Measuring the Flow Construct in Online Environments: A Structural Modeling Approach

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ABSTRACT

Though marketers are beginning to gain an understanding of the marketing strategies that will attract visitors to Web sites (Hoffman, Novak, and Chatterjee 1995; Morr 1997; Schwartz 1996; Tchong 1998), very little is known about the factors that make using the Web a compelling experience for its users, and of the key consumer behavior outcomes of this compelling experience.

Recently, the flow construct has been proposed as important for understanding consumer behavior on the World Wide Web. Although widely studied over the past twenty years, quantitative modeling efforts of the flow construct have been neither systematic nor comprehensive. In large parts, these efforts have been hampered by considerable confusion regarding the exact conceptual definition of flow. Lacking precise definition, it has been difficult to measure flow empirically, let alone apply the concept in practice.

Following the conceptual model of flow proposed by Hoffman and Novak (1996), we conceptualize flow on the Web as a cognitive state experienced during navigation that is determined by: 1) high levels of skill and control; 2) high levels of challenge and arousal; 3) focused attention; and is 4) enhanced by interactivity and telepresence. Consumers who achieve flow on the Web are so acutely involved in the act of online navigation that thoughts and perceptions not relevant to navigation are screened out and the consumer focuses entirely on the interaction. Concentration on the navigation experience is so intense that there is little attention left to consider anything else and, consequently, other events occurring in the consumer's surrounding physical environment lose significance. Self-consciousness disappears, the consumer's sense of time becomes distorted, and the state of mind arising as a result of achieving flow on the Web is extremely gratifying.

In a quantitative modeling framework, we use data collected from a large-sample Web-based consumer survey to measure flow and its influences, and fit a series of structural equation models that test Hoffman and Novak's (1996) theory. The conceptual model is largely supported and the improved fit offered by the revised model provides additional insights into the direct and indirect influences of flow, as well as the relationship of flow to key consumer behavior and Web usage variables.

A key insight from the paper is that the degree to which the online experience is compelling can be defined, measured, and shown to relate significantly to important marketing variables. As such, our flow model may be useful both theoretically and in practice as marketers strive to decipher the secrets of commercial success in interactive online environments.

1. INTRODUCTION

In the late 1990s, analyst estimates of business-to-consumer electronic commerce were repeatedly revealed after the fact to be too conservative. Forrester Research, for example, revised its initial $4.8 billion consumer e-commerce forecast for 1998 to $7.8 billion by the year's end (Forrester Research, 1998), while the Boston Consulting Group (Boston Consulting Group,1998) boldly upped Forrester's estimate to $13 billion. By the year 2000, Forrester expects electronic commerce in the consumer section to reach $33 billion (Forrester Research, 1998).

The United States Federal Government expects the digital economy created by the Internet to accelerate world economic growth well into the new millenium (Margherio, Henry, Cooke, and Montes, 1998). By the year 2003, Internet commerce conducted globally is expected to reach $3.2 trillion, representing five percent of global transactions (Forrester Research 1998). Exuberant statistics aside, few would argument argue that the need to develop a comprehensive understanding of consumer behavior in commercial online environments is urgent.

Among marketing academics and Internet practitioners alike, there is a lack of genuine knowledge about what contributes to effective interactions with online customers, although intuition and previous research (Hoffman and Novak 1996) suggests that creating a compelling online environment for Web consumers will have numerous positive consequences for commercial Web providers. Though marketers are beginning to gain an understanding of the marketing strategies that will attract visitors to Web sites (Hoffman, Novak, and Chatterjee 1995; Morr 1997; Schwartz 1996; Tchong 1998), very little is known about the factors that make using the Web a compelling experience for its users, and of the key consumer behavior outcomes of this compelling experience.

Hoffman and Novak (1996) recently proposed that creating a commercially compelling Web site depends on facilitating a state of flow (Csikszentmihalyi 1977) for its consumers, and suggest that an important objective for online marketers is to provide for these "flow opportunities" (Hoffman and Novak 1996, page 66). Previous researchers (e.g. Csikszentmihalyi 1990; Ghani, Supnick and Rooney 1991;

Trevino and Webster 1992; Webster, Trevino and Ryan 1993) have noted that flow is a useful construct for describing more general human-computer interactions. Hoffman and Novak extended the idea to encompass consumer navigation behavior in online environments such as the World Wide Web, and defined flow 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." To experience flow while engaged in an online pursuit, consumers must perceive a balance between their skills and the challenges of the interaction, and both their skills and challenges must be above a critical threshold.

Hoffman and Novak (1996) provided, but did not empirically test, a conceptual model of flow that detailed its antecedents and consequences. The construct is important to online marketers because it has implications for commercial Web site design, online advertising, market segmentation, and Internet marketing strategies. Theoretically, conceptualizing and modeling consumers' perceptions of flow on the Web can expand scholars' knowledge in this emerging discipline.

In this paper, we present the results of an extensive empirical test of Hoffman and Novak's conceptual model. We begin by describing the flow construct and previous models of flow that have been proposed. In the second section, we use prior theory to specify a range of hypotheses to be tested. Section three describes our online data collection and sample splitting procedures. The results of our empirical analysis are contained in sections four through six. We use a two-stage structural modeling approach to test the conceptual model. We begin by purifying the measurement model prior to fitting our base model. A series of model modifications applied to our calibration sample produces a revised conceptual model, which we cross-validate using a new sample. We introduce a new, straightforward approach for assessing the degree to which various aspects of the structural equation model cross-validate and provide evidence of the construct reliability of our measures. Section seven uses the constructs derived from our structural models to predict outcome variables corresponding to general and specific categories of Web usage. We conclude with a discussion of the theoretical and managerial implications of this effort that we believe represents the most comprehensive attempt to date to bring quantitative modeling to bear upon the measurement of *flow*.

1.1. Previous Models of Flow

Despite its relevance to computer-mediated environments, flow has proven to be an elusive construct to define. While Csikszentmihalyi has written extensively on the flow construct over the past 20 years (e.g. Csikzentmihalyi 1977, 1990, 1997; Csikszentmihalhyi & Csikzentmihalyi 1988; Csikzentmihalyi and LeFevre 1989), definitions provided in these sources, and by other researchers (e.g. Privette and Bundrick 1987; Trevino and Webster 1992; Ellis, Voelkl and Morris 1994; Ghani and Deshpande 1994) often lack consistency and comprehensiveness.

Most studies define flow in terms that make intuitive sense. For example, flow is “the holistic sensation that people feel when they act with total involvement” (Csikszentimihalyi 1977), or “a state of mind sometimes experienced by people who are deeply involved in some event, object or activity” (Ghani and Deshpande 1994). Yet, existing definitions of flow are constructed in terms of the wide variety of constructs an individual tends to experience in the flow state and do not lend themselves to immediate operationalization. Some definitions include constructs that define or cause flow, while others specify outcomes that are experienced as a result of being in the flow state.

Perhaps the most comprehensive definition is provided by Csikszentmihalyi (1997), who discusses eight constructs that comprise flow: 1) a clear goal, 2) feedback, 3) challenges match skills, 4) concentration and focus, 5) control, 6) loss of self consciousness, 7) transformation of time and 8) activity becomes autotelic. There are no structural relations specified among the constructs, except that they are grouped according to whether they specify antecedent conditions of flow (1,2 and 3), its characteristics (4 and 5), or the consequences of the experience (6, 7 and 8).

We present our formal structural model in section 2, but define it now. Flow on the Web is a cognitive state experienced during navigation in a CME that is determined by: 1) high levels of skill and control; 2) high levels of challenge and arousal; 3) focused attention; and is 4) enhanced by interactivity and telepresence. This cognitive state is somewhat difficult to describe, but it has been characterized as an “optimal experience” (Csikszentmihalyi 1997) that is “intrinsically enjoyable” (Privette and Bundrick 1987), comprising the “complete involvement of the actor with his activity” (Mannell, Zuzanek, and Larson 1988), “a balanced ratio of challenges to skills” (LeFevre 1988), and “experienced by people who are deeply involved in some event, object or activity...they are completely and totally immersed in it...Indeed, time may seem to stand still and nothing else seems to matter while engaged in the consumption event." (Lutz and Guiry 1994).

Thus, consumers who achieve flow on the Web are so acutely involved in the act of online navigation that thoughts and perceptions not relevant to navigation are screened out and the consumer focuses entirely on the interaction. Concentration on the navigation experience is so intense that there is little attention left to consider anything else and consequently, other events occurring in the consumer’s surrounding physical environment lose significance. Self-consciousness disappears, the consumer’s sense of time becomes distorted, and the state of mind arising as a result of achieving flow on the Web is extremely gratifying.

In this paper, we are concerned with flow on the Web in general, as opposed to flow on a specific Web site. Thus, the goal that may lead to flow is also not specific, as in, for example, shopping online for a sweater, but rather relates more generally to the process of network navigation occurring across Web sites within a particular Web session.

Previous simpler structural models of flow in the context of work-related human-computer interaction (e.g., Trevino & Webster 1992; Webster, Trevino & Ryan 1993; Ghani, Supnick & Rooney 1991; Ghani & Deshpande 1994) have generally supported prior theory. Consider the causal model fit by Ghani, Supnick and Rooney (1991) in their study of computer-mediated interaction. Control and challenges were found to predict flow, which was operationalized as four items for enjoyment and four for concentration. Control and flow predicted exploratory use, which in turn predicted extent of use.

Ghani and Deshpande (1994), in a later study exploring flow occurring among individuals using computers in the workplace, included skill as well as challenge. The resulting causal model is simple, but quite interesting, in that skill leads to control which leads to flow. Skill also directly affects flow, as does perceived challenge. This model provides empirical support for definitions that specify that flow occurs when challenges and skill are both high, since skill and challenges independently contribute to flow.

Trevino and Webster (1992) fit an alternative causal model in their study of workers' perceptions of flow during email and voice mail interactions. They used a different operational definition of flow that consisted of four items measuring control, attention focus, curiosity and intrinsic interest. Skill was measured, but not challenges. They also identified ease of use as a mediating variable between skill and flow.

Clearly, a key difficulty with the above research is the lack of consistency in operational definitions of flow. Constructs such as enjoyment, concentration, control, attention focus, curiosity and intrinsic interest are used to define flow, rather than being considered as either potential antecedents or consequences of flow.

"Flow channel segmentation models," based upon Csikszentmihalyi's definition of flow in terms of the congruence of skills and challenges, provide a simpler alternative to structural modeling (e.g., Ellis, Voelkl & Morris 1994; LeFevre 1988; Nakamura 1988; and Wells 1988). These segmentation models attempt to account for all possible combinations (channels) of high/low skills and challenges.

Early research identified three channels or segments: 1) anxiety (high challenge/low skill); 2) flow (high challenge/high skill or low challenge/low skill); and 3) boredom (low challenge/high skill). However, the greatest empirical support has been found for a reformulated four-channel model where anxiety and boredom are as before, but flow is now defined as only high skills and high challenges and apathy is introduced as low skills and low challenges.

