Association for Information Systems
AIS Electronic Library (AISeL)

PACIS 2010 Proceedings

Pacific Asia Conference on Information Systems (PACIS)

2010

The Effects of Ambiguity Tolerance and User Discretion on Spatial Task Performance and Display Choices

Russell Grant
University of Kentucky, rr_mozart@yahoo.com

Milton Shen
University of Kentucky, milton.shen@uky.edu

Melody Carswell
University of Kentucky, cmcars00@gmail.com

Radhika Santhanam
University of Kentucky, santhan@email.uky.edu

THE EFFECTS OF AMBIGUITY TOLERANCE AND USER DISCRETION ON SPATIAL TASK PERFORMANCE AND DISPLAY CHOICES

Russell Grant, Department of Psychology, University of Kentucky, Lexington, KY, USA, rr_mozart@yahoo.com

Milton Shen, School of Management, University of Kentucky, Lexington, KY, USA, milton.shen@uky.edu

Melody Carswell, Department of Psychology, University of Kentucky, Lexington, KY, USA, cmcars00@gmail.com

Radhika Santhanam, School of Management, University of Kentucky, Lexington, KY, USA, santhan@email.uky.edu

Abstract

Recent improvements in information technologies have led to the creation and advancement of numerous interfaces or visual displays. However, not all innovations in visual representations optimize their users' decisional performance. This research examines whether granting users discretion improves their decisional accuracy and expedites their decision making, as well as reduces their stress and mental workload. In addition, the current study utilizes an extensive, relatively stable construct in cognitive psychology – ambiguity tolerance – to represent individuals' openness to complexities and investigates the impacts on those decisional outcomes. The mixed results yield implications for future studies.

Keywords: Ambiguity Tolerance, User Discretion, Visual Display, Display Choices.

1 INTRODUCTION

In an age when technology is crucial to existence, visual displays are found ubiquitously and in every decisional aid. Examples range from maps of troops in Iraq, to charts depicting stock prices, to graphs showing pressure and heat inside a nuclear reactor. Nevertheless, research shows that using inappropriate visual displays degrades task performance by unnecessarily increasing the decision makers' mental workload and associated cognitive costs (Jarvenpaa et al. 1988; Vessey 1991; Wilson et al. 1999).

Cognitive fit theory (CFT) asserts that the congruence between tasks and display formats determines decisional performance, suggesting that no visual display is perfect for every task. Thus, providing multiple visual displays and granting users with discretion to choose among those displays for various tasks seem an appropriate approach to improve decisional effectiveness and efficiency. As a pilot study, this research investigates the impacts of user discretion on decisional performance, stress, and mental workload. Also, the current study explores how individuals' openness to the given complexities of a display design or a task influences their decisional outcomes.

The rest of this paper is structured as follows. In Section 2, we provide an overview of theoretical foundations and our research hypotheses. In Section 3 we propose the research design, and in Section 4 we show the experimental results. Section 5 concludes with limitations and conclusions.

2 THEORY AND HYPOTHESES

As the availability, performance, and cost-effectiveness of information technology constantly increase, numerous tools and decision-aids have been developed to improve decision makers' effectiveness and efficiency. However, not all technological innovations in visual representations successfully lead to improvements in their users' decisional performance (Tufte 2001). For example, three-dimensional (3D) graphs, maps, or other representations are increasingly used and advocated in the media, communications, and entertainments (e.g., Google Earth, 3D charts, virtual reality.) St. John et al. (2001) indicated that 3D displays are better for shape-understanding tasks, whereas two-dimensional (2D) displays contribute more to the recognition of relative positions. Bailey et al. (2007) found that 3D displays were useful only for tasks in which all three spatial dimensions must be used. Using 3D displays for pure 2D tasks (e.g., driving directions from City A to City B) actually degraded performance when compared with those using 2D displays. Both studies suggested that an extra dimension itself or newly developed technology does not guarantee better decisional performance.

According to Vessey's cognitive fit theory (CFT; see Figure 1), when the problem-representation and problem-solving tasks match, decision makers can formulate mental representations for task solutions more effectively and efficiently, leading to better decisional performance (Vessey 1991). A recent survey of more than one hundred studies on the applications of cognitive fit indicated that CFT is a robust theory that generalizes to any situation where tasks and problem representations are involved (Vessey 2006). One of CFT's implications is that it will be difficult, if not impossible, to find a problem representation that can optimize the decisional performance for every problem-solving task. Thus, offering multiple interfaces or visual displays is an appropriate way for system developers to render information, so that users can discretionarily choose the best representation to satisfy their own need. For example, on top of additional information (e.g., traffic, bicycling, real estate), Google Maps provides three different views – traditional map, satellite, and terrain, and allows its users to conveniently switch among those interfaces.

