoft XP Professional Version 2002 Service Pack 3
    - Hard Drive: Hitachi HTS541060G9SA00
    - Network Adapter: Dell Wireless 1390 mini-card
  - Hardware configurations of the second wireless client
    - Processor: Intel ® Core ™ i5 CPU M430 @ 2.27 GHZ 2.27 GHz
    - RAM: 4.00 GB
    - Operating System: Microsoft XP Professional Version 2002 Service Pack 3
    - Hard Drive: ST9320325AS
    - Network Adapter: Atheros AR5B93 Wireless Network Adapter
  - Software configurations
    - IDE used for developing client application: Netbeans version 6.7
    - Programming platform used for developing client application: Java, JDK 1.6

Appendix C. Figures

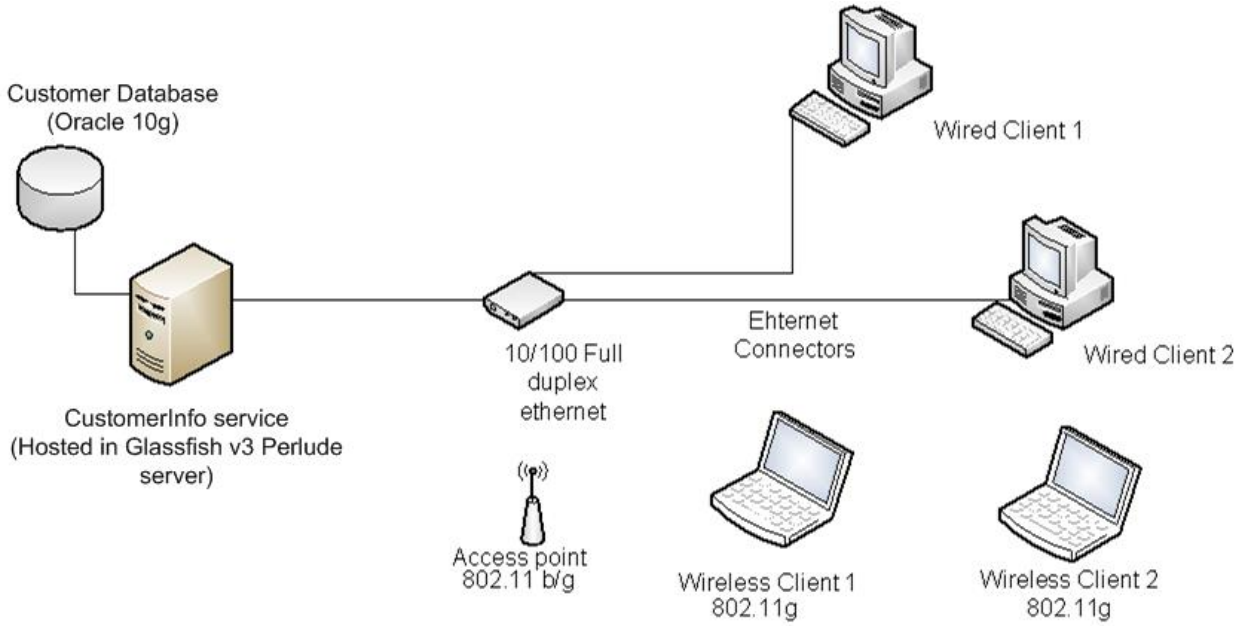

Figure C1. Experimental setup for running CustomerInfo service and client applications

```
Client Implementation Thread class
{
        Thread run method
        public void run ( )
        {
                someMethod (with correlation ID);
        }
        someMethod ( )
        {
                System time in milliseconds A of a particular thread X;
                Code for Operation;
                System time in milliseconds B of a particular thread X;
        }
}
```

Figure C2. Skeleton code for measuring response time

```
Client Implementation Thread class
{
        Thread run method
        Public void run ( )
        {
                publishMethod (with correlation ID);
                retrieveMethod (with correlation ID);
                modifyMethod (with correlation ID);
                deleteMethod (with correlation ID);
        }
        publishMethod ( )
        {
```

```
                System time in milliseconds A, of a particular thread X; (Timer started for the thread
                based on correlation ID)
                Code for operation with customer ID;
        }
        retrieveMethod ( )
        {
                Code for operation with customer ID;
        }
        modifyMethod ( )
        {
                Code for operation with customer ID;
        }
        deleteMethod ( )
        {
                Code for operation with customer ID;
                System time in milliseconds A, of a particular thread X; (Timer end for the thread
                based on correlation ID)
        }
}
```

Figure C3. Skeleton code for measuring response time for composition of all four service functions

```
Client class
{
        System time in milliseconds;-
        Code for requesting and getting the file;
        System time in milliseconds;
}
```

Figure C4. Skeleton code for measuring throughput

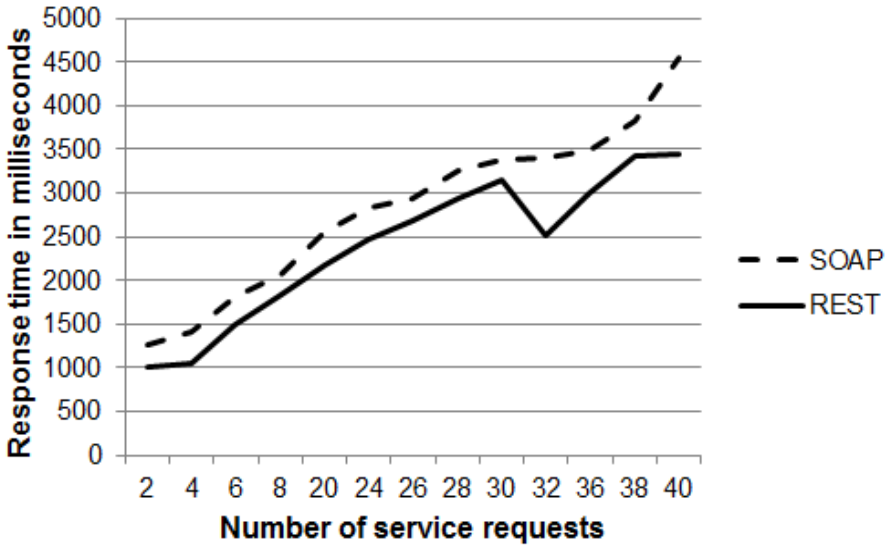

Figure C5. Response times for getCustomer function service requests from wired clients

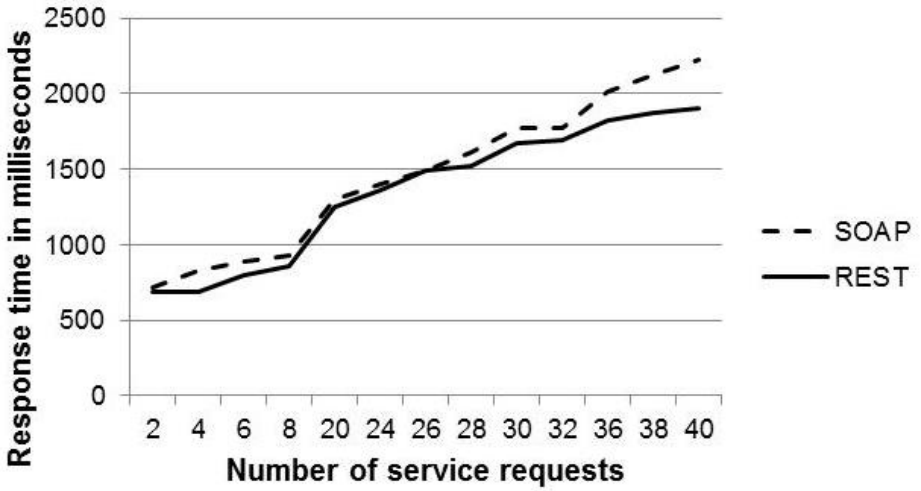

Figure C6. Response times for getCustomer function service requests from wireless clients

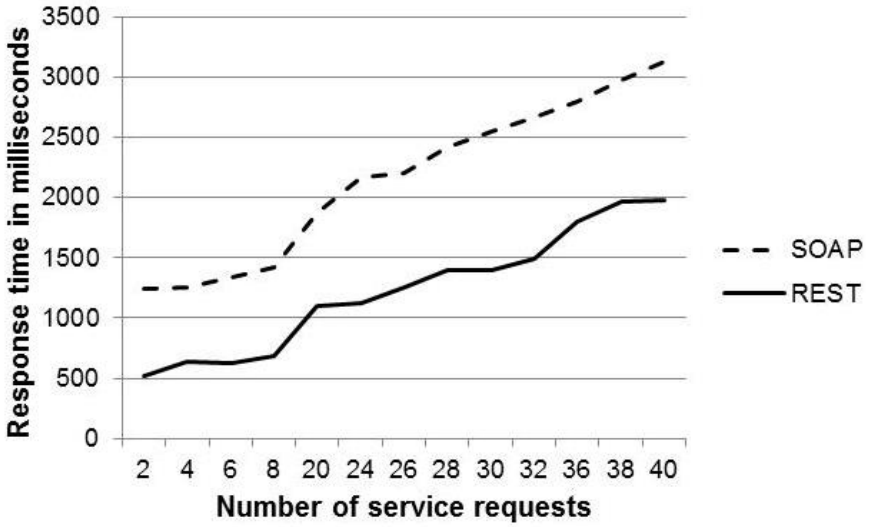

Figure C7. Response times for addCustomer function service requests from wired clients

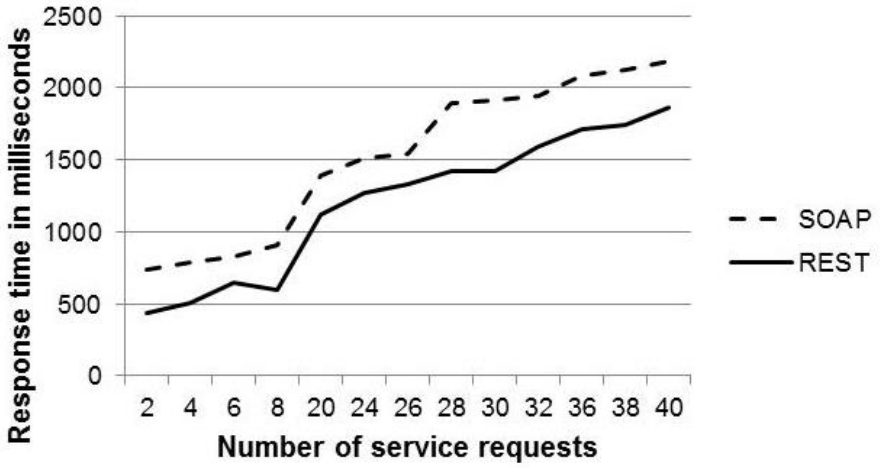

Figure C8. Response times for addCustomer function service requests from wireless clients

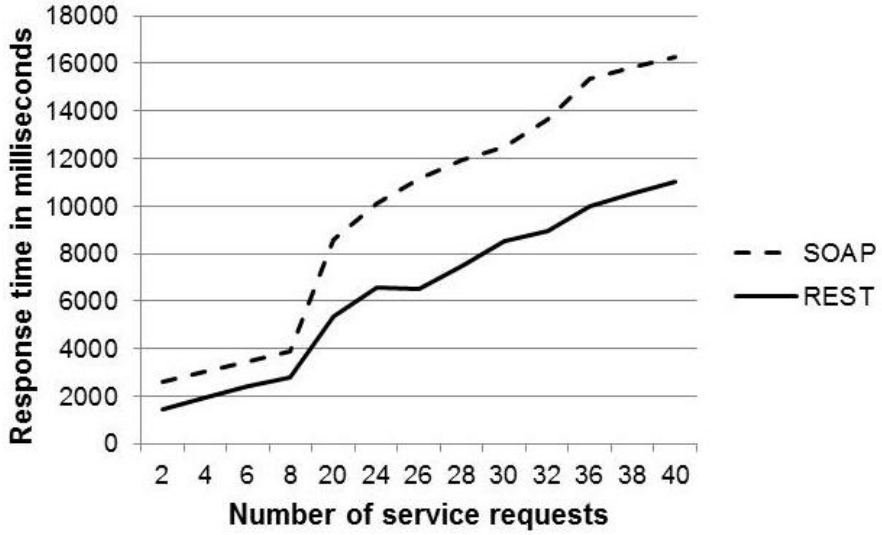

Figure C9. Response times for all for four functions service requests from wired clients