Numerous researchers (e.g. Ellis, Voelkl & Morris 1994; LeFevre 1988; Nakamura 1988; and Wells 1988) have found clear patterns of differences among the four "flow segments." An eight channel model (Massimini & Carli 1988; Ellis, Voelkl & Morris 1994) extended the four channel models by allowing for intermediate (moderate) levels of skill and challenge. Two intermediate segments denoted control and arousal introduce two new ideas. Control corresponds to high skill and moderate challenge, arousal relates to high challenge and moderate skill.

2. RESEARCH HYPOTHESES

2.1. Hoffman and Novak's model of flow

A general conceptual model of flow in computer-mediated environments (CME) is described in detail in Hoffman and Novak (1996). Their proposed model served to reconcile inconsistencies in previous definitions and models and laid the groundwork for formal empirical testing. In Figure 1, we summarize without loss of generality the key features of this comprehensive model of flow in computer-mediated environments, based upon Hoffman and Novak's conceptual model.

Hoffman and Novak's conceptual model of flow owes an important debt to previous models of flow conceptualized in the context of human-computer interaction, but is unique in several important ways. First, unlike previous models of flow, this new model specifies an explicit structure for direct and indirect influences on flow, and provides a mechanism for determining whether and how model constructs relate to external marketing variables. Second, it provides more rigorous operational definitions of key model constructs and establishes reliability and validity in a comprehensive measurement framework. Finally, it has been specifically formulated to represent flow in computer-mediated environments, with special attention to the commercial Web environment. This has been achieved by conceptualizing the constructs in terms of Web use and introducing new constructs more closely related to the Web usage experience. We are not aware of previous research specifying these relationships.

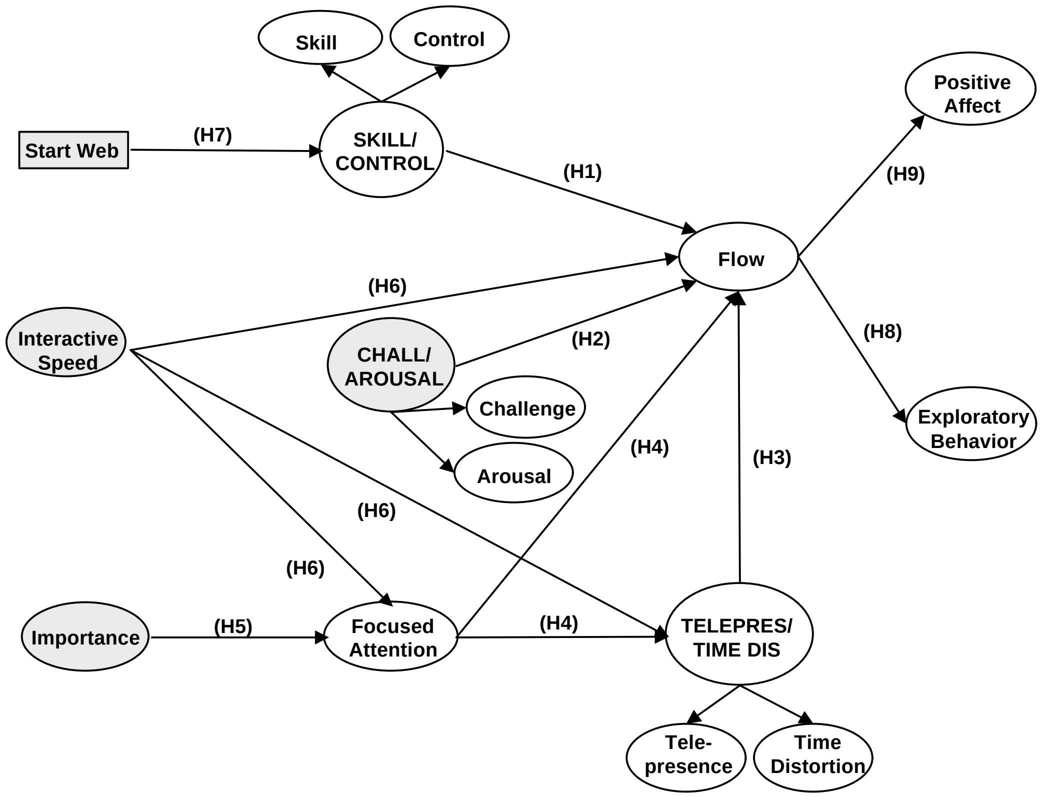

Figure 1 - Hoffman and Novak's (1996) Conceptual Model

2.2. Construct definition

The flow model we test in this paper has thirteen constructs. We operationalized these thirteen constructs using nine-point rating scales (scale values from strongly disagree to strongly agree) or semantic differential scales. In addition, three Web usage variables specify when the respondent started using the Web (StartWeb), how much time per day the respondent spends using the Web (Timeuse), and how much time the respondent expects to use the Web in the future (Expectuse). Timeuse and Expectuse, were not included in the base model, but are used later when we examine the relationship between the model constructs and consumer behavior variables.

Our survey instrument was developed on the basis of extensive pilot testing and, where appropriate, also incorporated existing scales. Appendix A summarizes a series of four small-scale, and two large-scale pilot tests used to develop our final survey instrument. Table 1 lists the 66 items corresponding to the thirteen constructs and three background variables used in our final survey.

Table 1 - Variables Used in the Flow Survey

Construct:	Variable Name:	Variable Description:
Web usage	startweb	When did you start using the Web? (6 categories)
	timeuse	How much time would you estimate that you personally use the Web? (6 categories)
	Expectuse	In the coming year, how much do you expect to use the Web, compared to your current level of usage? (5 categories)
arousal	A1	stimulated / relaxed
	A2	calm/excited (R)
	A3	frenzied / sluggish
	A4	unaroused/aroused (R)
challenge	C1	Using the Web challenges me.
	C2	Using the Web challenges me to perform to the best of my ability.
	C3	Using the Web provides a good test of my skills.
	C4	I find that using the Web stretches my capabilities to my limits.
	C5	How much does the Web challenge you, compared to other things you do on the computer?
	C6	How much does the Web challenge you, compared to the sport or game you are best at?
control	CO1	controlling / controlled
	CO2	influenced / influential (R)
	CO3	dominant / submissive
	CO4	guided / autonomous (R)
exploratory behavior	E1	I enjoy visiting unfamiliar Web sites just for the sake of variety.
	E2	I rarely visit Web sites I know nothing about. (R)
	E3	Even though there are thousands of different kinds of Web sites, I tend to visit the same types of Web sites. (R)
	E4	When I hear about a new Web site, I'm eager to check it out.
	E5	Surfing the Web to see what's new is a waste of time. (R)
	E6	I like to browse the Web and find out about the latest sites.
	E7	I like to browse shopping sites even if I don't plan to buy anything.
	E8	I often click on a link just out of curiosity.
flow	*Instructions:*	*The word "flow" is used to describe a state of mind sometimes experienced by people who are deeply involved in some activity. One example of flow is the case where a professional athlete is playing exceptionally well and achieves a state of mind where nothing else matters but the game; they are completely and totally immersed in it. The experience is not exclusive to athletics - many people report this state of mind when playing games, engaging in hobbies, or working.* *Activities that lead to flow completely captivate a person for some period of time. When in flow, time may seem to stand still and nothing else seems to matter. Flow may not last for a long time on any particular occasion, but it may come and go over time. Flow has been described as an intrinsically enjoyable experience.* *Thinking about your own use of the Web:*
	F1	Do you think you have ever experienced flow on the Web?
	F2	In general, how frequently would you say you have experienced "flow" when you use the Web?
	F3	Most of the time I use the Web I feel that I am in flow.

(R) indicates the item was reverse-scaled.

Table 1 (continued) - Variables Used in the Flow Survey

Construct:	Variable Name:	Variable Description:
focused attention	FA1	not deeply engrossed / deeply engrossed
	FA2	absorbed intently / not absorbed intently (R)
	FA3	my attention is not focused / my attention is focused
	FA4	I concentrate fully / I do not concentrate fully (R)
Interactivity (speed)	I1	When I use the Web there is very little waiting time between my actions and the computer's response.
	I2	Interacting with the Web is slow and tedious. (R)
	I3	Pages on the Web sites I visit usually load quickly.
involvement (importance)	IM1	important / unimportant
	IM2	irrelevant / relevant (R)
	IM3	means a lot to me / means nothing to me
	IM4	matters to me / doesn't matter
	IM5	of no concern / of concern to me (R)
playfulness	P1	I feel unimaginative when I use the Web. (R)
	P2	I feel flexible when I use the Web
	P3	I feel unoriginal when I use the Web. (R)
	P4	I feel uninventive when I use the Web. (R)
	P5	I feel creative when I use the Web.
	P6	I feel playful when I use the Web.
	P7	I feel spontaneous when I use the Web.
positive affect	PA1	happy / unhappy (R)
	PA2	annoyed / pleased
	PA3	satisfied / unsatisfied (R)
	PA4	melancholic /contented
skill	S1	I am extremely skilled at using the Web.
	S2	I consider myself knowledgeable about good search techniques on the Web.
	S3	I know somewhat less about using the Web than most users. (R)
	S4	I know how to find what I am looking for on the Web.
	S5	How would you rate your skill at using the Web, compared to other things you do on the computer?
	S6	How would you rate your skill at using the Web, compared to the sport or game you are best at?
telepresence	T1	I forget about my immediate surroundings when I use the Web. (R)
	T2	Using the Web often makes me forget where I am.
	T3	After using the Web, I feel like I come back to the "real world" after a journey.
	T4	Using the Web creates a new world for me, and this world suddenly disappears when I stop browsing.
	T5	When I use the Web, I feel I am in a world created by the Web sites I visit.
	T6	When I use the Web, my body is in the room, but my mind is inside the world created by the Web sites I visit.
	T7	When I use the Web, the world generated by the sites I visit is more real for me than the "real world"
time distortion	TD1	Time seems to go by very quickly when I use the Web.
	TD2	When I use the Web, I tend to lose track of time.

(R) indicates the item was reverse-scaled.

Eight sets of items - playfulness, focused attention, importance, arousal, control, positive affect, time distortion, and exploratory behavior - were identical to the items used in one or both of the two large-scale pilots. The seven item playfulness scale is from Webster and Martocchio (1992) (alpha = .782 and .828 in two pilot studies). The four item focused attention scale is from Ghani and Deshpande (1994) (alpha = .638 and .830 in the two pilots). We included McQuarrie and Munson's (1991) five item importance subscale for the involvement construct (alpha = .876 and .923 in the two pilots). Three constructs in the final survey - arousal, control, and positive affect - each consist of the four item scales used by Havlena and Holbrook (1986), based upon Mehrabian and Russell's (1974) longer original six original versions of these three scales. Coefficient alphas for arousal, control, and positive affect in the second pilot study were, respectively, .650, .685, and .861. The two-item scale for time distortion had a coefficient alpha of .703 in the second large-scale pretest. The eight item exploratory behavior scale is modified from Baumgartner and Steenkamp (1996)'s 20 item exploratory buying behavior tendencies scale. Items E1 through E8 were obtained by rewording items 8, 9, 1, 4, 11, 12, 16 and 20, to make them applicable to exploratory behavior on the Web. Coefficient alpha for this scale was .788 in the second large-scale pilot.