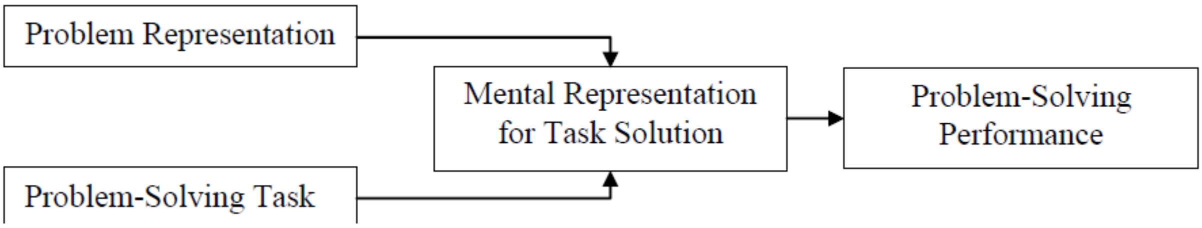


Figure 1 *Cognitive Fit Theory*

2.1 User Discretion

2.1.1 User Discretion and Decisional Performance

Before offering user discretion to problem solvers, it is crucial to examine whether their decisional performance will be improved. On one hand, using preferred visual displays may decrease decision makers' cognitive workload and associated costs, resulting in better decisional performance (Vessey 1991). On the other hand, user discretion may allow decision makers who have *familiarity bias* or *display inertia* to fixate on a specific type of interface or visual display that they have learned or frequently used (i.e., usually 2D displays) (Baddoo et al. 2003; Sena et al. 1988), even when a novel format is more task-compatible than their preferred displays (Bailey et al. 2007). Another bias in the selection of displays is *naïve realism*, or a tendency for users and some designers to prefer more photorealistic renderings of information based on their intuition that more realistic-looking displays must be more accurate (e.g., 3D rather than 2D displays of geospatial information) (Smallman et al. 2005). Those strong preferences in visual displays may lead to suboptimal decisional performance and thwart the intent of offering users more discretion. Thus, this research does not predict specific associations between user discretion and decisional performance.

H1-1: Users' decisional performance increases when they can choose their visual displays.

H1-2: Users' decisional performance decreases when they can choose their visual displays.

2.1.2 User Discretion and Stress

Considerable research has noted that the increase of user discretion decreases job stress (Averill 1973; Lazarus 1966; Lefcourt 1973). Karasek (1979) proposed that the degree of stress on a job is a function of both the strength of demands and the amount of decision latitude, or the amount of discretion permitted to the individual (Morrison et al. 2001). Specifically, she proposed that job stress will be the lowest when decision latitude is high and job demands are low. Payne's model was similar, (as cited by Morrison & Payne 2001); however; he applied the concepts of decision latitude and demands very broadly, which is consistent with Averill's hypothesis that a variety of situations may give an individual the impression of discretion, including "decisional control" (Averill 1973). *Demands* can have a variety of meanings from time constraints to specific attributes of performance (Morrison & Payne 2001). Thus, the presence of choice in the decision-making process may decrease psychological stress.

H2: Users' stress decreases when they can choose their visual displays.

2.1.3 User Discretion and Mental Workload

When given the choice of display, individuals may experience lower stress because of a likely increase in decision latitude, but the implementation of choice may increase task complexity. That is, individuals will not only have to be engaged in the task but they will also have to be both meta-cognitively and situationally aware if they are oriented toward improving their performance. For example, display users will not only have to monitor their strategies for successfully completing the task, they will also have to either note by trial and error which display was most successful with a given task, or they will use their cognitive resources to choose the superior display particular to the task. Thus, individuals who are given display choice will likely have higher mental workload relative to individuals who are not given display choice.

H3: Users' mental workload increases when they can choose their visual displays.

2.2 Ambiguity Tolerance (AT)

To maximize task performance, it is important not only to understand the inherent properties of the displays being used for a given purpose, but also to understand the properties of the user. For example, a painter may have trouble painting if given a pen. Likewise, the individual characteristics of display users may impact their choice of display as well as their engagement in the task. So, an individual's openness to the given complexities of a display design or a task may impact that person's ability to react to a situation.

