

# INTERFACE EFFECTS ON DATA INPUT PERFORMANCE USING WEB FORMS

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## ABSTRACT

The dramatic growth in Web-based data input interfaces by businesses, organizations and governmental entities, has in a few short years produced a paradigm shift in the manner in which individual data makes its way into data stores. The potential increase in error resulting from that change is unaccounted for in the Information Systems literature. In this study, a theory is presented in which the connection between the individual, the interface, and the context (or task) is explicitly modeled, building on the person-artifact-task theory of Finneran and Zhang (2003). Particular attention is paid to complex data constructs, conceptualized as data objects within the computer system and mapping to latent cognitive representations held by the user, which may be represented using graphical and/or audible paradigms within the Web-based data input interface. It is expected that such representation will increase the accuracy of data, reduce input errors, and improve performance.

## INTRODUCTION

Web-based surveys and e-commerce sites rely on Web forms for the input of user data, but current form controls are subject to many sources of error, and fail to leverage the dynamic and interactive environment of computer-mediated communication as represented in the concepts of vividness and interactivity (Steuer 1992; Coyle and Thorson 2001). The potential for input errors, item nonresponse, and malicious input is great, and research has shown that attempts to force a response, or to force a certain type of response, contribute to nonresponse (Dillman, 2000). Functional advantages of the Web form relative to paper-based questionnaires include the ability to conditionally skip questions or introduce follow-up questions, but the Web form interface itself is virtually unchanged from a paper-based questionnaire. Historically, that design has served as a conceptual bridge to the familiar and ubiquitous paper-based questionnaire, facilitating the societal transition from paper-based data collection to online data input.

In the years since the introduction of the Web form, there has been a substantial body of research published related to the retrieval and display of data (cf. Plaisant, 2004; Shneiderman and Plaisant, 2005), and the cognitive effects related to the interplay of the interface and data type (cf. Vessey, 1991; Vessey and Galletta, 1991), but almost no research has been published on issues related to data input. This historical focus on data output rather than input may stem from the view that a primary function of information systems is managerial decision support, often implemented as the compilation and presentation of data in a readily understandable form. Data input may have been less of a concern because in the past, data has been input from non-electronic sources, with integrity assured by training of skilled input personnel. But, with the growth of the Web and the concomitant growth in user-entered data, the need has evolved to

study the cognitive issues related to direct data input, such as the influence of the presentation and function of the Web form on data integrity and user behavior.

Research on this topic, and the potential bias in survey sample data that may be introduced by Web form design, appears to be broadest and most advanced in the field of sociology, but is lacking the theoretical context that might be provided from the field of information systems. Findings from sociology research show that interface design effects have the potential to reduce both measurement and nonresponse error associated with data input (Dillman, 2000; Dillman, Gertseva and Mahon-Haft, 2005; Jenkins and Dillman, 1997; Tourangeau, Cooper and Conrad, 2004). A cognitive model is presented here in an attempt to explain those findings through the extension and synthesis of existing information systems theory, and will be tested empirically in subsequent experimentation.

It is useful conceptually to view the cognitive influences within the model as contributing either to the user's intrinsic motivation or perceived efficiency of effort. Although intrinsic motivation and perceived efficiency are not modeled as constructs, they provide a conceptual framework to guide the development of theory.