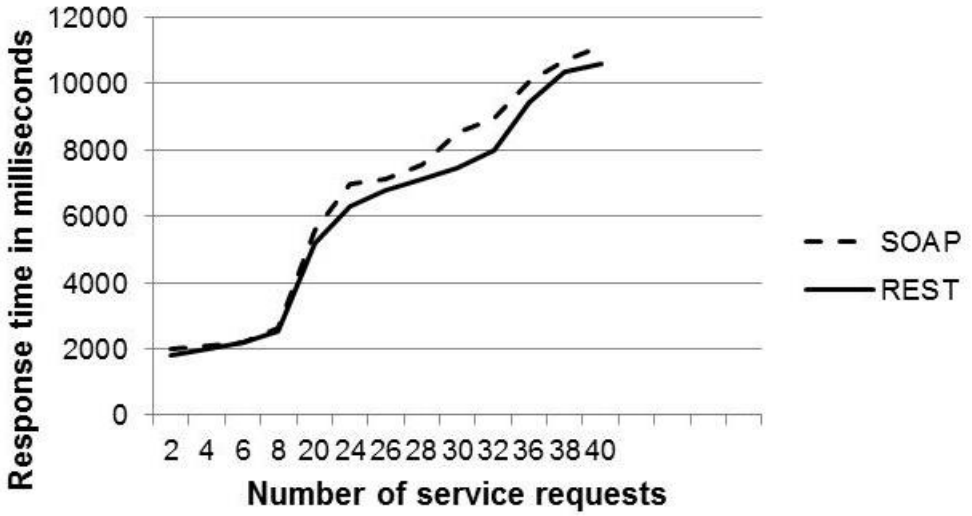

Figure C10. Response times for all four functions service requests from wireless clients

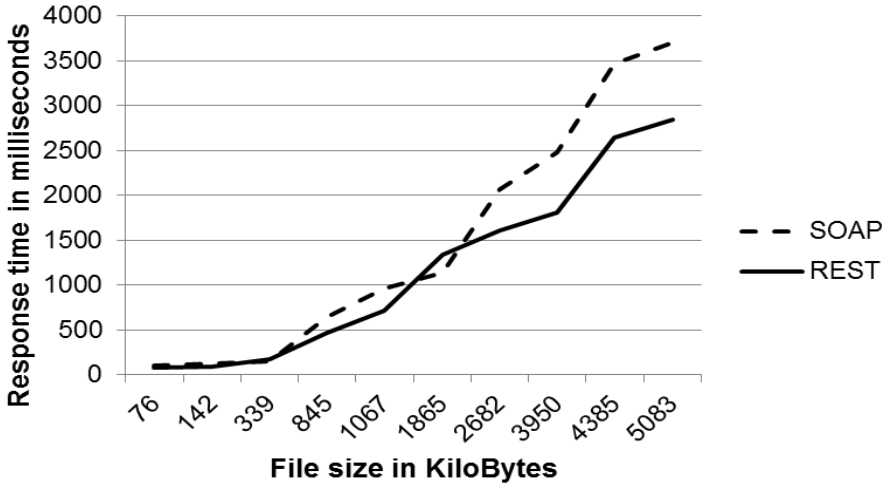

Figure C11. Response times for getTheFile function service requests from wired clients

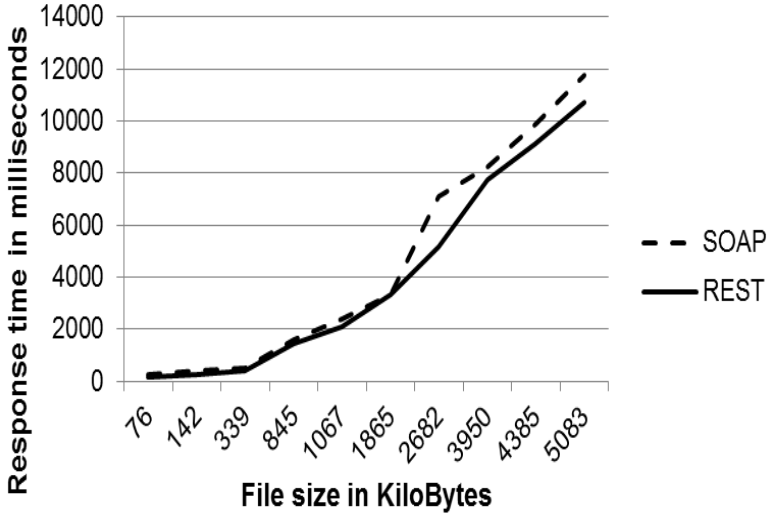

Figure C12. Response times for getTheFile function service requests from wireless clients

Figure C13. Throughput in KB per second for service requests from wired clients

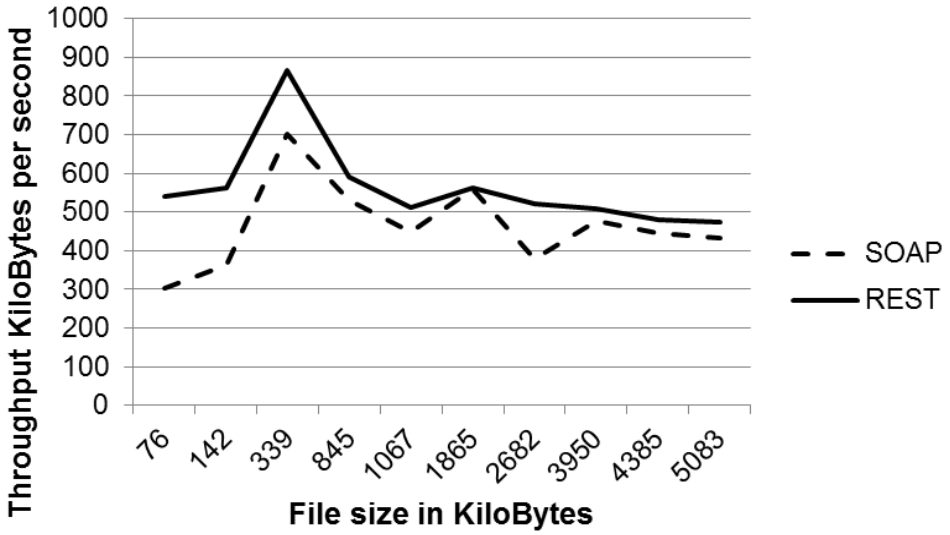

Figure C14. Throughput in KB per second for service requests from wireless clients

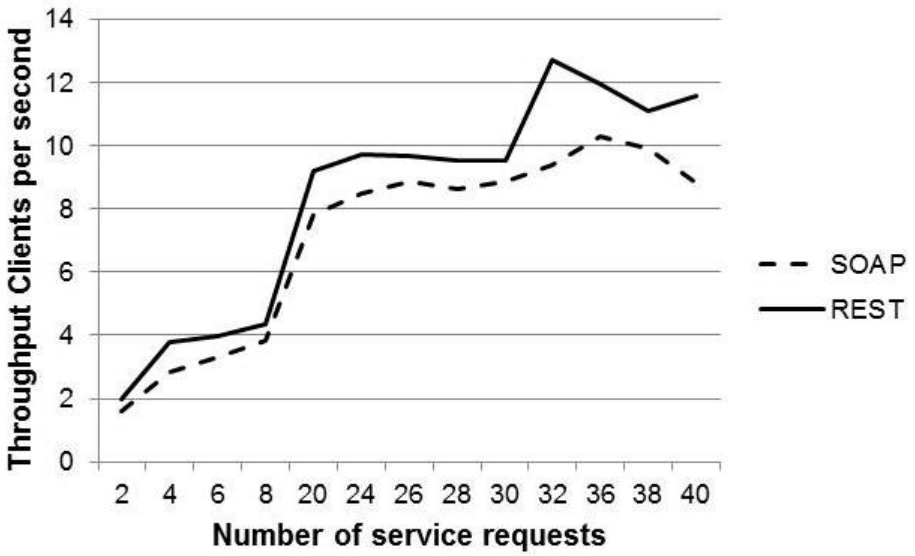

Figure C15. Throughput in clients per second for service requests from wired clients

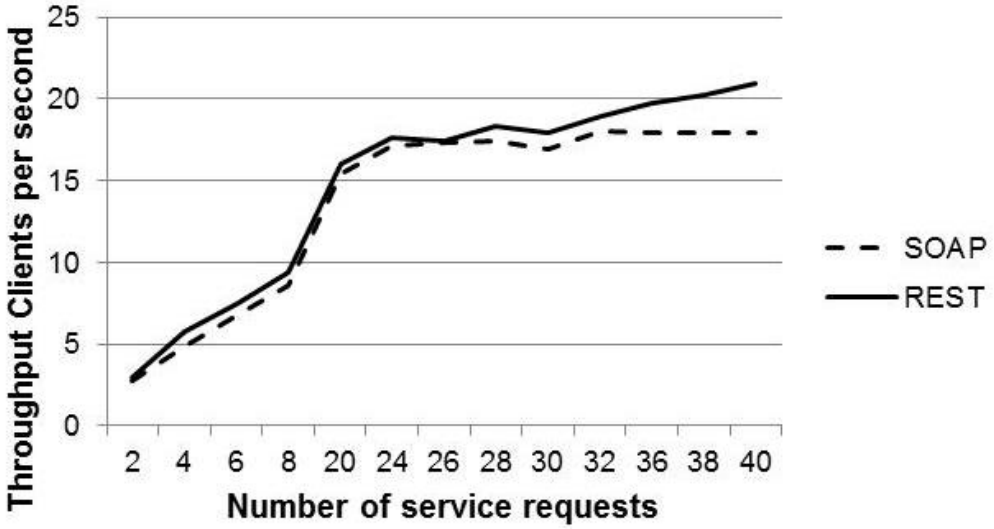

Figure C16. Throughput in clients per second for service requests from wireless clients

Appendix D. Tables

Table D1. Experimental runs and data collection for response time

Experimental Run	Number of Service Requests		
	Client1	Client2	Total
1	1	1	2
2	2	2	4
3	3	3	6
4	4	4	8
5	10	10	20
6	12	12	24
7	13	13	26
8	14	14	28
9	15	15	30
10	16	16	32
11	18	18	36
12	19	19	38
13	20	20	40

Table D2. Descriptive statistics for response times and throughput in clients per second experimental groups

Experimental Groups		N	Mean	Std. Error Mean	Std. Deviation	Skewness		Kurtosis	
						Statistic	Std. Error	Statistic	Std. Error
Response time – getCustomer function	Wired clients	26	2616.815	179.810	916.855	-0.139	0.456	-0.575	0.887
	Wireless clients	26	1412.249	93.831	478.446	-0.158	0.456	-1.203	0.887
Response time – addCustomer function	Wired clients	26	1691.391	147.687	753.059	0.284	0.456	-0.834	0.887
	Wireless clients	26	1365.740	105.959	540.289	-0.238	0.456	-1.170	0.887
Response time – All four functions	Wired clients	26	8149.871	899.897	4588.591	0.156	0.456	-1.092	0.887
	Wireless clients	26	6356.798	631.045	3217.713	-0.184	0.456	-1.364	0.887
Throughput in clients per second	Wired clients	26	7.758	0.650	3.313	-0.593	0.456	-0.974	0.887
	Wireless clients	26	14.296	1.149	5.857	-0.921	0.456	-0.760	0.887

Table D3. Descriptive statistics for response times for getTheFile and throughput in KB per second experimental groups

Experimental Groups		N	Mean	Std. Error Mean	Std. Deviation	Skewness		Kurtosis	
						Statistic	Std. Error	Statistic	Std. Error
LOG Response time – getTheFile function	Wired clients	20	2.856	0.129	0.576	-0.468	0.512	-1.349	0.992
	Wireless clients	20	3.317	0.142	0.637	-0.487	0.512	-1.210	0.992
LOG Throughput in KB per second	Wired clients	20	3.160	0.028	0.123	-0.881	0.512	1.114	0.992
	Wireless clients	20	2.700	0.022	0.098	0.144	0.512	1.501	0.992

