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THE DEVELOPMENT OF A JOB PERFORMANCE AID DESIGN MODEL FOR USE IN AVIATION

Anthony J. Adamski

The aviation industry depends heavily on the high-reliability of its equipment and human performers. One method used to assist human performance has been the job performance aid. Traditionally job performance aids were only considered repositories for information and substitutes for training. Today, however, job performance aids have taken on a new role that includes aiding the human information process. Consequently, it was determined that an effective job performance aid design model would be beneficial to those responsible for job performance aid design. This article presents an overview of a study that incorporated principles from the fields of instructional technology and aviation human factors, which identified variables that affected job performance aid design and pinpointed design activities necessary for effectiveness.

INTRODUCTION

The aviation industry is comprised of numerous high-risk organizational systems that require a state of high-reliability to maintain error free operations. High-risk organizational systems are those systems in which errors can lead not only to employee death or loss of equipment but to catastrophic consequences of such magnitude that they are unacceptable to the organization or the larger public (Von Glinow & Mohrman, 1990). High-reliability refers to the requirement for a tight coupling of system components that is necessary to meet the dynamics of changing situations and which places an emphasis on balanced objectives and team effort (Westrum & Adamski, 1999). Complex, technology-intensive organizations such as those in the aviation industry must operate, as far as humanly possible, to a failure-free standard.

One method used by high-risk organizations to improve human performance at the operations end of a system is the Job Performance Aid (JPA). Traditionally, JPAs were defined as "repositories for information, processes, or perspectives that are external to the individual and that support work activity by directing, guiding, and enlightening performance" (Rossett, 1991, p. 11). Additionally, JPAs have been considered a substitute for training. JPAs typically used in aviation include such items as aircraft checklists, maintenance trouble-shooting guides, operation manuals, approach charts, and passenger information cards. With today's emerging computer technologies the functions of JPAs have evolved to include

automated decision-aids, electronic checklists, and computerized information systems. Many of these functions are intended to serve not only as repositories for information but also to enhance operator information processing.

BACKGROUND

The need for a JPA design model was identified by NASA research scientists (J. Orasanu, personal communication, January 8, 1996. K. Mosier, personal communication, January 30, 1996). Consequently, a study was undertaken to develop a design model. The study incorporated a different approach from that of a traditional research format because of its developmental nature, its utilization of instructional technology and aviation human factors, and its incorporation of four distinct research phases.

The study used both literature reviews and the inputs from subject-matter-experts who represented the fields of instructional technology and aviation human factors. The data collected were used to establish the foundations for JPA design. Each of these fields had addressed the design and use of JPAs and it was theorized that a coalescence of data from the two disciplines would lead to a more robust JPA design model.

Aviation studies have demonstrated the important role JPAs play in effective performance and proficient decision-making (see Gross, 1995; Transport Canada, 1996; Turner, Huntley, & Volpe, 1991). Additionally, the field of instructional technology has recognized the importance of

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JPAs toward enhancing performance. There are few conditions in which JPAs are more important to aiding task performance than when used to prevent or correct errors in maintaining high-reliability in high-risk organizational systems such as in the cockpits of today's modern complex aircraft.

As this study progressed towards the development of a JPA design model, it became necessary to examine the concepts of design as applied to model development and to incorporate methods of developmental research. The initial literature review indicated that it was necessary to address three developmental factors: (a) the concept of design (see Richey, 1986; Rowland, 1993), (b) the employment of models (see Kirlik, 1993), and (c) the role of developmental research (see Kirlik, 1993; Richey, 1986; Richey & Nelson, 1996; Richey & Tessmer, 1995; Rowland, 1993).

Developmental research is defined as "the systematic study of designing, developing and evaluating instructional programs, processes and products that must meet the criteria of internal consistency and effectiveness" (Seels & Richey, 1994, p. 127). Within the context of this study, its ultimate aim was the improvement of the design and development processes. The more traditional view of research is that it involves the discovery of new knowledge and that development is the translation of that knowledge. Richey and Nelson (1996), however, take the position that research can also result in context-specific knowledge and serve as a problem solving function. They explain that "developmental research attempts to produce the models and principles that guide the design, development, and evaluation processes" (p. 1216).

THE FOUR PHASES OF THE STUDY

Because of its developmental nature, the study was conducted using four distinct phases. This format allowed for the use of both qualitative methods and quantitative methods when appropriate. Research questions and research methods were formulated for each of the four phases.

Phase One: JPA Design Considerations

The purpose of Phase One was to identify the foundations of JPA design. The methods used for Phase One consisted of a review of instructional technology and aviation human factors literature applicable to the design of JPAs. Additionally, interviews with a panel of Subject Matter Experts (SMEs) who represented the disciplines of instructional technology, human factors, and the field of

graphics design were conducted and analyzed. The data collected were used to identify variables for a JPA conceptual design model and to identify activities for a JPA procedural design model which were then developed in Phase Two of the study.

The SME panel was composed of three individuals who represented the discipline of instructional technology; three individuals who represented the discipline of human factors; and one individual who represented the field of JPA graphics design. The individuals selected from the field of instructional technology held doctoral degrees and were highly respected authorities in the field of instructional design. The individuals selected from the field of human factors also held doctoral degrees and were also recognized authorities within the field. The SME representing graphics design was asked to serve on the panel because of his JPA design background and experience in the design of airline passenger information cards.

The literature review encompassed a review of 132 publications. The publications consisted of 59 instructional technology publications, 63 human factor publications, 4 government aviation related reports, and 6 publications that addressed technology, design, and the aviation industry. Additionally, the 63 human factor publications included 13 research reports. The information gathered from the literature review provided a basis for the SME interviews.

The initial SME interviews consisted of telephone interviews conducted with each panel member. The initial interviews used a structured format in that each interview consisted of a set of 10 core questions. Interview data were recorded, transcribed, and entered into an information management database for further analysis

Two qualitative methods were used to analyze the data collected: (a) Interpretational analysis, and (b) reflective analysis. Interpretational analysis provided a means to examine the data collected from the literature reviews and the SME interviews in order to determine constructs, themes, and patterns that provided for the foundations of JPA design. Reflective analysis (see Gall, Borg, & Gall, 1996) involves a reliance on one's intuition, experience, and judgment in order to evaluate recommendations.

It was found that there were a variety of JPAs used in aviation that ranged from paper checklists to computerized automated decision aids. Based upon an analysis of the literature and the SME interviews, it was concluded that an examination of variables which influenced JPA design by

means of constructing a JPA conceptual design model was necessary to provide the foundation for identifying the activities to be displayed in a JPA procedural design model.

Phase Two: Model Development

The purpose of Phase Two was to analyze and transform the data collected in Phase One into a usable form that could be graphically presented by the use of models that depicted variables which influenced JPA design and presented activities that make up the JPA design process. The methods used in Phase Two consisted of three major activities: (a) a synthesis of data collected in Phase One, (b) the transformation of the data into representative models, and (c) the evaluation of the developed models by means of a two-round Delphi with the SME panel.

