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EFFECTS OF CONSPICUOUS PRINT, PICTORIAL ICONS
AND COLOR CODING ON THE EFFECTIVENESS
OF F-16 FLIGHT MANUAL WARNINGS

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KABUL VE ONAY BELGESİ

**EFFECTS OF CONSPICUOUS PRINT, PICTORIAL ICONS AND COLOR
CODING ON THE EFFECTIVENESS OF F – 16 FLIGHT
MANUAL WARNINGS**

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LIST OF SYMBOLS

- X_{djk} : Scaled experiment test scores of participants (points)
- d : Levels of color coding
- j : Levels of icon use
- k : Levels of border use
- A_d : Effect of color coding at level d
- B_j : Effect of icon use at level j
- C_k : Effect of border use at level k
- μ : True grand mean (points)
- $(AB)_{dj}$: Interaction between color coding and icon use over levels of border use
- $(AC)_{dk}$: Interaction between color coding and border use over levels of icon use
- $(BC)_{jk}$: Interaction between icon use and border use over levels of color coding
- $(ABC)_{djk}$: Interaction between color coding, icon use and border use
- ε_{djkln} : Random error component
- σ^2 : Variance
- F : F distribution value
- df : degrees of freedom
- p : Smallest level of significance

ABBREVIATIONS

WCEF : Warning – Centered Effectiveness Factors

HCEF : Human – Centered Effectiveness Factors

TAFA : Turkish Air Force Academy

ECL : English Comprehension Level

ANOVA: Analysis of Variance

SD : Standard Deviation



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ABSTRACT

EFFECTS OF CONSPICUOUS PRINT, PICTORIAL ICONS AND COLOR CODING ON THE EFFECTIVENESS OF F – 16 FLIGHT MANUAL WARNINGS

Design and utilization of warnings have been widely researched in ergonomics.

In this study, it was aimed to present the basic warning design concept, and to research the influence of certain physical warning design factors; color coding, pictorial icon and border use on the effectiveness of flight manual warnings.

In Chapter I, the position of warnings in ergonomics and product related safety concept was dealt with, in a broad view. Stages of hazard minimization and objectives of warning design were presented.

Chapter II included definitive information about warnings. Effectiveness of visual warnings and influential factors were elaborated along with relevant literature survey findings and a brief review of psychological theories on comprehension and memory in this chapter, to form a basis for experiment conducted on F- 16 flight manual warnings.

In Chapter III, function and features of manuals and manual warnings were identified more particularly.

Technical background, design and performance of experiment on the effectiveness of F – 16 flight manual warnings, statistical analyses of data and obtained results were presented in Chapter IV.

Consequently, conclusions and recommendations for future research are elaborated in Chapter V.

May, 2001

Oğuzhan ERDİNÇ

ÖZET

F-16 UÇUŞ KILAVUZLARINDAKİ UYARILARIN ETKİLİLİĞİNDE, DİKKAT ÇEKİCİ YAZIMIN, RESİMLİ SEMBOLERİN VE RENGİN ETKİLERİ

Emniyet uyarılarının tasarımı ve kullanımı, ergonomide geniş ölçüde araştırılan bir konu olmuştur.

Bu tez çalışmasında, temel uyarı tasarım konularının sunulması ve Hava Harp Okulu'nda gerçekleştirilen bir deney ile, F-16 uçuş kılavuzlarındaki uyarıların etkililiği üzerinde renk, resimli sembol ve çerçeve kullanımı gibi fiziksel tasarım faktörlerinin araştırılması amaçlanmıştır.

I. Bölümde, uyarıların ergonomideki yeri ve ürüne bağlı emniyet konuları geniş bir açıdan ele alınmıştır. Tehlike minimizasyonunun aşamaları ve takiben uyarı tasarımının amaçları sunulmuştur.

II. Bölümde uyarılarla ilgili tanımlayıcı bilgiler bulunmaktadır. Görsel uyarıların etkililiği ve önemli faktörler, konuyla ilgili kaynak araştırmasının bulguları, anlama ve hafızaya yönelik psikoloji teorileriyle beraber işlenerek, F-16 uçuş kılavuzları üzerinde yapılan deney için teorik temel oluşturulmuştur.

III. Bölümde kullanım kılavuzları ve kullanım kılavuzlarındaki uyarıların fonksiyonlarına ve özelliklerine ilişkin bilgilere yer verilmiştir

F-16 Uçuş kılavuzları üzerindeki deney ile ilgili teknik altyapı bilgileri, deneyin tasarım ve uygulama aşamaları, elde edilen verilerin istatistik analizi IV. bölümde sunulmuştur.

Son olarak V. bölümde, tez çalışması sonunda varılan sonuçlar ve değerlendirmeler ortaya konmuştur.

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CLAIM FOR ORIGINALITY

EFFECTS OF CONSPICUOUS PRINT, PICTORIAL ICONS AND COLOR CODING ON THE EFFECTIVENESS OF F-16 FLIGHT MANUAL WARNINGS

It has been proposed that, effectiveness in F – 16 flight manual warnings could be enhanced by manipulation and involvement of physical design factors; color coding, pictorial icon and border use, which are not found in today's manuals.

The results of the experiment conducted on F – 16 flight manual warnings revealed that use of red warning signal word and pictorial icon enhanced recognition of safety information in these warnings.

This finding can be implemented in wide variety of technical manuals. Appropriate pictorial icons can be inserted in warning messages and different safety colors can be applied in components of manual warnings in order to attain stronger retention via stronger memory they provide.

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Prof. Dr. Erkan TÜRE

Oğuzhan ERDİNÇ

I. WARNINGS IN SAFETY CONCEPT

I.1 INTRODUCTION

Today, maintaining a strong and dynamic air force is indispensable for our country to maintain an effective national defense. It is quite obvious that future warfare will depend mostly on air combat superiority, which makes non-stop progresses inevitable to compete in global scales.

Nevertheless, it is incredibly a costly field that entails constant investments and great amounts of source allocation, which is hard to meet for Turkey, owing to severe financial problems we have to handle. However importance of this strategic military need has been recently reprovved by recent operations took place in nearby regions, like Balkans, Iraq and more distant parts of world. Due to military confidentiality, related costs can not be presented in numbers, but it will not be wrong to claim that a pilot who is lost in an aircraft accident is irreplaceable in both humanity and managerial means, and financial loss in loosing an aircraft is too high to afford. This fact makes flight safety an utmost important concern in air force concept and any relevant improvement very worthwhile.

Technical training of military jet pilots is a long and demanding program. Study of technical documents, primarily of flight manual forms the core of technical training. Without the highest command of technical information about structure and operation of the aircraft, pilots would always run the risk of inability to react against emergencies as fast, accurate and consciously as required.

In this respect, ergonomic edition and design of flight manuals, particularly of warning messages in these manuals, becomes an essential issue in technical documentation.

Unlike most of visual warnings, which are viewed occasionally, safety information in flight manual warnings should address to the memory.

This information would be unavailable for pilots during flight and more dangerously during emergencies.

The critical values, operation limits (e.g. speed limits, crosswind limits, fuel limits) and more of specific information should be retained in cognition of pilots and be retrieved in necessary cases.

This retrieval operation should be performed in seconds, and even in shorter periods of time in some cases. Information processing in the minds of pilots should enable pilots to make accurate decisions.

This requirement to fast reaction capability, makes cognitive reinforcements necessary, which might be provided via physical warning design factors.

I.2 PRODUCT RELATED SAFETY AND HAZARD CONTROL

Safety, one of the main concerns of ergonomics, is reflected to users, consumers and operators on different aspects, such as environmental conditions, task design, one of which is product use safety. Unsafe products or inadequacies in safety concerns bring numerous potential perils to those who use it for varying purposes.

Product related hazard control principles could be delineated as:

(Lehto, 1992, Part 1)

*"-Eliminating hazards
-Containment of hazards
-Protection of users
-Training of users
-Warning of users"*

First two principles, which are most effective to ensure safety, could best be attained in product or process design stage.