This research utilizes an extensive, relatively stable construct in cognitive psychology to represent an individual's openness to the given complexities of a display design or a task – ambiguity tolerance (AT). Even the manner in which it is applied has little constraint; it can be thought of as a personality trait, a cognitive style, or a mechanism of defence (Frenkel-Brunswik 1948; Pratt 1980; Smock 1955). As a tolerant–intolerant continuum, AT first appeared in 1948 when Frenkel-Brunswik attempted to analyze the ethnocentric attitudes of 200 adolescents and 100 adults. She noted that prejudiced individuals are more inclined to the "rigid social dichotomatizing" and "premature reduction to certainty" of ambiguous stimuli. The next year, she published a paper to codify her construct, deeming AT as a personality variable that generalizes to the emotional and cognitive functioning of the individual (Frenkel-Brunswik 1949). However, it is conceivable that a third behavioral reaction could also be included in the manifestations of AT.

Budner (1962) defined *intolerance of ambiguity* as "the tendency to perceive ambiguous situations as sources of threat" and *ambiguity tolerance* as "the tendency to perceive ambiguous situations as desirable." Budner saw ambiguous situations as being novel (in which the individual can find no familiar cues), complex (in which the individual must consider a large number of cues), and insoluble or contradictory (in which cues conflict). He also hypothesized that individuals may react to ambiguity operationally or phenomenologically, referring to extrinsic and intrinsic reactions, respectively. Individuals low in AT, (*LATs* according to Budner), may react by denying the ambiguity or submitting to it operationally and phenomenologically, referring to extrinsic and intrinsic reactions respectively(Budner 1962). Thus, LATs may perceive that a situation is ambiguous, and then rigidly categorize the stimuli and cognitively submit to it, ignore the stimuli by cognitively denying it and become anxious about it, feel threatened by it and become angry with it, or emotionally submit to it (Bhushan et al. 1986; Grenier et al. 2005).

Several researchers have noted that LATs reach premature perceptual closure (Frenkel-Brunswik 1949) and maintain one solution—one that is likely low in ambiguity. Such a claim may imply that LATs qualify ambiguous stimuli perhaps before ascertaining sufficient information about those stimuli and, possibly, habitually react in the same way toward those stimuli. This hypothesis renders compelling implications for understanding problem-solving behavior. An LAT who perceives a problem as being ambiguous may not only misperceive the problem but also, rather than considering multiple solutions, may implement only one solution—likely the least ambiguous.

Lowe and Reckers (1997) concluded that LATs "tend to ignore other information such as the utilization of decision aids…and are more apt to close prematurely their decision process," which implies that LATs may make rapid, impulsive decisions and that they rely less on external information when making their decisions. Several studies have also suggested an interaction between task preference and AT. Crandall (1968) found that LATs prefer familiar tasks, whereas high AT subjects (HATs) prefer novel tasks. Shaffer et al. (1973) found that LATs preferred tasks requiring lower mental effort. If LATs ignore external information and prefer familiar, low mental-effort tasks to unfamiliar, high mental-effort tasks, they are likely to reject the ambiguity (specifically, novelty, complexity, and insolubility) of unfamiliar displays that may be more appropriate to the given task, and likely to reject strategies important in problem-solving behavior. LATs will be more likely to choose the same displays for each task, both because of familiarity bias and because they will not be as aware of the cues necessary to choose the display compatible with the task. Based on the discussions above, this research hypothesizes:

H4: Compared with LATs, HATs will be more likely to choose a variety of displays when given a choice.

H5: Compared with LATs, HATs will be less likely to choose a familiar display when given a choice.

2.2.1 Ambiguity Tolerance and Decisional Performance

Taube (1995) found that AT correlated strongly with need for cognition. He posited that HATs are more likely to engage in the solving, finding, and evaluation of tasks, while avoiding premature decisions. Many other researchers agree with this analysis (Schwenk 1982). If this is true, it may be conceived that LATs may not actively perceive an ambiguous situation as holistically as will their more tolerant counterparts, nor will they attempt to consider (and possibly understand) the more ambiguous aspects of a situation, but rather they will engage in premature closure in decision making. A considerable amount of research has noted performance differences between tolerant and intolerant individuals on a variety of tasks. In summary, LATs will likely be less aware of strategies important to the task and will probably not choose the display appropriate to the task; they will likely perform less accurately overall than HATs, especially when they choose their displays. This leads to the establishment of the following hypotheses:

H6: LATs will likely perform less accurately than HATs on all tasks, across all conditions.

H7: LATs will likely perform more quickly than HATs on all tasks, across all conditions.