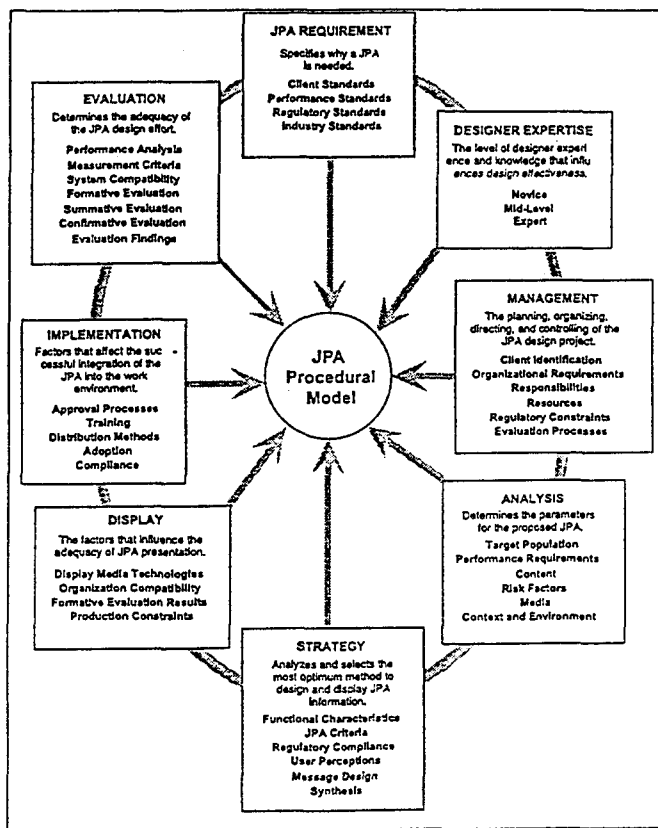
An initial JPA conceptual design model and a JPA procedural design model were constructed based on the frameworks established in Phase One. The draft of the models and associated definitions for the components and elements of the JPA procedural model were made available to the SME panel and a two-round formative evaluation

process was completed.

The data collected from the literature review and SME interviews were examined and clustered into major areas based on commonalities of purpose and relationships. The SME interviews data were analyzed using an information management database system and clustered into major themes that addressed model development and JPA design. Key terms and phrases were then compared with the findings of the literature review, synthesized, and categorized as either design variables or design activities.

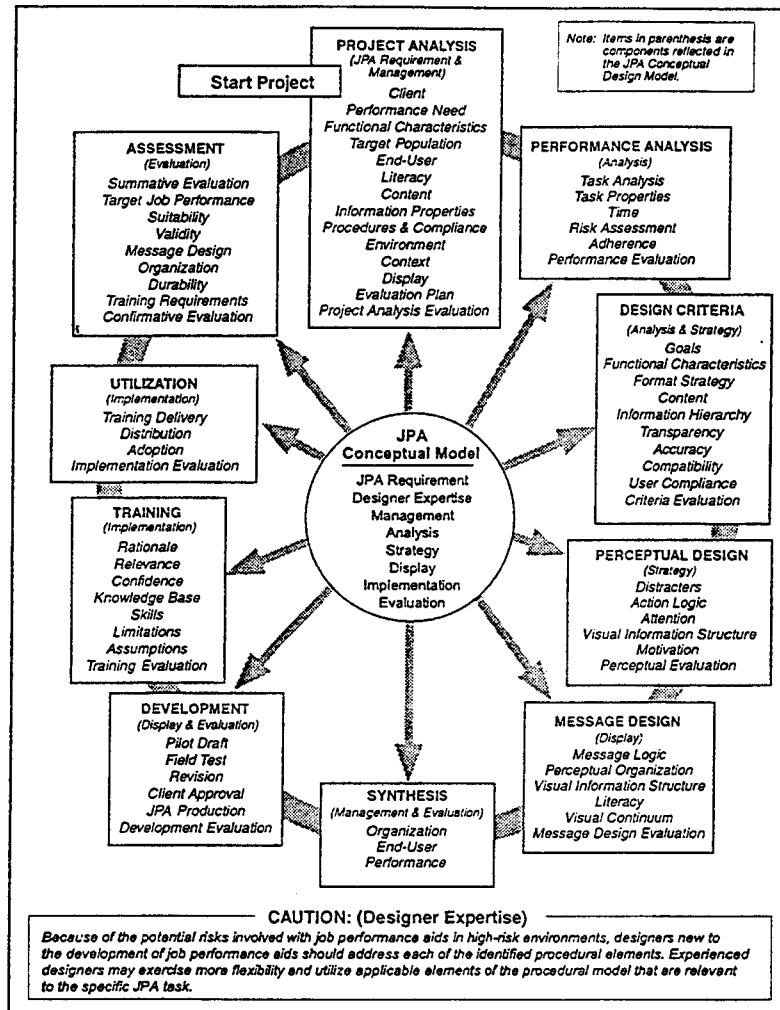
The design variables were then transformed into a visual representation by construction of a JPA conceptual design model (see Figure 1). The design activities were transformed into a visual representation by means of construction of a JPA procedural design model (see Figure 2). Furthermore, definitions for each of the JPA procedural model's components and elements were developed based on the analysis of the literature review and SME interviews.

Figure 1.
Initial Draft of JPA Conceptual Model



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Figure 2:
Initial Draft of the Job Performance Aid Procedural Design Model



The JPA models were evaluated using a two-round Delphi process with the SMEs that incorporated expert-review formative evaluations. The SME comments were entered into an information management database and examined. Common comments were then highlighted and extrapolated into a record of hits that were labeled as (a) conceptual, (b) procedural, or (c) definitions. The data were analyzed and clustered into critique items that provided the foundation for subsequent revisions. The models and definitions were then revised for the purpose of a second-round evaluation.

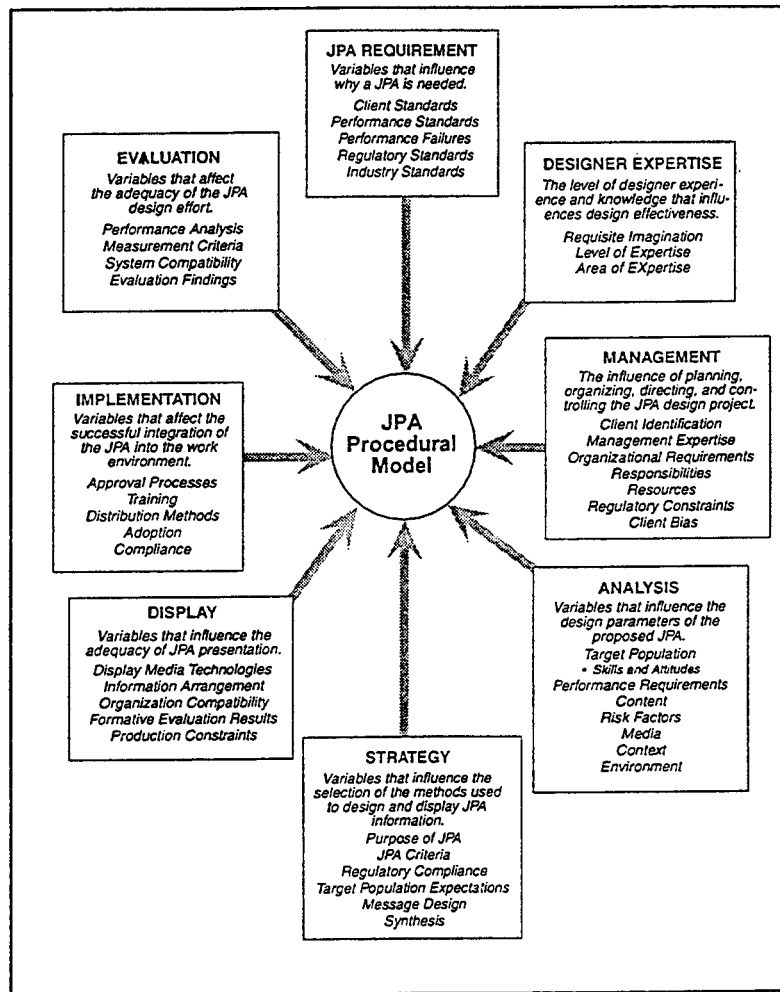
A second-round formative evaluation package was mailed to each SME that contained the revised models and procedural model component definitions. The data collected were used to make a final revision to the JPA conceptual design model, the JPA procedural design model, and

procedural definitions.

