Aviation Human Factors Division
Institute of Aviation

University of Illinois
at Urbana-Champaign
1 Airport Road
Savoy, Illinois 61874

# Factors Affecting Task Management in Aviation

Cristina Iani & Christopher D. Wickens

Technical Report
AHFD-04-18/NASA-04-7

December 2004

Prepared for

NASA Ames Research Center
Moffett Field, CA

Contract NASA NAG 2-1535

## ABSTRACT

The present paper summarizes the results of a study investigating task management and task prioritization processes in aviation. Forty instrument rated pilots flew three curves approaches in a high fidelity simulation using a Synthetic Vision System (SVS) display. In addition to the primary task of flying, during the last approach they were required to select the approach path on the basis of environmental information concerning weather. The level of immersion in the task, the nature, and saliency of the cues signaling the need to divert attention to the path selection task and the cost of not performing the secondary task were manipulated to investigate their influence on task prioritization. We found that cue saliency affected the frequency of the switch to the secondary task. Furthermore, pilots flying with the immersive display (tunnel display) were more likely to detect the change in the weather and were easily interrupted by the secondary task when priority was high. In terms of practical implications, the current results support the utility of the flight path tunnel display and suggest that some of the concerns, regarding the negative consequences of its compelling nature, may not be as pronounced as once thought.

## INTRODUCTION

During flights, pilots are frequently required to perform several tasks concurrently (e.g., searching for traffic or communicating to ATC while controlling the aircraft). While some tasks can be easily performed in parallel, others compete for resources (Wickens, 1984; 2002; Wickens et al., 2003) and, as a consequence, pilots need to juggle their limited resources in order to accomplish each task successfully.

Multiple-task performance is made possible by the intervention of executive processes that allow us to choose tasks, monitor and adjust performance, and interrupt a task in order to perform a different one when necessary (e.g., Arlington & Logan, 2004; Baddeley, 1986; Logan, 1985; 2003; Meyer & Kieras, 1997a, 1997b; Norman & Shallice, 1986; Shiffrin & Schneider, 1977). Even though executive functions have been widely explored in laboratory situations or, outside of the laboratory, in neuropsychological patients (Roberts, Robbins, & Weiskrantz, 1998), little is known about how these processes allow for the execution of real life complex tasks. One open issue is how executive control processes establish priorities among individual tasks and allocate resources to them thus allowing efficient multiple-task performance.

Under controlled laboratory conditions, performers seem to be very efficient in allocating attention according to the implicit or explicit priority given to a task (Gopher & North, 1977; Navon & Gopher, 1979). However, some studies seem to suggest that in real life settings, task prioritization is not always efficient. On the one hand, there is evidence that, when dealing with multiple tasks, people avoid using cognitive loading strategies such as carefully calculating the appropriate optimal sequence in which to perform tasks of different priority (Liao & Moray, 1993; Lauderman & Palmer, 1995; Moray, Dessouky, Kijowski, & Adapathya, 1991; Raby & Wickens, 1994). Furthermore, people tend to be more proactive in task management when workload is low and more reactive when workload becomes high (Hart & Wickens, 1990). On the other hand, even though advanced knowledge of when difficulties will arise allows pilots to plan when to execute a secondary low priority task, it seems to have no impact on performance (Segal & Wickens, 1990).

To overcome these limits, pilots' training stresses on the importance of following the "aviate, navigate, communicate and system management" (ANCS) hierarchy in deciding which task to attend to at any given moment (Schutte & Trujillo, 1996). The examination of incident and accident reports has revealed that this ordering of tasks is not always followed in a strict manner (Dismukes, Young & Sumwalt, 1998; Funk, 1991; Chuo, Madhavan & Funk, 1996; Damos, 1997; Strauch, 1997). Common violations include attending to one task when attention should instead be devoted to another or failing to perform a task at a proper time.