Four-item scales for skill and challenge were developed over the series of pilot tests, beginning with a set of 15 items for each construct. In the large-scale pilots the four skill items had a coefficient alpha of .864 and .858, and the four challenge items had a coefficient alpha of .876 and .799. In the final survey, we included two additional items for skill and control (items S5, S6, C5, and C6 in Table 1).

The seven-item telepresence scale was modified from items developed by Kim and Biocca 1997. As these items differed from the items used in the large-scale pilots, we do not report coefficient alphas from the pilot studies. Telepresence, described as "the compelling sense of being present in a mediated virtual environment" (Held and Durlach, 1992; Kim and Biocca, 1997; Steuer, 1995) is treated as a separate construct from time distortion, the perception of time passing rapidly when engaged in an activity.

The three-item speed of interaction scale is based upon Steuer's (1992) three-part conceptualization of interactivity. Our previous pilots attempted to measure three aspects of interaction, including 1) the *speed* of the interaction; 2) the *mapping* of the interaction (i.e., how natural and intuitive the interaction is perceived to be by the user; and 3) the *range* of the interaction (i.e., the number of possibilities for action at a given time). However, in the second large-scale pilot, we were only able to achieve acceptable alphas for speed of interaction (alpha = .688, two item scale) and use only that aspect here. For this study, we added a third item to measure speed of interactivity.

Finally, we measured flow in the present study with a three-item scale following a narrative description of flow. Chen, Wigand and Nilan (1999) have successfully used this approach in eliciting examples of experiences of flow among Web users. To minimize bias, these items appeared at the end of the survey. In August 1998, we conducted a small sample qualitative survey completed by 147 respondents, in which we provided them with the narrative description of flow shown in Table 1, and asked them if they had ever experienced flow on a *specific Web site*, and if so to describe that experience. Forty seven percent of the respondents said they experienced flow at specific Web sites, and provided descriptions of their interactions with these Web sites. No respondent expressed confusion about the definition of flow, and a reading of the verbatims of those who did report experiencing flow was highly consistent with reports of flow in other literature.

Below we discuss our research hypotheses. Hypotheses are not stated in a causal manner, because the direction of causality cannot be determined from our data. All hypotheses will be tested according to the paths in a structural model we fit to the data. In a structural equation model, the 'causal' relationships between variables are represented by directed paths. Significant paths between variables are assumed to provide support for the hypotheses.

2.3. Relationship Among Flow Model Constructs

2.3.1. Direct influences on Flow:

H1: Greater *Skill* at using the Web and greater perceived *Control* during the Web interaction correspond to greater Flow while using the Web.

H2. Greater *Challenge* and *Arousal* correspond to greater Flow.

H3: Greater *Telepresence* and *Time Distortion* correspond to greater Flow.

Skill refers to the Web consumer's capacity for action during the online navigation process and control taps the consumer's ability for action (Azjen 1988). Control comes from both the Web user's perception of her ability to successfully navigate through the Web environment and her perception of how the Web responds to her inputs. Challenges specify the consumer's opportunities for action on the Web and Arousal serves as a theoretical correlate of Challenge.

Hypotheses 1 and 2 taken together form the heart of most definitions of flow that have appeared in the literature. Only when consumers perceive that the Web contains challenges congruent with their own skills can flow potentially occur (Csikszentmihalyi and Csikszentmihalyi 1988). Otherwise, consumers may become bored or anxious (Ellis, Voelkl, and Morris 1994). The idea that flow requires high levels of skill and challenge is also consistent with optimal stimulation level theory (e.g. Holbrook and Gardner 1993; Raju 1980; Steenkamp and Baumgartner 1992).

Telepresence, or the mediated perception of the environment, is the perception that the virtual environment with which one is interacting is more real or dominant than the actual physical environment. Hoffman and Novak (1996) introduced this antecedent of flow and we include it here. The sense of a distortion in time perception (Csikszentmihalyi 1977) in which the consumer is unaware of time passing so that time appears to pass more quickly, is a correlate.

The eight-channel flow model (Massimini & Carli 1988; Ellis, Voelkl & Morris 1994) theoretically motivates the three higher-order factors in our structural model. The eight-channel model considers each of the three variable pairs, 1) skill and control, 2) challenge and arousal, and 3) telepresence and time distortion, to be multiple indicators of closely related underlying latent constructs.

Additionally, the three higher-order factors used to capture these effects in the model greatly simplifies the formulation and interpretation of the structural model.

H4: Greater Focused Attention corresponds to greater Flow, Telepresence and Time Distortion.

Focused attention refers to a "centering of attention on a limited stimulus field" (Csikszentmihalyi 1977, p. 40). Webster, Trevino and Ryan (1993) have noted that the computer functions as the limited stimulus filed and respondents report being "mesmerized" during their computer-mediated interactions. Note that we hypothesize that Focused Attention has both a direct effect on flow, as well as an indirect effect through its direct influence on telepresence and time distortion.

2.3.2. Indirect influences on Flow:

H5: Greater Importance corresponds to greater Focused Attention. Webster, Trevino and Ryan (1993) found a positive association between intrinsic interest and focused attention. Enduring involvement (Zaichkowsky 1986), operationalized here as importance, is formed by the presence of situational and/or intrinsic self-relevance and affects the attention effort (Celsi and Olson 1988). This hypothesis follows directly from Hoffman and Novak (1996).

H6: Greater Speed of Interaction corresponds to greater Focused Attention, Telepresence and Time Distortion, and Flow. As noted above, we consider only the speed of interaction and hypothesize its links to a number of constructs. Thus, our operationalization of interactivity is somewhat limited.

H7: The longer the respondent has been using the Web, the greater the Skill and Control. An individual's skill at using the Web and her perceived control over her online actions are, in part, a function of her online experience. Thus, the absolute length of time an individual has been online (StartWeb) is expected to exert a positive influence on these two constructs, which in turn are hypothesized to positively influence her ability to achieve flow.

2.3.3. Consequences of Flow:

H8: Greater Flow corresponds to greater Exploratory Behavior.

H9: Greater Flow corresponds to greater Positive Affect.

Previous research has identified numerous positive consequences of flow, including increased exploratory behavior (Webster, Trevino and Ryan 1993; Ghani and Deshpande 1994; Ghani, Supnick and Rooney 1991) and positive subjective experiences (Webster, Trevino and Ryan 1993, Csikszentmihalyi 1977). We hypothesize a positive relation for these two flow outcomes.

2.4. Relationships of Model Constructs to Consumer Behavior and Web Usage

The hypotheses below relate to how the model constructs relate to external variables.

H10: Flow, and closely related constructs such as Telepresence, Time Distortion, and Exploratory Behavior, will be greater for respondents who use the Web for "Experiential" uses, such as online chat, and entertainment, than for "Task-Oriented" uses such as work, searching for specific reference information, or online job listings. This is motivated by the theory that such experiential uses lead individuals to see the Web as a more playful environment (Ghani and Deshpande 1994; Hoffman and Novak 1996)

H11: Consumers who more recently started using the Web are more likely to use it for experiential activities; those who have been using the Web for a long time are more likely to use it for task-oriented activities (see Hammond, McWilliam and Diaz 1997). Along the same lines, Hoffman and Novak (1996) argued that a consumer's early Web experiences were more likely to be characterized by an experiential, time-passing quality, but that over time, Web navigation would evolve and become more goal-directed.

H12: Flow, and closely related constructs such as Telepresence, Time Distortion, and Exploratory Behavior, have a negative relationship with the length of time the respondent has used the Web. Hammond, McWilliam and Diaz (1997) found in a small-scale longitudinal study that after four months, ratings of four scales related to fun and exploration of the Web declined for novice, intermediate and experienced users, with the greatest declines occurring for novice users. We would also expect a decline in Flow, because we anticipate that a respondent's skill at using the Web (H7) will increase more rapidly than their evaluation of the challenge of the Web (which may even decline over time).

3. ONLINE DATA COLLECTION

Our final instrument was administered as a Web fillout form that was posted from April 10 to May 15, 1998, in conjunction with the 9th WWW User Survey[1] fielded by the Graphic, Visualization, and Usability Center (GVU) at the Georgia Institute of Technology. Respondents who registered to participate in the 9th WWW User Survey were given a unique identifying code, and were presented with an online menu of ten different surveys regarding Web usage behavior, including our flow survey, which they could potentially fill out.

As the GVU WWW User Survey employs non-probabilistic sampling and self-selection (GVU 1997), it is not representative of the general population of Web users. Comparison with population projectable surveys of Web Usage (e.g. Hoffman, Kalsbeek and Novak 1996) shows that the GVU User Survey sample contains more long-term, sophisticated Web users than the general population. Participants were solicited using both online and traditional media. These included announcements placed on Internet-related newsgroups, banner ads placed on specific pages on high exposure sites (e.g. Yahoo, Netscape, etc.), banner ads randomly rotated through high exposure sites (e.g. Webcrawler, etc.), announcements made to the www-surveying mailing list maintained by GVU, and announcements made in the popular press.

After the five weeks of the survey period, a total of 12,570 respondents filled out at least one of the ten surveys that comprised the 9th WWW User Survey. Of these 12, 570 respondents, 2,061 respondents completed our Flow survey. We eliminated 99 respondents who had missing data on any of the items in the survey. The missing data rate was so low because respondents were automatically prompted by the Web server to complete omitted items. This amounted to showing a respondent all items

[1] http://www.gvu.gatech.edu/user_surveys/survey-1998-04/

she did not complete and offering the opportunity to complete these items. This data collection strategy produced an initial analysis sample of 1962 respondents with no missing data.

In addition to the Flow survey items shown in Table 1, we also used items from a second survey, the "Web and Internet Usage Survey," fielded in the 9th GVU WWW User Survey. This survey was completed by a total of 9147 respondents. Then, we selected those 1654 respondents who completed both our Flow survey and the Usage survey. These 1654 respondents comprised our final analysis sample.

Following Cudeck and Browne (1983), we used a cross-validation procedure to assess model fit. To minimize capitalizing on chance when applying model modification procedures to the calibration sample, the sample of 1654 respondents was randomly split in uneven fashion, as recommended by Wickens (1989). The majority of respondents were randomly assigned into a calibration sample of 1154 respondents, and the remainder into a validation sample of 500 respondents.

4. PURIFYING THE MEASUREMENT MODEL

We adopted a two-step approach to model construction and testing (Anderson and Gerbing 1988). First, we "purified" the measurement model by eliminating measured variables and latent factors that were not well fit by an initial confirmatory factor analysis (CFA) model. Second, we fit a theoretical base model, and a series of revised models, to the measured variables retained in the first step.

4.1. Model Specification

Following Anderson and Gerbing (1988), the first assessment should be whether *any* structural model exists that has an acceptable goodness-of-fit. Thus, we began by fitting a Confirmatory Factor Analysis (CFA) model that included covariances between all pairs of latent factors. The base model for the CFA, model CFA1, included the latent factors and measured variables for Arousal, Challenge, Control, Exploratory Behavior, Flow, Focused Attention, Importance, Play, Positive Affect, Skill, Speed, Telepresence, and Time Distortion, all from Table 1.