Eight variables were identified in the analysis of data that heavily influenced the JPA design process. These variables were: (a) the requirement for a JPA, (b) designer expertise, (c) project management, (d) analysis of design parameters, (e) design and display strategies, (f) adequacy of JPA display, (g) implementation, and (h) evaluation.

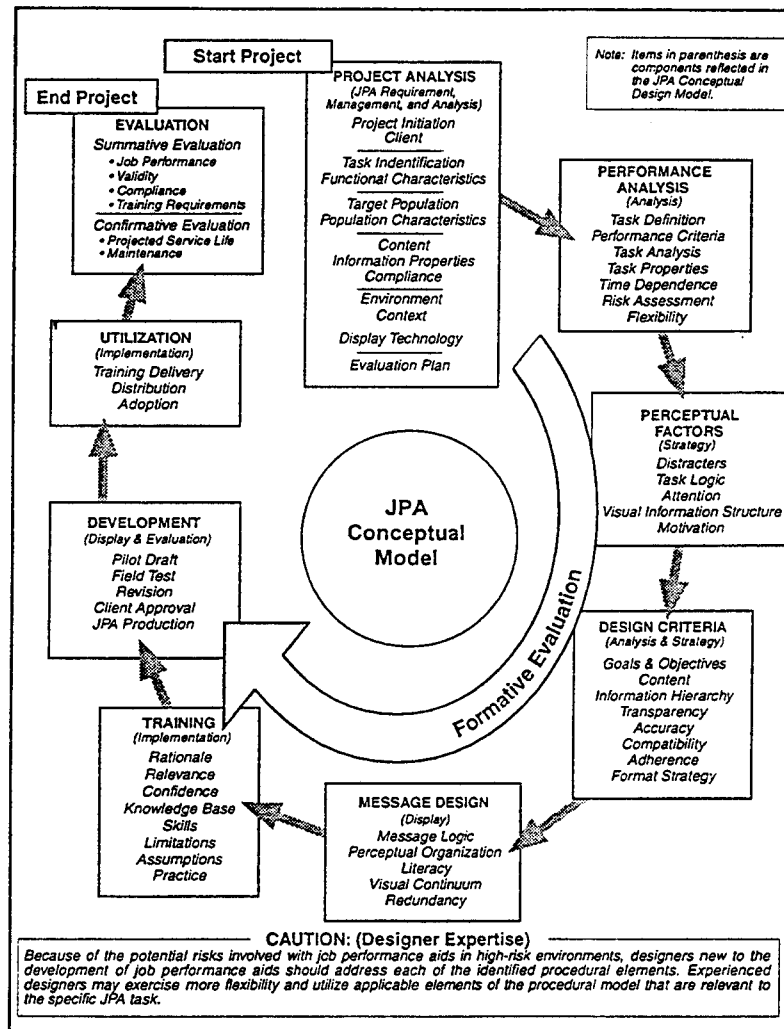
The second-round SME formative evaluations provided a means for closure to developing a synthesis between the instructional technology and human factor perspectives. The SME comments were minimal and primarily focused on the fine-tuning of the JPA models and associated definitions. The final versions of the conceptual and procedural design models are presented in Figure 3 and Figure 4.

Figure 3
Final Version of the Generic JPA Conceptual Design Model
That Reflects Variables Which Influence the JPA Procedural Design Process



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Figure 4
Final Version of the JPA Procedural Design Model



Phase Three: Application of the JPA Procedural Design Model

Phase Three of this study applied the JPA procedural design model to an actual JPA design project in order to evaluate its strengths and weaknesses. Additionally, the influence of the conceptual model on the design project was examined.

The evaluation of the model's application began by designing a task-specific JPA for use in an aviation high-risk and high-reliability environment using the elements reflected in the JPA procedural design model. The task-specific JPA was evaluated during the design and development processes in accordance with the evaluation element called for in the JPA procedural design model by

means of an expert review and small group evaluation as defined by Tessmer (1993). The design project selected was the construction of a JPA that displayed the procedures for a corporate flight attendant to prepare a corporate aircraft cabin and passengers for an emergency landing.

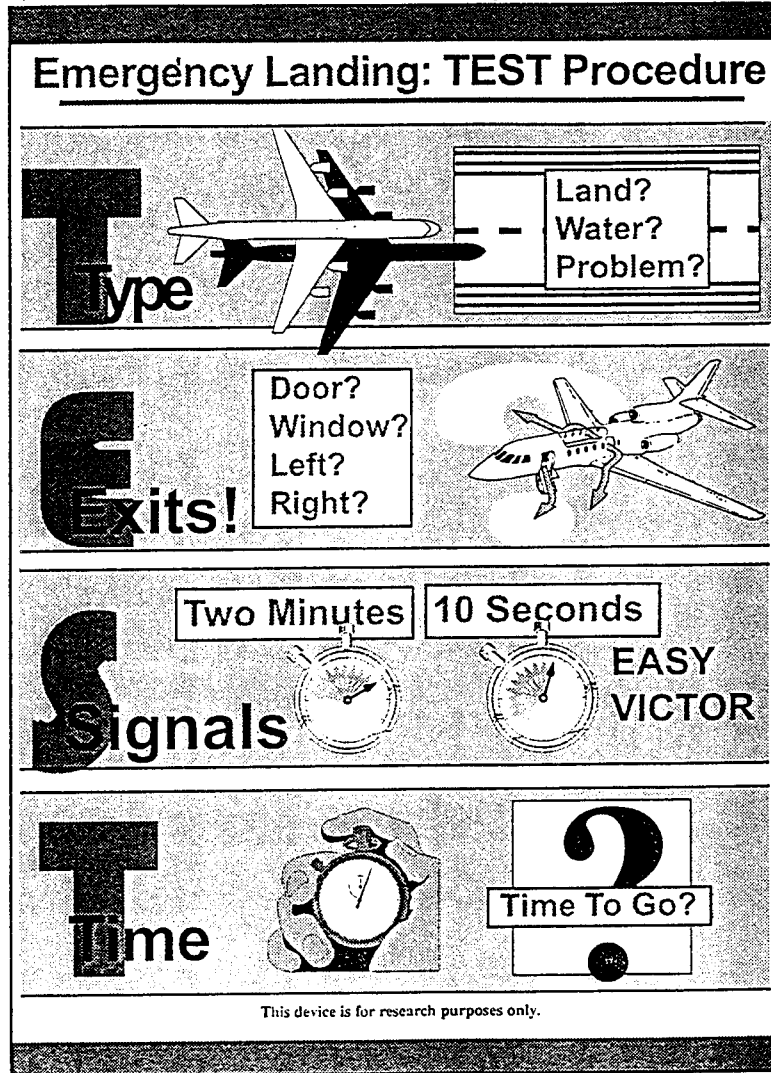
The initial draft of the JPA was evaluated by the principal trainer of the corporate aviation crew emergency training company. The suggestions were used to develop a second draft that was sent back to the training company for further expert review. The second draft was re-evaluated and revised into a third draft based on the second-round expert review.