2.2.2 Ambiguity Tolerance and Stress

Individuals who are intolerant of ambiguity may be more likely to perceive a problem as being ambiguous than those tolerant of ambiguity (Owen et al. 2002). So LATs possibly will react not only to ambiguous stimuli on cognitive, emotional, and behavioral domains; they will also be more likely to do so, even in conditions that more tolerant individuals may not perceive to be ambiguous. Several recent studies have included AT in their theories of generalized anxiety disorder (Dugas et al. 1997; Dugas et al. 1998). The former study identified "cognitive avoidance," or the avoidance of "threatening…images." In the second study the authors stated, "As a broad generalization, the relationship of…control to stress is…a function of the meaning of the control response to the individual." Both statements sound significantly like descriptions of AT. Shaffer et al. (1973) found that LATs were less interested and more frustrated by high mental-effort tasks (compared with low mental-effort tasks). Conversely, HATs preferred and were more interested in high mental-effort tasks (compared with low mental-effort tasks). If the stated conclusions are true, HATs will likely perceive a given stimulus to be more ambiguous and—because of the above emotionally submissive manifestations of ambiguity intolerance—will be more anxious and perceive the given stimuli as more stressful. LATs will likely perceive the experiment to be more ambiguous than HATs and will likely have higher psychological stress across conditions. However, because LATs will hypothetically root themselves in familiarity, will choose displays that are highly familiar to them, and likely will not vacillate throughout the tasks, they will likely experience lower stress in the choice condition. HATs will likely experience a greater difference between choice–no-choice conditions, because they perceive the ambiguities of the task to be desirable. Thus, this research hypothesizes:

H8: LATs will exhibit higher psychological stress across all conditions.

2.2.3 Ambiguity Tolerance and Mental Workload

Because HATs, compared with LATs, are consciously processing the tactics involved in the performance of the tasks, remembering and/or deciding which display is most appropriate for the given task, as well being cognizant of the cues involved in choosing the appropriate display (more so than individuals intolerant of ambiguity), it is likely that HATs will use more mental resources when permitted to choose their display. As compared with LATs, HATs will experience a larger decrement in mental resource when they choose their displays than in conditions in which the best display is automatically administered. Furthermore, HATs will likely experience a marked decrease in the use of mental resources when given the known best display for the particular task (because of their increase in decision latitude). In summary, compared with LATs, HATs will likely have higher mental workload across conditions because they are processing more information relating to tasks. Compared with LATs, HATs will also experience a greater difference in mental workload use between conditions in which individuals choose their display versus conditions in which they do not get to choose, because they will be more likely to be processing the cues of choosing the display (as mentioned earlier).

H9: HATs will experience higher mental workload across all conditions.

3 RESEARCH METHOD

3.1 Participants

Approximately 800 undergraduate college students enrolled in an introductory psychology course were pre-screened for ambiguity tolerance using Budner's (1962) Scale of Intolerance-Tolerance of Ambiguity. Approximately 80 participants were randomly selected from the upper and lower quartiles of pre-screened ambiguity tolerance scores, and then called and invited to participate for three hours of experiment exposure credit in their course. Those who elected to participate were randomly assigned. This included approximately one-fourth of the HATs (17 randomly selected individuals who scored in the upper quartile of Budner's scale), and one-fourth LATs (13 randomly selected individuals who scored in the lower quartile).

3.2 Measurements

3.2.1 Ambiguity Tolerance

Budner's Scale of Intolerance-Tolerance of Ambiguity was chosen to pre-screen for ambiguity tolerance. Although it is slightly less reliable than the AT-20 Scale, it differentiates between the types of ambiguity as well as the different reactions to ambiguity. Such differentiation is important for several reasons. One, our hypotheses depend on only one or two given possible reactions to ambiguity (i.e., phenomological and operative submission or denial). Also, the situations that we assume to be ambiguous may have been so based on only one of Budner's dimensions of ambiguity (i.e., novelty, complexity, or insolubility). For this reason, it may be necessary to examine relationships between the individual's scores on each differentiated item with both the corresponding dimension of ambiguity and behavioral reaction pertaining to the task context. For example, a given hypothesis is based on a participant's anxious reaction, but if the participant's questionnaire did not indicate that such a reaction should be expected (even though the participant may be considered intolerant), it may have diminished the effect size.