## LITERATURE AND THEORY

### MODELS OF EFFICIENCY OF EFFORT

#### FLOW

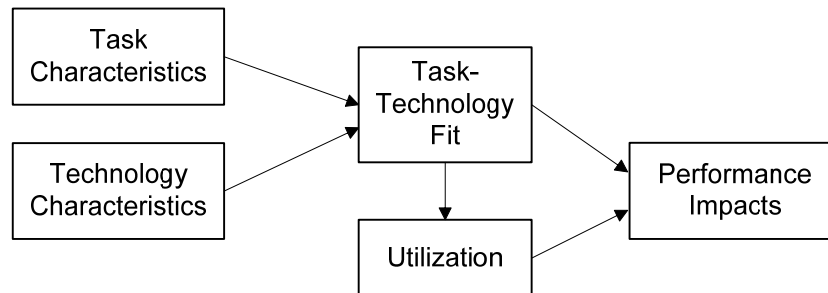
The concept of flow (Csikszentmihalyi, 1975) has been described as “the state occurring during network navigation, which is (1) characterized by a seamless sequence of responses facilitated by machine interactivity, (2) intrinsically enjoyable, (3) accompanied by a loss of self-consciousness, and (4) self-reinforcing” (Hoffman and Novak, 1996). Hoffman and Novak (1996) also note that concentration and an appropriate level of challenge must be present as antecedents to the state, and list several consequences of the state. Their model is unique among models of flow, however, both in structure and in constructs included. Koufaris (2002) and Agarwal and Karahanna (2000) proposed models based on flow with structures and concepts that differ significantly from Hoffman and Novak's (1996) model, noting that flow is too broad and ill-defined because of the numerous ways in which it has been operationalized, tested and applied. The addition of those new specifications to the literature neither produced a consensus nor supplanted earlier specifications, however, further compounding the problem. The substantial variation in conceptualizing and operationalizing flow may be due to the fact that originally Csikszentmihalyi did not articulate a clear set of dimensions for the construct, although more recently he has explicitly listed nine, including (1) clear goals, (2) immediate feedback, (3) personal skills well-suited to given challenges, (4) merging of action and awareness, (5) concentration on the task at hand, (6) a sense of potential control, (7) a loss of self-consciousness, (8) an altered sense of time, and (9) experience which becomes autotelic (i.e. self-fulfilling) (Csikszentmihalyi, 1993).

In a study of flow experienced by Web users, Chen (2006) articulated the factorization of seven of these dimensions, finding clear goals, potential control, immediate feedback, and merger of action/awareness to be antecedents to flow, and time distortion, concentration, and loss of self-consciousness to be associated with the occurrence of flow, with positive affect as a consequence of flow. The model and measures in Chen (2006) are more faithful to the original conceptualization of flow than the other studies cited above. Rather than arguing for the use of alternate measures for the flow dimensions, Chen (2006) constructed measures that incorporated items targeted at the desired latent constructs.

Flow is at the core of the research model proposed here, providing a theoretical framework for explaining why and how a change in the interface can influence the user's attitude and data input performance. Although flow is often discussed within the context of intrinsic motivation, the factors of which it is composed measure concepts more logically related to efficiency of effort. It is that efficiency, that effortlessness, that characterizes flow. Csikszentmihalyi (1975, 1990) records flow occurring in workers doing routine chores. While it is easy to imagine one entering an effortless state while working, it is difficult to imagine that state as being intrinsically motivating.

#### TASK-TECHNOLOGY FIT

Task-technology fit (TTF) models the constructs of task characteristics and technology characteristics as precursors to the concept of task-technology fit, defined as the degree to which a technology assists an individual in performing tasks, which directly and separately influences utilization and performance. Goodhue and Thompson (1995) introduced the Technology-to-Performance Chain model based on TTF theory, and found support for the direct influence of task-technology fit on performance but not on utilization. The subset of that model tested in their study is shown in Figure 1.

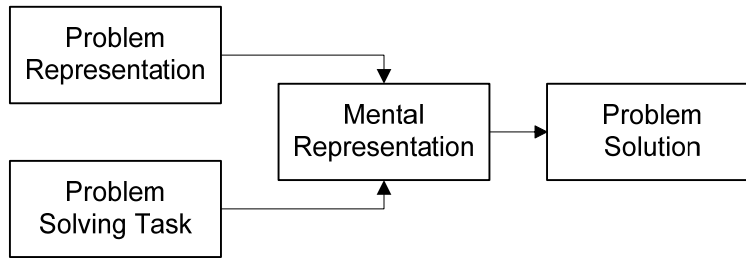


**Figure 1. Subset of Technology-to-Performance Chain**

The concept of task-technology fit is directly relevant to the research model presented in this paper, in that it models the direct interaction between the task and the interface, and the effect of that interaction both on user mindset as well as directly on performance. It is likely that the fit between task and artifact will impact performance after controlling for individual differences, and may be manifested in mechanical aspects of task-completion, such as number of keystrokes, that are independent of the cognitive aspects.