Table D4. REST and SOAP group descriptive statistics

Experimental Groups			N	Mean	Std. Error Mean	Std. Deviation
Response time – getCustomer function	Wired clients	REST	13	2403.775	231.907	836.152
		SOAP	13	2829.856	270.869	976.633
	Wireless clients	REST	13	1356.847	126.946	457.712
		SOAP	13	1467.651	141.624	510.634
Response time – addCustomer function	Wired clients	REST	13	1227.748	141.531	510.299
		SOAP	13	2155.034	187.143	674.754
	Wireless clients	REST	13	1204.787	139.028	501.274
		SOAP	13	1526.693	152.099	548.402
Response time – All four functions	Wired clients	REST	13	6430.974	938.153	3382.558
		SOAP	13	9868.767	1414.801	5101.136
	Wireless clients	REST	13	6136.475	878.411	3167.156
		SOAP	13	6577.121	937.841	3381.435
LOG Response time – getTheFile function	Wired clients	REST	10	2.814	0.185	0.584
		SOAP	10	2.899	0.189	0.597
	Wireless clients	REST	10	3.273	0.216	0.682
		SOAP	10	3.361	0.197	0.622
LOG Throughput in KB per second	Wired clients	REST	10	3.203	0.034	0.107
		SOAP	10	3.117	0.041	0.129
	Wireless	REST	10	2.744	0.024	0.075

	clients	SOAP	10	2.656	0.033	0.103
Throughput in clients per second	Wired clients	REST	13	8.389	0.992	3.577
		SOAP	13	7.127	0.841	3.033
	Wireless clients	REST	13	14.822	1.704	6.144
		SOAP	13	13.770	1.596	5.755

Table D5. Independent samples t-tests results

Experimental Groups: REST vs. SOAP			**Levene's Test for Equality of Variances**		**t**	**df**	**Sig. (2-tailed)**
			F	Sig.			
Response times – getCustomer function	Wired clients	Equal variances assumed	0.245	p>0.05	-1.195	24.000	p>0.05
		Equal variances not assumed			-1.195	23.444	p>0.05
	Wireless clients	Equal variances assumed	0.151	p>0.05	-0.583	24.000	p>0.05
		Equal variances not assumed			-0.583	23.718	p>0.05
Response times – addCustomer function	Wired clients	Equal variances assumed	1.529	p>0.05	-3.952	24.000	**p<0.01**
		Equal variances not assumed			-3.952	22.343	p<0.05
	Wireless clients	Equal variances assumed	0.178	p>0.05	-1.562	24.000	p>0.05
		Equal variances not assumed			-1.562	23.809	p>0.05
Response times – All four functions	Wired clients	Equal variances assumed	3.172	p>0.05	-2.025	24.000	p<0.05
		Equal variances not assumed			-2.025	20.843	p<0.05
	Wireless clients	Equal variances assumed	0.113	p>0.05	-0.343	24.000	p>0.05
		Equal variances not assumed			-0.343	23.898	p>0.05
LOG Response times – getTheFile function	Wired clients	Equal variances assumed	0.001	p>0.05	-0.324	18.000	p>0.05
		Equal variances not assumed			-0.324	17.991	p>0.05
	Wireless clients	Equal variances assumed	0.097	p>0.05	-0.301	18.000	p>0.05
		Equal variances not assumed			-0.301	17.851	p>0.05
LOG Throughput in KB per second	Wired clients	Equal variances assumed	0.094	p>0.05	1.613	18.000	p>0.05
		Equal variances not assumed			1.613	17.428	p>0.05
	Wireless clients	Equal variances assumed	1.029	p>0.05	2.184	18.000	**p<0.05**
		Equal variances not assumed			2.184	16.449	p<0.05
Throughput in clients per second	Wired clients	Equal variances assumed	0.407	p>0.05	0.970	24.000	p>0.05
		Equal variances not assumed			0.970	23.374	p>0.05
	Wireless clients	Equal variances assumed	0.051	p>0.05	0.451	24.000	p>0.05
		Equal variances not assumed			0.451	23.898	p>0.05

Table D6. Comparison of means test results

Experimental Groups		Mean Difference	Std. Error Difference	95% Confidence Interval of the difference		Pooled Std. Deviation	Effect Size (d)	Post Hoc Power
				Lower	Upper			
Response time – getCustomer function	Wired clients	-426.082	356.582	-1162.031	309.868	909.110	0.469	0.209
	Wireless clients	-110.804	190.192	-503.341	281.732	484.896	0.229	0.087
Response time – addCustomer function	Wired clients	-927.286	234.635	-1411.549	-443.022	598.205	1.550	0.966
	Wireless clients	-321.907	206.066	-747.206	103.393	525.367	0.613	0.323
Response time – All four functions	Wired clients	-3437.792	1697.584	-6941.434	65.849	4328.007	0.794	0.494
	Wireless clients	-440.646	1284.972	-3092.697	2211.406	3276.048	0.135	0.063
LOG Response time – getTheFile function	Wired clients	-0.086	0.264	-0.640	0.469	0.591	0.144	0.061
	Wireless clients	-0.088	0.292	-0.701	0.525	0.653	0.135	0.059
LOG Throughput in KB per second	Wired clients	0.086	0.053	-0.026	0.197	0.119	0.726	0.336
	Wireless clients	0.088	0.040	0.003	0.172	0.090	0.977	0.543
Throughput in clients per second	Wired clients	1.262	1.301	-1.423	3.946	3.316	0.381	0.154
	Wireless clients	1.052	2.335	-3.767	5.871	5.953	0.177	0.072

Appendix E. Statistical Analysis

The assumptions of population independence and Gaussian populations were tested. As REST and SOAP implementations were never executed together, data for each sample was gathered independently, moreover, REST and SOAP would never be implemented together (populations are also independent). Thus, the assumption of independence was not violated. The assumption of normal distribution was tested using observation of normal probability plots, histograms with normal curve, and the combination of skewness and kurtosis coefficients. Data gathered for response time (getCustomer, addCustomer, and all four functions) experiments and throughput in clients per second experiment indicate that dataset follow nearly normal distributions. However, response time for getTheFile function and throughput in KB per second experiments indicated that dataset did not follow a normal distribution. Data gathered for these experiments was transformed using LOG transformation function available within SPSS. Investigation of LOG transformed dataset revealed to follow a normal distribution. Descriptive statistics for the untransformed experimental groups are provided in the table D2 and for the transformed experimental groups are provided in the table D3.

Independent samples t-tests were conducted for each response time and throughput experiment groups. Table D4 provides REST and SOAP group statistics. Table D5 shows the results of the independent samples t-tests. Levene's test for assumption that the variances of the two groups are equal indicates that assumption is not violated (i.e., $p > 0.05$) for all experimental groups. Therefore, the equal variances assumed t-test statistics was used for analysis. From table D5, it can be observed, at the 5% level of significance, only addCustomer response time experiment with wired clients, and throughput in KB per second experiment with wireless clients were significantly different (i.e., $p < 0.05$). Difference between REST and SOAP groups for other experiments were not statistically significant at the 5% level of significance. The comparison of means (see table D6) reveals that REST had a lower response times and higher throughput than SOAP for all experimental groups.

Following Cohen's guidelines (Cohen, 1988), effect size (Cohen's d) was calculated to determine the magnitude of difference between REST and SOAP groups. Effect size was calculated by dividing the mean differences for REST and SOAP groups by the pooled standard deviation. The pooled standard deviation is calculated as the square root of the average of the squared standard deviations of REST and SOAP groups. Table D6 shows the effect size measure for all experimental groups. A larger than typical effect size ($d > 0.8$) was detected for response times for addCustomer function (wired) and throughput in KB per second (wireless) experiments. A typical effect size ($0.5 < d < 0.8$) was detected for response time-addCustomer (wireless), response time-all four functions (wired), and throughput in KB per second (wired) experiments. A smaller than typical effect size ($d < 0.5$) was detected for the rest of the experimental groups. Thus, the mean difference between REST and SOAP for response times for addCustomer function (wired) and throughput in KB per second (wireless) experiments are of both statistical and practical significance.

Post hoc statistical power analysis was performed using G*Power software (Faul, Erdfelder, Lang, & Buchner, 2007) to determine the likelihood of finding statistical difference between REST and SOAP for the given sample size and observed effect size. Typically, post hoc power between 0.5 and 0.8 are considered as adequate power and greater than 0.8 as high power (Onwuegbuzie & Leech, 2004). High power was observed for response time-addCustomer function (wired) experiment, thus, there is a high probability of observing similar findings in future experiments with a similar structure, effect size, and standard deviation at the 5% level of significance. Adequate power was observed for throughput in KB per second (wireless) experiment, thus, there is a moderate chance of observing similar findings in future experiments with a similar structure, effect size, and standard deviation at the 5% level of significance.

Global Diffusion of Virtual Social Networks: A Pyramid Model of Cultural, Developmental and Regulatory Foundations

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Abstract

Virtual social network (VSN) has become an international phenomenon, but its diffusion is far from even across different countries. Such a new form of global digital divide prevents many people all over the world from enjoying the benefits of VSN. The objective of this study is to find out what lead to the variation in the global diffusion of this innovation. It identifies relevant cultural, developmental and regulatory factors and conceptualizes them as hierarchical foundations of VSN diffusion in a pyramid model. The model was empirically validated with secondary data. The results suggest that the regulatory foundation has relatively strong but volatile impact on the diffusion of virtual social networks, whereas the cultural foundation yields relatively weak yet stable influence, and in between is the developmental foundation. The findings have important practical implications, especially for policy makers, on how to facilitate the diffusion of virtual social networks in different countries.

Keywords: virtual social network, global diffusion, digital divide, user culture, country development, telecommunication regulation

1. INTRODUCTION

Nowadays, more and more people are using virtual social network (VSN) applications such as Facebook and LinkedIn. They are websites on which users create and maintain relationships with each other (Boyd & Ellison, 2008). Compared with traditional computer-mediated communication applications (e.g. instant messaging), VSN allows users to easily create profiles, add friends, join groups, update activities and share personal experiences with each other (Quan-Hasse & Young, 2010; Waisanen, 2010). Virtual social networks have become a global phenomenon within a decade as over a billion Internet users spend a significant proportion of time on them (Meattle, 2007). For instance, Facebook alone tops 900 million monthly users in 2012 and the number is still quickly increasing, making it the world's leading virtual social network (Cohen, 2012).

The benefits of VSN applications can be captured with the concept of social capital, which generally refers to the collective value of all the relationships among people (Coleman, 1988). Through the mediation of VSN applications, users can establish, maintain and materialize social

capital for psychological wellbeing and practical benefits (Ellison, Steinfield & Lampe, 2007). Also, the tremendous social capital accumulated through collective use has great commercial potential in areas such as marketing and e-commerce (Yazdanifard et al., 2011). For instance, social gaming, a special type of VSN, is a billion-dollar market. The transactions of virtual goods through mobile social media services alone reached $3 billion in 2011 (Stratmann, 2011). Some VSN applications are not only used for personal purposes, but also for business purposes. For example, Facebook launched its services tailored for cooperate networks after the initial school networks (Cassidy, 2006). Based on the connections established, business partners can build closer relationships through information sharing (Saraf, Langdon, & Gosain, 2007).

Though VSN can bring huge benefits to human society at different levels, its global diffusion is far from even. For instance, a recent global survey of 10 countries (Australia, Brazil, France, Germany, Italy, Japan, Spain, Switzerland, USA and UK) found that the percentage of online population who actively use VSN applications ranged between 59% to 86%, and the usage time ranged between 157 minutes to 387 minutes per month (Heras, 2010; Van Grove, 2010). Most of the countries in the survey were developed countries, and the gap between the most and the least developed countries in VSN usage is much wider.

The uneven penetration of VSN in the world contributes to the widening global digital divide, the gap between information haves and have-nots across different countries (Roberts, 2008). At the individual level, it means that people in different parts of the world do not have the equal access to information services (Dekimpe et al., 2000; Quibria et al., 2003). At the national level, the disparity hampers the efforts of developing countries to catch up with developed countries in terms of knowledge-based social and business activities (Oxley & Yeung, 2001). Countries where information and communication technologies (ICT) are less accessible are not as competitive in the global economy, and their people and societies cannot fully benefit from such technologies (Antonelli, 2003).
Thus an important question is: what are the factors that lead to the uneven diffusion of VSN among different countries? Several existing studies have investigated the adoption of VSN applications at the individual level. For example, a survey study found that individual factors such as gender, race and ethnicity, educational background, computer experience and autonomy of use influence whether people use VSN applications or not (Hargittai, 2008). So far, few researchers have addressed the question at the national level. This study will identify the country-specific factors that make differences in the diffusion of VSN, and empirically examine the effect of each with secondary data collected from multiple sources.

The rest of the article will be organized as follows. First, it will identify the cultural, developmental and regulatory factors related to VSN diffusion based on literature review. Then it will propose a research model and describe the methodology to validate the model. After the presentation of analyses and findings, it will discuss theoretical and practical implications, followed by the conclusion.