3.2.2 Stress

The SSSQ is a relatively new shortened version of the Dundee Stress Questionnaire. It asks participants to rate on a 1-5 Likert-type scale: 1 indicating that the question *does not correspond* to them, 5 indicating that the question *strongly corresponds* to them—their moods or feelings (i.e., happy, dissatisfied), confidence, motivation, goals, and standards. The scale was used to assess the participants' psychological stress. Using factor analyses, previous domains were organized into three categories: engagement, worry, and distress (Helton et al. 2005). Engagement is considered to be the cognitive element of stress; distress is considered to be the affective element of stress; and worry is considered to be the cognitive element of stress (Helton et al. 2005). The above subscales were averaged to obtain the participants' overall level of psychological stress.

3.2.3 Mental Workload

The NASA-TLX was used to measure mental workload. This scale is subjective and multidimensional, designed to measure mental workload post-hoc. The participants were asked to rate their mental, physical, and temporal demands, their own performance, and their effort and frustration from 0 indicating virtually *no demands* to 100 indicting *very high demands*. Their overall scores can be calculated by averaging the above subscales. One dimension of NASA-TLX, physical workload, was eliminated because our focus was on mental workload.

3.2.4 Decisional Performance

Decisional performance was measured by two dimensions – speed and accuracy. The former was indicated by the reaction time for each participant to finish each block of tasks, whereas the latter was indicated by their average accuracy rates in answering each block of questions.

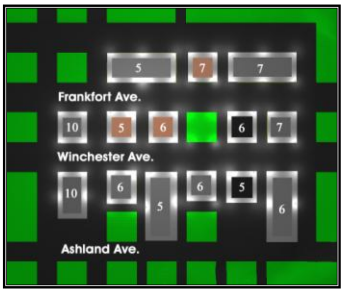
3.3 Instruments

3.3.1 Tasks

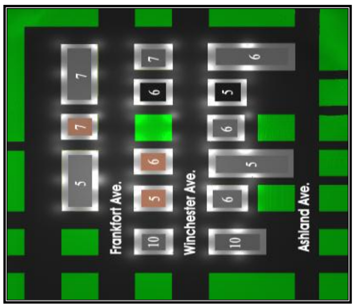
We asked the participants to complete three tasks: the Every Other Building (EOB) task, the Spot the Plot (STP) task, and the Firefighting (Fire) task. Each task required the use of information from different dimensions. The EOB Task required the participants to make binary decisions on whether each display fit the following characteristic: whether security guards (marked as a white dot in each building) could reach buildings without security guards by crossing only one street, meaning that the security guards could not cross diagonally and could not cross multiple streets. The STP task required each participant to notice patterns based on height information. Such a distinction was based on the following criteria: whether the top three building floors were highlighted, the bottom three were highlighted, the middle three were highlighted, or no configuration was present (i.e., no pattern). The Fire task required the participants to use information from both the horizontal and the vertical planes. They were asked whether the firefighters (highlighted in yellow) would be able to reach a fire (indicated by a fire-shaped icon) with a hypothetical stream of water from all three directions, meaning that nothing would impede the flow. Also, the participants had to check whether at least one fire fighter was located on a floor above and on a floor below the fire.

3.3.2 Displays

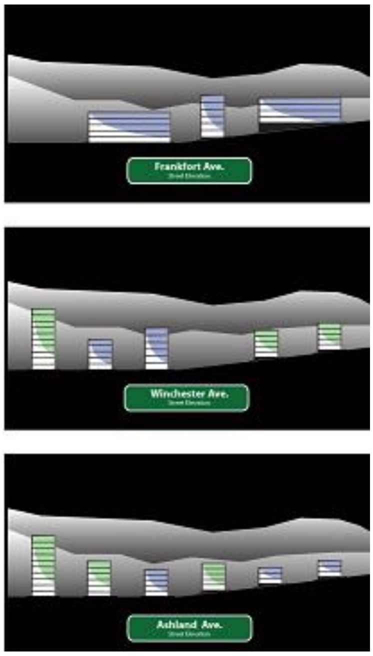
Five displays were used to complete each task. The 3D display, the *realistic display* (Panel E, Figure 2), is a computerized graphical image with approximately a 45-degree angle of orientation of a fictional urban area called College Branch, KY. Within the city were three main streets (Winchester, Ashland, and Frankfort) running at approximately a 45-degree angle, with three peripheral streets running perpendicular. Two elevation view displays included the Elevation Horizontal, (Panel D, Figure 2) in which the three main streets ran horizontally and the Elevation Vertical (Panel C, Figure 2), in which the three main streets ran vertically. The elevation views were cross sections of each street, cut out as if the viewer were standing in front of the buildings. For participants to see information from the horizontal planes, they had to mentally integrate each street into a three-dimensional mental model. The Plan Views (Panels A and B, Figure 2) were topographical views of College Branch, KY. They did not display height information. For participants to attain height information, we listed the number of floors in each building.