The JPA's third draft was then reviewed by a group of three professional corporate flight attendants. Each flight

attendant had over five years experience as a corporate flight attendant, and each was current in the same type and model aircraft. Additionally, they were very familiar with the emergency procedures depicted by the JPA. Their critique items were reviewed and used to revise the JPA into its final form. The final JPA was printed using a four-

color process. Side one displayed the briefing segment of the emergency procedure and side two displayed the passenger and cabin preparation segments of the procedure. A black and white reproduction of side one of the JPA's final version is presented in Figure 5.

Figure 5
Final Version (Black and White) of Side One
of JPA Used in the Study.



The two most influential variables of the conceptual model were found to be the Designer Expertise variable and the Analysis variable. It was found within the component of Designer Expertise that the requisite imagination of the designer(s) continuously surfaced. Requisite imagination is defined as the ability to anticipate what can go wrong in

some future state with a current design (Westrum & Adamski, 1999). Within the Analysis component, it was found that the element of performance requirements was the major factor. The determination and specification of desired performance was found to be a critical factor in the design of JPAs for use in high-risk situations.

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Phase Four: JPA Evaluation

The purpose of Phase Four was to determine the effectiveness of the JPA's design by evaluating the effectiveness of the JPA under simulated but realistic conditions. The JPA was tested during simulated aircraft emergencies aboard a corporate aircraft cockpit/cabin motion simulator by comparing performance between a control group and an experimental group consisting of professional corporate aviation flight attendants.

Six simulations were conducted for the experimental group and six simulations were randomly selected from a bank of videotapes of previous training sessions to form the control group. The videotapes that made up the control group were used as de-briefing tools from previous emergency training programs.

Each subject of the experimental group had just completed an initial emergency training program. Additionally, the JPA was introduced to the experimental group just prior to the simulation sessions. The introduction consisted of a short briefing on the purpose and use of the JPA. The introduction session also provided time for questions.

Subjects in the experimental group were provided access to the JPA during the actual simulation. Two JPAs were stored in the cockpit and were readily accessible to the pilot-in-command (PIC) and the flight attendant. Each simulation was videotaped in order to collect and preserve observational data for later analysis.

A post-test only design was used to compare the performance of the control group (cabin crew members who did not have access to the JPA) with the performance of an experimental group (cabin crewmembers who had access to the JPA). Two written instruments were developed to evaluate the effectiveness of the JPA.

The first instrument was a JPA Subject Evaluation Form that was designed by to assess the subjects' attitudes regarding five key design areas (see Appendix A). The five areas were (a) the level of need for a JPA to perform the specified task, (b) the level of perceived performance improvement, (c) the influence of training on using the JPA, (d) the degree of JPA clarity, and (e) the adequacy of the JPA's physical format. Each subject completed the JPA

Subject Evaluation Forms shortly after the subject's simulation.

The second instrument was a Subject Performance Score Sheet that was designed to assess subject performance (see Appendix B). Quantitative values were given to performance levels for each task scored in order to determine a subject's performance score. Levels of performance were determined by pre-defined errors of omission or commission, and whether certain passenger related safety items were or were not addressed.

The simulation consisted of an emergency situation involving an engine fire that occurred immediately after takeoff that required an immediate return to the departure airport. There was a minimum of six passengers in the cabin for each simulation. Additionally, the simulation scenario called for the fire to be severe enough to require an emergency landing and preparation for an emergency evacuation.

Each member of the experimental group completed a JPA Subject Evaluation Form immediately after their simulation. Prompt recall interviews were conducted with each subject within two hours of their simulation session.

The videotapes of each experimental group simulation and each control group simulation were reviewed and scored by the researcher using the Subject Performance Score Sheet. The scores were used to compare performances and to determine if there were any observable differences with the use of the JPA. Each videotape was reviewed a minimum of three times to provide the researcher an opportunity to observe the performances and determine if any common themes or patterns could be identified.

Phase Four generated a great amount of data that was analyzed in four stages.

Stage one analysis. Stage one consisted of analyzing the JPA Subject Evaluation Forms. Only the mean score for each statement was calculated to determine central tendency because of the small sample size. Additionally, responses to open-ended questions were reviewed to determine if any common theme could be identified. Table 1 presents the experimental group's raw data and summary of mean scores.

Table 1
Experimental Group: Raw Data and Summary of Mean
Scores and Standard Deviations of Responses From
JPA Subject Evaluation Forms
(N=6)

Item	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5	Subject 6	M	SD
1	5.00	5.00	5.00	5.00	4.00	5.00	4.83	.41
2	4.00	5.00	5.00	4.00	4.00	5.00	4.50	.55
3	5.00	5.00	5.00	4.00	5.00	5.00	4.83	.41
4	4.00	5.00	5.00	5.00	5.00	5.00	4.83	.41
5	2.00	5.00	5.00	4.00	5.00	5.00	4.33	1.21

Table 1 reflects that the subjects leaned towards the “strongly agree response” for the statements with the exception of statement five which asked if the user liked the JPA’s physical format and size. One subject (subject 1) responded that the JPA was too small and that it was “different” than what the subject had been used to in airline operations. The response was reflected in the standard deviation ($SD = 1.21$) for item 5 which was substantially larger than the other items. This response suggested that it was important for the JPA designer to pay careful attention to the target population’s characteristics as identified in the Project Analysis phase. Although the subject critiqued physical size, the JPA format did not appear to influence the subject’s performance. The comments of subject 1, however, did suggest a potential for “negative transfer” (see Santilli, 1982).

In the context of training, negative transfer refers to an attention problem that results in the use of a procedure which was learned in past training but is not applicable to (or possibly even safe for) the current situation or equipment. Consequently, it is argued that the designer of JPAs must examine past training practices and previously employed procedures unique to the target population in order to identify potential sources of negative transfer. The designer must also adjust the JPA’s display for these

potential conflicts by means of more effective message design and the designer should assure that any identified conflicts are addressed in training.

Stage two analysis. Stage two of the analysis consisted of exploring the prompt recall interview data. Each of the subjects of the experimental group indicated that the JPA did provide assistance in the performance of the emergency procedure. Five of the six subjects stated that the JPA was easy to read and easy to use, and all subjects indicated that the JPA helped them to stay in sequence.

Stage three analysis. Stage three consisted of an analysis of the data collected from the Subject Simulation Score Sheets. Subject scores were analyzed to determine the mean scores for each element of the passenger briefing segment of the emergency procedure, the mean scores for each element of the passenger and cabin preparation segment of the procedure, and the cumulative mean scores for all elements. An independent-sample t-test using a significance level of .05 was conducted to compare the means of each element and the cumulative means between the experimental and control groups. Table 2 presents a summary of performance for the experimental group, and Table 3 presents a summary of performance for the control group.