2. THEORETICAL BACKGROUND

To identify factors that are relevant to the diffusion of VSN technology, it is necessary to examine the phenomenon with an appropriate theoretical framework. VSN is an innovation based on the Internet technology, and its diffusion has been a worldwide phenomenon. For the study of how such an information technology is adopted by the people in different countries, Diffusion of Innovations Theory is well suited (Baskerville & Pries-Heje, 2003). Developed by Everett Rogers (1962), the theory describes the adoption process, provides an explanation of the means of diffusion, and predicts the success or failure of new inventions. Rogers specified the major components of innovation diffusion: a social system in which interrelated units are engaged in joint problem solving to accomplish a common goal, human decision process leading to the acceptance or rejection of an innovation, and various communication channels for marketing the innovation (Rogers, 1983, pp. 11-24).

The social system in this study is a nation in which a certain percentage of people adopt and use VSN. The diffusion pertains to both individual users and the organizations that provide and regulate VSN services. In particular, the telecommunication industry of each country establishes the necessary Internet infrastructure. The lack of broadband access constitutes the supply side of global digital divide, in contrast to the demand side related to people's need of information (Prieger, 2003). Accordingly, there are two aspects of issues related to uneven VSN

diffusion in the world: demand-side issues related to users and supply-side issues related to telecommunication industry.

In the study of innovation diffusion at the national level, researchers have found that countries at different development stages have different degrees of openness and receptiveness to innovations (Gomulka, 1971). Country development affects the VSN readiness of users (e.g. service affordability and computer literacy) as well as telecommunication industry (e.g. broadband infrastructure and policy). Thus, it is related to both the demand and supply sides of VSN diffusion, as shown in Figure 1.

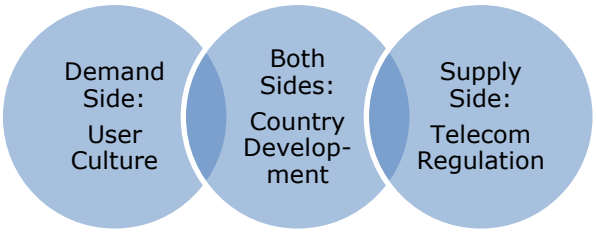

Figure 1. VSN Diffusion Factors

On the demand side, users communicate with each other through the mediation of VSN applications. It has been found culture is an important factor at the national level that regulates people's communication behavior (Singelis & Brown, 1995). Thus, user culture is the factor specific to the demand side. On the supply side, industrial regulation has a direct impact on the development and implementation of new technologies (Whitford & Tucker, 2009). Thus, telecommunication regulation is the factor specific to the supply side.

3. RESEARCH MODEL

User culture, country development and telecommunication regulation does not affect VSN diffusion in the same way due to their different natures. As a supply-side force, telecommunication regulation pushes or constrains VSN diffusion as it may facilitate or discourage (sometimes even prohibit) people's use of the innovation. As the demand-side force, user culture pulls or repulses VSN diffusion as it somewhat influences how individuals in a nation are likely to accept or reject the innovation. Country development, on the other hand, prepares both the people and industry for the VSN penetration. Therefore, the influence of telecommunication regulation is relatively direct and strong, the influence of user culture is relatively indirect and weak, and the influence of country development is somewhere in between.

These factors also vary in the durability of their influences. Telecommunication regulation needs to quickly adapt to the change in technological, commercial and political environment (Blackman & Srivastava, 2011). Thus, its impact on VSN diffusion is short and volatile in terms of years or even months. On the other hand, culture is rather stable, and its effect is long-lasting in terms of centuries (Hofstede, 1991; Smith, 1992). Country development takes the efforts of generations, and the durability of its influence is intermediate in terms of decades.

The pyramid model in Figure 2 reflects the different natures of telecommunication regulation, country development and user culture in terms of their influences on VSN diffusion. Telecommunication regulation has a relatively direct but volatile impact, and thus it is the foundation immediately underneath the VSN innovation. User culture has rather indirect but long-lasting influence, and thus it is the foundation at the bottom. Taking some effort and time to change, country development is related to both user base and telecommunication industry, and it is the foundation in the middle.

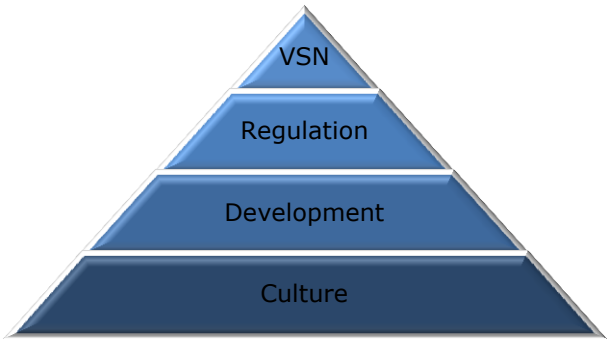

Figure 2. A Pyramid Model of VSN Diffusion

The understanding of how different types of factors affect VSN diffusion provides a guideline for designing an empirical study. Due to the hierarchical relationships among the regulatory foundation, developmental foundation and cultural foundation, it is necessary to examine each type of factors in an order. Culture is pertinent to the fundamental values of people in a country and may make differences in country development (Mbakogu, 2004). Together, the culture and development level of a country may also influence how the country makes policies for telecommunication regulation (Blackman &

Srivastava, 2011). Though the influence in the reverse direction may exist, it is not as strong. Therefore, the rest of this section will identify the specific variables of cultural, developmental and regulatory foundations respectively, and hypothesize their effects on VSN diffusion.

Cultural Foundation

There are many definitions of culture, but it is commonly agreed that culture is related to the fundamental values and beliefs shared among a population of people (Tarasa, Rowneyb & Steelc, 2009; Hofstede, 1991; Smith, 1992). The most influential framework to assess the influence of culture was developed by Geert Hofstede (1980). He initially proposed four dimensions of culture: 1) Power Distance: the extent to which the less powerful members of a society accept and expect an unequal distribution of power; 2) Uncertainty Avoidance: the extent to which members of a society feel threatened by uncertain and unknown situations; 3) Individualism versus Collectivism: the extent to which members of a society are integrated into strong cohesive groups; and 4) Masculinity versus Femininity: the extent to which a society attributes qualities such as assertiveness and material success to men, and modesty and quality of life to women.

Hofstede (1980) also developed a numerical score system for these dimensions. It greatly facilitates empirical studies of cultures in different settings and at different levels (e.g. Allik & McCrae, 2004; Benet-Martinez, & Karakitapoglu-Aygun, 2003; Earley, 1993; Gannon, 2004). Not many researchers, however, have taken culture into account in the investigation of information technology diffusion. Unlike individual applications, VSN facilitates computer-mediated communication (Boyd & Ellison, 2008). Hofstede's cultural dimensions are related to people's use of such an innovation as they explain human communication behavior to some extent (Singelis & Brown, 1995).

As for power distance, people tend to accept and expect differential social statuses in the cultures that are high in this dimension. However, VSN encourages equality in user rights and obligations to enhance social capital (Ellison, Steinfield & Lampe, 2007). Thus people in the cultures of lower power distance are more likely to adopt VSN.

As for individualism versus collectivism, individualists are less concerned with the thoughts and actions of others and tend to communicate with them more directly than collectivists (Singelis & Brown, 1995). To use a VSN application (e.g. Facebook), an individual establishes a personal space and invites others (e.g. friends) to join it. Compared with other virtual community applications such as Internet forum, VSN provides people a user-centric (rather than topic-centric) platform that allows them to display personalities (Bachrach et al., 2012). In this sense, individualists are more likely to adopt this innovation than collectivists.

As for masculinity versus femininity, this dimension is related to gender difference. Researchers found that females are more inclined and effective to use VSN than males (Thelwall, 2008; Thelwall, Wilkinson & Uppal, 2010). Thus, such a cultural dimension makes a difference in the new form of computer-mediated communication behavior. That is, masculinity may be negatively but femininity may be positively correlated with VSN usage.

As for uncertainty avoidance, cultures high in this dimension generally encourage compliance with norms and rules, but those low in this dimension encourage creativity and innovation (Triandis, 1989). As VSN is a relatively new innovation, people of high uncertainty avoidance may be hesitant to use it, or vice versa.

The above discussions lead to the following set of hypotheses:
H1: Cultural foundation affects VSN diffusion.
- H1a: Power distance has a negative effect on VSN usage.
- H1b: Individualism has a positive effect on VSN usage.
- H1c: Masculinity has a negative effect on VSN usage.
- H1d: Uncertainty avoidance has a negative effect on VSN usage.

Developmental Foundation

Because VSN is still an emerging phenomenon, few researchers have discussed the relationship between country development and VSN diffusion. However, VSN is an ICT innovation, and there have been many studies on how country development affects ICT diffusion. Most of these studies address the issue of digital divide in terms of why people have different levels of information access across and within countries (Chen & Wellman, 2004; Roberts, 2008; Hersberger, 2002-2003; Talukdar & Gauri,

2011). Thus digital divide is a complex issue as it involves countries at different development stages and people of different socio-economic statuses (Van Dijk & Hacker, 2003).

The development level of a country can be measured from multiple aspects. The most common aspect is the economic development. The diffusion of ICT in the world is closely related to economic growth (Bassanini & Scarpetta, 2002; Eagle, Macy & Claxton, 2010). Because VSN is an ICT innovation, economic development is likely to affect VSN diffusion. Economic development is also the foundation of other aspects of development, such as human development and technological development (Parente & Prescott, 1994). Such aspects of development may also influence the VSN diffusion.

As aforementioned, the development level of a country is related to both the individual users on the demand side and the telecommunication industry on the supply side of the VSN diffusion. Among different aspects of country development, the one that is more closely related to telecommunication industry is technological development, and the one that is more closely related to users on the demand side is human development. On the supply side, the importance of Internet infrastructure for the reduction of global digital divide has been well recognized by researchers (Warf, 2001). As for determining where a country is in the divide, its broadband Internet infrastructure is often used as an index to measure the development level of its telecommunication industry (Prieger, 2003). Each country needs to make a significant capital investment in form of ICT expenditure to establish and maintain such an infrastructure (Mohan, 2007). Therefore, this study adopts ICT expenditure as the independent variable to capture the technological development.

A puzzling phenomenon is that the same amount of ICT investment may lead to different results, such as digital divide and digital dividend, in different countries (Wong, 2002). It may be related to human development, the demand-side force determining how prepared people are to use ICT innovations. Education is the key for people to develop necessary knowledge and skills to use technologies (Bruce, 1997). This important aspect of human development leads to the human capital essential for technology adoption at the national level (Benhabib & Spiegel, 2005). The term human development describes the development of a country in this regard, which is about "creating an environment in which people can develop their full potential and lead productive, creative lives in accord with their needs and interests", according to the United Nations Development Programme (http://hdr.undp.org/en/humandev/). As a recent ICT innovation, VSN requires a certain level of human development to penetrate the population.

The three aspects of country development – economic development, educational development and technology development – are complementary to each other as they affect the global competitiveness of a country (Lall, 2001). All of them contribute positively to VSN diffusion. Because the cultural foundation has a more fundamental influence on VSN diffusion, the effect of the developmental foundation cannot be examined separately unless the former is controlled for its influence. Thus the relationship between country development and VSN diffusion can be hypothesized as follows:

H2: Controlled for the influence of cultural foundation, developmental foundation affects VSN diffusion.
- H2a: Economic development has a positive effect on VSN usage.
- H2b: Technological development has a positive effect on VSN usage.
- H2c: Human development has a positive effect on VSN usage.

Regulatory Foundation

VSN is an innovation based on the Internet. Though not many researchers have examined how regulatory factors affect VSN diffusion, there have been plenty of studies on the regulation of the Internet. There are generally two types of regulatory forces related to the diffusion of Internet technology: government regulation and industry regulation (Gibbs, Kraemer & Dedrick, 2003; Whitford & Tucker, 2009). It is generally agreed that Internet censorship is the main government regulation that directly impacts people's Internet usage (Dutton, Dopatka, Law & Nash, 2011). On the other hand, the competitiveness in the telecommunication industry is the main industry regulatory force that affects Internet penetration (Wallsten, 2002; Lie, 2002).

Almost all VSN traffics are transmitted over the Internet, both Internet censorship and

telecommunication competitiveness have direct impact on the diffusion of this innovation. For instance, during the protest in Egypt in 2011, the Egyptian government blocked Facebook and Twitter (Kessler, 2011). It shows how quickly telecommunication regulation can change people's VSN usage. In this sense, telecommunication industry competitiveness and Internet censorship constitute the regulatory foundation of VSN diffusion.