Protection and training of users address to work design stage, in which necessary measures against the hazard are specified and taken. Supervision is the higher- level control factor for those functions.

When first four principles fail, warnings are employed to minimize hazard as a supplementary component of safety concept.

In other words, general objective of ergonomics is to ensure that safety is attained through the design of products.

“If potential hazard cannot be designed out, then it should be guarded against. If guarding against the hazard is not possible, than an adequate warning system should be developed, enabling designers to convey potential dangers of the product only as a last resort.” (Rogers, Lamson and Rousseau 2000)

All those principles are also valid for process or system design, where they are resulted as products to put into human use.

I.3 STAGES OF HAZARD MINIMIZATION PROCESS

The requirements of product related safety concept and the major steps of hazard minimization process are presented below (Lehto and Salvendy 1995).

Product design

Products are used not only for their intended purposes, but also in other, mostly foreseeable ways, which requires a diverse survey of current users of similar products, and potential users for this new product in a prospective approach. Product design should include certain steps as presented below, in order to ensure safety and to prevent misuses :

1. Identification of

-Scope and

-Probable environment

in which the product would be used.

2. Identification of current and potential user population.

3. Postulating all possible hazards, probability of occurrences and severity of resulting harm.

4. Delineation and evaluation of alternative design features or production techniques that will mitigate or eliminate the hazards, including other hazards that might be introduced by these alternatives, and their effect on subsequent usefulness and ultimate cost of products.

The dangers could be avoided in that stage fundamentally ; the function and utilization of the product should be in strong accordance with safety requirements for end users. The purposes of design must be analyzed, since unexpected and unintended use of the products might bring severe accidents along. Virtually many of the products are used as the substitute of one another. (scissors vs. screwdrivers) Dangerous features should strictly be kept out the product design. Otherwise protection methods would have to be consulted.

More broadly, a hazard analysis ; ranging from accidents occurred in the past to potentially hazardous situations can also bring design safety further at that level, particularly when an existing product is improved or upgraded. (McCarthy, Ayres, Wood and Robinson 1995)

Given that product or process reveals a high hazard potential, redesigning and modifications should be applied.

Selection and Training of Users

Individuals varying a wide range regarding their abilities, which is a determining factor in product related safety. That the target users, (e.g. consumers, operators, personnel) have satisfactory abilities to use products properly, is of great importance to diminish accident probability. The skills required for users should be specified in that respect.

When the product is developed for work- related purposes, user becomes “personnel” or “ operator “, which makes selection and training a more appropriate and effective factor in safety provision. Initially the personnel with prerequisite abilities can be selected. Combining task requirements as to personnel and features of the product, a training program can be developed. The technical documents such as instruction manuals and checklists can be utilized.

However, when the public use and “consumers” are of concern, selection and a continuous training is not feasible. Consumer research surveys would be effective to frame the potential user population and precautions to take to obtain a safer product. Marketing techniques, which serve to specify intended users and auxiliary documentation such as instructional manuals, play an important role.

Work Design and Supervision

Work related specifications, methods, environmental conditions, frequency and periods affect hazard potential as well. The product has to match the work design physically and technically, to ensure safety in use. Besides, work organization techniques (e.g. rotation) can be a preventive approach to minimize injuries. From a behavioral view, improper work design can induce desirability of intentional unsafe behaviors, and violations of procedures.

Supervision, the administrative control of personnel, provides means of ensuring the compliance to safety rules, and application of safe work methods.

In public, function - design, which can replace work-design as a term, is not sufficiently controllable as in work atmosphere. A product in market is always available to the consumers who can afford it. After sale - legal use phase also can not be controlled in a strict manner, since there is no standardization in behavior of the consumers except the public education level. The regulations function as substitute for work supervision where illegality in product use is involved. These safety deficiencies for public, accounts for a higher potential and broader range of product related hazards.

Warning Design

Designing the dangers out of a product, and protection of users for the remaining hazards are most effective safety principles. On the other hand, function, marketability and financial issues often make it infeasible to design a totally safe product, and warnings are needed to supplement precautions. The most widely accepted role of a warning is alerting users to the presence of hazard, and informing, reminding, educating and persuading are other major functions. Formerly explained methods can not be replaced by warnings totally to maximize safety, but they can rather be supplemented by appropriately and effectively designed warnings.

Hazard minimization steps and intervention strategies incurred by these steps are integrated in most common unsafe behavior scenarios. (Lehto and Salvendy 1995)

Table 1.1 Common Unsafe Behaviors and Intervention Strategies

<u>UNSAFE BEHAVIOUR</u>	<u>INTERVENTION STRATEGY</u>
<p><i>Routine behavior</i></p> <ul style="list-style-type: none"> • Hazard perception failure • Memory failure 	<p><i>Product design</i></p> <ul style="list-style-type: none"> • Hazard signals • Interruptive features <p><i>Warning design</i></p> <ul style="list-style-type: none"> • Interactive warnings, combining interruptive features of product (e.g. placing a sign on speed bumps) • Non- visual – selective warnings (e.g. auditory warnings triggered when person press wrong button) <p><i>Training</i></p> <ul style="list-style-type: none"> • Developing necessary skills to interpret hazards (e.g. a special odor can indicate a gas leak)
<p><i>Forgetting intended action</i></p>	<p><i>Work design</i></p> <ul style="list-style-type: none"> • Job aids (e.g. available checklists for confirmation of actions taken) <p><i>Product design</i></p> <ul style="list-style-type: none"> • Relevant responses to hazard signals (e.g. relevant vibrations caused by speed bumps) <p><i>Warnings</i></p> <ul style="list-style-type: none"> • Reminders that stimulate error recovery (e.g. seat belt buzzers)
<p><i>Activating incorrect script</i></p>	<p><i>Product design</i></p> <ul style="list-style-type: none"> • Eliminating design features that afford inappropriate responses

Table 1.1 Common Unsafe Behaviors and Intervention Strategies(Continued)

<u>UNSAFE BEHAVIOUR</u>	<u>INTERVENTION STRATEGY</u>
<p><i>Psycho-motor variability</i></p>	<p><i>Product design</i></p> <ul style="list-style-type: none"> • Increasing hazard signal strength • Adjusting error tolerance <p>(e.g. adequate separation between controls)</p> <p><i>Training</i></p> <ul style="list-style-type: none"> • Reducing response variability in skill development <p>(e.g. pilot training on simulator)</p> <p><i>Selection</i></p> <ul style="list-style-type: none"> • Ensuring ability adequacy <p>(e.g. driver tests)</p>
<p><i>Non – routine behavior</i></p>	<p><i>Training</i></p> <ul style="list-style-type: none"> • Teaching safety procedures <p>(e.g. Flight training programs)</p> <p><i>Work design</i></p> <ul style="list-style-type: none"> • Provision of written safety document <p><i>Warnings</i></p> <ul style="list-style-type: none"> • Instructional procedures <p>(e.g. instructional manuals or stepwise on – product procedures)</p>
<p><i>Intentional violation</i></p>	<p><i>Supervision</i></p> <ul style="list-style-type: none"> • Making sure that safety rules are followed by enforcement <p><i>Work design</i></p> <ul style="list-style-type: none"> • Reducing cost of compliance and eliminating benefits of non-compliance <p>(e.g. easily available protective equipment)</p> <p><i>Training</i></p> <ul style="list-style-type: none"> • Teaching in order to give a conscious about safety rules

I.4 OBJECTIVES OF WARNING DESIGN IN SAFETY CONCEPT

Basic purposes of warning design in safety can be delineated as follows
(Sanders and McCormick 1987):

- Informing the current and potential users who could be exposed to a hazard, of which they may not be aware, that is inherent in the use or reasonably foreseeable misuse of the product.
- Providing current and potential users with information regarding the likelihood and/or severity of injury from the use or reasonable misuse of the product.
- Informing current and potential users about how to reduce the likelihood and / or severity of injury.
- Remind current users of a danger at the time and place where the danger is most likely to be encountered.
- Ultimately, and most crucially, to alter the behavior by encouraging the user either not to engage in a particular act or to change the manner in which the act is performed.