#### COGNITIVE FIT

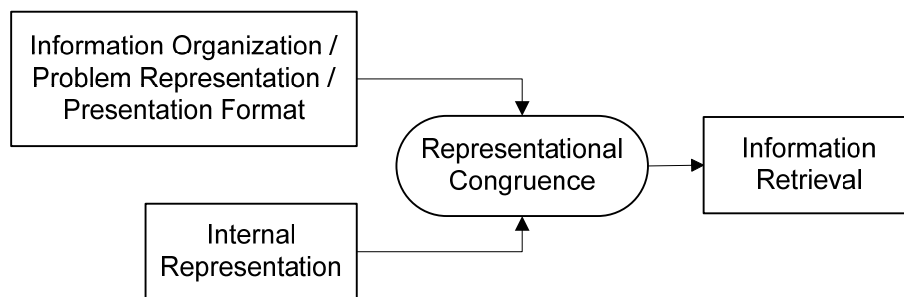
Cognitive fit theory (CFT), introduced in Vessey (1991) and applied empirically in Vessey and Galletta (1991), models the fit of task and technology as it relates to needs of the specific user, differing from TTF theory in that “it suggests that simply matching technology to task is insufficient...the user must also use appropriate processes, and thus develop appropriate mental representations, for performance effects to occur” (Vessey and Galletta 1991). As shown in Figure 2, processes act on information in the problem (or external) representation and the problem-solving task to produce the mental (or internal) representation. When the types of information in the problem representation and task elements match, the problem solver can more efficiently formulate a mental representation.



**Figure 2. General Problem Solving Model**

Vessey (1991) defined two types of task and problem representation, spatial and symbolic. Spatial tasks require making associations or perceiving relationships in the data, and may also include the interpolation of values. Graphs are spatial problem representations in that they present spatially related information. Symbolic tasks involve extracting discrete data values, and tables are symbolic problem representations because they present discrete data values. In their empirical test of CFT, Vessey and Galletta (1991) found that for spatial tasks, users solved problems faster using graphs, but were more accurate using tables. For symbolic tasks, users were both faster and more accurate using tables. Thus, the study offered some empirical support for CFT. Subsequent empirical studies of CFT, (cf. Dennis and Carte 1998; Speier et al. 2003) have produced further support for the theory.

In an empirical study of the effect of the interaction of problem-solving tool and task on performance, Agarwal et al. (1996) found partial support for CFT in that the match of a process-oriented tool and task improved performance, but the match of an object-oriented tool and task did not. In a follow-up to that study, Chandra and Krovi (1999) noted that the lack of an information organization variable may have accounted for the adverse findings with regard to the object-oriented match. They defined the external representation more broadly than in CFT, and narrowed the scope of the fit construct to emphasize the internal representation. This concept was named representational congruence (see Figure 3).



**Figure 3. Representational Congruence**

The empirical test of representational congruence studied differences between information presentation using the paradigmatic concepts of propositional networks and object-oriented structures, with the aim of discerning the relative efficiency of those different notions of how individuals internally organize information to form a mental representation. The results of this study were mixed, but found some support for the presence of object-oriented features in internal representations.

CFT is fundamental to modeling the contribution of efficiency in the theory to be developed in this paper, and the question of whether or not internal representations resemble object-oriented

structures is particularly relevant in that the latent data structures described later are well-suited to operationalization as software objects within the interface.

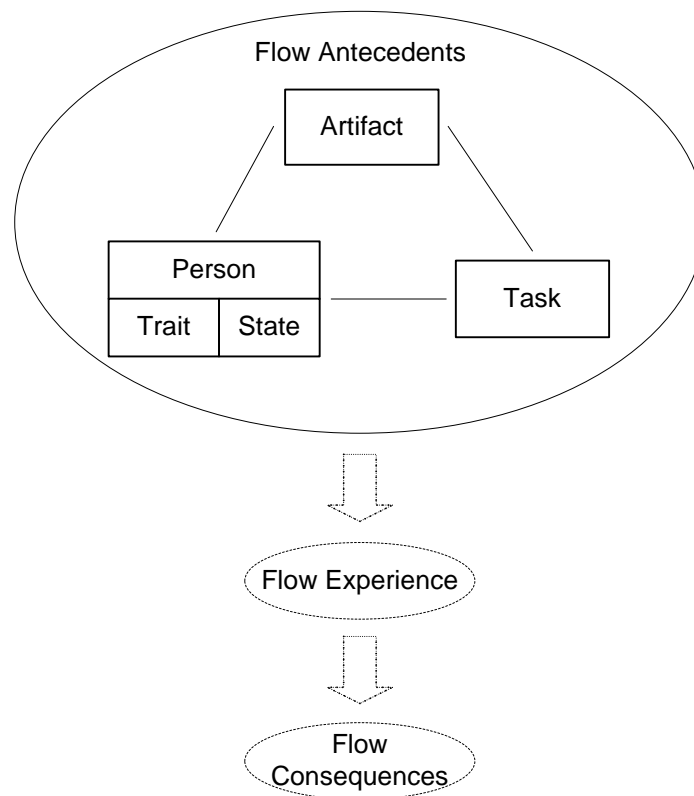
#### COMBINING FLOW AND FIT

In the person-artifact-task model, the concepts of flow and fit are combined, framing the interactions associated with fit within the process of flow. It is the single model upon which the research model of this study is most closely derived.