Internet censorship imposes restrictions and even fears on people to share information (e.g. political opinions) with each other through VSN applications. Thus Internet censorship is likely to have a negative effect on VSN diffusion. On the other hand, if a government encourages competition among telecommunication providers, it will lower the cost of Internet access compared with the case of monopoly. A more affordable Internet service means a larger user base for VSN. Thus telecommunication competitiveness is likely to have a positive effect on VSN diffusion. The accurate estimation of their effects requires the consideration of cultural and development foundations that have more fundamental influence. The discussions lead to the following hypotheses:

H3: Controlled for the influence of cultural foundation and developmental foundation, regulatory foundation affects VSN diffusion.
- H3a: Telecommunication competition has a positive effect on VSN usage.
- H3b: Internet censorship has a negative effect on VSN usage.

4. METHODOLOGY

In this study, all the variables need to be measured at the national level as the unit of analysis is "country". As for cultural foundation, Hofstede (2001) gave complete scores of the four cultural dimensions – power distance, uncertainty avoidance, individualism versus collectivism and masculinity versus femininity – for 78 countries. This study includes all of them in the dataset and the sample size is 78. The countries are from all the continents except for Antarctica.

As for development foundation, the most important aspect is the economic development as it is the basis for technological and human development. A common measure of economic development of a country is gross national income (GNI). It is necessary to take the population of each country into account to make GNI comparable across different countries. Thus, GNI per capita is used in this study. GNI data were collected from the World Bank's latest World Development Report (http://econ.worldbank.org/), and national population data were collected the Central Intelligence Agency's World Fact Book (https://www.cia.gov/library/publications/the-world-factbook/).

To assess human development, the United Nation Development Programme (UNDP) has developed the Human Development Index (HDI) (http://hdr.undp.org/en/humandev/). Because human development is related to economic development in terms of people's incomes, UNDP also gives non-income HDI by adjusting HDI values with average income. As economic development is already included as part of developmental foundation, this study uses non-income HDI to avoid high correlation between two aspects of development that may lead to a multicollinearity issue.

To measure the technological development of a country, this study uses the investment in information and communication technology (ICT). Like GNI per capita, ICT investment per capita was calculated by dividing the national amount with the population of each country to make it comparable across different countries. ICT investment data were collected from the World Telecommunication Database compiled by the International Telecommunication Union (http://www.itu.int/ITU-D/ict/statistics/).

As for regulatory foundation, it includes two factors: telecommunication competitiveness and Internet censorship. The measure of telecommunication competitiveness was obtained from the Global IT Report (Dutta & Mia, 2011). Internet Censorship was obtained mainly from the report by United Nations Educational, Scientific and Cultural Organization (UNESCO) (Dutton et al., 2011).

Finally, the dependent variable VSN diffusion is measured with the VSN usage index given in the Global IT report (Dutta & Mia, 2011). It was computed based on the percentage of VSN users in the total population and the time that they spend on VSN on average.

Based on the research model, there are three groups of independent variables in terms of cultural, developmental and regulatory

foundations, and they have hierarchical effects on VSN diffusion as the dependent variable. Thus, this study employs hierarchical regression method to control for the effects of lower-level factors for more accurate estimation of the effects of higher-level factors. This method also allows for the testing of the overall effect of each block of variables entered based on the differences in *R*-square and *F* statistic.

5. RESULTS

Table 1 gives the descriptive statistics of the observations. The value of virtual social network usage has a range of 3.37, and is left-skewed as the mean is closer to the maximum than the minimum. The distribution shows that more countries are closer to the innovators than the laggards in the diffusion of VSN innovation. The coefficient of variation (i.e. the ratio between standard deviation and mean) is close to 10%. It shows that the diffusion of VSN is very fast in most parts of the world, but some countries still lag far behind, forming a new digital divide.

Table 1. Descriptive Statistics

Variable	Range	Mean
Dependent		
VSN Usage	3.11-6.48	5.32(0.73)
Cultural		
Power	11-104	61.54(21.25)
Individualism	6-91	42.1(22.81)
Masculinity	5-110	50.21(17.53)
Uncertainty	8-112	65.58(22.39)
Developmental		
GNI per capita	737-59993	18837(14806)
ICT Investment	27-7669	1188(1363)
Non-income HDI	0.37-0.98	0.78(0.15)
Regulatory		
Competitiveness	0-6	4.94(1.52)
Censorship	1-5	2(1.28)

Note: Standard deviations given in the parentheses beside the means. GNI – gross national income; HDI – human development index.

As for the cultural foundation, the average range of the four dimensions is about 100, with the means in approximately the middle. The coefficients of variation are about 30%. As for developmental foundation, countries vary widely in economic development, technological development and human development. Except for human development, economic development and technological development are seriously right-skewed, indicating that the majority of countries in the world are still underdeveloped in these two aspects. In comparison, human development is more balanced, as the coefficient of variation is about 25%, in comparison to about 100% for economic development and technological development. As for regulatory foundation, telecommunication competitiveness is more right-skewed and Internet censorship is more left-skewed. This indicates that most countries recognize the harm of monopoly and encourage competition. On the other hand, Internet censorship is a common practice for many regimes in the world.

Table 2. Standardized Regression Estimates

Predictor	Model1	Model2	Model3
H1: Cultural			
-a: Power	-.15^{NF}	-.05^{NF}	.01^{NF}
-b: Individualism	.34**	-.01^{NF}	-.05^{NF}
-c: Masculinity	-.18	-.16	-.18*
-d: Uncertainty	-.15	-.19*	-.13
H2: Developmental			
-a: GNI per capita		.39**	.68***
-b: ICT Investment		-.07^{NF}	-.16
-c: Non-income HDI		.35**	.04^{NF}
H3: Regulatory			
-a: Competitiveness			.26***
-b: Censorship			-.30***
Model Comparison			
-R^2	.28	.52	.64
-*F* change	5.55***	8.95***	8.51***

Note: ^{NF} – Not significant at 0.2 level; * – significant at 0.1 level; ** – significant at 0.05 level; *** – significant at 0.01 level.

Table 2 reports the results of hierarchical regression analysis. The change of *F* statistic in model comparison shows that each of the three foundations significantly contributes to the explanation of VSN usage when the effects of lower-level foundations are controlled for the estimation of the effects of higher-level foundations. As the model *R*-square indicates, cultural foundation explains 28% of the variation of VSN diffusion, developmental foundation explains an additional 24% of it on top of cultural foundation, and regulatory foundation explains an additional 12% of it on top of both cultural and economic foundations.

All three models include cultural dimensions as the predictors of national VSN usage. In model 1 where only cultural foundation is considered, Individualism is significant at the 0.05 level. In model 2 where both cultural and developmental

foundations are considered, Individualism becomes insignificant, but Uncertainty Avoidance becomes significant at the 0.1 level. When cultural, developmental and regulatory foundations are all taken into account, masculinity becomes the only one that is significant at the 0.1 level. The directions of the significant relationships between these dimensions and the dependent variable are consistent with what are hypothesized: Individualism has a positive effect, and Masculinity and Uncertainty Avoidance have negative effects on national VSN usage. Power Distance is not significant in any of the models.

Both Models 2 and 3 include Economic Development, Human Development and Technological Development as the predictors of national VSN usage. In model 2 where cultural foundation and developmental foundation are considered, Economic Development and Human Development are significant, but Technological Development is not significant. In model 3 where the regulatory foundation is added, Economic Development becomes more significant but Human Development becomes insignificant. The directions of the significant relationships between different aspects of development and the dependent variable are all positive, consistent with the overall hypothesis that country development enhances VSN usage.

Finally, only Model 3 includes Telecommunication Competitiveness and Internet Censorship as the predictors of national VSN usage, and both variables are highly significant. As hypothesized, Telecommunication Competitiveness has a positive effect and Internet Censorship has a negative effect on VSN usage.

All the variance inflation factors (VIFs) are below 5 (the highest is 3.53 for Non-income HDI in Model 3), indicating that multicollinearity is not serious enough to confound the results. The moderate correlations among the independent variables also explain the changes in the significance levels of some variables when more significant variables are entered. In specific, the variation in the significance of specific cultural dimensions in different models is mainly due to the fact that their effect sizes are relatively small compared to the variables of developmental and regulatory foundations as the *R*-square and *F* change statistics show. When more significant variables are entered, the effects of original variables may change. For instance, Individualism is somewhat related to Human Development that encourages creativity and independent thinking. Also, it has been found that individualism is positively related to economic development of a country (Ball, 2001). Thus, when the developmental foundation is taken into account, Individualism becomes insignificant but Uncertain Avoidance becomes more significant.

The shift of salience from Uncertainty Avoidance in Model 2 to Masculinity in Model 3 may also be due to the fact that regulatory foundation implies assertive forces and uncertainty reduction. In addition, Human Development became insignificant after the regulatory foundation is taken into account. This may reflect that Telecommunication Competitiveness and Internet Censorship are somewhat correlated with Human Development: a country with higher Human Development is likely to have higher level of Telecommunication Competitiveness but lower level of Internet Censorship.

6. CONCLUSION AND IMPLICATIONS

Virtual social network (VSN) has become a worldwide phenomenon, and this study examines the national factors that influence its global diffusion. Through a literature review, it identifies three types of factors: user culture on the demand side, industry regulation on the supply side, and country development related to both. To capture how they influence VSN diffusion, a pyramid model is proposed based on their different natures in terms of influence and durability. As the model suggests, regulatory foundation has the direct impact on VSN diffusion but it is quick to change, cultural foundation has an indirect effect but it is quite stable, and developmental foundation is somewhere in between. The relationships between specific variables and VSN usage are hypothesized and empirically tested, and results of hierarchical regression analyses support the validity of pyramid model.

There are several limitations of this study. First, the observations are not randomly selected from all the countries in the world. The 78 countries included in the sample are the ones to which Hofstede gave the values of the four cultural dimensions. In this sense, this can be considered as a convenience sample. Because of the potential selection bias, the findings may not be generalizable to other countries. In addition, the effective sample size is 62 due to missing values. The excluded cases represent 20.51% of the

sample size. Three countries do not have virtual social network usage values, and 16 countries (including the previous three) do not have ICT investment values. As the countries with the missing values may be somewhat different from others, the exclusion of them may further increase the selection bias.

Despite the limitations, this study answers some important theoretical, empirical and practical questions. The pyramid model proposed in this study describes the hierarchical relationships between VSN usage and its cultural, developmental and regulatory foundations. Compared with traditional information technologies, VSN is unique in that it has been a social and global phenomenon since its birth. The model not only identifies the important foundations at the national level but also distinguish their natures related to VSN usage. In specific, cultural foundation is stable and hard to control, and it has an indirect and relatively weak influence on the diffusion of such a technology. On the other hand, regulatory foundation is volatile and possible to manipulate, and it has a direct and relatively strong impact on VSN diffusion. Developmental foundation takes time and effort to change and its effect is intermediate. Thus, this study contributes to the current innovation diffusion literature in that it enhances the understanding of the phenomenon from different aspects of country characteristics.

The hierarchical regression technique employed in this study provides the means to empirically test the relationships between VSN usage and cultural, developmental and regulatory foundations. Controlling for the effects of lower-level foundations when the effects of higher-level foundations are examined, the model comparison statistics (i.e. change in *R*-square and *F* statistic) confirm that they have hierarchical effects on the dependent variable as the pyramid model suggests. In addition, the analyses reveal that there are moderate correlations among the independent variables (variance inflation factors between 1 and 3.5), and the entering of higher-level variables changes the significance of some lower-level variables. This further supports the pyramid model in that cultural, developmental and regulatory foundations are not independent from but rather connected with each other. The results indicate that developmental foundation is related to both cultural and regulatory foundations as its model entrance leads to the change in the observed significance levels of several cultural variables, and the effects of its own variables shift when regulatory variables are added. This confirms that the developmental foundation is associated with the cultural foundation on the demand side and regulatory foundation on the supply side of VSN diffusion.

The findings of this study have important practical implications, especially for policy makers. As for industrial regulations, this study suggests that they have potentially great impact on VSN usage in a country. Enhancing the competition in the telecommunication industry facilitates VSN diffusion, but tightening Internet censorship constrains or even blocks it. Because the impact is direct and strong, governmental officials and industrial stakeholders need to be careful in making relevant policies. Compared with regulatory foundation, developmental foundation is beneficial in all aspects but it takes time and effort to materialize. Among the three aspects, the findings suggest that it is more important to advance economic development and human development than technological development as the latter depends on the previous two. Thus, economic development and human development are the keys for national diffusion of VSN, especially developing countries. Finally, cultural foundation is hard to change, but that does not mean that researchers and practitioners can do little in this regard. Rather, they can adapt VSN usage to a particular cultural environment by guiding user behavior. In a society that emphasizes collectivism, for instance, VSN service providers may encourage users to establish interest circles (e.g. hobby, shopping, social events) and make joint efforts.