In some cases, task management errors may have severe consequences. A classic example is represented by the Everglades crash in 1972 which caused the death of 99 people (NTSB, 1973): the flight crew was distracted from the primary task of controlling the aircraft altitude (aviate) by a malfunction of the landing gear position indicator (systems management) and became so absorbed by the diagnosis of the malfunction that they failed to notice a gradual descent and avoid the impact with the ground.

Because of the potential severe consequences of task prioritization errors, several studies have tried to discover which factors can influence this process (e.g., Colvin, 2000; Freed, 2000; Funk, 1999; Funk, Suroteguh, Wilson & Lyall, 1998; Moray et al., 1991; Segal & Wickens, 1990; Smith & Harris, 1994). Several factors have been considered. For instance, Moray et al.'s results (1991) suggest the role of task duration. In fact, they found that operators faced with various tasks of different durations prefer to start with the longest task first. Funk et al. (1998) analyzed Aviation Safety Reporting System (ASRS) incident reports to investigate whether automation affects the frequency of task prioritization errors and found that, even though failures to perform a high priority task occurred in both advanced and traditional technology aircraft, they tended to be significantly higher in the latter. In another study, Funk and colleagues (Suroteguh & Funk, 2001) investigated the effects of workload, number of concurrent tasks and flight path complexity on task management skills. Participants were presented, in a part-task flight simulator, with scenarios during which they had to respond to system failures. The results showed that workload had a significant effect on late task initiation. Both workload and the combination of flight path complexity with number of concurrent tasks created significant effects on task prioritization: task prioritization performance degraded as either one of these factors increased. Differently, the effect of alcohol does not seem to influence task prioritization (Smith and Harris, 1994).

Colvin (2000) appears to have conducted the most complete examination of factors affecting task management. When pilots in his study were asked to identify possible prioritization factors, they reported task status (i.e., degree of completion), procedure, and task importance. The analysis of their performance however showed only limited effects of task status, and instead strong effects of task importance.

Finally, Freed (2000) suggested that task management is influenced by four main factors: urgency, that is the time remaining to perform a task; importance, that is how costly can be not to perform the task; duration, that is how long it takes to perform a task; and interruption/switching cost, that is the cost associated with interrupting an ongoing activity and switch to another task. Unfortunately, they provided no empirical data to validate this model.

From the analysis of the studies reviewed above, several factors emerge as playing an important role in crew task management. The first factor is (1) **task complexity** which seems to influence the ability of the performer to both notice and allocate attention to tasks competing with the ongoing one. Performing two or more tasks in rapid succession requires the performer to disengage from the ongoing task in order to engage to the new one and these operations require attentional resources (Monsell, 2003). When an ongoing task is particularly demanding or complex, fewer attentional resources may be available for the switch (Jersild, 1927; Logan, 2003; Rubinstein, Meyer, & Evans, 2001). However, there are also cases in which attentional resources are "locked" into an ongoing task, even though task complexity is moderate. This concept of (2) **cognitive or attentional tunneling** is well known in the human factors field. For instance, Woods (1984) introduced the term "keyholing" to indicate the lack of awareness of changes or other elements on the periphery of a display caused by the compelling or attention focusing characteristics of the center. Since then, this effect, also known as "attentional tunneling", has received some further investigation (e.g., Kerstholt, Passenier, Houttuin, & Schuffel, 1996; Olmos, Wickens, & Chudy, 2000; Wickens, Thomas, & Young, 2000; Thomas & Wickens, 2004). Taken together, the results of these studies suggest that the compellingness, and not necessarily the complexity, of the task at hand may decrease the awareness that other tasks need to be performed in general, and decrease our ability to notice cues signaling the need to switch to another task. In other words, if the ongoing task is compelling individuals are less likely to switch to other tasks, and the switch may be slower.