#### PERSON-ARTIFACT-TASK

The person-artifact-task (PAT) model, introduced in the theoretical study of Finneran and Zhang (2003) is oriented in the concept of flow, but in the authors' words, is "in agreement in principle with both the cognitive fit and the task-technology fit". PAT models the main effects of the person, artifact, and task, as well as the interaction effects between each and between all three simultaneously. Those effects and interactions have a direct impact on the flow experience and its consequences. There have been no empirical tests of PAT, which may be due at least in part to the complexity of the interaction and order effects among the constructs.

The most notable characteristic of PAT is that it fully accounts for the interplay of the technological artifact, the task, and the person. In contrast to TTF, in which the focus is on task matching technology, and CFT, in which the focus is on problem representation matching task, PAT models the task, its external representation, and its internal representation. The theory presented in our study is framed within a structure that parallels PAT.



**Figure 4. Person-Artifact-Task Model**

## MODELS OF INTRINSIC MOTIVATION

Intrinsic motivation captures the user's desire to engage the interface and the system behind it for no other reason than the utility that comes from the act itself, irrespective of whether that leads to completion of a task. A substantial part of the effect of the novel Web form controls studied here is expected to be intrinsic motivation associated with the playfulness of the controls.

### COMPUTER PLAYFULNESS

Computer playfulness is an individual trait, defined as "the degree of cognitive spontaneity in microcomputer interactions" (Webster and Martocchio 1992). Empirical support for the concept was demonstrated in Webster and Martocchio (1995) and Webster and Ho (1997). Agarwal and Karahanna (2000) cited the argument made by Webster and Martocchio (1995) that computer playfulness should be a significant antecedent of the state of flow in support of their decision to model it as an antecedent to the flow-like construct of cognitive absorption. In the model developed by Woszczynski et al. (2002), computer playfulness is an antecedent to a composite concept containing flow and a playfulness state that interacts bidirectionally with flow. Similarly, in a study of interface design effects, Hess, et al. (2005) modeled computer playfulness, as well as gender, personal similarity, and vividness as antecedents to the flow-like felt involvement construct from the consumer research literature (cf. Celsi and Olson 1988), finding that users with higher levels of computer playfulness were more likely to use the interactive feature of the interface.

### PERCEIVED PLAYFULNESS

Although the individual trait of computer playfulness has been shown to be a stable and significant concept (cf. Yager et al. 1997), it is incapable of explaining situational variation in individual playfulness, or the individual perception of situation-specific interface attributes as playful, or the interaction of that perception and the innate trait of computer playfulness. This suggests that the dynamic aspects of attitudes and behavior related to cognitive playfulness are not measured well by computer playfulness, an intuitively unappealing conclusion in that playfulness is an inherently dynamic concept.

In a study from the communication literature, Ha and James (1998) identify playfulness as one of the five dimensions of interactivity in a Web site, measured by the presence of curiosity arousal devices and games. Although this is an arbitrary measure, it seems that it should be strongly related to interface playfulness as perceived by the individual.

In a study from the consumer research literature, Mathwick and Rigdon (2004) examined the relationships between perceived play, involvement, and attitudes toward Web sites and brands, but perceived play was defined as a subset of the dimensions of flow, rather than a distinct concept.

In the information systems literature, Moon and Kim (2000) added as an antecedent to TAM the state construct perceived playfulness, rooted theoretically in the concept of flow. Unfortunately it is not really a distinct concept either, as the scale designed to operationalize perceived playfulness in that study is also measuring dimensions of flow, and the items in it can be matched to a subset of the individual dimensions of the cognitive absorption scale. Despite the items of the perceived playfulness scale appearing to be a subset of the items of the cognitive absorption scale, Moon and Kim (2000) do not elaborate how perceived playfulness might be related to cognitive absorption, or why it should be seen as distinct from that concept.