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Table 2
Summary of Simulation Performance Scores
for the Experimental Group
(N = 6)

Item	Sub 1	Sub 2	Sub 3	Sub 4	Sub 5	Sub 6	Total	<i>M</i>	<i>SD</i>
TEST 1	5.00	5.00	5.00	5.00	5.00	5.00	30.00	5.00	0.00
TEST 2	1.00	5.00	4.00	4.00	2.00	3.00	19.00	3.17	1.47
TEST 3	5.00	4.00	5.00	3.00	3.00	3.00	23.00	3.83	.98
PREP 1	4.00	5.00	5.00	5.00	5.00	4.00	28.00	4.67	.55
PREP 2	3.00	3.00	5.00	2.00	5.00	2.00	20.00	3.33	1.37
PREP 3	5.00	5.00	3.00	2.00	4.00	2.00	21.00	3.50	1.38
PREP 4	3.00	5.00	5.00	4.00	5.00	1.00	23.00	3.83	1.60
PREP 5	5.00	5.00	4.00	5.00	4.00	4.00	27.00	4.50	.55
Total	31.00	37.00	36.00	30.00	33.00	24.00	191.00		
<i>M</i>	3.88	4.63	4.50	3.75	4.13	3.00		3.98	(.59)

Note. The cumulative mean score for the experimental group is displayed in bold. The standard deviation is shown in parentheses.

Table 3
Summary of Simulation Performance Scores
for the Control Group
(N = 6)

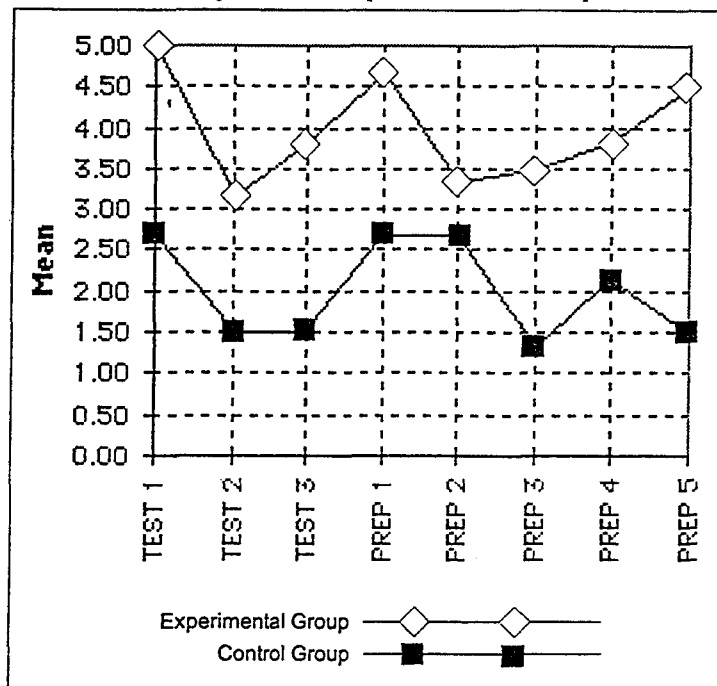
Item	Sub 1	Sub 2	Sub 3	Sub 4	Sub 5	Sub 6	Total	<i>M</i>	<i>SD</i>
TEST 1	2.00	1.00	3.00	3.00	4.00	3.00	16.00	2.67	1.03
TEST 2	1.00	1.00	2.00	1.00	2.00	2.00	9.00	1.50	.55
TEST 3	3.00	1.00	1.00	1.00	1.00	2.00	9.00	1.50	.84
PREP 1	3.00	1.00	2.00	3.00	3.00	4.00	16.00	2.67	1.03
PREP 2	4.00	3.00	2.00	2.00	4.00	1.00	16.00	2.67	1.21
PREP 3	1.00	1.00	1.00	1.00	1.00	3.00	8.00	1.33	.82
PREP 4	2.00	1.00	3.00	1.00	4.00	2.00	13.00	2.17	1.17
PREP 5	1.00	1.00	4.00	1.00	1.00	1.00	9.00	1.50	1.22
Total	17.00	10.00	18.00	13.00	20.00	18.00	96.00		
<i>M</i>	2.13	1.25	2.25	1.63	2.50	2.25		2.00	(.47)

Note. The cumulative mean score for the control group is displayed in bold. The standard deviation is shown in parentheses.

A comparison of means between the experimental group and the control group indicated that there was an improvement in performance when the JPA was used (see Figure 6). Although the improvement was not as great as

anticipated, the analysis reflected that there was a positive improvement.

Figure 6
A comparison of means between
the Experimental Group and the Control Group.



Lastly, it was concluded that when a JPA of this type is introduced into a high-risk environment, it is important to include training as a design component during the design process and to utilize training during the implementation of the JPA. In the design process, the limitations of the JPA must be identified and addressed by training. In the implementation process, training must include practice with the actual JPA.

Stage four analysis. Stage four involved the observation and reflective analysis of the simulation videotapes in an attempt to identify common patterns within each group and conduct a comparison of those patterns. A number of patterns were identified that included the influence of past training as well as the influence of current training on performance. These patterns substantiated the need to include training as part of the implementation process for a new JPA.

The influence of negative transfer was readily recognized during the performance observations as the experimental group included three people who had previous airline flight experience. It became evident that the airline trained subjects had trouble following the sequence of procedures as displayed on the JPA and taught in the classroom as they reverted to past procedures that were not applicable to the current equipment and procedures. It is theorized that past training monopolized the experienced subjects' thinking, and consequently influenced their actions when they were highly stressed.

Lastly, the reflective analysis pointed to a subtle but distinct pattern within the experimental group that was not apparent in the control group. This pattern involved the behavioral separation of the briefing segment and preparation segment of the emergency procedure. This behavior involved a subtle physical transition from the

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briefing of the passengers to the preparation of the passengers. Each subject within the control group overlapped and mixed the briefing and preparation segments of the emergency procedure that led to confusion and errors of omission.

JPA DESIGN STEPS AND ACTIVITIES

The definitions of the JPA procedural design model's components and elements provide a detailed description of the steps and activities found necessary to design a JPA. The definitions for the design steps and activities depicted in the model are as follows:

Project Analysis

The Project Analysis component addresses the purpose of the JPA, the type of audience, the job or performance requirement, the environment in which the JPA will be used, and organizational factors that will affect the JPA's design, development, and implementation.

Project initiation. This element defines who initiates a JPA project and why. For example, the initiator may be an organization such as an aircraft manufacturer that requests the development of an aircraft checklist, a regulatory body such as the Federal Aviation Administration that requires the development of a passenger safety information card, or an individual such as an airline safety director who identifies a need for a JPA.

Client. This element identifies who holds the ultimate authority for the JPA design project. It specifies who the decision makers are regarding project approval, control of resources, and application of evaluation results. The client may or may not be the project initiator.

Task identification. This element defines the task(s) that the JPA is to display. It examines gaps in actual performance or potential gaps in performance and provides the background information and framework to define the functional characteristics of the JPA.

Functional characteristics. This element defines the specific purpose of the JPA. It answers the question, "What is the JPA supposed to do?" It defines whether the JPA is a decision aid, a performance guide, a trouble-shooting guide, memory device, or other type of performance tool.

Target population. This element defines the specific segment of the organization's population for whom the JPA is intended. It defines the task performer. For example, the target population could consist of only pilots or only of flight attendants, or the target population could

consist of a flight crew that is made up of pilots and flight attendants. This element also addresses whether the JPA is intended for use by an individual, by a team, or both.

Population characteristics. This element addresses the characteristics of the intended target population. User characteristics include skills and knowledge, attitudes, and levels of visual and textual literacy. The element includes an assessment of the population's level of comprehension in order to reduce the potential for procedural misinterpretation. Additionally, the influence of cultural and language differences is examined if applicable.