4.2. Assessment of overall model fit

Maximum likelihood estimation was used to fit the CFA model described in 4.1 using the calibration sample of 1154 respondents. Overall goodness of fit for this initial model was reasonable, with root mean squared error of approximation (RMSEA) equal to .051. Browne and Cudeck (1993) suggest that RMSEA values about or below .05 indicate a close fit of the model of model in relation to degrees of freedom, and values below .08 indicate a reasonable fit. However, Bentler's (1990) comparative fit index (CFI) was .854, below the minimum value of .9 suggested (Bentler 1990) as indicative of good model fit, and below the median CFI of .95 in 14 marketing studies as summarized by Baumgartner and Homberg (1995). Thus, we proceeded to improve the fit of the model via a series of model modification tests.

4.3. Model modification procedure

Lagrange Multiplier (LM) tests were used to identify measured variables that loaded on multiple latent factors, and latent factors on which numerous extraneous measured variables loaded. Such measured variables and latent factors were deleted from the model, as summarized in Table 2. All measurement models were fit to the calibration sample data. The final measurement model, CFA7, eliminated latent factors for Play (p1-p7) and Positive Affect (pa1-pa4), and also eliminated measured variables t1, s1-s4, and c5-c6. Fit of this final model in the calibration sample was excellent, with CFI = .922 and RMSEA = .044 ± +/- .02.

Table 2- Model Modification Process for Purifying the Measurement Model

Model	CFI	RMSEA	Variables Deleted	Reason for deletion using Lagrange Multiplier Test
CFA1	.854	.051	--	None: base model for CFA
CFA2	.881	.047	p6, c1, c2, c4	Deleted variables double-loaded on additional latent factors
CFA3	.893	.045	p7, c3	Deleted variables double-loaded on additional latent factors
CFA4	.899	.047	p1, p2, p3, p4, p5	Many measured variables loaded on the latent factor for Play (p1-p5)
CFA5	.904	.047	pa1, pa2, pa3,pa4	Many measured variables loaded on the latent factor for Positive Affect (pa1-pa4)
CFA6	.911	.045	t1	Deleted variable double-loaded on additional latent factors
CFA7	.922	.044	s5, s6	Deleted variables double-loaded on additional latent factors

5. STRUCTURAL MODELS

5.1. Test of Hoffman and Novak's (1996) Conceptual Model

Based on the model purification process, our empirical modeling was based on only the latent factors and forty-five measured variables that were used in model CFA7. The base model shown in Figure 2 was fit first. The standardized parameter estimates are shown in Figure 2. The base model is based upon prior theory as it corresponds to Hoffman and Novak's (1996) conceptual model shown in Figure 1, with one modification. Because Positive Affect was eliminated in the process of purifying the measurement model, it was not included in the base model.

The base model provides an excellent initial fit[2] (CFI = .892, RMSEA = .050). In many ways, one could argue that the base model provides an *acceptable* fit. However, we still fit a series of model modifications to identify ways in which the fit could be improved, and any problems with the base model.

While CFI for the initial base model is less than the minimum value of .9 suggested by Bentler (1990), Baumgartner and Homberg (1995) note that there is a sizeable negative relationship of model complexity to CFI, whereas RMSEA is unaffected by model complexity.

[2] During the model modification process, the variance estimate of the latent factor for skill produced by EQS was constrained at the lower bound of zero. Thus, we constrained the variance of skill to the variance of the higher-order factor for telepresence/time distortion, which was the latent factor with the smallest estimated variance.

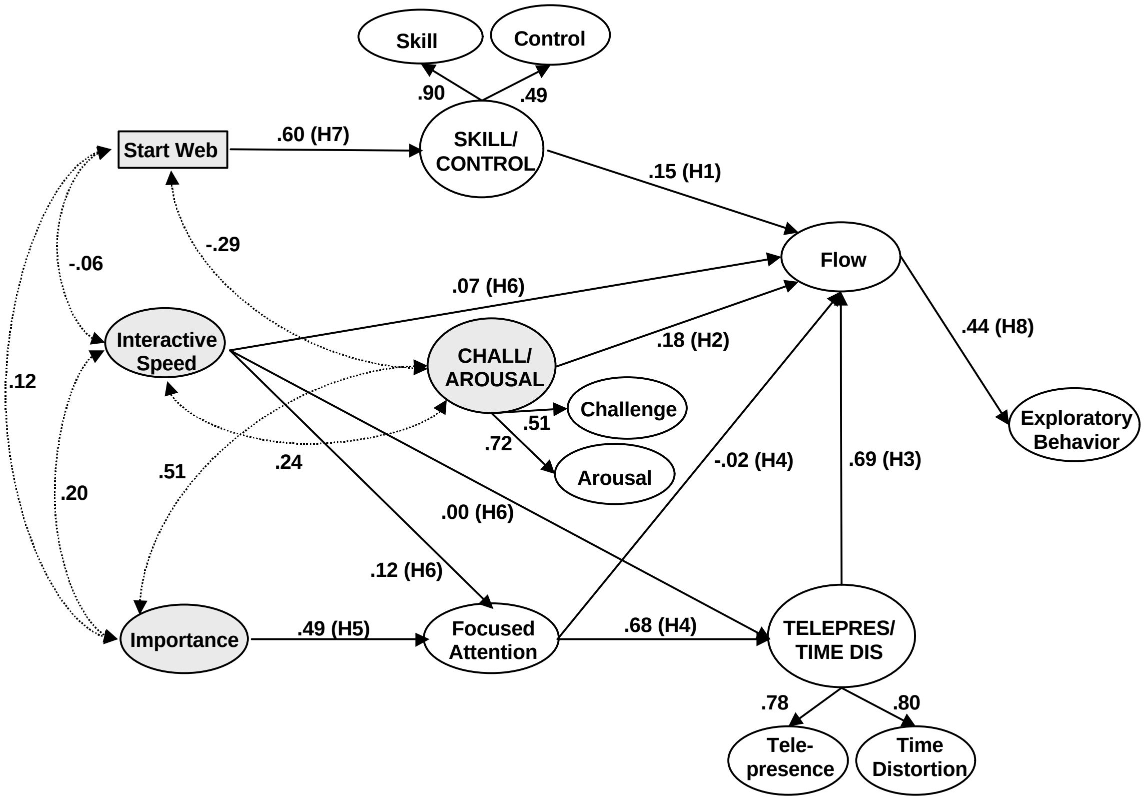

Figure 2
The Base Model

It is important to note that our model is considerably more complex than models that have typically appeared in the marketing literature. Comparing our theoretical model to median values in 73 studies summarized by Baumgartner and Homberg (1995), we find our initial theoretical model has a much greater number of measured variables (45 vs.11), number of parameters estimated (111 vs. 32), and degrees of freedom (924 vs 49). Our calibration sample size, at 1154, is much larger than the median of 180. In fact, the largest sample size reported by Baumgartner and Homberg, out of 184 marketing studies that used any type of structural equation model, was only 305. Thus, due to the negative relationship with model complexity, comparisons of CFI for the complex models fit in the present study with CFI values reported for the considerably simpler models in the published marketing literature must be viewed with caution. While we report CFI as an overall measure of fit, RMSEA is better justified as a basis of comparison.

The standardized path coefficients in Figure 2, with the exception of the paths from interactivity/speed to telepresence, and focused attention are all significant at $p<.05$. All significant coefficients were in the hypothesized direction. Estimated correlations among the four independent variables in the Base model, StartWeb, Speed, Importance, and Challenge/Arousal, were all significant ($p<.05$), with the exception of the correlation between StartWeb and Speed (t = -1.91)**.** Table 3 reports R^2 statistics for each structural equation in the initial theoretical model.

Table 3 - R-Square Statistics for Structural Equations

	Base Model	Revised Model A	Revised Model B
Skill (F1)	.806	.841	.833
Challenge (F2)	.257	.242	.242
Speed (F3)	---	---	---
Focused Attention (F4)	.273	.611	.628
Telepresence (F5)	.637	.651	.608
Arousal (F6)	.512	.623	.621
Control (F8)	.242	.269	.270
Importance (F9)	---	---	---
Time Distortion (F10)	.603	.627	.643
Exploratory Behavior (F11)	.191	.197	.356
Flow (F12)	.580	.576	.543
SKILL/CONTROL (F13)	.365	.491	.496
CHALLENGE/AROUSAL (F14)	---	.348	.347
TELEPRESENCE/TIME DISTORTION (F15)	.469	.459	.514

5.2. Refining the Theoretical Model

5.2.1. Model modification procedure.

Wald tests of free parameters (Bentler and Dijkstra 1985; Bentler, 1995) suggested which paths in the theoretical base model with small t-statistics should be dropped from the model. In addition, Lagrange Multiplier (LM) tests suggested numerous parameters that could be added to the model (Bentler and Dijkstra 1985; Bentler 1995). We performed a series of revisions to our base model, using the Wald and

LM tests, which are summarized below in Table 4. All models were fit to the calibration sample data[3]. As can be seen, the successive model changes were very minor.

Table 4 - Model Modification Process for Purifying the Theoretical Model

Model	CFI	RMSEA	Model Modifications
Base	.892	.051	(none - base model)
--	.900	.048	Drop: focus → flow Drop: speed → telepresence/time distortion Add: challenge/arousal → focus
--	.906	.046	Drop: speed → focus Add : importance → skill/control
Revised Model "A"	.906	.046	Drop: covariance of startweb and speed Convert challenge/arousal from an independent to dependent variable (change covariances with startweb, speed, and importance to paths)
--	.911	.045	Add: telepresence/time distortion → explore
Revised Model "B"	.911	.045	Drop: flow → explore

First consider Figure 3 showing Revised Model A, which provides a somewhat better fit (CFI=.906) than the Base model. Two paths (Challenge/Arousal to Focus, and importance to skill/control) were added, and three paths and one covariance between independent variables were deleted. In addition, Challenge/Arousal was converted from an independent to dependent variable, which does not affect the goodness-of-fit. This was deemed a more reasonable structure than that hypothesized in the base model because conceptually, when a consumer started using the Web, interactive speed, and importance are more fundamental than the challenge of the interaction. Revised Model B in Figure 4 is a slight variation, in which the path from Flow to Exploratory Behavior is replaced by Telepresence/Time Distortion to Exploratory Behavior.

[3] As in the base model, in the revised model shown in the second row of in Table 4, the variance estimate for latent factor for skill was constrained to the variance of arousal (the latent factor with the smallest estimated variance). Constraints were not required in subsequent models.