Chung and Tan (2003) sought to extend the work of Moon and Kim (2000) by defining a set of behavioral and technological antecedents to the state of perceived playfulness. That research is noteworthy in its recognition of the need to model the influence of the information system on playfulness, a relationship that can exist only if playfulness is modeled as a state rather than trait. Moon and Kim (2000), and Chung and Tan (2003) addressed that issue by conceptualizing playfulness as a state, but failed to incorporate prior theoretical constructs into their models or explain why they are not needed

## PLAYFULNESS AS AN LST CONSTRUCT

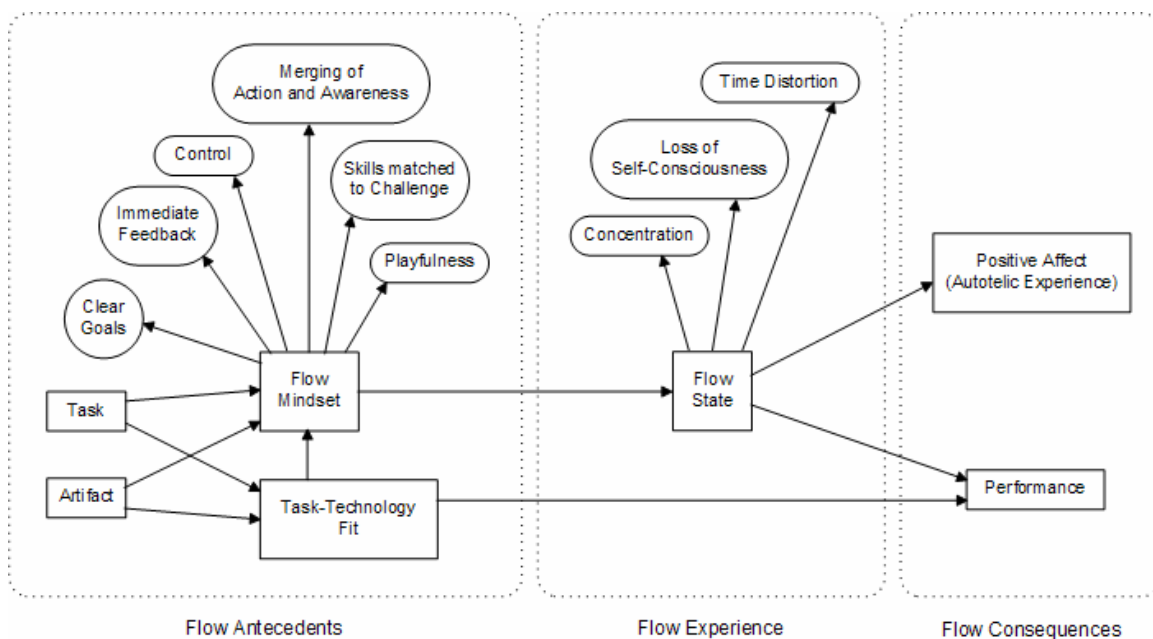
A promising area for future research related to playfulness involves the application of latent state-trait theory (Steyer and Schmitt 1990; Steyer, et al. 1999), in which computer playfulness would be modeled as a composite state and trait construct. Although playfulness in the context of technology use might be modeled as separate personality trait and situation-specific state constructs, a more flexible and general approach involves modeling computer playfulness as a single construct within latent state-trait (LST) theory, a generalization of classical test theory from the psychological measurement literature. LST theory uses structural equation modeling with latent variables to simultaneously model characteristics of the person (traits), the situation, and the interaction between the person and the situation, which collectively create a psychological state varying with situational changes (Steyer, et al. 1999). In LST theory, an observable variable  $Y_{ik}$  is a function of the true score variable  $\tau_{ik}$  and the random error variable  $\varepsilon_{ik}$ , where the index  $i$  represents the measurement (e.g. a psychological test), and index  $k$  represents the occasion of measurement. The true score variable  $\tau_{ik}$  is also called the latent state variable, and is the expectation of the distribution of  $Y_{ik}$  conditional on the person in the situation. It is a function of a trait component  $\xi_{ik}$ , which is an unconditional measure of the person, and an occasion-specific residual  $\zeta_{ik}$ , which captures situational and/or interactional effects.

Playfulness as it appears in the research model here will be in the form of a latent state-trait construct developed as a psychometric scale during the empirical stage of the research.