II. STRUCTURAL OVERVIEW OF VISUAL WARNINGS AND LITERATURE SURVEY

II.1 DEFINITION AND CLASSIFICATION OF WARNINGS

II.1.1 DEFINITION

Virtually “a warning” can be described as anything that alerts one’s attention. (Rogers, Lamson and Rousseau 2000) Lehto and Miller delineate another definition, which differentiates warnings from other informative sources. (Lehto, 1992, Part 2)

“Warnings are specific stimuli which alert a user to a presence of a hazard thereby triggering the processing of additional information regarding the nature, probability and magnitude of the hazard. This additional information may be within the user’s memory or may be provided by other sources external to the user.”

Through the consideration that warnings should be adequately effective to create a change in behavior in order to hinder any potential accident or injury which user would be exposed to, Doris and Purswell (Lehto, 1992, Part 2): defined warning messages as:

“ ... a message intended to reduce the risk of personal or property damage by inducing certain patterns of behavior and discouraging or prohibiting certain other patterns of behavior. ”

Warnings are encountered whenever one should function in systems, ranging from the most casual and simplest to the most complicated and specific ones. The warnings should reach to users in their natural context, since without reaching to the target user, none of the objectives can be realized.

Warnings are classified in perceptual divisions in the literature. The selection of most effective type of warning is a key issue to achieve the goals of safety concept.

- Nature of hazard
- Environmental circumstances
- Work and workplace design
- Characteristics of the user
- Effectiveness potential

are leading factors in selection of the most appropriate and effective warning type.

II.1.2 VISUAL WARNINGS

Warning signals, on-product warning labels, verbal warning messages of all kinds and their combinations comprise the major visual warnings. Each of these types has different features with respect to the effect of their elements.

When warning activity requires being informative to the user, verbal material should be utilized. However, even without verbal text, pictorial signs may well suffice to communicate existing hazards. With the increasing attention to multi-culturalism and worldwide trade, pictorials have begun to be used in a wider range to convey important warning messages. At just a glance, suitably designed warnings are able to express lots of information not only to the occasional users, but also to those who cannot read a printed verbal message due to their visual problems, low-level verbal skills, or insufficient knowledge of the language used in warning text. Nevertheless as will be discussed in next chapters about warning effectiveness, conveying safety related information solely via pictorials brings by a certain risk of lack of understanding and misinterpretation, which also may lead to serious accidents and injuries.

II.1.3 AUDITORY WARNINGS

When visual warnings are not applicable or inadequate, particularly when the target users are moving around or can not attend visual displays with some reason, auditory warnings are more suitable to use. They are also useful in noisy environments and they have a particular merit of immediacy differing from visual warnings. Owing to these characteristics, auditory warnings have been found to produce higher levels of compliance, whereas their identification and recognition are more of a problem relative to visual warnings (Sanders and McCormick 1987).

- Diaphones
- Horn
- Siren
- Oscillator
- Chimes

are examples of commonly used auditory warnings. In the cases where simple responses are of mention, audio signal intensity and reaction time become two determining variables in effectiveness of auditory warnings. Researches have shown that, intensity levels of auditory warning devices have to be adjusted in accordance with the response requirements placed on the user. When different signals are to be used to represent different conditions, which require varying responses, each of the signals should be distinguishable. It would be beneficial to develop separate communication systems that are not used for other purposes than warning. Auditory warnings are also important to blind people to announce dangerous situations.

II.1.4 OLFACTORY WARNINGS

Odors are often depended to facilitate olfactory sense to give information about the objects that would not be noticeable otherwise. While nose is apparently very a sensitive instrument to detect the presence of odors, substance characteristics and individual capabilities also have effects on the level of olfactory sense. The number of different odors that can be identified depends on numerous variables such as type of odors or training level of user.

Olfactory devices have useful applications as warnings; the gas materials can be added specific, distinguishable odors that indicate the hazardous situation and startle the response for safety. Dangerous gas leakage, mine evacuation systems have proved to be smart instances of olfactory warnings. Olfactory warnings have the advantage of penetrating closed and ventilated areas, which might not be reached by other means economically.

Olfactory warnings as a unique form of risk communication, could be creatively integrated through particular situations, and can be strong supplements to other, more widespread warning forms (Sanders and McCormick 1987).

II.2 EFFECTIVENESS OF VISUAL WARNINGS AND INFLUENTIAL FACTORS

II.2.1 CONCEPTUALIZATION OF WARNING PROCESS

In general terms, warning process can be analyzed through three stages from the cognitive and behavioral standpoint.

Perception –

Visual warnings should be adequately distinctive to catch the attention of target user. Without being perceived, no warning would function properly to achieve safety objectives. Moreover, physical elements that make a warning sensed do not ensure that it was perceived through reading. As the attention is directed to the

warning cognitively, verbal and symbolic content is encoded; that is this external information is translated into some internal representation when verbal part is read and symbolic elements are processed. Sensing, (Sanders and McCormick 1987) noticing and encoding (Rogers, Lamson and Rousseau 2000) are other terms, which refer to this stage in the literature.

Comprehension and Memory

Being perceived, warning messages, has to be fully understood as intended by target viewers. Strong comprehension leads to correct learning of the safety information in warning. Misinterpretation of warning elements, especially symbols and pictorials as well as prose materials, can cause severe accidents or injuries. Warning design has to be understandable and easy - to - learn in this respect, to elicit correct actions against the dangers. Certain types of visual warnings do not entail to be remembered since they are faced at each operation. (e.g. traffic signs) However, in some cases warnings, or documents in which warnings are inserted are not available during operation or use of products. In such cases warnings should also address to memory of the viewer. Cognitive retention of safety information should be provided for later operations. In next section, relevant psychological literature on these terms is reviewed.

Compliance

The core aim of the warnings is to create a change in behavior of the user. Occurrence of first two stages does not ensure that warning will be heeded. More than physical features of warning itself, personal and external factors might become substantially influential in determining the compliance level of the user.

Another approach to warning process, by Lehto and Miller (Lehto, 1992, Part 2) has explored these three stages into a more detailed delineation :

1. Exposure to warning stimulus
2. Attention and active processing of the warning stimulus
3. Comprehension and agreement with the warning message
4. Retaining the message in the memory
5. Retrieval of the message at the time it is relevant
6. Deciding to respond consistently with the message
7. Performing the response
8. Adequacy of the response for preventing accidents

Literature survey made by this study strongly suggests that, former three stage model is concise , clear and sufficient in clarifying the warning process.

Warning Effectiveness Criteria

The ultimate measure of warning effectiveness is whether the user complies with the warning, that is; intended behavioral change attained on the target user, avoiding totally or diminishing the likelihood of the relevant hazard and probable injury.

However, the factors and design methods that consider other intermediate measures, perception and comprehension also reinforce this ultimate goal of warnings. These factors are elaborated through next sections about influential variables that affect warning performance and the experiment on F- 16 flight manuals.

II.2.2 PSYCHOLOGICAL BASIS FOR COMPREHENSION AND MEMORY

(Farr, 1987 ; Gordon, 1989)

II.2.2.1 LEARNING AND COMPREHENSION

While comprehension is the essence of verbal learning, recognition and recall address to memory of warnings, and retention capability of viewers. Cognitive structure and behavior of human is studied in psychology. Therefore, psychological connections of these processes should not be underrated, to obtain a thorough perspective on warning effectiveness.

Learning can be defined as the activity that is involved when new meanings for stimuli acquired or new responses developed, during which associations are formed between stimuli and other events. The acquisition of these new stimuli is related with these cognitive associations.

Learning can be observed and evaluated by the relatively permanent change in an organism's response potential that is resulted from prior experience or practices. Since the measurement of the associations is questionable, behavioral studies are carried out to indicate the response of associations.

The type of learning through reading and listening, the major cognitive process in academic setting is Verbal Learning, in which verbal symbols are linked together.

Verbal learning has been studied within cognitive ergonomics, including the instructions and warnings, due to the fact that human behavior heavily rely on language or verbal symbols. Language is not only a way of communication, but also a medium for thought processes. Verbal learning involves how concepts are learned, how meanings are derived from the text materials and how verbal symbols are represented in memory.