A third factor is (3) **task importance**, which may be specified independently of complexity and compellingness. Ideally, the performer should allocate resources to a task according to its importance relative to other tasks and there is some evidence that is indeed the case (Colvin, 2000; Wickens et al., 2003, Schutte and Trujillo, 1996). However, under some circumstances shifts in task priority are determined by a fourth factor, (4) **the physically salient** properties of stimuli and events present in the environment: certain stimulus properties may automatically capture attention, irrespective of the observer's intentions (Theeuwes, 1991, 1994; Yantis & Egeth, 1999). This tendency to attract attention is generally termed "salience". Salient stimuli are not only extremely difficult to ignore, but they may also interfere with the ongoing task. For instance, there is evidence that salient sensory annunciators or reminders are more likely to trigger a switch to a task than less salient properties or purely memorial representations (Wickens & Seidler, 1997) and tend to distract subjects from even higher priority tasks (Chou et al., 1996). There is a general finding that auditory events are more salient and attention-capturing than visual events (Latorella, 1998, 1999; Spence & Driver, 1996; Wickens & Liu, 1988; Ho, Nikolic, Waters, & Sarter, 2004).

Ho et al. (2004) examined the role of both interrupting task salience (auditory versus visual modality) and importance in an interruption task paradigm in which the ongoing task was an air-traffic control task. They found that, under some circumstances, the auditory interrupting task led to a faster switch than the visual one, and that higher priority interrupting tasks were initiated more rapidly than those of lower priority. However neither of these effects was evident in the performance of the concurrent ongoing task. Furthermore, a third experimental variable – automated preview of the interruption – affected the ongoing task, but had no bearing on the interrupting one. Thus generally the authors failed to find a **reciprocity** between effects on the interrupting and the ongoing task, with a single variable influencing both tasks in reciprocal fashion. The current study, like that of Ho et al. (2004), examined the modality-defined salience and the priority of the interrupting task, along with a third variable, the *compellingness* of the ongoing task.

To test the influence of these factors on task management strategies, participants in a flight simulator were required to fly curved approaches over rugged terrain, through potentially hazardous weather. This flight task was called the "ongoing task" (OT). In order to manipulate task engagement or compellingness, we used two Synthetic Vision Systems (SVS) display formats (Prinzel et al., 2004), depicting 3D terrain either with or without tunnel guidance. Previous studies indicated that the tunnel of the SVS supports better flight performance (Wickens et al., 2004), but represents a particularly "compelling" display, from which attention may be less easily switched (Ververs & Wickens, 1998; Thomas & Wickens, 2004; Wickens et al., 2003; Wickens et al., 2004).

In order to explore the role of "compellingness" in resisting interruptions, during the last of the three approaches, pilots were required to select a flight path on the basis of weather information available on the display. We varied the importance of this flight path selection task -

- the interrupting task or IT -- by varying how safety-critical was the weather decision. We manipulated the saliency of the cue signaling the need to switch attention to the IT task by presenting the identical information relevant for the flight path decision in different modalities. Our assumption was that auditory presentation would be more salient than the visual one (e.g., Latorella, 1998, 1999). The need to allocate attention to the navigation path selection task (and away from the aviate path tracking task) could therefore be signaled either by a visual cue (low saliency) or by an auditory cue in combination with the visual one (high saliency).

If the tunnel display is highly engaging, then less spare resources should be available for the secondary task. Hence, the switch of attention to the secondary task should be neglected or delayed when pilots are presented with this display layout. This behavior should be translated into lower weather change detection rates and unsafe flight path choices. Furthermore, if the auditory cue is more likely to capture attention than the visual one, then we should expect higher detection rates and safer path choices. In addition, if the auditory cue is more likely to disrupt the ongoing primary task, then we should find disruption in flight path tracking performance after cue delivery. Finally, increasing the weather task importance should increase the switching speed, improving response to the weather task, at the greater expense of ongoing flight path tracking. Thus our experiment examined the existence of reciprocity across the three independent variables.

## METHODS

### Participants

Forty instrument certified pilots (38 males, 2 females; age, M=22.1 years, SD=5.9; experience, M=430 hours) from the Institute of Aviation of the University of Illinois participated in the present experiment and were compensated for their time.