## RESEARCH MODEL

In prior research involving the collection of economic data, I have observed that certain types of questions produce sets of data that have full meaning as a set, but much less as individual data points (e.g. a set of proportions representing the allocation of some resource across a set of choices). As a result, that particular subset of the data exists within the physical structure of the data store as a latent data structure, whether or not it is recognized as such. Visual metaphors can be identified to represent such latent data structures. The metaphors can then be developed into software objects that be instantiated as form controls within a Web form. Such controls should be more efficient than standard form controls, allowing faster data entry, and by the inherent design of the control, allowing no data entry errors other than nonresponse. Support for that assertion was shown in unpublished research on one such control, developed using DHTML and tested against standard form controls using a posttest-only control group experimental design. Other studies that have provided support for the influence of the interface and its interactions with the individual and the task on the efficiency of data input and retrieval include Speier and Morris (2003) and Peng (2005). In related research on data input interfaces, Schneider and Plaisant (2005) proposed a set of five data entry objectives. The novel form controls described above are designed to meet those objectives in that they are consistent across transactions, minimize input actions by the user, minimize memory load on the user, display the data in a format compatible with the data itself, and have some flexibility for user control of the data entry.

The key antecedents in modeling the effects of such controls are the task and the IT artifact (i.e. interface). The task involves reading and processing a request for data, followed by the formulation of a response and the input of that response. In this study, the element of the task that will be varied across treatments is the type of latent data structure expected in the response to a request for data. Much research has been published on the influence of elements such as question wording and page design on the cognitive load associated with this task, but little research has been published on the influence of interface controls in data input. The artifact in this study represents the type of data input control, either conventional or novel. The task-technology fit element is not a construct as defined in Goodhue and Thompson (1995), but rather the multiplicative interaction of task and artifact. The flow mindset construct models the antecedent conditions to the state of flow, including the additional factor, playfulness. The state of flow is modeled through the flow state construct. The outputs of the research model are positive affect, a proxy for the autotelic experience dimension of flow, and performance, which may be measured using both objective standards and cognitive scales.



**Figure 5. Research Model**

Consistent with PAT, it is expected that interactions will exist between the person, the artifact, and the task. Since the task involving the input of data with a latent structure is expected to require greater cognitive processing:

H1: The latent structure task will have a negative influence on flow mindset.

Conversely, the novel Web form control artifact is expected to reduce the cognitive load, and therefore

H2: The artifact will have a positive influence on flow mindset.

The interaction of task and artifact when task is matched to artifact should reduce cognitive load and increase performance through subconscious channels, therefore;

H3: The interaction of task and artifact will have a positive influence on performance.

H4: The interaction of task and artifact will have a positive influence on flow mindset.

Flow theory predicts that flow mindset will lead to flow state and subsequently, autotelic experience, therefore:

H5: Flow mindset will have a positive influence on flow state.

H6: Flow state will have a positive influence on positive affect.

## METHODS

### EXPERIMENTAL DESIGN

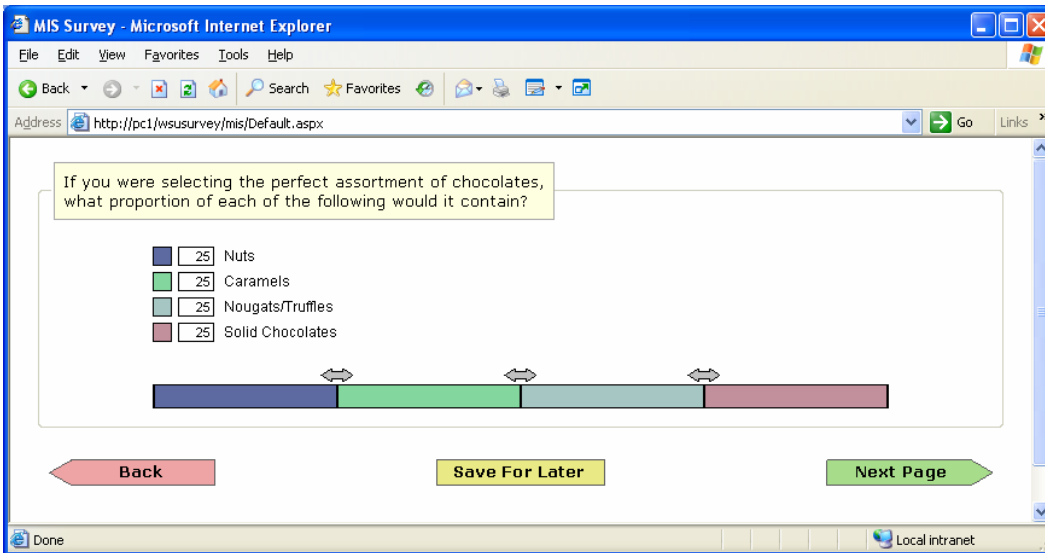
The empirical analysis will be performed using a balanced 2x2 repeated within-subjects experimental design for each of the latent data structures identified for study. The use of the within-subjects design will reduce error variation, increasing the likelihood of achieving statistical significance in the modeled relationships. The need for such a design is supported by the results of the pilot study, performed as a posttest-only control group experimental design. In that study, none of the relationships achieved significance, despite a sample size of 200. The within-subjects design also will enable the study of temporal and interaction effects related to repeated use of the Web form controls, such as learning effects and novelty effects. To compensate for the influence of unwanted order effects, the structure of the experimental design will be counterbalanced, such that each respondent will use both conventional form controls and novel form controls, but with the order in which each are used determined by random assignment.