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Do Experiments using Immersive and Interactive 3D Structures Improve Memorization?

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Abstract

The paper focuses on the experiment of human computer interaction in an immersive and interactive 3D structure by students during their courses**.** We want this article to examine the real effect of the New Technologies on the students and in particular how virtual reality could improve education, specifically in the ease of reception of knowledge. We study in particular the effects of virtual reality (3D, vision headset, total immersion) on the long-term memory of the students and the different form of communication that the specific type of media imposes. In our study, we compared the case of different form of courses from a traditional course (an oral media-based course/ a media-based course in PowerPoint without taking notes/ and with note taking) to a media-based course in virtual imagery (3D, vision headset, total immersion). We analyse the type of communication with the use of an immersive, interactive structure, giving the sensation of presence. Our experiment entails a 3D device in the setting of media-based, educational communication (Peraya, 1998; 2000) in scholarship.

Keywords: human computer interaction, 3D Head Mounted Display, virtual image, levels of communication.

1. INTRODUCTION AND POSITION OF PROBLEMS

Much research has shown that technology could improve education. For example, Kulesza, Dehondt, and Nezlek (2011) wrote that "educational institutions use the appeal of technology to attract students, academicians advocate technology as a means of engaging students in learning material rather than simply presenting it, and research suggests that students are more engaged with classroom material when it is accompanied by technology." In this paper, we examine the real effect of the New Technologies and in particular how virtual reality could improve education, specifically in the case of reception of knowledge. We will study the effects of virtual reality on the long term memory of the students and the different form of communication that the specific type of media imposes. In this paper, we want to show that the human computer interaction is a complex process.

In our study, we compare the case of different form of courses from a traditional course (an oral media-based course/ a media-based course in PowerPoint without taking notes/ and with note taking) to a media-based course in virtual imagery (3D, vision headset, total immersion). We analyze the type of communication with the use of an immersive, interactive structure, giving the sensation of presence. Our experiment entails a 3D device in the setting of media-

based, educational communication (Peraya, 1998; 2000) in scholarship.

We created five homogeneous groups of students (18 students per group in the second year of initial training, DUT (Diplôme Universitaire Technologique) of TC (Techniques de Commercialisation, IUT (Institut Universitaire Technologique.) at the IUT of Université du Sud, in the setting of our courses in the Psycho-sociology of Organizations, ninety students were tested. The content of this course was the same in the five groups:

1. An oral, media-based course: the course was dictated but the students did not take notes.
2. A media-based course in PowerPoint alone but without note taking. The images and the diagrams were the same as those that were used in the course in synthetic images.
3. A media-based course in PowerPoint, with note taking. The images and the diagrams were the same as those that were used in the course in synthetic images.
4. A media-based course in virtual imagery and synthetic images (3D, vision headset, total immersion).
5. A control group course, the pre-test and the post-test only.

We compared the five courses on:
- -The cognitive and memorial aspects (long-term explicit memory)
- -Identifying the different types of communications

We ventured two hypotheses:

H1: A course in virtual images allows a better memorization compared with other types of media-based presentations (auditory, PowerPoint without notes, PowerPoint with notes);

H2: the type of media-based presentation acts on the communication of course content and the students experienced the four types of media-based presentation differently.

Our initial hypothesis was calling upon an increasing number of sensory modes which have made simultaneously possible the increasing performance of the long-term explicit memory of the information delivered by the didactic content (Paivio, double coding theory, 1971, 1986, 1991; Paivio and Caspo 1969). As far as our experiment is concerned, we have tested long-term / explicit memory. In fact, that is the form of memory at work when memorizing a course, even if learning brings several forms of memory into play. The result of our study showed that students did not have better memory performances in 3D virtual image course with HMD. It is the reason why we thought that these results could be explained by students' resistance to change.

Our approach combined:
1. A quantitative analysis based on hypothetical-deductive reasoning (first hypothesis) in order to analyse if an immersive 3D structure in the framework of our courses would have effects on memorization and to test the sensation of presence in the course presented by means of virtual images
2. A qualitative analysis (second hypothesis) a) in order to understand how the students experienced the different communications situations across the four types of media-based presentation; and b) to study the different types of reluctance face to change and the ambivalence of this concept.

For our first hypothesis, the differences in results obtained by the courses were calculated by variance analysis (Anova). We used a t-test to examine the sensation of presence in the virtual environment. The results of the Anova and the t-tests are exposed in this article.

For our second hypothesis, we interviewed 18 students in the course in virtual images with HMD. The results of these qualitative interviews are presented in this article. First, we present our case study.

2. CASE STUDY: an immersive and interactive structure, giving the sensation of presence

We can describe the structure of our experiment as 1) immersive, 2) interactive structure and 3) giving the sensation of presence.

A total immersive structure

Many authors have likened this term to a technical notion, which might act on the user's senses. Cadoz (1994) asserts that immersion is "a technology, an interface technique between man and machine and does not involve the psychological state of the subject". The physical immersion of a subject in a virtual environment is performed by sensory information (sight, hearing, etc.) alone.

For Pimentel and Texeiria (1993), immersion is "the state of a participant when one or more of his senses ... is isolated from the exterior world and he no longer registers any information that does not come from the computer".

According to Seipels (2003), a virtual environment is considered in total immersion when the totality of the user's senses is called upon on the one hand, while on the other hand there is total immersion of each sense (even if this total immersion is seldom attained in practice).

According to Slater and al. (2001), in an immersive environment, the users have an egocentric view of the virtual world, that is, a view from the inside of the environment or of the phenomenon, as opposed to an exocentric view from the inside of the environment, where the user does not directly take part in the virtual word. For systems of these types, immersive technologies are used: data loves, CAVE o HMD headsets, etc. Technologies of this kind allow visual immersion of the user in a virtual environment. Our structure was a total immersive structure because the students had a 360 degrees vision and an egocentric view of the virtual world.

An Interactive Structure

In virtual environments, the user's interactions are said to be subordinated to four tasks, according to Fuchs et al. (2001), as regards functional interaction. The user's four tasks are to:

1) Observe the virtual world
2) Navigate in the virtual world
3) Act upon the virtual world
4) Communicate

Observing the virtual world is a stage that allows us to prepare ourselves for other actions and that is necessary for understanding the virtual world.
Navigating, acting and communicating presume an action on the user's part. The structure of our experiment can thus be considered as interactive in the sense that it allows the user to perform these four actions.

A Structure Giving the Sensation of Presence in a Virtual Environment

The feeling of being present in a virtual environment is sometimes combined with that of immersion, but it forms the psychological aspect, while the notion of immersion refers more to the technological aspect. The notion of "presence" in a **virtual** world is "the psychological feeling of being there in the environment, of which immersion is the technological basis" (Slater and al., 2001).

For our experiment, the students were equipped with:

A HMD (Head Mounted Display, that is, a Sony Glasstron LDI-D100B ruggedized vision headset (LCD screen, Resolution 800x600, non-stereoscopic, visual field 26° Horizontal, 19.6° vertical, headphones with stereophonic sound - see Figure 1).
A Tracker (movement detector) Intersense intertrax² (3 degrees of freedom, angular resolution: 0.02°, latency time 4 ms: internal refresh rate of 256Hz), mouse buttons as navigation tools.
Software used: Unreal 2004, 3D Studio max, Actor X, and PowerPoint.

The students were in total immersion, in an interactive structure giving the sensation of presence.

Figure 1 Head Mounted Display

The People Involved in the Project

Doctor Eric Malbos, physician and neuro-psychologist, who has elaborated a system conceived within a virtual environment in order to treat patients suffering from phobias by successive habituations. He created the storyboard of the course in virtual imagery, the animations and the course in virtual imagery.
A professor of Psycho-Sociology of organization who prepared a doctorate thesis (Lombardo, 2007) was the project leader.

A media engineering student from the University of Toulon and the South (Wallid), a specialist in synthetic images, has created, in the framework of a proficiency grant, the 3D images for the course in virtual imagery.

Experiment, Report, The Courses
Group 1: An oral, media-based course: the course was dictated; the students did not take notes.

Group 2: A media-based course in PowerPoint alone but without taking notes. The images and the diagrams were the same as those that were used in the course in synthetic images.

Group 3: A media-based course in PowerPoint, with note taking. The images and the diagrams were the same as those that were used in the course in synthetic images.

Group 4: A media-based course in virtual imagery and synthetic images (3D, vision headset, total immersion).
Group 5: A control group course, the pre-test and the post-test only.

An example of virtual environment: the students had to get into the university and cross 23 classrooms (Figure 2)

Figure 2 An example of the virtual environment seen by students

3. METHODOLOGY H1

A way of verifying hypothesis H1 was to construct a quasi-experimental system that allowed us to vary the different dimensions of the Independent Variable (IV) and to create teaching structures each one of them corresponded to a mode of the IV that we wanted to test, that is the structure of the media-based presentation.

4. DATA PROCESSING H1

The IV has several modes: course 1 auditory, course 2 PowerPoint without note taking, course 3 PowerPoint with note taking, course 4 by means of virtual images in immersive 3D.

The differences in results obtained by the courses were calculated by variance analysis (Anova), and by a test T. of the Student.

5. ANOVA RESULTS H1

Group 3 (PowerPoint with note taking) is the one that had the clearest significant improvement in performance.

By decreasing order of performance, group 2 came next (PowerPoint without note taking), then group 4 (virtual images), then group 1 (auditory) and last came group 5 (the control group).

6. RESULTS OF THE TEST OF PRESENCE H1

The results show that the students had a feeling of presence within the virtual environment of the course in immersive 3D.

7. RESULTS OF THE QUALITATIVE TREATMENT H2

The recurrent themes in the 4 groups (auditory, PowerPoint with note taking, without note taking, and by virtual images) were the following:

Theme 1: emotional

1) Positive emotional dimension: original universe/ environment; innovation/social network; funny.
2) Negative emotional dimension: unreal; "small lab rats".

Theme 2: physical

1) Positive physical dimension: sensation of presence in virtual environment
2) Negative physical dimension: discomfort/sick; headache

Theme 3: cognitive
Positive cognitive dimension: simulation as help in learning; simulation as help in understanding the reality; experiment as a source of motivation

Negative cognitive dimension: no human aspect: learning boundaries

Theme 4: intentional
Positive intentional dimension: emulation to take the course in virtual image

Negative intentional dimension: technical aspects of virtual device

Emotional Dimension: The Device (Structure) in Virtual Images: an Original and Pleasant "Universe" for Students
In our case study, we notice that students have positive or negative responses.

Positive Emotional dimension: original universe / environment
The course in virtual image has emerged as "a universe" (student 5V), a world", "virtual world" (Student 2V), "and thus we entered directly into a virtual world. It was a world that we were not used to being into "(Student 3V)," then I walked into this world "(Student 3V). The characteristics of environment played a positive role (positive emotional dimension) in the perception of change recipients (students).

Positive Emotional / innovation / social network
Many students noticed the novelty of the device, particularly highlighting the fact that it was new for them, the surprising aspect of the device appeared to them as positive: "It was a first" (Student 1V), "So we were expecting something really innovative, that's why we were surprised because it's true that it has changed us, it was innovative" (Student 3V). The innovative aspect of the device is also linked to the idea (and fantasy) of a future where education will go through the virtual "yes we realized that it might be the future of an educational standpoint, this would happen, and it is true that compared to whatever is happening to video games, the virtual world, it seems to be a fairly logical way for the future "(Student 3V). (The structure in virtual image as an Innovative changed the patterning of Students' actions in the social network).

Positive Emotional / funny
The lighter side of the device is often linked to the playful aspect of the device: "First of all, the playfulness" (Student 3V) "I found it really interesting, the virtual world, to recreate a building, I thought it was really nice after I find that to learn the course, it's true that it's more fun yes, it is a fun side in the course "(Student 2V)," it is true that the 'playfulness that I really appreciated "(Student 3V)," and I took it as something fun "(Student 5V).

We noted that the communication is a complex mixture of context, attitudes and processes. The characteristics of environment played a positive role (positive emotional dimension) in the perception of students. The structure in virtual image as an innovation changed the patterning of Students' actions in the social network.