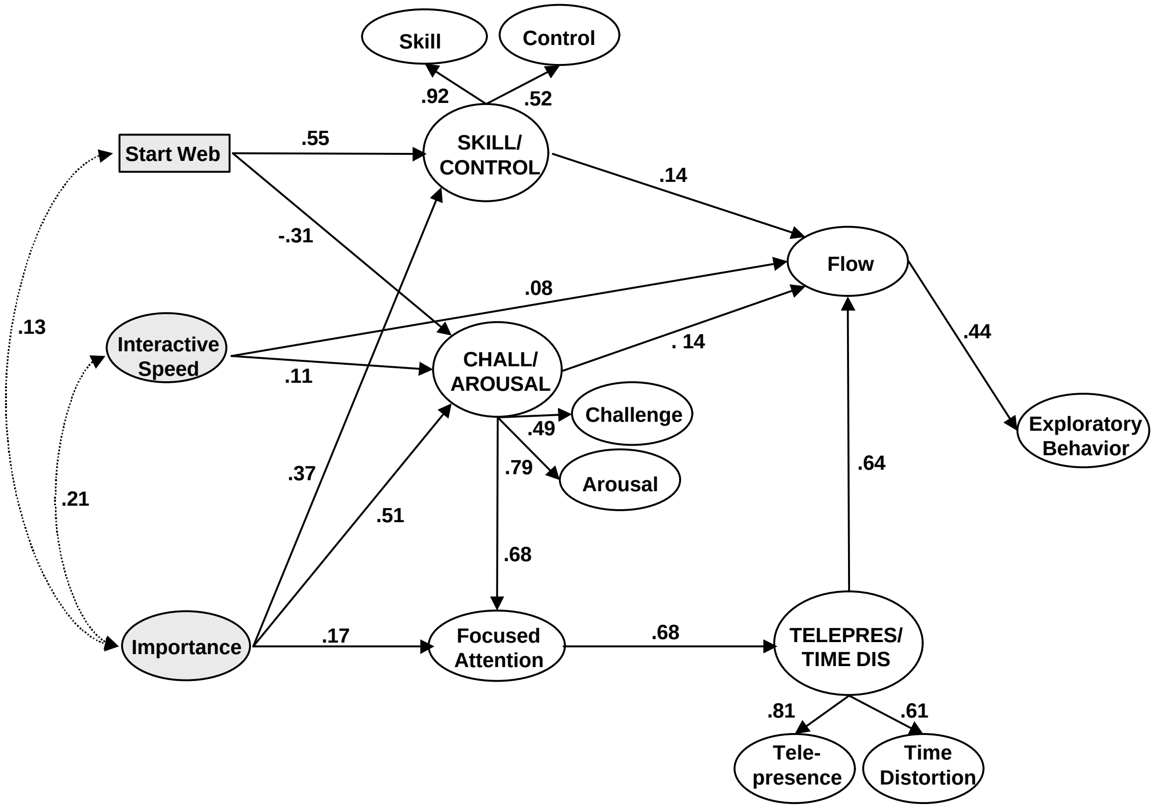

Figure 3
Revised Theoretical Model "A"

5.2.2. Assessment of overall model fit and the latent variable model.

Overall fit in Revised Model A is improved, with RMSEA=.046 and a 90% confidence interval of (.045, .048), and CFI=.906. Fit in Revised Model B improved slightly more, with RMSEA=.042, with 90% confidence interval of (.044, .047) and CFI=.911. While Revised Model A provides an acceptable fit, and incorporates minimal changes from our original theoretical model, Revised Model B offers a competing explanation of the relationships among Exploratory Behavior, Telepresence/Time Distortion, and Flow. It appears that Exploratory Behavior is better modeled in these data as an outcome of Telepresence/Time Distortion, than of Flow. Thus, future research will need to determine whether Exploratory Behavior is best thought of as an outcome of Flow (H8), or a parallel (and independent) outcome of Telepresence. Comparing the calibration sample Schwarz criterion (Schwarz 1978) for the

Base Model and Revised Models A and B (see Table 7), we note that the Schwarz criterion, which takes into account the number of parameters (i.e. model complexity) is minimized for Revised Model B. This is consistent with the CFI and RMSEA statistics.

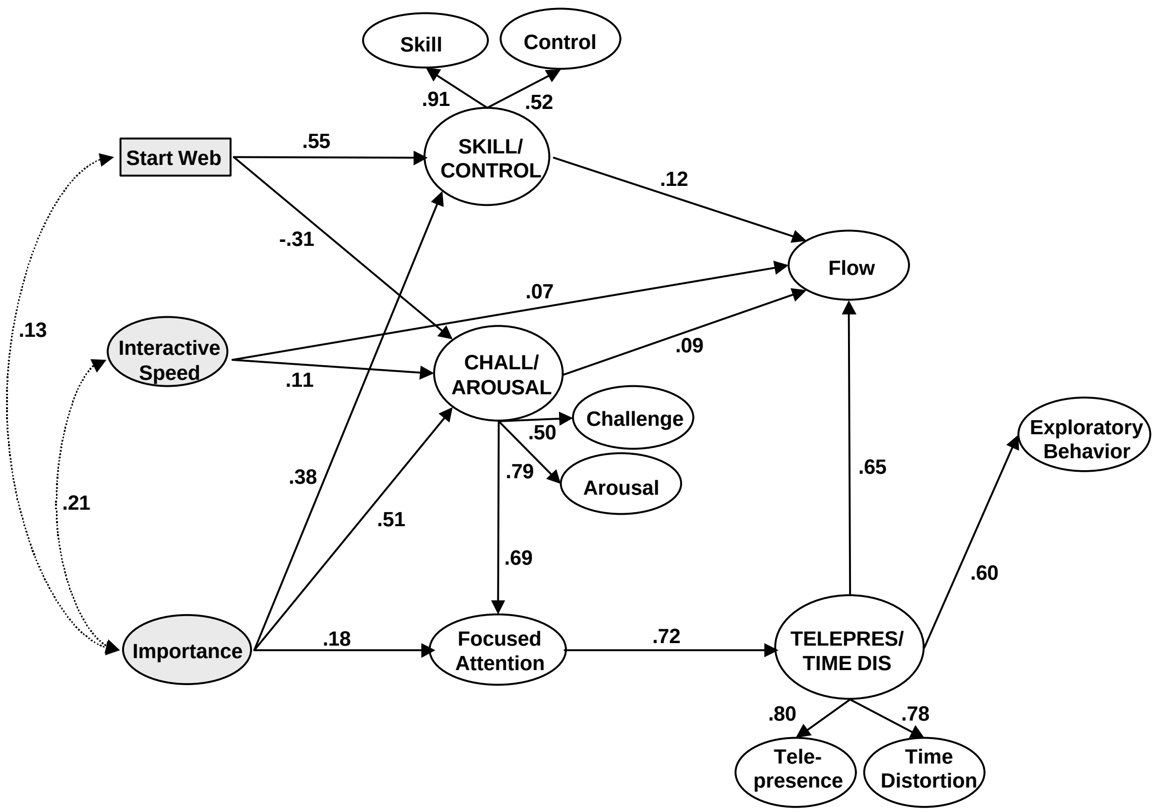

Figure 4
Revised Theoretical Model "B"

From Table 4, R^2 statistics for structural equations improve in Revised Model A over the initial Base model for Focused Attention, Arousal, and the higher order latent factor combining Skill and Control. Further improvement in R^2 is noted in Revised Model B for Exploratory Behavior and the higher order latent factor combining Telepresence and Time Distortion, suggesting Revised Model B is providing a better explanation of these constructs than Revised Model A.

5.2.3. Assessment of the measurement model.

Table 5 provides composite reliabilities estimated from revised Models A and B[4] in the calibration sample. Composite reliabilities for the Base Model were essentially identical, and are not shown. With the exception of control and arousal, all constructs have reliabilities greater than .750. Even though the reliabilities for the control and arousal constructs are below .6, previous research has found these two constructs to be reliable, and we include them in our structural models. However, future improvement in measuring these constructs is desirable.

Table 5 - Estimated Composite Reliabilities for Structural Models, Calibration Sample

Latent Factor:	Revised Model A	Revised Model B
Skill (F1)	.858	.858
Challenge (F2)	.851	.851
Speed (F3)	.775	.775
Focused Attention (F4)	.810	.809
Telepresence (F5)	.871	.871
Arousal (F6)	.574	.574
Control (F8)	.533	.533
Importance (F9)	.921	.921
Time Distortion (F10)	.772	.767
Exploratory Behavior (F11)	.808	.807
Flow (F12)	.914	.914

5.3 Implications for Hypotheses

For the most part, our hypotheses were supported. The direct paths to flow from Skill (H1), Challenge (H2), and Telepresence (H3) are positive and significant. However, there was no support for the hypothesis that greater Focused Attention corresponds directly to greater Flow (H4), although

[4] Let the expression, $y = B\,x + e$, be a general form for a set of structural equations, where y is a vector of measured variables for a particular latent construct in question, B is a matrix (or a vector) of regression coefficients of y on x, which is a vector of predictor variables including the latent construct in question and possibly some other predictors (when specified in the equations), and e is a vector for measurement error.

The reliability coefficient is defined conceptually as the ratio of the stable part of the variance of $1'y$ to the total variance of $1'y$, where 1 is a vector containing all one's. The total variance of $1'y$, as measured by the structural equations, is: $1'B\,\text{Cov}(x)\,B'1 + 1'\,\text{Cov}(e)1$, where Cov($x$) is the covariance matrix of the predictor variables, (i.e., the latent factor in question, and if applicable, the response tendency factor and any other relevant measured variables), and Cov(e) is the covariance matrix for the measurement errors, which is always a diagonal matrix in our

Focused Attention was found to correspond to greater Telepresence and Time Distortion (H4), thereby influencing Flow indirectly through these variables. Interactive Speed exerts a direct positive influence on Flow (H6), but greater Speed did not correspond to greater focused attention or telepresence and time distortion (H6). Greater Importance was positively associated with greater focused attention (H5), and the longer the respondent had been using the Web, the greater her Skill and Control in the Web environment (H7).

Although we did not hypothesize paths between Challenge and StartWeb, speed, and importance, we included covariance terms for each of these pairs in the base model. In the revised model, Challenge negatively relates to StartWeb, and positively relates to Speed and Importance. Two significant relationships were not anticipated. Challenge was positively related to focused attention, and importance was positively related to skill. Estimated correlations among the remaining independent variables are similar to those in the initial theoretical model. As noted above, it is unclear whether flow corresponds directly to Exploratory Behavior or should be considered as an outcome of Telepresence (H8). Finally, as Positive Affect was dropped from the model in the measurement purification process, H9 was obviously not supported.

5.4. Exploratory Structural Model

In section 7, we will examine how the latent factors in the structural model relate to a series of consumer behavior variables. Because the latent factors are fairly numerous (and also correlated), this complicates the task of predicting outcome variables. To address this, we used the following procedure. Estimated scores for the 11 first-order latent factors from Revised Model B were computed in the calibration sample using the least-squares method. The estimated covariance matrix for the latent factors and all measured variables was obtained from the model estimates and structural equations. Least-squares regression coefficients of the factor scores on the observed variables were obtained using this

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model. The stable part of variance of the composite is just the first term in the above expression, that is: $1'B$ Cov(x) $B'1$. B and Cov(x) were estimated from the fitting of the structural model.

estimated covariance matrix, and linear combinations of the variables using these regression coefficients were used as the estimated latent factor scores.

An exploratory principal components analysis on the scores on the 11 latent factors, and the measured variable StartWeb was performed, to investigate their correlational structure in the calibration sample. Three eigenvalues were greater than 1, and together explained 66.2% of the variance. The rotated Varimax factor pattern matrix appears in Table 6. The first factor corresponds to the “Flow Experience,” the second to “Skill,” and the third to “Challenge.” We note that the three factors correspond closely to Mehrabian and Russell (1974)'s three dimensions of emotions: dominance (skill), arousal (challenge), and pleasure (the flow experience). We anticipate that our three dimensions of Web beliefs may be useful in characterizing types of activities that people perform on the Web. Since these three exploratory factors are orthogonal, scores on the three exploratory factors will be used subsequently to provide a more parsimonious analysis, along with scores on the 11 latent factors from Revised Model B, of how the latent factors from the structural model relate to consumer behavior variables.