Comprehension, which refers fully understanding of materials, provides organizational coherence and integration of information mentally. Comprehension leads to stronger learning and augments memory and retrieval of retained information. It also strengthens retrieval of retained information by supplying necessary cues, helping to recognize the relationship of verbal items.

The factors that influence verbal learning:

- *PROCEDURAL FACTORS:*

Procedural factors pertain with how verbal materials are presented to a subject for learning.

a. Number of presentations

Practically, more opportunities one has to learn a set of materials, the better the learning performance is. Learning of verbal items increases as more learning trials occur.

b. Distribution of trials

Distributed practice has found to be superior on verbal learning rate to massed practice in wide variety of circumstances. 5 Learning trials spaced over 5 days would be more effective than 5 trials all occurring on the same day.

c. Organization of material presentation

The position, physical, functional features of the material influence verbal learning rate.

- *CHARACTERISTICS OF VERBAL MATERIALS*

a. Meaningfulness

The term meaningfulness has been defined in various ways. A word is found to be meaningful, if a subject can think of several word associations for that. In terms of word familiarity, words that occur with greater frequency in written or verbal

communication become more familiar and meaningful. Also, the degree to which a word elicits a clear mental picture in a subject, “imagery value” enhances meaningfulness level. Furthermore, pronounciability and containing letter strings with great frequency have been proposed to make a word more meaningful by some other researchers.

b. Similarity

The degree of similarity has robust effects on the verbal learning rates. The researchers have been concentrated on three types of similarities:

- Formal similarity ; which refers to the degree to which materials share the same letters (run – gun)
- Meaningful similarity ; which refers to the synonymy of the words (gun – pistol)
- Conceptual similarity ; which refers to the degree of belonging to the same concept (gun – knife)

- SUBJECT STRATEGIES

a. Coding: Transformation of verbal item

Coding involves learning a code for a given verbal item, rather than the item as it is presented. (e.g. the word ‘ psalm’ could be coded as ‘palms’, a more meaningful form) The coding strategy clearly brings verbal learning advantage to the subjects, facilitating learning process, unless the decoding of a transformed word is difficult.

b. Use of mental imagery

The use of mental pictures to match the verbal material in mind is a powerful strategy to employ during learning process, posed by ‘dual- coding’ theory of Paivio.

c. Natural Language Meditation

This strategy involves linking items together on the basis of common language associations used. (e.g. To learn to associate words ‘dog’ and ‘purr’ the word ‘cat’ can be placed between these words.)

II.2.2.2 MEMORY

Memory can be defined as the internal record or representation of some prior event or experience. However, this definition should not be misleading, it is proper to conceptualize memories as fabrications based on real events, more than exact replicas of the happenings.

Memory Trace is defined as the organic residual effect left by sensations or events, which are strong enough to register and to be cognitively processed. A set of related events or concurrent stimuli might result in a complex, multi – attribute, multi – layered trace.

MEMORY PROCESSES

a. Encoding

Encoding process is characterized as the set of operations performed on incoming stimuli to convert them to a usable format or code, in a similar way to information processes in computers. Additionally, encoding involves organizing the stimuli by relating them to other bits of information in memory.

b. Storage

Storage is the operation of placing and registering information into the memory system and maintaining it there for later use.

c. Retrieval

Retrieval involves the necessary operation for locating and calling up specific information from memory store. In order for successful remembering, a selective retrieval process must be posited, involving locating and contacting the target trace containing related and associated information.

II.2.2.3 RETENTION, RECALL, RECOGNITION

Retention is the capability to keep and remember information that has already been stored in memory, after a course of time.

The levels and amount of memory processing, and distinctiveness of the memory codes have been suggested to be influential on retention by related studies. Particularly distinctiveness of retained items enhances the retention level.

Recall and recognition; two retrieval test techniques are sound measures of retention, involving different retrieval processes.

Recall involves retrieval of something retained in memory by means of certain given cues, which are related with the target, without seeing it at the time of test.

Recognition, instead, involves selecting the retained items, which have been presented or learned before, amongst multiple distracter items, that is presented for the first time.

In both cases, items must be represented in memory. Generally accepted that under most circumstances it is easier to recognize an item that has been stored than to recall the same item.

FACTORS THAT INFLUENCE RETENTION:

a. Degree of original learning

There is an agreement that amount or level of initial learning is an important determinant verbal retention. It plausibly follows that, the trace decay can be diminished and delayed by overlearning, that is receiving learning trials beyond initial mastery point, and by enhanced learning. It should be posed that too much overlearning facilitate retention of a decreasing rate.

b. Task characteristics

Type, complexity, organization or cohesiveness of task is major characteristics that influence acquisition and retention. High cohesiveness, integration, learner – oriented organization would decrease the potential of decay and forgetting.

c. Retention Interval

Noise period, that is, interference of contextual occurrences makes contributions to trace – decay and forgetting processes.

d. Instruction Strategies and Learning Conditions

Numerous instructional design ingredients are involved in retention performance, such as:

- Learning mastery criteria
- Major pedagogical approaches such as computer assistance in instruction programs
- Teaching strategies
- Supplementary material that enriches instruction
- Exemplification and adequate explanation
- Using mnemonic aids and communication means to enhance retention(i.e. visual elements, signs)

Since retention of verbal materials is a desired process in educational grounds, design of text material is widely researched in order for specifying relatively effective components to attain strong retention. Varying physical manipulations, and degree and types of cognitive processes performed over text materials have been suggested to increase the number, distinctiveness and strength of pathways in memory, which facilitate strong retention. Paivio's dual -coding theory is also valid here. Besides learning, this theory asserts that, a verbal code combining with an imaginable code (e.g. a pictorial icon) lead to a better memory than either code alone, presumably via richer cognitive presentations they form which makes retention and retrieval of information easier.

e. Retrieval Conditions

Different measures of retention and memory; such as recall and recognition may yield different degrees of apparent retention. Appropriate evaluation techniques should be employed so that misleading results are evaded.

f. Individual Variability

Abilities and characteristics of individuals (e.g. age, background, and motivation) are directly related with cognitive acquisition and retention. Whether the demands of materials to be learned and retained could be met, depend largely on individual variability. Relatively higher, more intensive information processing demands would result in more retrievable traces and stronger retention.

II.2.2.4 RELATION BETWEEN LEARNING AND MEMORY

Memory and learning are closely related in such a way that learning triggers memory formation, and memories are formed upon what is learned. In this sense, memory can be accepted dependent on learning. On the other hand learning is also dependent on the memory since learning follows the associations of events which are separated in time, and those associations could not be formed unless representation of the events are retained in mind. If memory would not function as such, event would be viewed in isolation and to recognize the connections amongst the events would not be possible.

Thus it is suitable to claim that without learning, memory would have little to remember, and without memory, learning wouldn't occur.

Despite of this close relation, to equate the terms memory formation and learning is not correct. Pertinent surveys have evidence that although the learning factors often influence both memory and recall, content of memory and retrieval ease do not depend entirely on the factors present at the time of learning. It is strongly suggested in psychology literature that there are factors that affect learning but have little or no influence on remembering ability such as meaningfulness of verbal materials. Reciprocally, the different features as suggested by some studies can influence memory and memory content may be altered at the time of recall.

The philosophical differences in the study of learning and memory also pinpoints the relation in between. Given that the goal of research in psychology was to discover the lawful relationships between environmental events and on organism's behavior, the early researchers have attempted to find the variables that produces behavioral changes occurring in the organisms.

In parallel with the Darwinian perspective of early behaviorists, seeing mankind as the continuum of species, and having the idea that rules of learning should be similar in both animals and humans in many respects, animals have been frequently used as experimental subjects.

Memory researchers have focused on the internal cognitive processes that result in knowledge and how knowledge is structured, provided that cognition refers to act of knowing or acquiring knowledge, and while occurrences are concretely observable, the knowledge is not present in environment itself, instead is formed and stored within organism.