Negative Emotional dimension: unreal - "small lab rats"
Psychological immersion is not felt with the feeling of being truly present, but as a "game" that does not correspond to "real life" by some students, "The problem is that I was a little troubled by the virtual world. I, too, never felt like myself. ... It's not real. Even if the atmosphere was nice, it is not real life, but it's well done, but after what I told you ... it's something else, it's a game for me"(Student 2V). This is consistent with the idea of being in a "universe" that has been identified by many students as we have seen.

The course is seen as an experimental laboratory study, "I said, ah, my psychology teacher, she wants to brainwash me for her thesis!" (Student 2PSN).

The course in virtual images caused an excitement and a kind of fantasy so that the students saw it as an imaginary being, a science fiction world, "Because it was different. Because we were not in a lecture hall, 90, listening to someone speak. It's different. And I remember with one of my colleagues, we said we will have a helmet, we will believe in "Back to the Future" in fact it was not like this story helmet, we had a good laugh about it" (Student 1PSN).

Some students felt they were "small lab rats" and they thought it was rather funny: "we amused ourselves by saying we were small laboratory rats, but it was fun, it was quite lively"(Student 3PAN)"As I told you, when we went to the course, we said we will play small laboratory rats, but it was so good-it was not negative, that we knew very well that we were used (in quotes) for an experiment but it amused us all that ... So we did not have to say, no we will not go, we will be used, we didn't think that at all "(Student 2PAN).

PHYSICAL DIMENSIONS: The real body, to test the technical and informational device in the virtual images

Positive Physical
The physical immersion was felt by many students in the course virtual images, "I said through the headset and looking directly at the video, we felt really "in", like almost in the character. There was someone who was driving, which met after the questions, we were in the character, the main character, and it is true that I was fully integrated in this virtual world, I had returned"(Student 3V)"The sensation of moving the head, that was interesting" (Student 1V).

Negative Physical dimension: discomfort / Sick; headache
Regarding the binding aspects of the device, they are of several types: first the physical discomfort caused by the device "for the first time, it is not too comfortable, what I felt, I was not well, I remember, I was really sick "(Student 1V)

The evil of heart (to feel sick) and headache (headache) were also often mentioned, but it seemed to appear to students as a problem of adaptation to the device "I think it gave a little bit of heartache anyway ... it's true, then we must get used to "(Student 2V)

It was also noticed that physical tiredness often went through the eyes: "The eye fatigue. The sound is not annoying, but after a while I think it can be tiring" (Student 5V). The "eye tiredness" seems to cause disorientation. Another student talked about a total loss of direction due to the HMD, "Headaches, disorientation and loss of landmarks"

The helmet was part of the technical (technical constraint) often noticed, "It hurts to the forehead, I remember now, finally, after a while, it is a little better.

We have the feeling of bearing the course, "and also all that is helmet and all, it seems we are passive and we are imposed that mode of education, of instruction, we are here and we suffer a bit with the helmet and the video "(Student 3V), the device appeared in some less interactive than a traditional course:" Not necessarily because there is an interaction, we "suffered" in quotes "(Student 5V).

COGNITIVE DIMENSION

Positive cognitive dimension: **simulation as a help in learning; simulation as a help in understanding the reality; a source of motivation**
The simulation appears to be necessary in learning when describing situations that cannot be simulated in real life; it helps the understanding of a phenomenon (the student evokes a course in 3D simulation he followed during his training): "I remember everything from Art History, the representation, so we were told this, you have such a perspective, something like that, and then they showed us a 3D simulation that really gave it so we understood really well" (Student 2V) "I do not know there was an experience, we had imagined drawing reflections of mirrors with all that, and, actually, they really showed us the mechanism inside with different views, it's true that if the teacher wants to explain it like this, it would be difficult. Here it is true that we understood better" (Student 2V).

The simulation is therefore necessary to simulate case studies that in reality cannot be, "Here, they are real case studies" (Student 2V).
A memory aid student think the course in virtual imaging allows better remembering: "By not taking notes after the PowerPoint, I don't think it was a good method, I think the virtual image can help ... after I do not know what it is exactly but I think that I would have preferred virtual imaging "(Student 3PAN).

Having lived an experimental course was seen as a source of motivation, "Well first, it's true that experimentation had motivated me more than usual, knowing that it was an experiment, I went in class, but it's true that I was more motivated, I was more careful when I filled out the questionnaire, when I experienced, I ' was really more focused than usually "(Student 3V).

The fact that this is an experiment that had motivated students because they wanted to be useful and please the teacher: "We were a bit more involved, because we knew it very well ... There was a desire (in quotes) to help you, since you've done all the researches "(Student 3PAN). Therefore, they were more attentive, "Bluntly, we listened a little more because we always knew the teacher had to find some benefits from the experiment. So perhaps we were a little more attentive" (Student 3PAN). In addition, they showed more motivation, "Yes, because I

know very well that there is an experience" (Student 3PAN).

Negative cognitive dimension: no human aspect: learning boundaries

The fact that there is no teacher also appeared to be a constraint for the human and relational aspect, "So, yes, what really bothered me, was that, well first it's true that there was no teacher, no human aspect, and I found it a bit annoying "(student 3V).

Also the absence of teacher seemed to lead to a lack of motivation "and also, I may leave the classroom for a short moment without anyone to notice as "the teacher" is a computer, the contrary, it's true that nothing can replace the human side, we are more attentive" (Student 3V). The teacher appears as a person to the student, who will be boosted and motivated, "So I really prefer education with a teacher, a real person, who can touch us, motivate us, whereas with this virtual version, it's true that there, we cannot do anything, it cannot motivate us, tell us what to do, so it's really ... a cold means of instruction. So I really prefer having a teacher" (Student 3V).

The role of the Professor is very important in breaching of agreements and restoring trust in students.

Intentional Dimension

In the Intentional dimension, we show that change recipients (students) propose improvements for the virtual device.

Positive Intentional dimension

There was indeed some emulation to take a course in virtual imaging, and thus, in the end, a certain disappointment to those who had not followed (randomization): "I believed that I was, I know, in the dark, with glasses, we saw things, I imagined the big thing, and I wasn't picked, it was a shame" (Student 5A).

Having had such an experience seemed to have been a source of motivation, so that the whole course seemed to tend towards that goal: "During my first year of psychology, we had not really done that kind of experiment, which was so interesting and useful. So I might get more invested next year "(Student 5A).

Negative Intentional dimension

Some students were disappointed not to live the experiment in virtual images, "Honestly, in the beginning we were a little disappointed because we were told it would be us who would do the virtual images course, we heard about it, so we wanted to discover it, because, the PowerPoint, taking notes ... this is a usual course"(Student 3PAN).

Technical improvements doubled the inclusion of an interactive character

The improvement of the device appeared necessary for some students, particularly in the technical aspects: "It is true that we thought it was more impressive than that usual experiment, it was fairly new and I think it especially needed some serious change".

We can say it was really a "prototype""(Student 3V).

The attenuation of the monotony could go through the distinction of classrooms: "Well, I think that if all the rooms were different, it would be a plus" (Student 5V).

The notion of feedback also seemed to be a source of improvement, if it would include an interactive character: "If we were told the course by a character, that would be a plus"(Student 5V) "But I think that it was fun enough, even if, instead of being read, the text should be told by a character, it would be a nice change, it would vary a little"

Taking notes also appeared as a possible improvement of the device "because it has not been possible to take two or three notes"(Student 4V).

Remove the text and use the virtual image alone, appears also as an opportunity for improvement, "But to return to the information, it is true that read, hear, move, it was perhaps too much and if we had simply done it as a video game, or simply controlling virtual elements by removing the text, perhaps I should have paid more attention to the sound, without rereading, etc.. So that, it might be added to the next experiment"(Student 3V).

Depending on their personal experience

A student was afraid and wondered a lot about the course; he was older than the others and was working, he was following the course in a continuing education course: "I was a little tired, stressed; I was doing odd jobs, so I was afraid but I took and finish this course, fingers in the nose"(Student 4PSN)"

Some students wondered how the experiment would take place, particularly in relation to the medical question sheet, "Yes, they wondered what was going to be experimented, you had to follow attentively through the course, because you had a questionnaire and that it might cause minor problems, so they were wondering how it would happen" (Student 4PSN).

8. THE LIMITS OF OUR STUDY

We assume that the average score of students in the group 'virtual images' could be explained by:

1. The cognitive load theory: in fact, sometimes students were embarrassed by the HMD, they experienced headaches or heartaches, indeed, the hardware could cause mental or cognitive overload. Mayer (1997, 2003) or Schnotz, and Böckheler Grzondziel (1999) took into account in their models the notion of mental activity associated with multimedia learning, Sweller, Paas and Van Merrienboer (1998) defined the concept of cognitive load by placing it in the problems of multimedia learning. These authors define cognitive load as the mental workload that the execution of a task imposes on the cognitive system. Varies depending on the quantity and quality of information presented in a multimedia educational product, the cognitive load is assumed to depend on storage capacity and processing information in working memory learners. The theory of cognitive load may partly explain the poor performance of students in memory if the current 3D immersive virtual images;

2. The effect of habituation may be too long (we had planned to let students get used to the device for a quarter of an hour, but this time perhaps it has not been sufficient. So, another experiment might be lead by allowing students to have time to get used the device for a much longer time.

9. CONCLUSION: HUMAN/COMPUTER COMMUNICATION IS A COMPLEX PROCESS

In this paper, we wanted to show that the human/computer interaction is a complex process. First, we showed that a course in virtual reality hadn't improved the long-term memory. Secondly, we showed that the students felt as if they were present in the virtual world. Thirdly, we showed that communication in virtual reality course had taken four dimensions:

The emotional dimension is an important factor in communication between students and teacher because the virtual images could be symbolized like a cyber-fear or a cyber-utopia (the 3D device is in the same time symbol of modernity like an innovative device and symbol of an inhuman world where the students felt quite alone)

The physical dimension is to take into account because the bodies of the students are involved in the process (the structure gave them headaches for example)

The cognitive dimension is important too, because the results of our study show that the virtual images did not allow a better memorization.

Intentional dimension shows that the course in virtual images gave them a real emulation.

These four dimensions are complex because they could take a positive or negative meaning. For example, the emotional dimension is both positive and negative. All the speech about the virtual images and a cyber-world created an emulation for the students and they felt like participating into this sort of course, however, most of them were disappointed by this course because it was not enough interactive.

The complexity of the communication is also present in the role of the teacher and the students. The teacher is in participative observation; she is a part of the experiment and participates in the resistance to change. As a teacher, she has authority and influences the beliefs of the students. Simply saying that she would do an experiment influenced the students. They felt they were little "lab-rats". Also, the environment had an influence on the students and the teacher's beliefs. The speech around the virtual world was spooky (self-fulfilling prophecies and Pygmalion effect) but also showed a positive image (virtual images as a symbol of modernity and multiplicity of realities) or a negative one (the world where one feels alone, abandoned). These beliefs were transcribed in the interviews of students (verbatim).

Students who followed the course in virtual imaging were enthusiastic to participate in this experience because the teacher has passed on her enthusiasm (theory, experiment never done before), a doctor in medicine was involved in the

experiment (control of the health of students before the experiment) he was a figure of "authority". The relationship between the teacher and students were based on trust, she prepared the students to the course with sense-making.

So, we think the role of the perception of people in the process of communication is a very important part in the process of human /computer interaction. After this study, we can assume that some new patterns of the "good" teacher, who would like to drive a course with computer interactions, are emerging.

First, the teacher who wants to drive this sort of course has to consider the importance of the global design of this kind of courses. Second, the dynamism of the teacher has a preponderant role in the good implementation of this course and the management and participative democracy (student were volunteers) has to be taken into account. Third, the teacher has to be iconic and charismatic. Fourth, the tools used during the courses have to be analyzed: (the speech around the technology was very important in our study): the course must be an extraordinary activity and not a common activity. Last, the teacher must take into account the ambivalence of communication mediated by computer (not all negative / not all positive for example).

To conclude, we can say that students are not the only actors in the process, and there is a co-construction of meaning made by teachers and students. The human/computer interaction and communication are complex processes and the teacher has to take into account all the dimensions of this type of communication (emotional, physical, cognitive and intentional, reluctance to change).

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Analysis of Electronic Health Record Implementation and Usage in Texas Acute Care Hospitals

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Abstract

Despite a consensus that the use of health information technology should lead to more efficient, safer, and higher-quality care, there are no reliable estimates of the prevalence of adoption and physician usage of electronic health records (EHRs). Data from the American Hospital Association was examined for the presence of specific electronic-recorded functionalities. We also examined the differences in implementation and usage of EHRs to specific hospital characteristics.