Content. This element examines what content information is required to complete the task and what content information sources will be used. It includes a determination of the kind of information that will be displayed (e. g., quantitative, qualitative, warnings, signals, system status).

Information properties. This element determines whether the type of information that will be displayed in the JPA is static or dynamic. Static information, such as the information displayed in a printed trouble-shooting guide, does not change. Dynamic information reflects a constant changing system such as the information displayed in an automated electronic aircraft checklist or flight management system.

Compliance. This element addresses the rules and regulations that the JPA must meet, including equipment manufacturer specifications, government regulations, organizational policies, and others.

Environment. This element addresses the physical and social environment in which the JPA will be utilized. It examines the probable and possible physical work conditions and the range of those conditions in which the JPA will be used. Physical conditions include such factors as lighting, noise, vibration, external cues, and physical accessibility of the JPA. It also examines the probable and possible social conditions in which the JPA will be used to determine if the JPA will be used on an individual basis or in a group setting.

Context. This element encompasses an analysis of the range of circumstances under which the JPA will be used. The context element defines whether the JPA will be used in normal operating situations or emergency operating situations or a combination of both.

Display technology. This element determines the technology that will be used to display the JPA based upon

the analysis of the previous elements (e. g., an automated electronic checklist, a printed operations manual, a visual and audio warning device).

Evaluation plan. This element determines the evaluation processes that will be employed during and after the JPA project in order to reach a state of agreement between the client and the designer. Additionally, it establishes the criteria for project evaluation.

Formative Evaluation

The Formative Evaluation component is reflected as an ongoing process in the JPA procedural design model. It begins with the completion of the Project Analysis component and ends as an element of the Development component. Its purpose is to remind the designer to evaluate each design activity, determine if any corrections are necessary, and determine if any corrections have an influence on previously completed design activities

Performance Analysis

The Performance Analysis component defines the desired performance that is to be achieved with the use of the JPA. It is comprised of the following elements.

Task definition. This element, based upon the initial task identification, defines the specific task(s) to be accomplished with the use of the JPA.

Performance criteria. This element assesses and defines the level of performance required to complete the task(s) to meet operational and safety requirements.

Task analysis. This element analyzes the task(s) to determine the steps and behaviors necessary to perform the task(s) to meet the performance criteria. The analysis should also include an examination of task properties.

Task properties. This element assesses the model-of-expertise that will be used as the basis for the desired performance. It examines the complexity of the task structure and the potential for ambiguity including an analysis of the types of decisions that the target population will likely encounter. It determines whether more than one course of action is possible and if alternate-courses-of-action need be presented in the JPA. Additionally, this element re-examines the previously selected display technology to assure that the technology can display the type and amount of information required.

Time dependence. This element examines the influence of time on the desired outcome(s) and desired level of performance. It assesses whether the outcome(s) and performance are under any time constraint, and if so,

defines that constraint.

Risk assessment. This element forecasts the potential risks while the task(s) is conducted. It explores the types of risks involved including the physical and non-physical, and it provides a framework to assess whether performance flexibility is available or desirable.

Flexibility. This element examines if any variance (and if possible, to what degree) is available to the task performer to deviate from the JPA's displayed procedures including the potential for risks associated with the use of individual heuristics by the task performer.

Perceptual Factors

The Perceptual Factors component addresses design considerations that influence information processing. It determines the detailed design specifications that encompass known perceptual factors which influence decision making associated with the desired task.

Distracters. This element addresses potential distracters that could degrade effective use of the JPA. It identifies specific areas of the JPA's display which must be adjusted for distracters. Distracters include: (a) environmental factors such as heat, cold, light, noise, vibration, time constraints, and the physical working space; and (b) human factors such as biological, psychological, or sociological stressors, and (c) situational factors such as the operating conditions (normal or emergency) in which the JPA will be used.

Task Logic. This element constructs a mental representation (the logic) of the task performance as viewed by an expert or experts who devised the instructions to conduct the task. Its purpose is to match the expert's mental representation of the task with that displayed in the JPA.

Attention. This element specifies the physical properties of the JPA that affect the task performer's pre-attentive and attentive perceptions. It also details the specifications for the amount of contrast between levels of information, and provides for sufficient stimulation to compensate for predicted distracters.

Visual information structure. This element provides for detailed specifications of the selected display technology. It examines and details display methods which allow the task performer to construct a mental map of the information displayed. Visual information structure organizes information by use of typography, graphics, tables, etc.

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Motivation. This element examines the motivational factors that influence the use of the JPA by the task performer in the desired manner. Such factors include: (a) accessibility, (b) ease-of-use, (c) clarity, (d) relevance, (e) risk and potential for personal harm, (f) personal value, and (g) probability of success.

Design Criteria

The Design Criteria component addresses the process by which the detailed specifications for the development of the JPA are determined.

Goal(s) and objectives. This element defines and prioritizes the specific goal(s) and objectives of the JPA design project. The goal(s) is a clearly defined general statement that broadly describes the purpose of the JPA design project. The objectives are clearly defined conditions and specifications of the steps necessary to meet the JPA design project goal(s).

Content. This element is a detailed specification of the information necessary to be displayed to achieve desired performance. This element also specifies the information necessary in the event alternate courses of action are required to be displayed.

Information hierarchy. This element specifies how the content information will be organized and prioritized to achieve ease-of-use and comprehension.

Transparency. This element determines the level of information detail necessary for systems understanding. It determines the depth of rationale necessary to display in order to justify the recommended courses of action reflected in the JPA.

Accuracy. This element examines the reliability and accuracy of the information displayed.

Compatibility. This element identifies the potential for conflict between the proposed JPA and other JPAs used in the specific work environment. It also addresses the potential of multiple fault situations in which more than one JPA may be used. (e. g., the use of two separate emergency checklists that each address a different system malfunction.)

Adherence. This element is a detailed specification of the level of compliance with the JPA that is required by the task performer. It examines if flexibility in performance is allowable and determines the likelihood that the task performer can or will deviate from the JPA's displayed procedures. Adherence determines when warnings, cautions, and notes should be displayed.

Format strategy. This element determines the specifications for the JPA's physical and content format. It specifies the amount of information to be displayed and a detailed specification of the display technology (e. g., a printed trouble-shooting guide or an automated electronic checklist). Format strategies include:

1. A **directive format** that assumes the target population knows little or nothing about the task and requires the JPA to display all information necessary to complete the task;
2. A **deductive format** that is intended for a target population who have knowledge of the tasks and have had training or experience in performing the task and the JPA provides information which serves as a memory device for the task performer; or
3. A hybrid format that incorporates both directive and deductive strategies.

Message Design

The component of Message Design consists of the application of message design principles to the development of the JPA. Since the field of message design has numerous design principles and techniques, it is not the intent of the procedural JPA design model to provide specific message design methods; rather, the intent is to provide the designer with the primary message design factors applicable to JPAs.

Message logic. This element addresses the type of message that will be displayed in the JPA. The logic analysis is based on the functional characteristics as determined during the project analysis. Message logic adapts the type of message to the purpose of the JPA (see Adamski & Stahl, 1997). Message types may consist of (a) alert messages that call for action, (b) regulatory messages that present legally binding information or company rules, (c) procedural messages that depict the actions necessary to complete a specific task, (d) instructional messages that provide trouble-shooting information, and (e) integrated messages that have the elements of more than one message type.