### Equipment and Displays

The experiment was carried out in a high-fidelity Frasca flight simulator (Frasca Model 142) configured as an Archer Piper III single engine aircraft, with a forward field of view will be 180 degrees. The simulator was equipped with equipped with a Synthetic Vision System (SVS) display (figure 1). The SVS display overlaid a computer-generated map of terrain that mimicked the actual view of the terrain that could be seen when looking forward. Standard flight dynamics were coupled with turbulence in the vertical axis to impose a modest level of workload, and to force some level of engagement with the primary flight task (aviate).

Ownship was represented as a green “W”. A white predictor measuring 20ft x 60ft x 20ft represented the pilots’ estimated position five seconds ahead of ownship. The predictor’s position in space was generated based on ownship’s current X and Y position, altitude, heading, airspeed, rate of turn and vertical speed. A 2D electronic map, representing the Navigation/Hazard Display, was placed in the lower right corner of the SVS display. It depicted terrain, flight course, airplane position, and weather hazards. The pilot’s path was represented on the Navigation/Hazard Display in green with a bright pink arrow representing ownship along the path. Weather information was presented in the form of moving color-coded concentric ellipses. The ellipses could range in color from green, indicating areas with least severe weather, to red, indicating areas with most severe weather. The instrument panel included speed, altitude, and heading indicators and a vertical situation display. A data link display, providing flight path commands, was positioned just below the terrain representation.

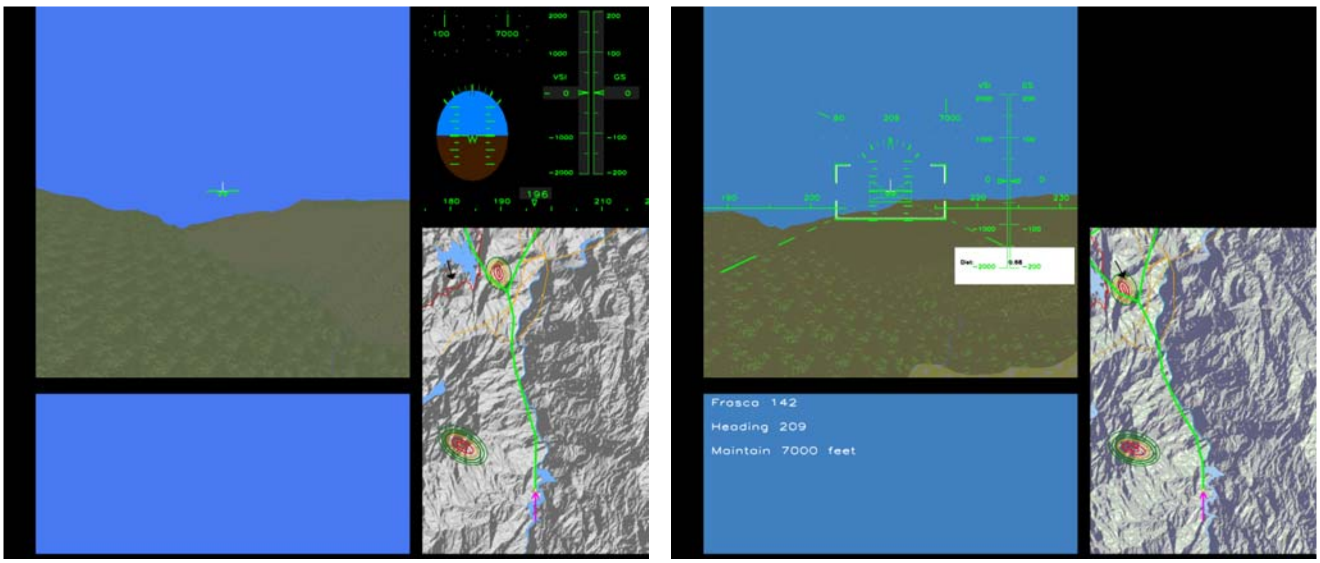


Figure 1. The baseline (left) and immersive (right) Synthetic Vision System (SVS) displays used in the study.