The study of memory includes, perception and retention processes as the part of memory formation and function mechanisms in mind.

Contrary to objective of learning research, cognitive psychologists study behavior not as itself, but as a tool for analyzing internal entities and processes. Moreover, vast majority of the cognitive researches has been carried out with human subjects, since humans are viewed different from other organisms, on the basis of their cognitive abilities, and absence of verbal behavior among non-human species.

Contemporary theories and studies of memory and learning are far more close than the early periods, emphasizing the close relation between two concepts, bringing about a brief conclusion that processes of learning and memory are inseparably linked, though interdependent in structure.

II.2.3 EVALUATION METHODS FOR VISUAL WARNING EFFECTIVENESS

(Lehto, 1992, Part 1)

There are numerous variables that influence the occurrence and depth of the warning processes, and warnings can be evaluated, via different methodologies which also shapes the common research approaches.

Reaction Time

Viewer reaction time is accepted as an evaluation measure especially warning signs, based on the assumption that symbol quickly reacted is more salient (attention demanding) than one that is reacted slowly. When quick reaction is an actual requirement of the task, reaction time becomes a valuable measure. However if it is not in the essence of the task, other measures can be preferred.

Legibility Distance

As recommended by certain safety standards, warning signs can be evaluated in terms of maximum distance at which subjects can recognize them. Evaluation can be made by means of either a computer software that consider factors such as sign luminance, contrast and visual angle, or direct measurement of distance between signs and subjects.

Eye Movements

The tracking of eye movements during the viewing of warnings has also been proposed as an evaluation method. This way, insight can be obtained about how much attention is devoted to specific elements of a warning. The parts of warnings which are hard to perceive, and the sequence in which those parts are visually traced can be pinpointed by this method.

Accuracy or Errors

Perceptual errors are commonly used to evaluate the elements of visual warnings, by developing confusion matrixes. In a confusion matrix, various stimuli are listed in the same order on the x and y axes, where x-axis will correspond to given stimuli and the y axis will correspond to user's responses. Correct responses, described by cells for which the presented signal and elicited response are the same, are tabulated as the diagonal line, while other cells correspond to confusions. This approach has also been used to document the confusions between automotive pictographs.

Recognition and Message Recall

Recognition and recall tests are applied to evaluate memory and retention of visual warnings in different forms.

Recognition tests, can be organized either by asking participants to provide responses to presented symbols and textual information included in visual warnings, or as matching test where applicable responses (e.g. meanings of symbols) are selected from a list. Evaluation of recognition is commonly used for symbolic elements in warnings. However, since symbol-text combinations are used in many types of warnings, manipulation of explicitly described textual warning information in recognition tests, strengthens the evaluation process.

The degree to which the messages within visual warnings are correctly recalled after viewing period provides an additional measure of warning performance. Consideration should rather be given to textual warning content, and the interval between viewing and test in recall test. This interval also indicates the course of memory that the target information is contained in cognition.

In recall tests, participants are asked to provide responses to open –ended questions about the message of warning. Semantic criteria such as target keywords, which reveal the occurrence of cognitive processing, can be used.

Experimental Settings and Field Observations

To evaluate ultimate effectiveness of warning, there is a strong need to analyze compliance yielded by warning, due to the hardships in predicting human behavior.

Behavioral evaluation methods widely involve experimental setups in which participants use a product, or carry out a process using other related material under simulated conditions. Real-time incidents indicated by the warnings may be inapplicable or too hazardous to set artificially. However under laboratory-type experimental conditions, simply the presence of an observer, or knowledge that an experiment is being performed may change the behavioral patterns of the participants. These two aspects should be balanced by either omitting the possible influences of experiment or conducting field studies when safety of participants is assured. Cases that involve warnings, which do not address fatal hazards, are good instances for field studies.

Furthermore, desired behavioral change may be inconsistent with prevalent behavioral patterns, which elicit a resistance against complying with warning procedures. (e.g. wearing seat belts)

Another fact is that the effectiveness of warnings is influenced by the context they are in. These considerations pose the utmost value of realistic behavioral observations and field studies.

II.2.4 VISUAL WARNING EFFECTIVENESS FACTORS

II.2.4.1 CLASSIFICATION OF EFFECTIVENESS FACTORS

The factors that play a role in effectiveness of a visual warning can be classified in two divisions:

- Warning-Centered Effectiveness Factors (WCEF); which are directly related with structural and functional features of warnings, and
- Human-Centered Effectiveness Factors (HCEF), which are related to personal characteristics of target viewers, who are likely to be exposed to these warnings.

The influences of these factors are studied through experimental researches, and as a result, majority of the consequent findings is yet empirical due to the diversity of human behavior.

Considering the scope and orientation of this study, warning process-wise factor elaboration and literature survey interpretations are confined in physical WCEF.

WARNING - CENTERED EFFECTIVENESS FACTORS (WCEF)

* PHYSICAL WCEF

-Signal Words

-Color Coding

-Symbology

-Arrangement of Warning (Size, Shape, and Conspicuousness)

-Typography of Text

* FUNCTIONAL WCEF

-Placement of Warning

- *Task interference level*
- *Danger avoidance potential*
- *Point of placement*
- *Surrounding environment*
- *Viewing time and frequency*
- *Attention taking potential*

-Selection of Unknown Hazards

-Standardization of Warning Presentation

-Interactivity with Viewer

(e.g. warning labels which has to be removed before using the product)

-Explicitness or Complexity of Warning Message

-Theme Variation for Particular Products

(e.g. using warning labels about drunken driving, harms of alcohol on pregnancy or on general health issues rotationally on alcoholic drinks)

-Cost of Compliance

(e.g. having to wear protection goggles that do not fit and give disturbance)

-Model Behavior

(e.g. showing users a video that demonstrates other people complying with a warning and wearing gloves)

-Credibility of Source

(e.g. Using "US Government Warning " phrasal as a signal heading on a cigarette warning label)

-Number of Warnings to Be Viewed by the User

HUMAN- CENTERED EFFECTIVENESS FACTORS (HCEF)

- Age
- Gender
- Educational Background
- Hazard Perception
(e.g. the degree that user perceives a product or process dangerous)
- Control Perception
(e.g. belief of having control over the risk pointed by the warning)
- Visual Ability
- Attention Level
- Comprehension Level
- Fatigue
- Working Memory
- Habituation due to Standardization
- Ability to Comply
(e.g. to afford a requisite safety device , physical disabilities that hinder heeding the warning procedure)
- Motivation

II.2.4.2 SIGNAL WORDS

Providing a signal word or word group at the top of a textual warning is recommended in warning design guidelines. (McCarthy, Ayres, Wood and Robinson 1995)

Signal words, which are used in warnings, have shown to affect noticeability phase of perception and comprehension as tools to convey message strength and signal level of hazard. It is considered that using this kind of terminology will minimize possible misperception of the significance of warned - against hazards. (Lehto, 1992, Part 2) ANSI (American National Standards Institute) guidelines(1998) describe the circumstances under which particular signal words should be used (Lehto, 1992, Part 1):

*“**DANGER**: Indicates an imminently hazardous situation, which if not avoided, will result in serious injury. This signal word is to be limited to the most extreme situations...*

***WARNING** : Indicates a potentially hazardous situation which, if not avoided could result in death or serious injury...*

***CAUTION** : Indicates a potential hazardous situation, which if not avoided, may result in minor or moderate injury. It may also be used to alert against unsafe practices.”*

To arouse a conscious about the hazard communicated by warnings, congruent signal words should be chosen . Familiarity with the risks associated with signal words may ease the comprehension of the warnings.

Data suggested by numerous studies on signal words are equivocal. The levels of hazard perceived by common signal words like “danger, warning or caution“ has found to be comparable and even indistinguishable by different studies. (Rogers, Lamson and Rousseau 2000 ; Hartley, 1981) Varying manipulations of signal words are also experimented in different settings, to observe the interaction between other variables such as color coding (Braun and Silver 1995) or warning source attribution. (Wogalter, Kalsher and Rashid 1999) However , general acceptance in literature is that the presence of a hazard – communicating signal word contributes to warning performance and specification.