Keywords: electronic health records, health information technology

1. INTRODUCTION

Electronic health records (EHRs) have been proposed as a sustainable solution for improving quality of medical care. EHRs provide a longitudinal electronic record of patient encounters and patient health information, including patient demographics, progress notes, problems, medications, vital signs, medical history, immunizations, laboratory data and radiology reports (Medicine 2003) . Robust EHRs automate and streamline the clinician's workflow by allowing order entry for medications, laboratory tests, and diagnostic procedures. The highest functioning EHRs provide clinicians with real-time evidence-based decision support and the potential for aggregating and reporting quality and outcome measures (Society 2006).

Promoting the adoption and use of health information technology (HIT) is a major priority for U.S. policy makers as a means of managing health care costs and improving quality. The American Recovery and Reinvestment Act (ARRA) authorized incentive payments through Medicare and Medicaid to providers that implement certified electronic health records and demonstrate their "meaningful use." The U. S. Department of Health and Human Services (HHS) recently finalized the meaningful-use criteria for the first two years of the three-stage incentive program (Services. 2010). These criteria are intended to ensure that doctors and hospitals will use health IT to improve the quality, efficiency, safety, and other aspects of care (Chaudhry, Wang et al. 2006; CM, EG et al. 2010).

Despite the appeal of EHRs, U.S. hospitals have been slow to implement and physicians appear to be reluctant to utilize EHRs. Jaana et. al (2012) reported that 2.7% of acute care hospitals in the United States have a "comprehensive" electronic records system implemented in all clinical units, and 9.2% have a "basic" system present in at least one clinical unit. In contrast, other countries, such as Australia and the United Kingdom, are nearing universal adoptions of EHRs (Simon, Jenter et al. 2008). Available data suggest that in the U.S. the larger, nonprofit, urban hospitals have made more headway than critical-access hospitals, small and medium-size hospitals, and public and rural hospitals (Ashish, DesRoches et al. 2010). Further, and most importantly, a 2003 national survey from the Commonwealth fund suggests that only 27 percent of physicians are utilizing the available EHRs (Audet 2004).

While literature recognizes the potential life-saving benefits of EHR in healthcare, the majority of EHR literature available takes a management perspective and concentrates mainly on adoption, implementation, acceptance and barriers (Overhage, Suico et al. 2001; Ash and Bates 2004; Miller and Sim 2004; Chiang, Boland et al. 2008; Withrow 2008; Zandieh, Yoon-Flannery et al. 2008). Meanwhile, research that examines the actual usage of EHRs by physicians in healthcare systems is sparse. Further, extant literature tends to focus on the EHR system as a whole entity instead of as a composite system that encompasses varying functions (Simon, McCarthy et al. 2008).

The purpose of this study is to examine the availability of electronic health record systems and their usage by physicians in Texas acute care hospitals. Additionally, we advance current research by analyzing hospital EHRs that have been categorized into four functional groups classified by the American Hospital Association:

- *Patient information data*; medications, orders, and clinical notes
- *Results management*; results from laboratory tests, radiology studies, and other tests
- *Order entry*; orders for laboratory tests radiology studies and other tests
- *Decision support*; knowledge sources, drug alerts, reminders, and clinical guidelines/pathways

The breaking down of EHR systems into these four functional categories takes previous research one step further by allowing separate analysis on the differing functions of an EHR system. This knowledge will provide a better understanding of what stage hospitals are in with regard to their adoption of EHRs, which functions of EHRs are most often implemented, and what percentage of physicians are utilizing them. Further, dissecting the data by hospital characteristics (size, teaching status, and ownership) provides insight into the disparity that currently exists between hospitals and gives an improved view of the direction future policies and incentives should take.

2. METHODS

This study is an exploratory study that envelops the implementation and physician usage of electronic health records. Along with descriptive statistics, analysis of variance is performed to determine if any differences exist between hospitals of varying characteristics.

Sample

The American Hospital Association (AHA), funded by the National Coordinator for Health Information Technology, administers a supplement to its annual survey of all acute care hospitals, in the state of Texas, to assess the adoption of electronic health records and their use in each facility. A paper copy of the survey was sent to each hospital's chief executive officer, who asked the person most knowledgeable about the hospital's health IT efforts to complete the survey in its entirety. The health IT expert was also responsible for the collection of physician usage data from the hospital's electronic health record system that logs usage of EHRs broken down by functional category.

The AHA EHR supplement was sent to 500 Texas acute care hospitals. The data from the AHA was analyzed for missing records and this resulted in a final sample of 374 Texas acute care hospitals.

Descriptive Statistics

Classification trees found that 27% of the variation occurring in the data can be attributed to hospitals of varying size. Through partitioning using JMP 7.0 (visual discovery software from SAS) hospitals were grouped into

small, medium, and large size based on general and specialty beds available. The groups were defined as small being all hospitals with less than 100 beds, medium consisting of hospitals with between 100 and 300 beds, and large hospitals categorized as having more than 300 beds. This classification coincides with current nursing literature (Henderson 1965; General 1988; Khuspe 2004; Ward, Diekema et al. 2005).

Table 1 displays the demographic characteristics of hospitals; including facility ownership status, affiliation types, and size.

Survey Instrument

The AHA supplemental survey that was sent to each hospital consisted of three main questions. The first question addressed if the hospital had an EHR. Possible responses where: Yes, fully implemented; Yes, partially implemented; and No. The second question was for respondents that answered yes (partially or fully) to the EHR question. This question pertained to if the EHR that was implemented consisted of specific applications (sorted into the four functional categories described earlier.) Possible responses available to choose from where: Yes, fully implemented; Yes, partially implemented; or No.

Finally, the percentage of treating physicians in each hospital was noted for: 1) Routinely ordering medication electronically and 2) Routinely ordering laboratory or other tests electronically. Response options were: 0%, 1-24%, 25-49%, 50-74%, and 75-100%.

Results

Preliminary analysis of data found that over half of Texas hospitals do not have an electronic health record available for use, one third of the hospitals have only partially implemented EHRs, and only ten percent of the hospitals have a fully implemented EHR (table 2).

Evaluation of the four functions of EHR systems revealed that results management and order entry are the two most often fully implemented components. These two functions have been found to be most beneficial to physicians because of their ability to aid in the capacity to have quick access of past and new test results that support interfaces from labs and permits efficient data entry of all orders and documentation by authorized clinicians (table 2).

Additionally, while patient-level data is not fully implemented often, (15.5%) when combined with partially implemented (23.3%), it totals 38.8% implementation. This is higher than the component of decision support. As hospitals realize the benefit of electronic patient record data and its ability to facilitate a more efficient flow while assisting administrative and physician duties, it is likely that we will see an increase in the implementation of this EHR component. This is an interesting area for future research and is discussed further in said section.

Most importantly, when analyzing EHRs, physician usage is extremely valuable information and often a noted limitation in current literature (Liner, Ma et al. 2007; Kazley and Ozcan 2008). Table 3 presents a breakdown of percentage of time physicians reported actually utilizing the EHR system for electronic ordering of medications and lab/other tests among hospitals with EHRs implemented. Astonishingly, according to our data, over 80% of doctors never use these functions and very few utilize them often.

Analysis of variance was performed on the data to establish if a statistically significant difference exists in mean availability of EHRs and physician usage of EHRs between hospitals of varying characteristics – such as size, ownership, and teaching status. Assumptions of ANOVA were tested using the Shapiro-Wilk test and results showed that we could not reject normality. A modified Levine p-value of .95 along with plots of residuals gives no reason to doubt equal variance or independence.

Results showed that a difference does exist with regard to size, for all four EHR functions (table 4). Further, post-hoc tests revealed the difference lies between small and large hospitals. This makes intuitive sense. Larger hospitals have more resources at their disposal than small hospitals.
Hospital teaching status was shown to also have an impact on two of the EHR functions and both electronic medication ordering/lab tests (table 5). The difference seen between teaching and non-teaching hospitals follows the same reasoning as with size; teaching hospitals have more resources to adopt EHRs and physicians in a teaching environment are more likely to be open to new technologies.

Finally, hospital ownership (public, private, government) was analyzed. Here we see a

statistically significant difference between the majorities of EHR functions, but no difference emerges with regard to electronic ordering of medication/lab tests (table 6).

3. CONCLUSIONS

In Texas in 2007, only 9.9% of hospitals reported having a fully implemented electronic health record system. With policies and programs set in place by the government (American Recovery and Reinvestment Act of 2009 and Health Information Technology for Economic and Clinical Health Act), these numbers may have increased. However, current research suggests otherwise (Menachemi, Ford et al. 2007; Simon, Jenter et al. 2008; Jha, DesRoches et al. 2009).

There are many barriers to implementation of EHR systems (cost, acceptance, technology proficiency), but change is inevitable. It is an extremely important topic in today's society and continues to be one surrounded by much controversy. This study brings to light the slow adoption of EHRs and more importantly the reluctance of physicians to utilize the available systems.

While having an EHR available is extremely important, if physicians are not utilizing these tools the potential benefits never come to fruition. There are several reasons why hospitals may not invest in EHRs and one of the top reasons is the substantial financial cost that generally sees negative return on investment (Thompson and Brailer 2004). This brings up the question, "Is EHR implementation truly to blame for the negative return on investment or is the lack of physician usage of the EHR system the underlying principle?"

Future research will examine which functionalities of EHRs result in the most improvement in clinical outcomes and how physician usage of EHRs affects patient safety and quality of care. Further, a time series analysis is planned for the years 2006-2010 to investigate when a positive gain is realized for EHR adopters and identify any lag time.

Limitations

This study does have limitations. First and foremost, this research was conducted on a single state, Texas, which is not necessarily representative of the population of hospitals in the entire United States. However, the authors chose the state of Texas as it is one of the largest states and encompasses many distinctly different demographics in varying metropolitan and rural areas.

Further, there is the possibility that hospitals that have better information technology systems, are better managed, or have more resources, are likely to have reported EHR data more accurately.

Finally, the counting of EHRs and their components has limitations. This approach does not account for length of time EHR was in place. This could have an impact on the percentage of physician utilization; as using new technology generally encompasses a learning period.

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Appendix

System Affiliation

	Frequency
No	170
Yes	204
Total	374

Teaching Status

	Frequency
	311
	63
	374

Profit

	Frequency
For Profit	118
Not-For Profit	126
Government	130
Total	374

Size

	Frequency
Small	59
Medium	108
Large	207
Total	374

Table 1 Hospital Demographics

EHR		
	Frequency	**Percentage**
Not Available	213	57
Partially Implemented	124	33.2
Fully Implemented	37	9.9
Patient-Level Data		
Not Available	229	61.2
Partially Implemented	87	23.3
Fully Implemented	58	15.5
Results Management		
Not Available	212	56.7
Partially Implemented	54	14.4
Fully Implemented	108	28.9
Order Entry		
Not Available	229	61.2
Partially Implemented	54	14.4
Fully Implemented	91	24.3
Decision Support		
Not Available	254	67.9
Partially Implemented	76	20.3
Fully Implemented	44	11.8

Table 2 Hospital EHR Availability

Electronic Medication Orders		
Reported % of Use	**Frequency**	**Percentage**
0	322	86.1
1-24	24	6.4
25-49	4	1.1
50-74	7	1.9
75-100	17	4.5
Electronic Ordering of Lab/Other Tests		
0	300	80.2
1-24	30	8.0
25-49	5	1.3
50-74	9	2.4
75-100	30	8.0

Table 3 Physician Usage of EHRs

	F	**Sig**
EHR	4.878	0.028*
Patient Data	6.595	0.011*
Results Mgmt.	3.863	0.050*
Order Entry	3.368	0.067
Decision Support	1.609	0.205
Medication	3.963	0.047*
Labs/Other Tests	5.292	0.022*

Table 4 Hospital Size as Factor

	F	Sig
EHR	15.749	0.000*
Patient Data	20.410	0.000*
Results Mgmt.	18.80	0.000*
Order Entry	11.013	0.000*
Decision Support	16.546	0.000*
Medication	2.6690	0.071
Labs/Other Tests	0.2190	0.804

Table 5 Hospital Teaching Status

	F	Sig
EHR	2.721	0.067
Patient Data	5.793	0.003*
Results Mgmt.	5.740	0.004*
Order Entry	2.002	0.137
Decision Support	5.716	0.004*
Medication	0.336	0.715
Labs/Other Tests	0.254	0.776

Table 6 Hospital by Ownership