Table 6 - Varimax Factor Loadings from Exploratory PCA of Scores on Latent Factors, Revised Model B

Factor 1	Factor 2	Factor 3	Latent factor:
89	-3	5	time distortion
86	-5	2	telepresence
78	12	13	flow
77	6	**43**	focused attention
69	6	19	exploratory behavior
61	-3	**57**	arousal
9	**90**	1	skill
11	**76**	19	control
-17	**74**	-23	Started using the Web
46	**48**	**43**	importance
1	15	**71**	speed
29	-29	**61**	challenge

While we originally obtained these factors for the purpose of generating uncorrelated predictor variables for predicting consumer behavior variables, inspection of the factor pattern matrix suggested an alternative structural model, with three higher-order factors. These three factors suggest an alternative, exploratory structural model fit to the calibration sample, which is shown in Figure 5. All coefficients are significant ($p<.05$) except for those between Factor 2 and Factor 3, Arousal and Factor1, and Importance and Factor 1, This Exploratory Model fits very well (CFI = .908, RMSEA=.046).

Comparing the Schwarz criteria of the Exploratory Model to that of the Revised Models A and B, the Schwarz Criteria is still minimized for Revised Model B. Thus, while the Exploratory Model based upon a higher-order factor analysis structure fits well, Revised Model B remains the best fitting model. Nonetheless, the Exploratory Model represents an alternative way of looking at structural relationships that may also be useful. At a minimum, it provides justification for considering scores on three higher-order factors.

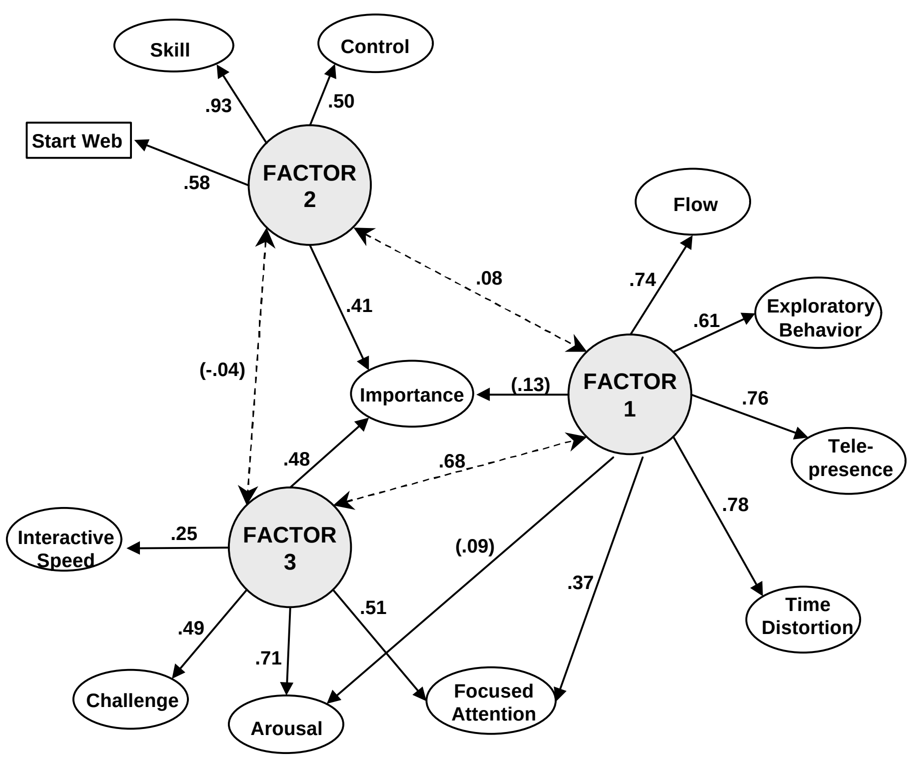

Figure 5
Exploratory Alternative Structural Model

6. CROSS-VALIDATION OF STRUCTURAL MODELS

We used two approaches to cross-validation. Four models were cross-validated: the Base Model, Revised Models A and B, and the Exploratory Model. For each model, a less restrictive cross-validation was performed first by fitting the revised measurement and latent variable model shown in Figure 3 to the validation sample, but with the parameters re-estimated. Second, a usual cross-validation (as described in Cudeck and Browne, 1983) was performed by applying the final structural model with the estimated parameter values from our calibration sample to the validation sample.

6.1. General Cross-Validation Results

We first re-estimated the parameters of the measurement and latent variable model in the validation sample, for Revised Models A and B, and for the Exploratory 3-Factor Model ("Validation 1" column in Table 7). Validation sample RMSEA was acceptable in all three models (.048, .046, and .047), and CFI dropped only slightly below .9 (.887, .896, and .893). For the Base model, CFI dropped from .892 to .879, while RMSEA remained unchanged at .050.

In our second approach to cross-validation ("Validation 2" column in Table 7), we applied calibration sample parameter estimates to the validation sample. This produced an anticipated drop in overall goodness-of-fit beyond that found in the first approach. RMSEA was still reasonable in Revised Models A and B, and in the Exploratory 3-Factor Model (.050, .048, and .049), but CFI dropped to .866, .874, and .869. The Base Model CFI dropped to .857 with this more stringent validation, but RMSEA remained about the same at .051.

As noted earlier for the Calibration sample, the Schwarz criterion is minimized for Revised Model B, in both approaches to cross-validation.

Table 7 – Cross-Validation Results

Model:	Statistic:	Calibration	(without fixed estimates) Validation 1	(with fixed estimates) Validation 2
Base Model	df	924	923[a]	1035
	Chi-square	3570.587	2068.794	2386.383
	CFI	.892	.879	.857
	RMSEA	.050	.050	.051
	RMSEA 90% CI	(.048, .052)	(.047, .053)	(.049,0.540)
	Schwarz criterion	-2944.527	-3667.289	-4045.736
Revised Model A	df	925	925	1035
	Chi-square	3215.398	1998.120	2311.169
	CFI	.906	.887	.865
	RMSEA	.046	.048	.050
	RMSEA 90% CI	(.045, .048)	(.045, .051)	(.047, .052)
	Schwarz criterion	-3306.767	-3750.393	-4120.950
Revised Model B	df	925	925	1035
	Chi-square	3103.910	1909.378	2226.089
	CFI	.911	.896	.874
	RMSEA	.045	.046	.048
	RMSEA 90% CI	(.044, .047)	(.0432, .049)	(.045,.051)
	Schwarz criterion	-3418.255	-3839.134	-4206.030
Exploratory Model	df	928 [a]	927	1035
	Chi-square	3180.300	1936.603	2278.241
	CFI	.908	.893	.869
	RMSEA	.046	.047	.049
	RMSEA 90% CI	(.044, .048)	(.044, .050)	(.046,.052)
	Schwarz criterion	-3363.020	-3824.335	-4153.878

[a]In the Base and Exploratory Models, there are more degrees-of-freedom in the Calibration sample than in the Validation sample without fixed estimates, since a constraint was set for convergence in the Calibration sample. This constraint is sample specific and was released with estimating the model in the Validation sample.

6.2. T-Tests of Model Parameters

This analysis builds upon the first validation, in which we re-estimated parameters in the validation sample. Here, we test the equivalence of calibration and validation sample parameter estimates. We report results only from Revised Model B, as results from Revised Model A are essentially identical. As our interest is in cross-validating specific aspects of the revised theoretical structural model, results for the Exploratory 3-Factor Model are not reported.

We devised a simple methodology to test whether the parameters estimated in the validation sample differed from those in the calibration sample. Let a_c be a parameter estimate in the calibration sample and a_v be the corresponding parameter estimate in the validation sample. A simple t-ratio defined by $t = (a_c - a_v) / s_d$, where s_d is the standard error for the difference of parameter estimates, was used to test whether a_c and a_v were significantly different from each other. Assuming normal distributions of the parameter estimates, the t-ratio could be compared against the tabled values of the standard normal distribution. As a_c and a_v are based on two independent samples (with mutually exclusive sets of independent observations), the difference of two normal variables is also normally distributed[5].

Altogether, we performed 110 tests of the equivalence of the unstandardized parameter estimates between the calibration and validation samples, for Revised Model B. Table 8 summarizes these results: 20.9% of all parameters were significantly different with $| t | > 1.96$, the critical value of a standard normal variable that will entail 5% chance of false alarm of real difference, and 10% with $| t | > 2.58$ (with 1% chance of false alarm). Although the observed rate of 20.9% rejections seem to be much higher than the corresponding nominal rate of 5%, it is noted that the estimates obtained within each sample were correlated. Hence, the 110 tests were not independent and the 5% nominal rate, which assumes 110 independent tests, could only serve as a rough benchmark. It is thus more useful to treat these test results as indications of potential model refinement or modification in the future modeling. Of particular interest are the test of differences in path coefficients among latent factors, and the measured variable StartWeb.

[5] To use the t-ratio as purported, we must address two questions. The first question is to justify the (approximate) normality of a_c and a_v. The other is to find a good estimate for s_d. The normality of the parameter estimates is justified by the asymptotic theory of the covariance structure modeling, and our large calibration and validation sample sizes. As for the estimate of s_d, we first note that the asymptotic variance for either a_c and a_v is in the form of s^2/n, where n is the sample size. Because a_c and a_v are based on two independent samples with sizes n_c and n_v, it follows that $s_d^2 = s^2 (1/n_c + 1/n_v)$.

To estimate s^2 in the above equation, we rely on the standard error estimates for a_c and a_v in the EQS output. Let s_c and s_v be the standard error estimates, then s^2 is estimated by $n_c\, s_c^2$ and $n_v\, s_v^2$ in the two samples, respectively. To combine these two estimates, a pooled estimate for s^2 was obtained as ($n_c^2\, s_c^2$ +

Estimates of only two such path coefficients differed across calibration and validation samples, as shown in Table 9, suggesting that Revised Model B cross-validates well.

Table 8 - Pairwise Tests of Parameters in Calibration and Validation Samples

		number of parameters where:			
	total	$\lvert t \rvert < 1.96$	$1.96 \le \lvert t \rvert \le 2.58$	$\lvert t \rvert > 2.58$	% parameters $\lvert t \rvert \ge 1.96$
path coefficients among latent factors and startweb	16	14	0	2	12.5%
path coefficients for regression of measured variables onto latent factors	33	26	3	4	21.2%
covariances of independent variables	2	2	0	0	0%
variances of independent variables	59	45	9	5	23.7%
all parameters	110	87	12	11	20.9%

Table 9 -Significant Differences in Structural Equation Paths Between Calibration and Validation Samples

Path coefficients between latent factors:	standardized coefficient (calibration sample)	standardized coefficient (validation sample)	t-statistic
(Challenge/Arousal) → Focused Attention	.692	.390	3.12
Importance → Focused Attention	.176	.424	-3.28

7. RELATIONSHIP OF MODEL CONSTRUCTS WITH CONSUMER BEHAVIOR VARIABLES

In this section, we relate estimated scores on model constructs to a series of outcome variables dealing with consumer behavior on the Web. We have two sets of measured variables that we consider as outcomes of constructs in the Flow model: (1) Web *Applications* consisting of 21 rating scales dealing

$n_v^2\, s_v^2)/(n_c + n_v)$. After simplification, s_d^2 is thus estimated by $n_c\, s_c^2 / n_v + n_v\, s_v^2 / n_c$, the square root of which was used in the denominator of the t-ratio.

with extent of Web use, and specific applications the Web is used for (n=1654 in the combined calibration and validation samples); and 2) *Web Shopping* consisting of 13 binary variables specifying features that are "most important" when shopping, or considering shopping, on the Web (n=481 respondents in the combined calibration and validation samples who completed an additional survey on Internet shopping). Additionally, we 3) examined how the model constructs change over time, by exploring the relationships among the constructs and when the respondent starting using the Web.