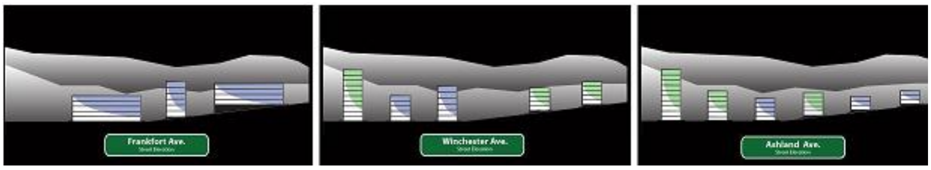
Panel A – Plan View - Horizontal



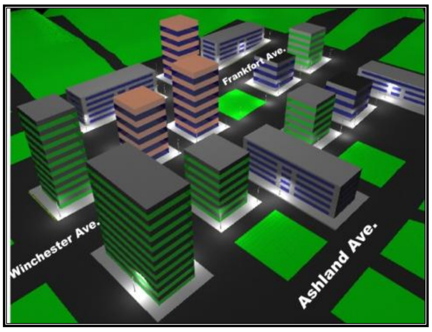
Panel B – Plan View - Vertical



Panel C – Elevation View - Vertical



Panel D – Elevation View - Horizontal



Panel E - 3D View

Figure 2 Visual Displays

3.4 Experimental Procedure

Participants within both conditions (i.e., choice and no-choice) were familiarized with each display. The experimenter used a PowerPoint presentation to explain what could be seen with each display as well as their orientation within each display. Participants then proceeded through practice tests in which they were informed that their data would not be recorded. Three different practice blocks were used, one for each task (the EOB task, the STP task, and the Fire task. Within each practice block, participants were given 20 different displays and randomly assigned a different display (3-D, both Elevation and Plan Views). After each trial, they were immediately given accuracy feedback. They were given 20 more trials, except with time constraints. After the practice tests (in both conditions), participants were given the NASA-TLX and the SSSQ. Participants were then encouraged to take a break to preserve their concentration.

The main experiment consisted of 12 blocks. Each block was composed of three task changes. Each task change represented five trials with each task. E-Prime randomly assigned the order of each task. So each block represented 15 trials, five trials of each task. For example, E-Prime may administer the Fire task for task change 1, the STP task for task change 2, and the EOB task for task change 3 on block 1, but the EOB task for task change 1, the Fire task for task change 2, and the STP task for task change 3 on block 2. Within the main experiment, participants were not given accuracy feedback until each block was complete (that is, after they completed all five trials for all three tasks). The NASA-TLX and SSSQ were re-administered after the sixth block of the main experiment. After the 12th block of the main experiment, we re-administered the NASA-TLX and SSSQ, administered the manipulation check, and gathered descriptive data. We then debriefed and dismissed the participants.

4 RESULTS

4.1 User Discretion

Hypotheses 1-1 and 1-2 examined the impacts of user discretion on decisional performance, which was measured by two dimensions – accuracy and speed. As indicated in Table 1, participants with choices on visual displays demonstrated slightly higher accuracy rate (not significant) and spent more time on answering questions in each block of experiments (not significant). Inconsistent with the prediction of Hypothesis 2, participants with choices on visual displays showed significantly higher stress than those without choices (p = .02). The difference in mental workload between two groups was not significant, inconsistent with Hypothesis 3.

	Choice (n = 15)		No-Choice (n = 15)		F	Sig. (1-tailed)
	Mean	Std. Error	Mean	Std. Error		
Accuracy	10.04	.21	9.89	.23	.243	0.31
Reaction Time (in ms)	32814.44	2753.80	30678.02	2953.12	.280	0.30
Stress	12701.04	1833.78	7052.22	1966.50	4.414	0.02**
Mental Workload	49.62	3.27	49.30	3.51	.004	0.47

Table 1 The Effects of User Discretion

4.2 Ambiguity Tolerance

Hypothesis 4 predicted that HATs will be more likely to choose a variety of displays when given a choice. As indicated in Table 2, HATs, on average, chose 3.75 displays out of 5 possible selections, whereas LATS chose 3.43. Although the direction was consistent with the prediction, the difference was not significant (p = .29). Hypothesis 5 tested whether HATs will be less likely to choose a familiar display than LATs (i.e., plan view). The average frequency of HATs to choose plan view displays was 46.2%, slightly lower than that of LATs (43.7%). The difference was not significant.