The pilot study also revealed that respondents vary in attitudes toward acceptance of the new control and vary in skills as well, which is controlled for in the within-subjects design, which ignores innate differences among individuals while accounting for change over time for each individual. An alternative design that could be used to reduce the variance associated with attitudes and skills, while being immune to threats to validity associated with repeated measurement of the same individual, is the randomized-blocks design, in which respondents are grouped by attitude or aptitude as determined by pre-test, and then randomly assigned across treatment conditions.

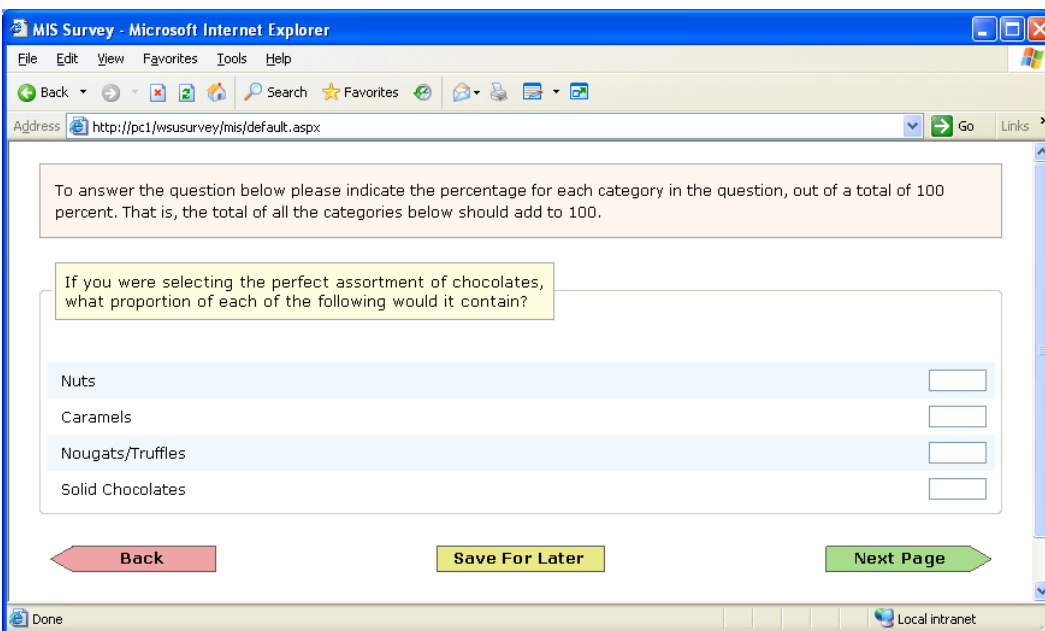
Subjects for initial studies will be students, recruited on campus. Later studies will use subjects recruited from the general population, either as a representative sample or as a convenience sample adjusted on key demographics to be pseudo-representative. The form controls will populate a Web form that the students must visit regularly during a semester, providing them with incentive to participate over the course of the study, which will run the duration of the semester.

### TREATMENT

A set of latent data structures will be selected to be conceptualized as visual metaphors within the Web form interface. The novel controls will be designed as playful form controls, inviting respondents to participate, and to do so in a manner such that providing information occurs easily and naturally. An example of one such metaphor-based form control, called the Allocator (Figure 6), was tested against a conventional form control, a textbox list (Figure 7), in a pilot study. Others (Mathieson 2003; Scaife and Rogers 1996; Shneiderman 1997) have studied the use of similar novel form controls, but in an atheoretical context. This study will be the first in which the effects of features of the Web form data input interface have been studied in the context of cognitive theory.