The terrain was a 36 Km square section of the Yosemite National Park. The database was produced from a 1 degree, 1 arc-second digital elevation model from the United States Geological Survey at the California Spatial Information library.

**Experimental Task and Procedure**

The experiment took approximately one hour to complete. Participants were required to fly three 5-min curved approaches to a synthesized airport over rugged terrain using a digital depicted environment, under instrument meteorological conditions (IMC). The first two scenarios were used as practice.

Each scenario started at the beginning of one of the approach paths to a small airport. During the last scenario, one of the weather systems visible on the navigational display unexpectedly changed direction. If noticed, this change required the pilots to decide whether to take a shorter approach path (which was a straight continuation of their current path), risking to fly into bad weather, or to take a longer, and more circuitous detour path in order to avoid bad weather. The decision required pilots to divert some attention from the “aviate task” (OT) to the navigational choice (IT).

Pilots were instructed to assume they were pilots flying a commercial aircraft for a company with a considerable need to maximize profit (e.g., minimize fuel consumption and maintain on-time arrivals to the destination airport) while, at the same time, balancing safety concerns regarding traffic and weather. These instructions were given to induce the pilots to fly the shortest path.

After the experiment was completed, pilots were asked retrospectively if they noticed any change to the weather pattern.

### Design

A 2 (ongoing task engagement: high – tunnel vs. low – no tunnel) X 2 (cue saliency: high – auditory and visual vs. low – visual only) X 2 (secondary task importance: high vs. low.) between-subjects design was used. Five pilots participated in each condition.

Ongoing task engagement was manipulated by using two SVS layouts associated with different locations of various sources of information. The two displays can be seen in Figure 1. Under the low engagement condition (herein, baseline condition), guidance information supporting the ongoing task was distributed and provided by commands displayed on the data link panel; to navigate pilots had to pay attention to all parts of the display. Under the high engagement condition, the instrument panel and a tunnel providing flight path guidance were overlaid on the terrain display. The tunnel was represented by a series of connected green boxes, 300ft apart. A sliding white box followed the path five seconds ahead of ownship. Pilots maintained their position in the center of the path by keeping the predictor in the center of the tunnel.

Cue saliency was manipulated by using different modalities to present the information relevant for a flight path decision. In the low saliency condition (herein, visual cue or V condition), the need to switch attention to the path selection task was signaled by a discrete change in the direction of movement of one of the weather systems visible on the navigational map. This change took place right before pilots were required to choose which path to take for the final approach, and influenced the ideal path to be chosen. Before the weather change, the shorter path was as safe as the longer one. After the change, the weather would take a course directly over the shorter path, while leaving the longer path risk free. In the high saliency condition (herein, auditory-visual cue or AV condition), the need to pay attention to the interrupting task was signaled by an ATC call, informing about the presence of a thunderstorm on the shorter approach path.

Task importance (high vs. low) was manipulated by changing the severity of the weather. Under the low importance condition, the change would appear to have little effect on the safety of the shorter path. In fact, the weather system was moderate in severity and even though it was moving on the shorter approach path, it would not cross the airplane’s path. Differently, under the high importance condition, the change in weather direction was designed to decrease the safety of the shorter path. At the end of the experiment, pilots were asked whether they had noticed the change in the trajectory of the weather system.

## RESULTS

The following dependent variables were analyzed: mean absolute tracking deviation (combined lateral and vertical deviation), path choice, and retrospective weather change detection. Because of the relatively low sample size within each cell of the 2X2X2 design (N=5), data were only examined for main effects and two-way interactions, availing 10 subjects/group for comparison.

Deviations in the data larger than 3 standard deviations from the means were considered as outliers and removed (less than 5% of the data). Because of technical problems with data recording for one pilot, all analyses of tracking performance were performed on the data of thirty-nine participants.

**Overall Flight Performance**

A one-way analysis of variance (ANOVA) was performed on mean absolute flight path deviation data with display format (immersive vs. baseline) as between-subjects factor. Because the data were not normally distributed we used the Kruskal-Wallis test.