Using the approach described in section 5.4, we constructed scores on the 11 first order factors and 3 three higher-order factors from Revised Model B in the calibration sample. Once these scores were obtained, factor scoring coefficients from the Varimax rotated solution from section 5.3 were applied to the 11 first-order factors and StartWeb, to create scores on the three factors from the exploratory PCA (Table 6) in the calibration sample. Instead of directly obtaining scores based upon the estimated covariance matrix from the Exploratory Model, we used this approach since we sought *uncorrelated* rather than correlated scores on three higher-order factors.

We then recreated scores on the eleven latent factors in the validation sample, using calibration sample weights. Then, scores on the three factors from the exploratory PCA were created in the validation sample, using calibration sample weights. The resulting three factor scores were approximately uncorrelated in the combined calibration and validation samples. To determine whether calibration and validation sample data could reasonably be combined, we fit a series of multiple regression models for the set of Web Application variables, and a series of logistic regression models for the sets of Primary Use and Web Shopping variables, predicting the dependent variables from a dummy variable specifying membership in the validation sample, scores for Factor 1, Factor 2, and Factor 3, and interactions of the dummy variable with the three factor scores. The three factor scores were used, rather than the scores on the eleven first-order latent factors from Revised Model B, to avoid problems of interpretation that would result from correlated predictor variables. Two of 63 interaction terms were significant ($p <.05$) in the set of Web application variables, 0 of 21 in the Primary Use set, and 5 of 39 in the Web Shopping set, for a total of .057 percent of the tests, just slightly above the expected chance level of .05 significant tests.

Thus, we concluded that the calibration and validation samples could be combined for subsequent analyses involving the relationship of the three Exploratory PCA factors with the outcome variables.

7.1. Web Applications and Flow

Table 10 reports significant ($p<.05$) correlations of a) StartWeb, b) scores on eight latent factors from Revised Model B, and c) scores on the three Exploratory Factors, with 21 Web Applications variable. The significant correlations in the first column of Table 10 support H11, as consumers who have used the Web for the shortest period of time are more likely to use it for experiential activities, while experienced users are more likely to use the Web for task-oriented activities. The correlations with the three 2nd order exploratory factors shown in the last three columns of Table 10 have a clear interpretation. Fun, playful, and recreational activities relate to the flow experience (factor 1). Work and goal directed activities (including shopping) relate to skill (factor 2). Challenge (factor 3) is predictive of expected use in the next year.

Table 10 - Significant (p<.05) Correlations Between Scores on Model Constructs and Outcome Variables for Web Applications

	Model Constructs from Revised Model B:									2nd Order Exploratory Factors:		
	Start Web	Speed F3	Import F9	Focus F4	Skill/ Control F13	Chall Arous F14	Telep/ TD F15	Flow 12	Explore F11	FACT 1 Flow expe	FACT 2 Skill	FACT 3 Chall
Expected Use	-.128		.105	.181	-.065	.229	.143	.081	.118	.133	-.088	.163
Medical Info (NU24)		.102	.103	.143	.044	.145	.110	.100	.164	.092		.137
Chat groups (NU25)	-.099	.115	.155	.187	.059	.206	.257	.204	.198	.240		.102
Instead of TV (NU20)	-.086	.092	.181	.205	.065	.208	.291	.222	.304	.282		.074
Fun (NU3)		.113	.133	.145	.095	.140	.227	.184	.242	.217	.064	
Personal (NU5)		.106	.163	.152	.168	.137	.198	.187	.186	.187	.139	.057
Hours used (NU2)	.200	.157	.340	.229	.408	.218	.207	.220	.203	.194	.359	.155
Time Use	.222	.186	.360	.203	.406	.198	.200	.211	.190	.180	.370	.163
Telephone listings (NU28)	.133	.109	.160	.108	.200	.108	.098	.126	.118	.084	.190	.105
Reference Material (NU21)	.182	.109	.237	.135	.315	.124	.075	.110	.088	.068	.295	.116
Maps (NU29)	.155	.117	.153	.090	.217	.066	.070	.087	.118	.058	.209	.075
Product information (NU19)	.201	.074	.216	.097	.302	.077	.057	.077	.092	.053	.290	.078
Newsgroups (NU17)	.097	.070	.075		.139			.059			.137	.057
Electronic news (NU18)	.130	.089	.137	.076	.187	.068		.055	.086		.182	.092
Frequency of visit (NU1)	.360	.127	.284	.081	.495			.101			.481	.076
Research Material (NU22)	.236	.083	.179	.056	.302	.057		.060			.296	.089
Shopping (NU30)	.198		.176	.072	.259			.061	.079		.257	
Financial Info (NU23)	.198		.083		.176						.190	
Job listings (NU26)	.152		.120	.061	.166		.056	.079	.078	.056	.155	
Real estate (NU27)	.140		.081		.137				.061		.136	
Work (NU4)	.371		.127	-.073	.356	-.094	-.176	-.074	-.189	-.163	.372	

To more easily interpret the pattern of correlations, we performed a canonical correlation of the 21 Web Application variables with StartWeb and scores on the eight model constructs shown in Table 10. Four canonical correlations were significant ($p<.0001$), with squared canonical correlations of .355, .278, .061, and .045. As there is a substantial drop in magnitude from the second to third squared canonical correlation, we display only the two-dimensional plot here. However, inspection of correlations with the third canonical variable reveals that Challenge/Arousal is the model construct correlating most with the third canonical variable (.610), and Expected Use is the usage variable correlating most (.180); thus, the third canonical variable serves to separate Challenge/Arousal from the other model constructs, and the observed correlation in Table 10 is consistent with this interpretation.

Figure 6 presents a plot of the correlations of StartWeb and the eight model constructs (columns of Table 10) with their first two canonical variables, shown as vectors. Also shown are correlations of the 21 Web Application variables (rows of Table 10) with the same two canonical variables. These 21 variables are represented as points to simplify the visual display, but are, of course, also vectors from the origin. Since we have chosen the set of canonical variables for the model constructs as the basis for the plot, so as to best represent these variables, the correlations of the model constructs with the canonical variables are larger than those of the 21 Web Application variables.

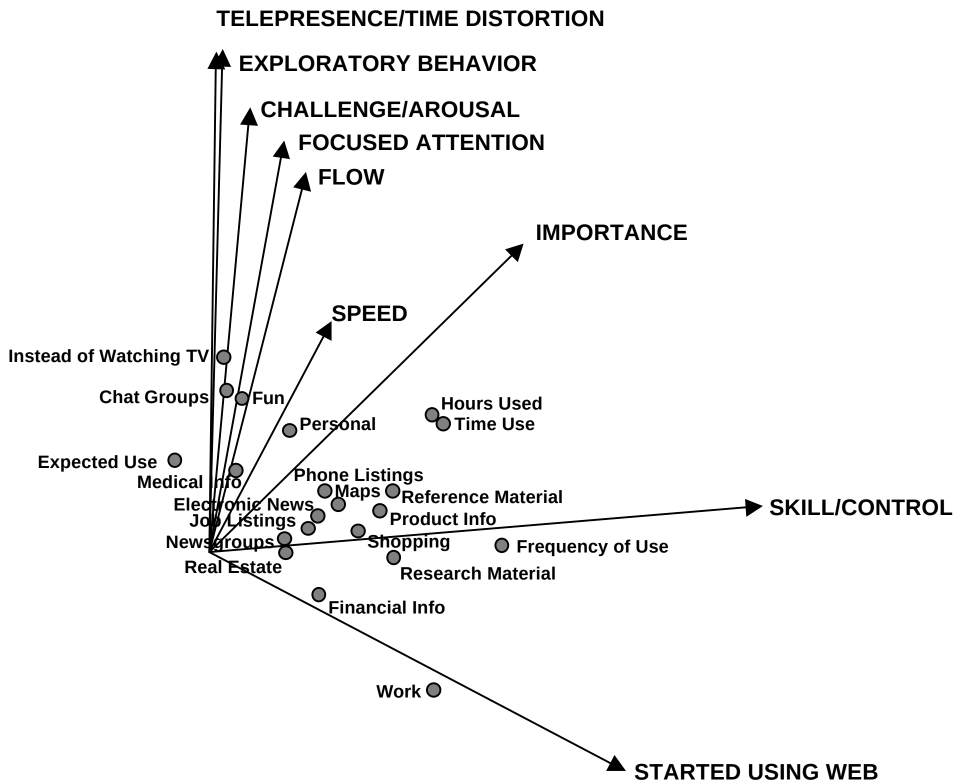

Figure 6 – The Relationship Between Model Constructs and Web Applications

The vertical direction of Figure 6 shows that model constructs related to the "Flow Experience" (Telepresence/Time Distortion, Exploratory Behavior, Focused Attention, and Flow), as well as "Challenge/Arousal," are correlated with recreational and experiential uses of the Web, such as instead of watching TV, chat groups, fun, and personal use. The horizontal direction relates Skill/Control to more task-oriented activities, such as reference material, research, shopping, and product information. StartWeb is positively correlated with Skill/Control, but negatively correlated with the set of items related to the "Flow Experience." Work use correlates with StartWeb and Skill/Control, but negatively with Flow Experience constructs. As noted earlier, H10 is supported.

7.2. Online Shopping and Flow

We previously found that Skill, rather then the Flow Experience, relates to product search and purchase behavior. Now we specifically examine attitudes of Web shoppers. Table 11 presents results from our set of Web shopping items, for the subsample of 481 respondents who completed an additional survey on Internet shopping. The items shown in Table 11 represent a checklist of features which respondents find important when they shop on the Internet. Table entries are the proportion of consumers checking each feature, for those with low (below the median) and high (above the median) scores on the three Exploratory PCA factors.

Those scoring above the median on "Flow Experience" are more likely to rate as important shopping features which produce a smooth shopping experience: easy ordering, easy to cancel, easy payment, support, quick delivery, and easy to contact. Those above the median on Skill are more likely to desire quality information. And, those above the median on challenge are more likely to seek variety, in addition to several features desired by those above the median on Flow Experience (easy ordering, easy to contact).