II.2.4.3 COLOR CODING

Color has been cited to have certain effects on overall warning processes and warning performance. Associated meanings and perceived hazard levels are equivocal for different color codings in safety literature. However colorful warnings have been found to be more effective than black and white warnings in hazard communication. (Braun, Kline and Silver 1995 ; Adams and Edworthy 1995)

Red is typically accepted to convey the highest level of risk, although there is a contradiction about saliency when compared to black in print. The common foreign warning standards also support this claim including some other colors as presented below (Lehto, 1992, Part 2) ;

<u>Color</u>	<u>Associated meaning</u>
- Orange	Hazard
- Yellow	Caution
- Green	First aid
- Blue	Safety information source

In Turkish standard [TS 7248] “ Safety colors and safety signs” (1998) associated meanings of colors are identified as follows :

<u>Color</u>	<u>Associated meaning</u>
- Red	Stop, to stop, prohibition (Also used in fire fighting equipment)
- Blue	Obligatory action
- Yellow	Warning, danger risk
- Green	Safe situation

However these tabulated meanings are not thoroughly parallel with widely accepted findings. Use of color in warnings is evidently found to enhance perception, by drawing attention and cognitive encoding (Rogers, Lamson and Rousseau 2000). Nevertheless, due to the higher contrast of black on the white background, signal words are suggested to be colorful while other textual parts remain in black print, to increase effectiveness.

Hazard perception, which makes understanding the associated risk level of warning easier has been found to be influenced positively by color. The effect of color on compliance has been suggested to be significant as well (Rogers, Lamson and Rousseau 2000).

II.2.4.4 SYMBOLOGY

The use of symbology has been cited to reinforce warning performance. In psychology, symbols are accepted to increase the memorability of items viewed by people.

Substantial amount of research have been conducted on the symbols and pictorials which are used in warnings to attract user attention, to provide a stronger perception, comprehension and subsequently compliance.

Pictorials refer to pictures that represent the concept of interest, (e.g. picture of a fire extinguisher) and symbols are more abstract representations of concepts, the meaning of which must be learned. (Rogers, Lamson and Rousseau 2000) (e.g. the use of a flame symbol to denote fire danger)

Relevant ANSI standard for symbols (1998) combines these two in definition of a symbol (Rogers, Lamson and Rousseau 2000) :

“ a configuration consisting of an image... which conveys a message without the use of words. As used in this standard, the word ‘symbol’ includes graphic art, such as pictograms, pictorials and glyphs “

In Turkish Standard 2856 (January 1989) “ General principles for the creation of graphical symbols for use on electrical equipment “, graphical symbol is defined as ;

“ the representation which is perceived visually and used to convey an information to users, independent of any language.”

Perception of the presence of a warning with pictorials has been shown to be quicker than the warnings without pictorials. Furthermore, the combination of pictorials with other warning factors (e.g.color coding, conspicuousness) has been suggested to make contributions to warning effectiveness. (Young and Wogalter 1990)

Pictorials might be especially important to communicate safety related information to those who can not read the language used, or who are illiterate. When legibility is a main concern, viewing distances are long, message intended to be conveyed by pictorial is simple, not integrating multiple messages, clear from unnecessary visual clutter, and concrete enough to retain viewer spending longtime studying it, pictorials are better than prose material.

Particularly in European market, along with the internationalization and uniting of countries, tools like safety pictorials, that can cross language barrier, attract great interest owing to their capability to remove the need to explain all consumer information or safety messages in thirteen languages. (Davies, Haines, Norris and Wilson 1998)

The findings about comprehension of symbolic representations is inconsistent and majority has found to be dependent on HCEF such as age, population segment or education level. In contrast with prose material, which requires reading and cognitive processing, an appropriate symbol is expected make the meaning of the warning implicit, obvious and immediate. Thus the comprehensibility of pictorials to be used have to be tested. ANSI Z535.3 provides relevant comprehension criteria for symbols : (Lehto , 1992, Part 1)

- 1.Obtaining a representative target audience of at least 50 people, which includes subgroups with a unique problem.
2. Evaluating the meaning that the test audience associates with the symbol. A minimum of 85% correct responses and a maximum of 5% critical confusions (opposite of correct) are required before a symbol is deemed acceptable. (Correct response rate for acceptance is 67% in ISO 3664)

Contextual elements are questionable in assisting the comprehension and memory of meanings of concise warning signs with symbols or pictorials. Plausible distracters that exist in the natural context of the warnings are worth studying to draw realistic conclusions about the expressive strength of the warnings.(Wolff and Wogalter 1998)

II.2.4.5 ARRANGEMENT OF WARNING : (SIZE, SHAPE AND CONSPICUOUSNESS)

Arrangement of warnings has been found to have effects on perception rather than comprehension and compliance. Size, shape and conspicuity of warnings mostly function to grab attention of viewers.

Some studies have shown that increase on the size of warning enhances its noticeability. However, size is often limited by the available space in most of the environments, such as on-product warnings. (e.g. drug bottle labels) If possible, warnings should be large enough to avoid crowding of components, in order to provide legibility of warning messages. (Lehto , 1992, Part 1)

In this respect shape of warning is a more functional variable that should be studied to analyze the possible gains in attention. Wide variety of shapes has been examined by conducted experiments and equilateral triangle was found to be the most likely to attract attention. (e.g. traffic signs) It is followed by diamond, hexagon or octagon shapes. Pointed shapes have been suggested to be more effective than circles or rectangular shape, which is, oriented parallel to ground. (Lehto, 1992, Part 2) If the use of a warning shape has initially been standardized, habituation can take place after a certain course of time, which alleviates the effectiveness of warning.

Relatedly, but less studied, orientation in which warning is presented might influence its noticeability. Horizontally printed on-product warnings have been found to be more noticeable compared with vertically printed warnings.

Conspicuousness can be defined as the degree to which warnings are distinguished, involving arrangement, print style and surrounding context. It has been suggested that reduction on surrounding information load enhance noticeability of visual warnings.

Combination of color and highlighting technique that is used to make warning messages more conspicuous has been suggested to strengthen perception, memory and comprehension of warnings. (Rogers, Lamson and Rousseau 2000 ; Young and Wogalter 1995)

Another type of warning arrangement elements ; borders, which are used to surround warning content have been found to contribute to conspicuousness. When applied in combination with other physical features, border has been found to reduce the time required noticing and locating the visual warnings. (Adams and Edworthy 1995)

Brightness contrast, which influence conspicuousness, should be at least 50 % between text and background to make a warning sufficiently noticeable. If color is used as well, the influence of contrast in legibility and noticeability should not be underestimated.

During warning design process, potential adverse effects of viewing environment ; such as presence of dirt, grease, smoke, haze or other contaminants has to be analyzed to ensure accuracy of arrangement, and resistance to degradation and environmental wear.

Warnings should be replaced if possible when they are damaged. The quality of warning material, which determines the physical aging rate of a warning, should be maintained. Visual warnings should not be allowed to become abraded during normal use. Particularly for on- product or on-equipment(apparatus) warnings damage threatens the presentation of safety procedures to user.

II.2.4.6 TYPOGRAPHY OF TEXT

Typographic features such as font size, text height, contrast, capital letter use have been suggested to influence perceptual performance of visual warnings.

Primarily, physical properties of text material should maintain legibility, to make perception efficient. If target population is identified, HCEF , especially age and visual ability should also be analyzed. Given adequate illumination, visual angle has been suggested to affect legibility. (Lehto, 1992, Part 1) A strokewidth to height ratio of 1:8 has been recommended for achromatic script, and contrast between text and background also influence legibility extensively.

There is no clear experimental result on selection of type style and font size in warning literature. Variety of currently used word processor softwares, complicates the research methodologies in that same fonts can be rendered differently by different softwares. The results of present surveys have suggested that narrower types might be more difficult to perceive, and that font size of text might affect warning effectiveness and compliance. (Rogers, Lamson and Rousseau 2000 ; Adams and Edworthy 1995)

Another typographic variable ; length of warning message text, has been linked to the likelihood that the warning will be thoroughly read. Present data suggests that longer text would increase this likelihood due to a common assumption that length of warning message is directly proportional to the level of associated hazard.