Perceptual organization. This element details the specifications for the visual organization of information by means of a visual information structure. This structure includes the principles of proximity, similarity, continuity, closure, and connectedness. Visual information structure is the application of message design techniques that provide for effective interpretation of the message. The techniques include the use of fonts and type sizes, typographical cues,

the use of headings and advanced organizers, and the use of appropriate white space. Perceptual organization provides for an effective arrangement and visual flow of the message.

Literacy. This element applies the techniques of message design that are appropriate to the target population's visual and textual literacy.

Visual continuum. This element determines the level of realism and detail that is to be displayed in the JPA. It determines and defines any symbols used and assesses the level of detail necessary in any graphics or icons employed in the JPA. This element selects the most appropriate point on the visual continuum which ranges from the concrete to the abstract.

Redundancy. This element examines the need to provide a means to check that a performance step displayed in the JPA results in the desired outcomes. For example, if a procedural step states to move a throttle to the cut-off position, this element determines the information that should be presented in the JPA for the task performer to assure that the desired results take place.

Training

The Training component addresses the training content required and delivery methods necessary to implement the JPA effectively into the workplace.

Rationale. This element presents the purpose of the JPA. It describes what the performance task is and how the JPA relates to the requirements of the task.

Relevance. This element presents those factors that make the JPA relevant to the required performance. It addresses the visible and invisible variables that created the rationale behind the development and use of the JPA.

Confidence. This element addresses the reliability of the JPA that is based on the analysis and design evaluations. Its purpose is to enhance the target population's confidence that the JPA will do what it is intended to do.

Knowledge base. This element determine the prerequisite knowledge that is required for the target population to interpret and comprehend the information displayed in the JPA. Any knowledge deficiency is presented during training. Examples of knowledge areas may include such areas as equipment systems, environmental factors, teamwork, and situational factors.

Skills. This element addresses the prerequisite skills necessary to perform the desired task displayed by the

JPA. Any skills that the target population does not possess are identified, described, and practiced. Such skills may involve use of a new type of data-entry key board, scrolling an automated electronic checklist, interpreting digital data, interpreting specific icons or symbols used in the JPA, etc.

Limitations. This element addresses the capabilities and limitations of the JPA to be presented in training. It describes what the JPA can do and what the JPA cannot do. System variables and human factors that may affect the capabilities or limitations of JPA interpretation are explained.

Assumptions. This element addresses any misconceptions or misunderstandings of the JPA's capabilities or limitations that are identified during the training program.

Practice. This element determines the need for and amount of practice required to effectively use the JPA.

Development

The Development component involves the process of translating design specifications into the JPA's physical form. It addresses the processes by which the JPA is produced and implemented into the workplace.

Pilot draft. This element consists of the construction of a JPA prototype that is based upon previous data collected.

Field test. This element involves the testing of the prototype JPA under actual or simulated field conditions with a representative sample of the target population. An evaluation is made to determine if the prototype meets previously defined needs. A pilot training program is recommended to be conducted in conjunction with the JPA field test. Findings are documented to validate design or to substantiate revisions.

Revision. This element provides for correcting the JPA's design or training for any discrepancies discovered during the field test and pilot training program..

Client approval. This element provides for the final approval by the client prior to the JPA going into final production.

JPA production. This element consists of those activities necessary to complete the production of the approved JPA.

Utilization

The Utilization component involves the process of introducing the JPA into the workplace and evaluating its adoption by the intended target population.

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Training delivery. This element addresses the means available to most effectively deliver the required training to the organization's target population.

Distribution. This element addresses the means by which the JPA will be distributed in the workplace and made accessible to all required work stations and members of the target population.

Adoption. This element is a form of confirmative evaluation. It evaluates and confirms whether the JPA is being properly used and accepted by the target population.

Evaluation

The Evaluation component addresses summative and confirmative evaluations that are conducted after the JPA project is completed. Formative evaluations (the evaluations conducted after each component as reflected in the graphic model) are ongoing throughout the design process.

Summative. This element is the evaluation process conducted shortly after the JPA project has been completed and implemented. It reviews all previous formative evaluation findings and evaluates any revisions. It also evaluates how well the JPA has been adopted into the workplace.

Confirmative evaluation. This element involves an evaluation of the JPA that is conducted at specified intervals after implementation. It includes addressing projected service life and JPA maintenance. The projected service life involves evaluating the JPA's effectiveness, accuracy, and regulatory compliance at specified time intervals. The time intervals depend on the nature of the JPA, the frequency and impact of regulatory changes, revisions to manufacturing specifications, and revised operating procedures.

JPA maintenance involves periodic evaluations to determine the durability of the JPA. It assesses how well the JPA has maintained its physical properties and withstood damage due to repeated use or long term storage in the work environment.

SUMMARY

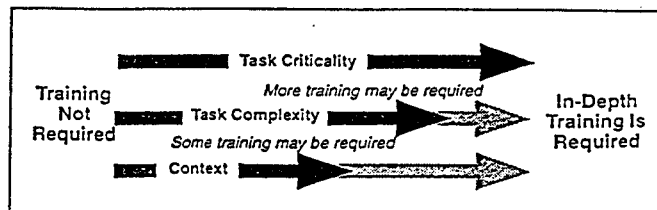
The study demonstrated the necessity for identifying,

exploring and modeling the variables that influence those activities that make up the components of a procedural design model. The JPA conceptual design model was intentionally designed to be a generic, recursive, design model that reflected those variables that influence JPA design in an implicit, intuitive manner. The variables depicted are found in any JPA design project, yet the model is recursive in that there is no starting and ending point. The model's components may be revisited as needed and there is no specific sequence or flow that must be followed.

The JPA procedural design model was designed to be a task-specific, systematic, procedural model that meets the needs of the expert, the experienced, and the novice designer. Regardless of the designer's experience, it is argued that JPA design should address each of the components of the JPA procedural design model to the extent possible. It is recognized that expert and experienced designers have a tendency to "leap frog" about a design model in order to meet time and resource constraints. The designer is cautioned, however, that the design of JPAs for use in high-risk organizations requires an extreme attention to the components and associated elements that are depicted in the JPA procedural design model. Omission by convenience of any of the procedural model's components or elements can result in dire consequences.

Traditionally, the field of instructional technology has viewed JPAs as substitutes for training, but this study has indicated that a strong relationship exists between JPAs designed for use by high-risk organizations and training. It was found that training, which included practice in using the JPA, was a necessary ingredient to successful implementation of some types of JPAs into a high-risk environment. The types of JPAs that required training for implementation were not specifically explored in this study, but a number of factors were identified that pointed to a training need. This need was reflected in a proposed model of a training continuum. Figure 7 presents the suggested training continuum model.

Figure 7
The Training Continuum



The model represents that a need-for-training point exists at some point on the continuum. This theoretical point indicates that a degree of training is necessary in order to successfully implement a JPA into a high-risk organization. It must be noted that this discussion does not attempt to determine what degree of training is required or how to calculate an exact point on the continuum; rather, this discussion argues that a training continuum does exist and it is an area that requires further research.

The findings of this study identified three factors that appeared to move the need-for-training point towards the in-depth training is required end of the continuum. These factors were: (a) the criticality of the task, (b) the complexity of the task, and (c) the context of use.

RECOMMENDATIONS FOR JPA DESIGN

The following recommendations are based on the design experiences encountered during the course of this study. It is hoped that they will provide practical and useful information to the practitioner in the field.