Consistent with the results of previous studies (Wickens et al., 2004), the immersive display ($\underline{M}$=14.8 m, $\underline{SD}$=21.9) supported much better flight performance, H=28.98, p<.0001 compared to the baseline display ($\underline{M}$=202.6 m, $\underline{SD}$=137.7).

**Performance on the Interrupting Task: Weather Change Detection**

Table 1 presents the percentage of pilots who retrospectively (at the end of the experiment), reported noticing the change in the trajectory of one of the weather system at the time it occurred in the last scenario.

Table 1. Subjective retrospective reports (in percentage) of noticing the weather change as a function of ongoing task compellingness and cue saliency.

| | Cue saliency | |
|---|---|---|
| | Low: visual only | High: auditory & visual |
| Immersive display | 40 | 80 |
| Baseline display | 0 | 40 |

The main effects of display layout and cue saliency were assessed by using the Chi-square test. Retrospective weather change detection rates were significantly higher for the participants who flew with the immersive display, $X^2$=6.67, p<.01. Also, pilots more frequently reported a weather change when it was cued by the salient auditory ATC call than by the less salient visual changes (baseline display: $X^2$=5.00, p<.02; immersive display: $X^2$=3.33, p<.07).

**Path Selection**

Table 2 presents the percentage of pilots whose path choice was influenced by weather change.

Table 2. Percentage of pilots influenced by weather change as a function of ongoing task compellingness and cue saliency.

| | Cue saliency | |
|---|---|---|
| | Low: visual only | High: auditory & visual |
| Immersive display | 30 | 60 |
| Baseline display | 20 | 50 |

Overall, participants tended to stay on the shorter, more risk-prone (because of the weather) path when the need to divert attention was signaled only by a visual cue, $X^2=3.75$, $p<.05$. Choice was not affected by display compellingness, nor by secondary task importance.

*Interruption of the ongoing task: flight performance at the time of change*

To assess the extent to which differences in saliency of the IT and compellingness of an OT could differentially interfere with primary task (OT) performance, we compared mean absolute flight path deviation before and after the change in weather direction, under the assumption that a more disruptive interruption would, to a greater extent, lead to increased deviations – the cost of the attention switch. We computed tracking performance in the 10 seconds following the change in weather as percentage change from the baseline measure of performance in the five seconds preceding the change. Since data for the two SVS display conditions were differentially skewed, we performed different transformations on the data: a log transformation (natural logarithm) was performed on the data for the immersive display, while a square root transformation was performed on the data for the baseline display. For each SVS display condition, the data were then entered into a separate ANOVA for repeated measures with cue saliency (high vs. low) and task importance (high vs. low) as between-subjects factors, and time (10 seconds following weather change) as within-subject factor. The Huynh-Feldt correction was used when the sphericity assumption was violated (Wiener, 1970).

Surprisingly, for both display formats, cue saliency had no effect on tracking performance. As shown in figure 2, for the immersive display, we found instead a significant interaction between task importance and time, $F(9,144)=2.52$, $p<.04$. Posthoc comparisons showed that tracking error after the change significantly increased only when secondary task importance was high. No main effect and no interactions were evident for the baseline display.

In order to better assess the effect of task importance on tracking performance, we ran a linear regression on each participant's data to obtain a coefficient of the slope of the functions depicted in figure 2. These coefficients were then entered into a one-way ANOVA (Kruskal-Wallis test), run separately for each display layout, with task importance (weather severity) as between-subjects factor. Figure 3 depicts the mean slope coefficient for the two displays as a function of task importance.