In some design guidelines, certain typographic recommendations are found :
(Lehto , 1992, Part 1)

- Where legibility is of primary concern , text characters should be sans serif(e.g. Arial) for short messages and serif fonts for lengthy prose material.
- Text characters should be dark against a light background
- Width to height ratio of the characters should be between 1:1 to 1:3.5 .



III. INSTRUCTION MANUALS AND MANUAL WARNINGS

III.1 INSTRUCTION MANUALS

Instruction manuals are technical documents that present necessary information to the target users on structural, operational procedures and potential hazards, introduced by a product.

Most products are accompanied by instructional operator or user manuals that describe their assembly, operation and maintenance, including safety information concerning the precautions that should be taken while installing, using and storing the product. (Wogalter, Vigilante and Baneth 1998)

Especially for complicated, hi – tec systems designing a product with all of its features and potential hazards kept apparent to the user is not often possible. Thus, manufacturer is obliged to supply relevant technical documentation to users. This obligation has made manuals a broad research field in technical writing literature, involving various issues such as manual effectiveness, user friendliness, technical communication, product liability and technical writer's safety responsibility. Instructions in the manuals should provide information for specific procedures such as; product shipment, installation, prestartup conditioning, startup, operation, shutdown, maintenance and troubleshooting in an adequately manner, considering experience, training and skill of a reasonable potential user.

Based on this premise, instructions in manuals must be ;

- “ - *Factually correct*
- Complete in scope*
- Clear , concise and easily read* “

(Conrads, 1987)

There are numerous factors that influence the manual dexterity :

(Gleason and Wackerman 1984)

Organization

Organizational structure should be very apparent to the user, a well – organized manual has a complete index, section set off by tabs, and a table of contents. The information should be sectioned according to the common performed task or the ways people use of the product. The sections should be broken into elements that are same for each section(e.g. preview , a system overview ,the main content , practice exercises and review) Structural format enable user to locate the information they search for and they can skip sections they are sure to know.

Content

The material should focus on operator task, contain practice exercises, provide clear illustration and be concise. “ Illustration” technique (which is a contraction of words “illustration” and “instruction”), referring to step wisely illustrated instructions can be employed to enhance communication effectiveness of manual content. (Conrads, 1987)

Language

The textual material should be conversational, and easy to read, geared toward secondary – school education level. The involvement of jargon and term variety for the same concept should be avoided in technical documentation and simple terms should be preferred in a consistent manner.

To ensure manual effectiveness, hazard communication and usefulness, along with the structural design methodologies, technical writers should strongly take into consideration certain HCEF:

* Specific factors of human performance

- Individual differences
- Motor skills
- Attention
- Perception
- Comprehension
- Learning
- Memory

- Motivation
- Context and Adaptation
- Fatigue
- Stress

*Prediction and Modification of Behavior

* Individual Characteristics

III.2 INSTRUCTION MANUAL WARNINGS

Instruction manuals have a crucial function of presenting essential safety information to users as a responsibility that should be beard by both manufacturers and technical writers. It may often be impractical to display warnings on the product itself because of either size limitations and/or number of required warnings. Therefore users are directed to the warnings in manuals. The purpose of manual warnings is to communicate the nature of potential hazards associated with the product and procedures for using the equipment so that accidents and injuries could be avoided.

From the product liability standpoint ; when a product is dangerous , this fact is or should be known by the manufacturer or seller, and if the danger involved is not the one, which is obvious, known or readily discoverable by the user, warning provision becomes a seriously essential duty. Inadequacy of warnings is an indication of defectiveness of a product.

Besides, increasing reliability of the product through increased attention to maintenance and perception of manufacturer company as oriented toward user safety are secondary benefits of supplying adequate warnings to users. Manuals, which are currently in use, should be continuously updated by automated delivery systems whenever new safety concerns have surfaced.

"Manual warnings" is a specific subtopic in visual warning literature. While most of the WCEF (such as placement, procedural explicitness, Frantz, 1994) and HCEF (such as familiarity, Wogalter, Barlow and Murphy 1995) remain valid for instruction manual warnings, being embedded within instructions and functional variations in manual use bring some specifications for manual warnings.

Researches suggest that relying solely on warning design guidelines, dealing with WCEF and standards that do not consider user's cognitive and behavioral

activities during product use can not be expected to yield maximum warning effectiveness. Primarily the conscious of users toward manuals is a determining point in warning effectiveness. When not consulted, not only the safety information but also the procedures would not be read, nullifying any prospective benefit. Thus, it is of great importance to consider the nature of interaction between the product, user and product information.

Because users may not always have the available manuals while they operate hazardous products, memory and retention becomes two important concerns in effectiveness of instruction manual warnings. Manual warnings should be designed not only to facilitate comprehension of the safety information for the first time that user operates the product, but also to enhance memory of safety information in warnings for later uses. Provided that stronger memories would lead to a stronger long term retention, the improvements in memory of warning messages enable user retain and retrieve these messages whenever they are needed.

To improve the noticeability and to increase the likelihood that the warning will be read by means of modifications on physical features is a proper approach to reinforce memory of hazard messages. This process involves making warning text more conspicuous than other text material in the surrounding context. Certain features such as, highlighting, pictorial use and color coding have been studied and suggested to be influential on comprehension and memory of instruction manual warnings. (Young and Wogalter 1990)

As previously mentioned in II.2.2.2 memory, enhancement on memory, obtained by pairing pictorial icons with verbal material has theoretical support in human memory literature by Pavio's dual – code theory.

In warning literature, the studies that analyze sole effects of those elements; color, conspicuous print and pictorial icons are very sparse and there exist no such research elaborating the main effects and interactions of all those three factors, hence this step is often mentioned in the literature as a futurework.

The experiment on effectiveness of F- 16 flight manual warnings has been designed and performed to fill that gap and to carry current studies and findings further in a global scope.

IV. EXPERIMENT ON EFFECTIVENESS OF F- 16 FLIGHT MANUAL WARNINGS

IV.1 OBJECTIVE OF EXPERIMENT

Objective

To examine the influence of color coding, pictorial icon and border use on the comprehension, recognition, and recall of F – 16 flight manual warnings.

IV.2 BACKGROUND ON F- 16 FLIGHT MANUALS AND MANUAL WARNINGS

Structure and Function of F – 16 Flight Manuals and Manual Warnings

Flight manuals are fundamental technical documents that form the basis of pilot training.

Flight manuals contain necessary information and illustrations for safe and efficient operation of the aircraft. The instructions in the manual provide a general knowledge of the aircraft, its characteristic and specific, normal and emergency procedures, best possible ways of actions under most conditions. Pilot experience is recognized, therefore basic flight principles are avoided, still the instructions are prepared to be understandable to the least experienced pilot who can be expected to operate the aircraft.

Contents of F- 16 flight manual is as follows:

- Description and Operation
- Normal Procedures
- Emergency Procedures
- Crew Duties
- Operating Limitations
- Flight Characteristics
- Adverse Weather Operations
- Glossary
- Performance Data

The operating procedures and safety information is constantly updated and all changes are promptly forwarded as supplements.

Warnings are found in three degrees in the manual:

Warning: Operating procedures, techniques etc., which could result in personal injury or loss of life if not carefully followed.

Caution: Operating procedures, techniques etc., which could result in damage to material if not carefully followed.

Note : An operating procedure, technique etc., which is considered essential to emphasize.

Some words in the manual are used to indicate different requirements:

Shall or *Will* is used to indicate a mandatory requirement.

Should is used to indicate a nonmandatory desired or preferred method of accomplishment.

May is used to indicate an acceptable or suggested means of accomplishment.

As desired allows pilot reference in switch / control positioning.

As required indicates those actions which vary based on mission requirements.

During flight, pilots have to overcome any technical problem or emergency within such a short time interval that there is even no time to “think about” what to do. Key issue in the flight safety is the reaction time of pilots in emergency situations.