1. Identify the client. It is important that the designer carefully identify the person in the organization who holds the ultimate approval authority over the JPA design project. It is important that agreement be reached between the designer and the client regarding responsibilities, time lines, resources, and analysis and evaluation processes.
2. Precision and accuracy are necessary when dealing with procedures. The JPA designer must keep in mind the necessity of precision and accuracy in the analysis and display of procedures.
3. Use caution when bypassing any element of the JPA procedural design model. Time and resource constraints may tempt one to bypass elements of the procedural design model. Be sure that such bypassing is justified and based on knowledge and experience.
4. Take advantage of evaluation opportunities. Unplanned or unscheduled evaluations of the design can be very fruitful. This study revealed that it is very beneficial to accept evaluation feedback when it is offered. The designer,

however, must be aware of when feedback becomes repetitive and no longer provides new information.

5. Include the real-world JPA user in the design and evaluation processes. Do not rely only on those in supervisory or expert positions. The operator at the sharp end of the system can provide some of the most usable data.
6. Designing by conjecture is dangerous. Base the JPA's design on solid knowledge-based and research-based foundations, not on looks. Just because one believes the JPA looks good, it does not necessarily mean it will work as intended. Test it.
7. Evaluate the JPA's language. Do not assume that all the symbols, icons, acronyms, abbreviations, text, and graphics used in the JPA design are understood by all members of the target population.
8. Self evaluation can be very effective. As a particular design task is completed, put it aside and come back to reflect on it at a later time. This was found to be a very beneficial and effective technique.

9

Training is a component of JPA design. Address training requirements during the JPA design process. Do not wait until the design project is completed. Identify JPA limitations and acknowledge them in training.

JPA design for high-risk organizations is becoming an important facet of instructional technology and human factors. As technology becomes more complex and the human-machine interface becomes more sophisticated, the need for quality JPAs will become more critical to the enhancement of human performance. Hopefully, this study will help designers create effective JPAs, assist organizations in successful implementation, and provide designers and high-risk organizations the incentives to continually and consistently evaluate their JPA designs in the field. □

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Appendix A Subject Evaluation Form

Please indicate your response to the following statements by checking the appropriate box. After you complete this evaluation form, you will be asked to review your performance in the simulator. Your simulation videotape will be played and stopped approximately every 30 seconds. The facilitator will guide you through this process. Thank you for your assistance.

1. The use of some type of Job Performance Aid is necessary in order to perform the emergency procedures effectively.

Strongly Disagree	Somewhat Disagree	No Opinion	Somewhat Agree	Strongly Agree
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

2. I believe that the use of the "pilot" Job Performance Aid improved my performance during the simulation.

Strongly Disagree	Somewhat Disagree	No Opinion	Somewhat Agree	Strongly Agree
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

3. Training on how to use the "pilot" Job Performance Aid is very important in order use it properly.

Strongly Disagree	Somewhat Disagree	No Opinion	Somewhat Agree	Strongly Agree
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

4. The visual information structure (the pictures, symbols, and text) used in the Job Performance Aid were clear and easy to understand.

Strongly Disagree	Somewhat Disagree	No Opinion	Somewhat Agree	Strongly Agree
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

5. I liked the size and physical format of the "pilot" Job Performance Aid.

Strongly Disagree	Somewhat Disagree	No Opinion	Somewhat Agree	Strongly Agree
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Please write a short comment:

What I liked best about the "pilot" Job Performance Aid was:

What I liked least about the "pilot" Job Performance Aid was:

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**Appendix B
Subject Simulation Score Sheet**

Subject # _____ Date: _____
 Start time: _____ End time: _____ Total elapsed time: _____

Briefing Segment

1. Crew briefing performance:

- ___ [5] Excellent (Appeared very attentive, no hesitation, read back accurate).
- ___ [4] Good (Appeared attentive, some hesitation, needed to clarify one element in read back).
- ___ [3] Average (Appeared attentive, hesitant, required clarification of more than one element in read back).
- ___ [2] Fair (Appeared apprehensive and uncertain, required a third clarification of one element).
- ___ [1] Poor (Appeared very apprehensive, required a third briefing of all elements).

2. Briefed all elements:

- ___ [5] Excellent (No hesitation, explained each element professionally, easy to hear and understand, did not use confusing language).
- ___ [4] Good (Appeared slightly apprehensive but did not miss any elements or present mis-information).
- ___ [3] Average (Appeared apprehensive, was hesitant during presentation).
- ___ [2] Fair (Appeared very apprehensive or presented mis-information regarding one element).
- ___ [1] Poor (Missed one element regardless of presentation style or presented mis-information in more than one element).

3. Transition performance from the briefing segment to the preparation segment.

- ___ [5] Excellent (No hesitation, transition smoothly).
- ___ [4] Good (Slight hesitation, or slight pause in transition).
- ___ [3] Average (Demonstrated a major hesitation between procedures)
- ___ [2] Fair (Appeared unsure of transition phase).
- ___ [1] Poor (Improper transition performed).

Preparation segment

1. Preparing passengers for brace positions (Forward, side, aft facing):

- ___ [5] Excellent (Appeared professionally assertive, all procedures followed with no hesitation).
- ___ [4] Good (All procedures followed but appeared hesitant at times).
- ___ [3] Average (All procedures followed, but demonstrated some confusion).
- ___ [2] Fair (Failed to correct one improper brace position).
- ___ [1] Poor (Failed to correct more than one improper brace position).

2. Preparing passengers, "cleaning up" performance (Pens & pencils, eye glasses, high-heel shoes, jewelry):

- ___ [5] Excellent (All passenger items addressed, handled questions professionally).
- ___ [4] Good (All passenger items addressed, but did not handle questions professionally).
- ___ [3] Average (Failed to address one passenger item but gave proper instructions to those addressed).
- ___ [2] Fair (Failed to address two passenger items).
- ___ [1] Poor (Failed to address over two passenger items or gave improper passenger instructions regarding items).

3. Ready cabin performance (secure carry-on, food/beverage service, non-essential electric):

- ___ [5] Excellent (Announcement clear, all items properly stored, galley secured, non-essential electric off).
- ___ [4] Good (Announcement not clear, all items properly stored, galley secured, non-essential electric off).
- ___ [3] Average (Failed announcement, all items properly stored, galley secured, non-essential electric off).
- ___ [2] Fair (One item missed regardless of announcement style).
- ___ [1] Poor (More than one item missed regardless of announcement style).

4. Evac review (Brace positions, assign tasks, procedures review):

- ___ [5] Excellent (All procedures followed correctly, properly addressed passenger concerns).
- ___ [4] Good (All procedures followed correctly, appeared hesitant at times when assigning tasks).
- ___ [3] Average (All procedures followed correctly but appeared very hesitant or confused during tasks assignment).
- ___ [2] Fair (Missed one item during cabin ready element or gave one incorrect task assignment).
- ___ [1] Poor (Missed more than one item or failed to give task assignments or gave over one incorrect task assignment).

5. PIC report performance:

- ___ [5] Excellent (All procedures followed correctly, continued passenger instructions in a professional manner).
- ___ [4] Good (All procedures followed correctly, appeared somewhat hesitant in giving continued passenger instructions).
- ___ [3] Average (All procedures followed correctly, appeared hesitant or confused in giving continued passenger instructions).
- ___ [2] Fair (Failed to perform one element of procedure).
- ___ [1] Poor (Failed to perform more than one element of procedure).

Total score Briefing _____ Total score Preparation _____ Total cumulative score _____
 Mean score Briefing _____ Mean score Preparation _____ Total mean score _____