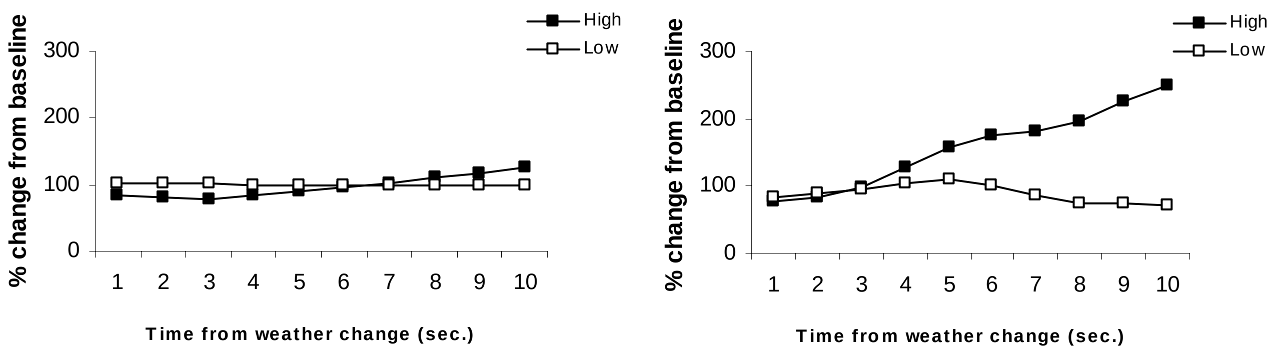


Figure 2. Second-by-second tracking deviation in the ten seconds following weather change for the (a) baseline and (b) immersive displays. Tracking deviation is expressed as percent baseline.

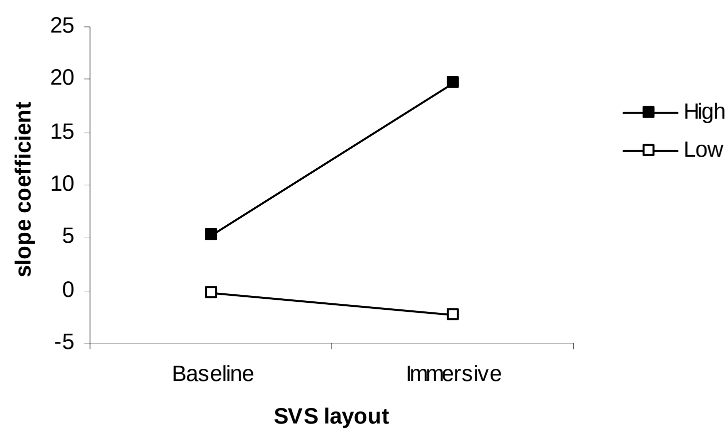


Figure 3. Slope steepness coefficients as a function of display type and task importance. Higher coefficients indicate steeper slopes. Slope direction is indicated by coefficient sign.

For the immersive display, the main effect of IT importance was significant, $H=4.16$, $p<.04$, with a steep positive slope under the high-importance condition (beta=19.65) and a slightly negative slope under the low-importance condition (beta=-2.28). The difference between high- and low importance conditions was only marginally significant for the baseline display, $H=3.23$, $p<.07$, in the same direction.

## DISCUSSION AND CONCLUSIONS

The main objective of the present work was to empirically test the influence of ongoing task compellingness, secondary task importance, and switch cue salience on attention allocation strategies.

A relatively simple model of attention switching is represented in table 3, which distinguishes between properties of, and influences on, both the ongoing task (OT; here flight path tracking) and the interrupting task (IT; here the navigational choice). According to this simplified model, factors that increase the interruptability or intrusiveness of the IT will improve its performance, at the expense of the OT, and a converse, reciprocal relationship should be expected.

Table 3. A simplified model summarizing the interaction (predicted and found) between properties of, and influences on, the ongoing task (OT) and the interrupting task (IT). A plus sign indicates performance improvement, a minus sign indicates performance disruption, and a zero indicates no effect.

| | OT | | IT | |
|---|---|---|---|---|
| | Expected | Found | Expected | Found |
| Compelling display for OT | + | - * | - | + |
| Increasing IT importance | - | - | + | 0 |
| Increasing IT salience | - | 0 | + | + |

* When the importance of IT is high

In table 3, on the left side of each column (representing the OT and IT), are presented the predictions of this simplified model, in terms of performance improvement (+), or disruption (-). Thus, a compelling OT display should protect the OT at the expense of the switch to the IT. Conversely, an IT that is either of great importance (endogenous influence) and/or delivered auditorally (exogenous influence) should disrupt the OT, to favor its own performance. On the right side of each column, we show the extent to which these simplified predictions of a “reciprocity” of effects between the IT and OT we obtained, adding a “0” when no effect was found.