Table 11 – Model Constructs and Web Shopping

	Flow Experience (factor 1)		Skill (factor 2)		Challenge (factor 3)	
Important when shop:	**Low**	**High**	**Low**	**High**	**Low**	**high**
Variety	.70	.78	.72	.76	**.69**	**.80**
Easy returns	.41	.46	.47	.41	.41	.46
Quality Information	.71	.73	.68	.75	.69	.75
Easy Ordering	**.65**	**.79**	.71	.72	**.67**	**.78**
Easy to Cancel	**.37**	**.46**	**.48**	**.35**	.39	.44
Reliability	.68	.70	.67	.71	.70	.68
Easy Payment	**.45**	**.57**	.51	.51	.51	.52
Support	.46	.55	**.57**	**.45**	.47	.53
Security	.77	.75	.76	.76	.76	.76
Quick Delivery	**.57**	**.67**	.61	.62	.63	.60
Low Prices	.65	.66	.62	.68	.69	.63
Cutting Edge	**.11**	**.19**	.14	.15	.14	.15
Easy to Contact	.43	.51	.47	.47	**.39**	**.56**

Shaded pairs not significant at p<.05

Finally, we investigate changes over time for the 11 first-order latent factors and the three higher order factors from Revised Model B. Here, we dichotomized scores on the 14 latent factors to create binary variables indicating whether the respondent was above or below the median on each factor. Table 12 reports the proportion scoring above the median on each dichotomized factor by levels of the "Startweb" variable. The results support H12. Note that while "Flow" decreases with years of experience, there is still a sizeable proportion of respondents in each of the high experience groups (3+ years) who experience Flow and related constructs. Change in skill is most dramatic over time.

Table 12 – Changes in Model Constructs Over Time

	When started using the Web:					
	<6 months (n=84)	6-12 months (n=125)	1-2 years (n=241)	2-3 years (n=374)	3-4 years (n=605)	4+ years (n=225)
Sklll	.05	.18	.28	.41	.67	.76
Challenge	.73	.65	.57	.52	.46	.35
Speed	.55	.58	.54	.44	.53	.42
Attention	.67	.54	.56	.50	.46	.46
Telepresence	.67	.62	.57	.49	.45	.44
Arousal	.74	.58	.55	.51	.47	.38
Control	.13	.28	.36	.49	.60	.66
Importance	.35	.42	.46	.47	.56	.55
Time distortion	.61	.61	.61	.51	.45	.40
Exploratory behavior	.63	.60	.57	.49	.49	.36
Flow	.57	.55	.50	.52	.48	.45
SKILL/CONTROL	.02	.10	.21	.41	.70	.82
CHALLENGE/AROUSAL	.80	.64	.59	.52	.44	.35
TELEPRESENCE/TIME DISTORTION	.70	.61	.59	.51	.45	.38

8. DISCUSSION

Our new model of flow in computer-mediated environments specifies an explicit structure for direct and indirect influences on flow, as well as how the model constructs relate to behavioral outcomes. We have demonstrated empirically that the cognitive state of flow experienced by consumers on the Web can be measured, as hypothesized, by 1) high levels of skill and control; 2) high levels of challenge and arousal; 3) focused attention; and is 4) enhanced by interactivity and telepresence. The effect of focused attention on flow is not direct, but rather appears to exert its influence through telepresence and time distortion.

Contrary to our hypothesis, higher levels of interactive speed were not associated with greater focused attention or telepresence and time distortion. In part, this is likely due to the fact that our measure of interactivity is unidimensional and so does not fully capture interactivity. On the other hand, Dellaert and Kahn (1999) found that Web waiting time only negatively affects consumer evaluation of Web site content when slow speeds are not well managed, for example, by failing to provide information on waiting times. Thus, this recent research lends support to our result that interactive speed seems to affect challenge, but not attention.

Not surprisingly, we found that the more important consumers considered the Web to be in general, the more likely they were to focus their attention on the interaction and the more likely they were to be skilled at using the Web. The latter is consistent with Mitchell and Dacin's (1996) observation that enduring involvement is related to expertise. Additionally, as we expected, the longer consumers reported using the Web, the greater their levels of skill and control during the navigation process. In the revised model, challenge negatively relates to StartWeb, and positively relates to Speed and Importance. Unexpectedly, greater challenge corresponded to greater focused attention. This means that engaging consumers online will arise in part from providing them with excitement.

8.1. Implications

Our research has relevance to both academic marketing scientists and industry practitioners interested in the commercialization of the World Wide Web. This is because the flow model depicted in Figure 4 embodies the components of what makes for a compelling online experience. Our formulation provides marketing scientists with rigorous operational definitions of key model constructs and establishes reliability and validity in a comprehensive measurement framework. Further, our flow model constructs relate in significant ways to key consumer behavior variables and Web usage.

The flow experience is positively correlated with fun, recreational and experiential uses of the Web, expected use of the Web in the future, and the amount of time consumers spend online, but negatively associated with using the Web for work-related activities. Those who experience flow on the Web appear to seek online shopping experiences that emphasize ease of use. Task-oriented activities such as work, and online search for product information and purchase relate to skill and control, but not flow. However, this does not mean that such activities will not necessarily lead to flow. Instead, it is more likely that as currently implemented, online shopping, for example, is simply not a flow-inducing activity. That is, most task-oriented online activities may not currently offer the requisite levels of challenge and arousal, nor do they induce the sense of telepresence and time distortion, necessary for flow to be achieved. These findings demonstrate the utility of the model for enhancing understanding, and profitable development, of the commercial Web environment.

The framework we tested and refined in this paper can further managerial understanding of the nature of consumer interaction in computer-mediated environments. Demonstrating that flow can be reliably measured and possesses significant predictive ability is an important first step toward subsequent predictive modeling with critical marketing variables. For example, evidence is emerging that online environments offering full information improve the decision making process for consumers and offer greater benefits to online retailers than environments with less information (Haubl and Trifts 1998; Lynch and Ariely 1998). Though providing full information to consumers may increase the possibility of price competition, providing a compelling online experience may significantly mitigate price sensitivity in such environments.

8.2. Future Directions

Toward these aims, future research should build upon the structural model of flow shown in Figure 4. Improved measurement of telepresence and interactivity is necessary. Research effort may also be fruitfully directed at the behavioral influences on flow. We restricted our investigation of involvement to enduring involvement, as measured by the importance of the Web to the respondent. The role of situational involvement is unexplored in this research, as are distinctions between task-oriented and experiential navigation behavior, and the role of consumer demographic variables.

Investigating the relationship between the consequences of flow and online consumer outcome variables may also be productive. For example, the model results presented here suggest that the "interactivity metrics" of duration time and browsing depth recently proposed to measured marketing effectiveness on advertising sponsored Web sites (Novak and Hoffman 1997) will be highly positively correlated with flow. Ultimately, knowledge of the relationship among the flow model constructs and marketing outcome variables can lead to more effective interactions with online customers.

Our measure of flow was very general, in that it measured the respondent's tendency to experience flow *while using the Web* - not while engaging in specific activities on the Web. Thus, our study does not address the specific activities that are likely to lead to flow. It appears that consumers researching information, for example, do not achieve flow and that flow is more strongly correlated with more experiential Web activities. Research specifically addressing this issue is warranted.

We would like to propose a broader framework for flow that incorporates flow as a segmentation basis with flow experienced during specific activities. Consumers can be segmented according to the degree in which they experience flow on the Web. Consumers who more often experience flow tend to see the Web as fun; those who more often do not experience flow tend to see the Web as work. With in the first, "high-flow" segment, some consumers may find flow during experiential activities, some during task-directed activities, and some during both. Within the second, "low-flow" segment, if flow is experienced at all, it will most likely be during task-oriented activities. This also suggests that it will be important to investigate reduced forms of the flow model that describe different modes of consumer behavior on the Web.

The present research may be effectively extended beyond a retrospective general evaluation of flow on the Web to the modeling of the flow construct in specific online situations. For example, apart from speed of interaction, the present research has not considered the specific elements of commercial

Web site design that facilitate the consumer experience of flow, nor how the flow experience is likely to vary across the wide range of commercial sites found on the Web today.

Because our online sample is not representative of the general population of Web users, we are not able to generalize the findings to the entire population of Web users. However, as our sample does represent more skilled Web users, we feel that the results do apply to an important segment of the Web population. Additionally, over time, more and more novice users are likely to enter this more sophisticated segment, suggesting that our results offer a window on what we can reasonably expect in terms of this important domain of Web consumer behavior. Future research should strive to replicate these results with samples that represent the broader population of Web users.

Our modeling has produced two competing explanations involving Exploratory Behavior, Telepresence/Time Distortion, and Flow. Future research is also necessary to determine whether Exploratory Behavior is best thought of as an outcome of Flow, or a parallel (and independent) outcome of Telepresence.

Finally, it is important to point out that flow is not the only concept relevant for understanding consumer experiences in online environments and their outcomes. Constructs such as costs and benefits of Web use, for example, will also relate to outcome variables and should be considered in further modeling efforts.

8.2. Concluding Remark

The importance to the global economy of commerce conducted over the Internet is no longer in doubt (Margherio, Henry, Cooke, and Montes 1998). Determining how to create commercial online environments that engage consumers and ultimately satisfy important marketing objectives such as extended visit durations, repeat visits, and online purchase are critical marketing tasks. We believe that modeling efforts emphasizing the relations among components of what makes for a compelling online experience represents an important first step on this path.

Appendix A - Pilot Tests

A series of pilot tests, consisting of four small-scale pretests, and two full-scale pilot field tests, were conducted over a one year period from December 1996 to November 1997. The purpose of the pilot tests was to provide input into the development of the series of items used to measure the constructs discussed in the previous section.

Pretest 1) n=49, in-person 22 item written questionnaire administered in person to MBA students at a private business school in the southeastern US, December 1996. *Pretest 2*) n=108, 59 item Web fillout form[6] administered to Project 2000 Pretest Panel, January 1997. *Pretest 3)* n=86, in-person 59 item written questionnaire administered in person to MBA students at a private business school in the southeastern US, February 1997. *Pretest 4)* n=146, 78 item Web fillout form[7] Project 2000 Pretest Panel, March 1997.

First Large Scale Pilot. The final pilot test survey consisted of 77 items, and was administered as a Web fillout form[8] which was posted from April 10 to May 10, 1997 in conjunction with the 7th WWW User Survey fielded by the Graphic, Visualization, and Usability Center (GVU) at the Georgia Institute of Technology[9]. 19,970 respondents filled out at least one of the 13 surveys that comprised the 7th WWW User Survey, and 4,232 useable responses were obtained for our pilot test survey.

Second Large Scale Pilot. The second pilot test consisted of 75 items, and was administered as a Web fillout form which was posted from October 10 to November 17, 1997 in conjunction with the 8th WWW User Survey. In five weeks, over 10,000 respondents filled out at least one of the 11 surveys that comprised the 8th WWW User Survey, and 2,037 useable responses were obtained for our pilot test survey.

[6] http://www2000.ogsm.vanderbilt.edu/cgi-bin/SurveyArchive/pretest.jan97.pl
[7] http://www2000.ogsm.vanderbilt.edu/cgi-bin/SurveyArchive/pretest.march97.pl
[8] http://www2000.ogsm.vanderbilt.edu/gvusurvey/project2000.gvu.html
[9] http://www.gvu.gatech.edu/user_surveys/survey-1997-04/

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