Hypotheses 6 and 7 examined the associations between ambiguity tolerance and decisional performance. On average, HATs answered 10.24 questions correctly, slightly more than LATs did (9.81). The difference was not significant; thus, Hypothesis 6 was not supported. HATs spent 36,585 ms in answering questions in each block, marginally faster than LATs did (28,528 ms; p = .06).

As predicted in Hypothesis 8, LATs demonstrated significantly higher stress (2.33) than HATs did (2.10; p = .03). The direction of Hypothesis 9 was correct but not significant because HATs' mental workload was 52.1, whereas LATs' mental workload was 50.1

	Choice (n = 15)		No-Choice (n = 15)				
	HAT	LAT	HAT	LAT	Planned		Sig.
Group Code	A	B	C	D	Comparisons	F	(1-tailed)
Number of Display Chosen	3.75 (.382)	3.43 (.41)			H4: A>B	.330	.29
% of Plan View Chosen	46.2% (.059)	43.7% (.063)			H5: A<B	.085	.61
Accuracy	10.32 (.399)	10.08 (.427)	10.17 (.377)	9.50 (.461)	H6: A,C > B, D	1.10	.15
Reaction Time (in ms)	40379.79 (4898.2)	29377.91 (5236.5)	33212.63 (4618.1)	27536.48 (5656.0)	H7: A,C > B, D	2.57	.06*
Stress	2.13 (.116)	2.26 (.124)	2.08 (.109)	2.42 (.133)	H8: A,C < B, D	3.75	.03**
Mental Workload	53.81 (5.634)	49.84 (6.023)	50.66 (5.311)	50.32 (6.505)	H9: A, C> B, D	.135	.36

Table 2 The Effects of Ambiguity Tolerance

5 LIMITATIONS AND CONCLUSIONS

5.1 Limitations

As the first step of a program of study, this research collected only 30 participants to examine the impacts of ambiguity tolerance and user discretion on spatial task performance and display choices. The small sample size might explain why several hypotheses showed only correct directions but not significance.

When investigating whether user discretion contributes to decision makers' accuracy, we assumed that the chosen visual displays were appropriate enough to answer questions in each block. However, such assumption is a trade-off of experimental simplicity; otherwise, the 2X2 design should have been expanded as 2 (HAT vs. LAT) X2 (Choice or Not) X2 (Can or Cannot Choose Appropriate Displays)

This research failed to include some interesting and important impacts of ambiguity tolerance and user discretion. For example, the pattern of participants' display choices may show the influences of learning effects. Because the sample size was constrained, we did not examine interactions in this study.

5.2 Conclusions

Similar to Wilson and Zigurs (1999), we found in this research that user discretion on display choices does not improve users' decisional accuracy significantly, suggesting that display choice behavior may be considerably more complex than originally conceived. Refining the research design, adding other control variables, or increasing sample size may help explore the association between user discretion and decisional accuracy. As expected, offering user discretion lengthened decision makers' reaction time. Whether such delay is a justifiable exchange for better decisional accuracy is an interesting and practical research question, especially when both accuracy and speed are important (e.g., emergency rescue). Inconsistent with the literature, this research showed that user discretion significantly increased users' stress. Future studies should further scrutinize the discrepancy.

This research is one of the first studies to utilize ambiguity tolerance (AT), an extensive, relatively stable construct in cognitive psychology to represent individuals' openness to the given complexities of a display design or a task. The overall results suggest that AT can be appropriate for capturing individuals' innovativeness or willingness to change.

References

Averill, J. "Personal control over aversive stimuli and its relationship to stress," *Psychological bulletin* (80:4) 1973, pp 286-303.

Baddoo, N., and Hall, T. "De-motivators for software process improvement: an analysis of practitioners' views," *Journal of Systems and Software* (66:1) 2003, pp 23-33.

Bailey, K., Carswell, C.M., Grant, R., and Basham, L. "Geospatial Perspective-Taking: How Well Do Decision Makers Choose Their Views?," 51st Annual Meeting of the Human Factors and Ergonomics Society, Santa Monica, CA, 2007, pp. 1246-1248.

Bhushan, L., and Amal, S. "A situational test of intolerance of ambiguity," *Psychologia* (29:4) 1986, pp 254-261.

Budner, S. "Intolerance of ambiguity as a personahty variable," *Journal of Personality* (30:1) 1962, pp 29-50.