It is noteworthy that the predictions of reciprocity for the simple model were not entirely obtained, although the effects of the two IT properties of importance and saliency were not contradicted by the data. First, increasing IT importance was predicted to increase compliance with the IT, but its effects were muted here, as indicated by a significant effect of task importance on OT primarily when participants were presented with the immersive display.

Second, increasing IT salience (through auditory delivery) was predicted to produce greater OT disruption, and again its effects were muted. In fact, auditory switch cue presentation captured attention for the IT, as indicated by the higher weather change report rates and led to safer flight path choices, but did not produce greater disruption of the flight path tracking (the OT), thereby replicating the findings of Ho et al. (2004).

Most prominent in the current data is the direct contradiction with the predictions regarding the "compellingness" of the ongoing task display's (top row of table 3). Such compellingness was predicted to better sustain performance on the OT (resisting interruptions), while leading to greater delay of (or less compliance in) responding to the IT message. Nearly the opposite pattern was observed. Pilots flying with the tunnel were more likely to detect the change in weather and were easily interrupted when the change in weather represented a threat to the safety of the flight. In interpreting these latter effects, we consider that a compelling display such as the tunnel acts as a two edged sword. On the one hand, its greater ease of processing, well documented here and in prior studies (e.g., Wickens et al., 2004), avails more resources, rather than fewer, to monitor other important areas, and to deal with newly arriving information, hence leading to better processing of that information (fewer high risk choices were made) and also more rapid disengagement from the flight control task (as witnessed by the higher error shown in figure 2). On the other hand, under some circumstances, not examined here, it appears that the very compellingness of the tunnel may shut out the processing of other ITs, such as those of noticing very unusual events (Thomas & Wickens, 2004). Thus we account for this difference between Thomas and Wickens' (2004) results (tunnel hurts), and those reported here (tunnel helps) in terms of the difference in expectancy of the IT. Here, although the weather heading change was not directly forecast, pilots were nevertheless aware of the presence of weather. In other studies where display-driven cognitive tunneling has been noted, the consequences are failure to note **very** unexpected events caused by a system failure, such as the automated tunnel guiding the aircraft into the path of another aircraft (Alexander, Wickens, & Hardy, 2003), which can only be noticed by looking at the outside world.

In conclusion, the results reported here support the view of the auditory modality as having important attention-capturing features, but may suggest also that this capture does not necessarily disrupt ongoing tasks of high priority (aviating), given the ability of the auditory modality to support parallel processing of visual flight control information. The general absence of reciprocity of interruption effects between the OT and the IT replicates the pattern found in the three independent variables examined by Ho et al. (2004), and suggests that these may not act as "two sides of the same coin".

The question of whether the advantage of the tunnel in supporting lower effort flight control may be offset by the cost of its more compelling nature appears from these data to be answered in the negative when pilots have to deal with expected events. Since the time to detect changes in the environment signaling the need to switch to a secondary task seems to be sensitive to the type of tasks involved (e.g., Goodrich, Quigley, & Cosenzo, in press), future studies should investigate the effect of task compellingness with secondary tasks of different nature.

In terms of practical implications, the current results provide another positive data point supporting the utility of the flight path tunnel or "highway in the sky". Its advantages for conventional flight path tracking, confirmed here, have been long known. However the current data also suggest that some of the concerns, regarding the negative consequences of its compelling nature, may not be as pronounced as once thought.

## ACKNOWLEDGMENTS

We acknowledge the contributions of Ronald Carbonari and Jonathan Sivier for software development and of Ben Hammer for helping with data collection.

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