**Figure 6. Novel Web form control for allocative distribution**



**Figure 7. Standard Web form control for allocative distribution**

The Allocator control enables the division of a visible space in two dimensions on the computer screen into a set of smaller, differently colored spaces within the larger space. The user dynamically resizes the smaller spaces by drag-and-drop using the mouse until the relative sizes correspond to the desired allocation of proportions. Because the process is a visual one, no mathematical processing is necessary to perform the allocation, and the only actions required for data input are the mouse movements to resize the spaces. It is designed to represent a latent data structure in which a set of values sum to an allowable total, such as a set of proportions that sum to unity. That sort of question is common to economic surveys, and has been represented in the past by a group of textboxes. But, through its innate design the Allocator form control solves many of the problems that plague the textbox design. For example, there is no need for

protection against erroneous or malicious input, nor is there a need to make sure that the values add up to the proper sum. In addition, the results from the pilot study indicate that respondents are more likely to respond using this control - that is, a reduction in nonresponse was observed. Whether or not that effect was due to the novelty of the control, in which case it might decrease over time, is a topic for further research, and is one of the reasons that this study is planned as a longitudinal study.

The set of textboxes that display the numeric values selected using the Allocator have been included to meet Section 509 requirements for accessibility, which apply to all federal government and university Web forms. The textboxes are designed to allow keyboard entry for users who are unable to use a mouse. They would not be displayed in the experimental treatment in order to avoid introducing confounding influences into the design, but might be included in a production setting.

## MEASURES

The measured outcomes of the study will include scores from a set of cognitive scales, and an index of performance, measuring a set of items such as elapsed time to task completion and number of data entry errors.

The flow mindset and flow state controls will be operationalized as multidimensional psychometric scales, similar in specification to Chen (2006). Flow mindset reflects all the antecedent components of flow (Csikszentmihalyi 1993), as well as the constructs of playfulness. Chen (2006) developed measures for all of the antecedent dimensions except the match of skills and challenge, which is expected to be measurable as a self-assessment, similar to the concept of computer self-efficacy, but within this particular context. Flow state reflects the three components of the Flow state itself, also measured in Chen (2006). The outcome of flow, the autotelic experience, is represented by positive affect, which may be measured using the index developed by Chen (2006) or by a cognitive scale developed as part of the study.

## DATA ANALYSIS

Because a primary goal of the research is to establish and validate theory, the statistical analysis will be performed using structural equation modeling (SEM) techniques such as LISREL or partial least squares (PLS). SEM enables the simultaneous estimation of model parameters among the multiple relationships that exist within the theoretical model. A principle goal of the sampling design will be to obtain a large enough sample to use AMOS or LISREL in estimation rather than PLS because the former methods yield fit indices directly.

## CONCLUSIONS AND DISCUSSION

The research model builds upon the evolution of theory within the field of information systems (IS) to advance understanding of the emergent phenomenon of direct data entry by the user within the context of the World Wide Web, and to predict the influence of the data input interface upon the user's intrinsic motivation and efficiency. It also has relevance to the real world in that it incorporates the information technology (IT) artifact explicitly into the theory as a primary antecedent and models performance as the dependent variable. Both issues are critical to the relevance of IS theory as applied in the business environment, and are lacking in part or in whole from most studies in this area. In the overall socio-technological information system, the IT artifact, with its stable and well-defined properties and relative uniformity across instances, is the object which practitioners can most readily change to achieve effects on performance goals, so it is useful to explain how a given change or type of change to the artifact might influence

performance, and in the business environment, performance, in all its dimensions and contexts (e.g. efficiency, data integrity) is the ultimate goal of the IS, so it is useful that it be the measured outcome of the model. As a consequence, the research model should find broad application in the study of the Web interface and its effects on data input performance.

## LIMITATIONS

A limitation of the initial sampling design is that it produces a convenience sample, and as such is not representative of the student population from which it is drawn, but even if it were, the student population is not representative of the general population, so the results of the study will not be generalizable. That notwithstanding, the experimental design will attempt to ensure through random assignment that the only differences between treatment groups will be the treatment itself, and therefore any differences observed in measured outcomes should be attributable to the effect of the treatment. As a result, even though that knowledge may not be strictly generalizable to the larger population, it will allow researchers to make qualitative statements regarding the expected size and direction of effects, and will be useful in the development of theory for modeling the cognitive processes involved in this human-computer interaction.

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