Crandall, J. "Effects of need for approval and intolerance of ambiguity upon stimulus preference," *Journal of Personality* (36:1) 1968, pp 67-83.

Dugas, M., Freeston, M., and Ladouceur, R. "Intolerance of uncertainty and problem orientation in worry," *Cognitive Therapy and Research* (21:6) 1997, pp 593-606.

Dugas, M., Gagnon, F., Ladouceur, R., and Freeston, M. "Generalized anxiety disorder: A preliminary test of a conceptual model," *Behaviour Research and Therapy* (36:2) 1998, pp 215-226.

Frenkel-Brunswik, E. "A study of prejudice in children," *Human relations* (1) 1948, pp 295-306.

Frenkel-Brunswik, E. "Intolerance of ambiguity as an emotional and perceptual personality variable," *Journal of Personality* (18:1) 1949, pp 108-143.

Grenier, S., Barrette, A., and Ladouceur, R. "Intolerance of uncertainty and intolerance of ambiguity: Similarities and differences," *Personality and individual differences* (39:3) 2005, pp 593-600.

Helton, W., Fields, D., and Thoreson, J. "Assessing daily stress with the Short Stress State Questionnaire (SSSQ): Relationships with cognitive slips-failures," Human Factors and Ergonomics Society, 2005, pp. 886-890.

Jarvenpaa, S., and Dickson, G. "Graphics and managerial decision making: research-based guidelines,") 1988.

Karasek Jr, R. "Job demands, job decision latitude, and mental strain: Implications for job redesign," *Administrative science quarterly*) 1979, pp 285-308.

Lazarus, R. *Psychological stress and the coping process* McGraw-Hill, New York, 1966.

Lefcourt, H. "The function of the illusions of control and freedom," *American Psychologist* (28:5) 1973, pp 417-425.

Lowe, D., and Reckers, P. "The Influence of Outcome Effects, Decision Aid Usage, and Intolerance of Ambiguity on Evaluations of Professional Audit Judgement," *International Journal of Auditing* (1:1) 1997, pp 43-59.

Morrison, D., and Payne, R. "Test of the demands, supports-constraints framework in predicting psychological distress amongst Australian public sector employees," *Work & Stress* (15:4) 2001, pp 314-327.

Owen, W., and Sweeney, R. "Ambiguity tolerance, performance, learning, and satisfaction: A research direction," ISECON Meeting, San Antonio, YX, 2002.

Pratt, J. "The Effects of Personality on a Subject's Information Processing: A Comment," *Accounting Review*) 1980, pp 501-506.

Schwenk, C. "Effects of inquiry methods and ambiguity tolerance on prediction performance," *Decision Sciences* (13:2) 1982, pp 207-221.

Sena, J., and Smith, L. "Applying software engineering principles to the user application interface," *Human factors in management information systems*) 1988, p 103.

Shaffer, D., Hendrick, C., Regula, C., and Freconna, J. "Interactive effects of ambiguity tolerance and task effort on dissonance reduction," *Journal of Personality* (41:2) 1973, pp 224-233.

Smallman, H.S., and John, M.S.T. "Naive Realism: Misplaced Faith in Realistic Displays," *Ergonomics in Design: The Quarterly of Human Factors Applications* (13:3) 2005, pp 6-13.

Smock, C. "The influence of psychological stress on the" intolerance of ambiguity."," *Journal of Abnormal and Social Psychology* (50:2) 1955, pp 177-182.

St John, M., Cowen, M.B., Smallman, H.S., and Oonk, H.M. "The Use of 2D and 3D Displays for Shape-Understanding versus Relative-Position Tasks," *Human Factors: The Journal of the Human Factors and Ergonomics Society* (43:1) 2001, pp 79-98.

Taube, K. "Critical Thinking Ability and Disposition as Factors of Performance on a Written Critical Thinking Test,") 1995.

Tufte, E. *The Visual Display of Quantitative Information*, (2nd ed.) Graphics Press, Cheshire Connecticut, 2001.

Vessey, I. "Cognitive fit: A theory-based analysis of the graphs versus tables literature," *Decision Sciences* (22:2) 1991, pp 219-240.

Vessey, I. "The Theory of Cognitive Fit," in: *Human-computer Interaction and Management Information Systems: Foundations,* P. Zhang and D. Galletta (eds.), M.E. Sharpe, Armonk, New York, 2006, pp. 141-183.

Wilson, V.E., and Zigurs, I. "Decisional guidance and end-user display choices," *Accounting, Management and Information Technologies* (9:1) 1999, pp 49-75.