Pilots must have such a concrete training that they could react almost “automatically” when a problem is faced. Thus, pilots are obliged to have an excellent command of technical information in checklists, manuals, and manual warnings to maintain flight safety.

Certain cognitive processes, which were previously presented, should be improved within pilot training programs with regard to flight safety information in technical documents:

- **Comprehension**

Contents of manuals and manual warning messages have to be comprehended and subsequently learned by pilots in operation level.

- **Memory and retention**

Specific information, mostly safety related issues those displayed in warning messages have to be encoded and stored in pilot’s cognition. This memorized information should be retained in long term and “immediately” retrieved whenever needed. (e.g. emergency situations) Recognition and recall tests address to memory and retention of information in manuals.

- **Compliance**

In common with requirements of general safety concept, ultimate aim of safety information and warnings is to yield compliance of pilots with the necessary procedures. Absolute compliance is a vital side of military jet pilotage, since enormous speed of aircraft never tolerates any “second”, which is lost due to hesitation, or consideration phase.

Comprehension, memory and retention of flight manual warnings were explored in terms of certain physical WCEF, yet compliance is beyond the scope of this study.

IV.3 SUBJECTS

56 Turkish Air Force Academy (TAFA) first year cadets participated in the experiment as a survey assignment. (Mean age: 19.08 SD: 0.69 / 53 males , 3 females) The selection of participant group involved certain experimental concerns:

- Cadets from same class were selected to obtain highest homogeneity in terms of age, academic, military and pilotage background.
- First year cadets were preferred since they follow a single curriculum and they have minimum “prior knowledge” about pilotage, compared to superior classes. *
- All participant cadets have English level of minimum 70 (out of 100) ECL (English Comprehension Level – official English examination prepared by United States Air Forces) grades. F –16 flight manuals are originally English and so they are studied by pilots. Therefore English level is an important factor addressing to the homogeneity of participant group and experimental efficiency.

Experiment groups with 7 subjects are formed randomly amongst these 56 cadets.

IV.4 EXPERIMENTAL DESIGN

IV.4.1 VARIABLES

Main effects and interactions of three fixed factors;

- Color coding
- Pictorial icon use
- Border use

On the effectiveness F – 16 flight manual warnings have been explored in 2*2*2 setting by 8*7 subject groups.

Independent variables: Presence and absence of each effectiveness factor

Dependent variable : Scaled scores of comprehension, recognition, recall tests

* All cadets have to succeed in a T – 41 Cessna flight training camp after high school graduation to be able to attend to TAFA. During academy years, the flight training continues increasing their pilotage experience. Besides, certain lectures on avionics and aeronautics are included in curricula. These facts contribute to “ prior flight knowledge” of superior cadets.

Table IV.1 Experimental Design

	Red Signal Word		Black(Achromatic) Signal Word	
	Icon Present	Icon Absent	Icon Present	Icon Absent
Border Present	Group 1	Group 3	Group 5	Group 7
Border Absent	Group 2	Group 4	Group 6	Group 8

IV.4.2 MODEL

X_{djk} = Scaled comprehension / recognition / recall test scores of participants with d^{th} level of factor A (color coding), j^{th} level of factor B (icon use), k^{th} level of factor C (border use)

Factor A : Color coding $d=1$ (black “achromatic” signal word), 2 (red signal word)
 Factor B : Icon Use $j=1$ (icon absent design), 2 (icon present design)
 Factor C : Border Use $k=1$ (border absent design), 2 (border present design)

$$X_{djk} = \mu_{djk} + \epsilon_{djk} \quad (IV.1)$$

$$X_{djk} = \mu + A_d + B_j + C_k + AB_{dj} + AC_{dk} + BC_{jk} + ABC_{djk} + \epsilon_{djk} \quad (IV.2)$$

μ ; The true grand mean

A_d ; The effect of color coding at level d

B_j ; The effect of icon use at level j

C_k ; The effect of border use at level k

$(AB)_{dj}$; The interaction between color coding at level d and icon use at level j over levels of border use

$(AC)_{dk}$; The interaction between color coding at level d and border use at level k over levels of icon use

(BC)_{jk}; The interaction between icon use at level j and border use at level k over levels of color coding

(ABC)_{djk}; The interaction between color coding at level d, icon use at level j and border use at level k

ϵ_{djk} = Random error component

* All ϵ_{djk} 's are assumed independent, normally distributed with mean 0 and variance σ^2 .

* Experimental unit is 'points' for scaled test scores of participants.

IV.5 MATERIAL

IV.5.1 MANUAL TEXT BOOKLET

(See Appendix 1)

Prior to selection of manual part to use in experiment, F -16 Flight manual was scrutinized in search of a subtopic or a section that first year cadets would understand by their own, rather limited flight experience and related knowledge. This section shouldn't have been too complicated, unfamiliar or specific technically, and should have included adequate number of warning messages.

A section on landing, after landing and engine shut down procedures was selected and rewritten in Microsoft Word with 11 point Times New Roman Tur font type, and same font boldfaced signal words, in harmony with original manual script. The borders around the signal words in "Warning" and "Caution" messages are excluded to be able to apply tested factors in script of warning messages.

Manipulations of Effectiveness Factors(see Appendix 2)

- Color Coding

In parallel with fatality in the meaning of warning messages and literature knowledge, red is considered suitable for experiment. In color – present booklets, the "WARNING" signal words were printed in red, whereas black in achromatic (colorless) booklets.

- Pictorial Use

The pictorial icon of black “skull and cross-bones” was chosen amongst numerous alternatives to convey fatality indicated by warning messages. This icon is recommended to use for “fatal poison risk” In Turkish standard 7248 on safety colors and safety signs, and for “toxic gases” in Turkish standard 10999 on pictorial warning labels –dangerous goods, in air transport. Warning signal words were accompanied by this pictorial in icon-present booklets, and no icon is used in others.

- Border Use

A black print, single line, shaded 1,5 nk border was used around all warning message to attain conspicuousness for half of the material, complying with the experimental design principles, and print was clear of borders otherwise.

Followingly, a 9 - pages experiment booklet is designed in coordination with experienced F- 16 pilots. The contents of the booklet:

- 4 pages of manual text
- 1 page landing pattern figure which is inserted between 2nd and 3rd pages of text as in the original version of manual
- 2 pages of vocabulary section for potentially unfamiliar words and technical abbreviations
- 2 pages of technical aircraft figures, which are included to assist participants visualize the aircraft and parts mentioned in text

The text included 7 warning messages from which test questions were produced.

IV.5.2 TEST BOOKLET

(See Appendix - 3)

Each of the comprehension, recognition and recall tests contained four questions. Questions were distributed over all 7 warnings to the extent possible. At least one question and due to the length and content of warning, a second question was produced from each warning message, for different tested process.

In comprehension test, participants were asked paraphrase type, multiple-choice information questions about the content of the messages.

In recognition test, a sentence from a warning message was presented to participants among different sentences from other parts of the text, in a multiple choice question format. It was asked to find the sentence from the warning messages.

Recall test was designed by "Fill in the blanks" type questions. Participants were asked to recall specific information (e.g. speed limits) included in warning messages.

To ensure that tests would measure real comprehension, recognition and recall of the participants, a confidence part is added to all questions. The participants were asked to mark one of three options below, according to their confidence in each of the answers:

- Very sure of the answer
- Fairly sure of the answer
- Guessed the answer

The function of confidence part is explained in 4.7 Scoring section.

IV.6 PROCEDURE

In order to detect unforeseen flaws of material and measure the necessary text study time in advance, trial experiments were conducted with 2 officers and a civilian education consultant whose English levels were satisfactory.

No problem was faced in material and 1 hour was found to be long enough to study all text booklet.

The groups were formed on the list of participants randomly. Test booklets were randomized as well to omit any possible effect of experiment material. The order of questions within each of the factor tests and order between factor tests were randomized. It was assured that all members in a group were given different type of test booklets.

The aim and subject of the experiment was not announced to participants to prevent prior cognitive readiness. They are told that they would participate in an R & D study.

The participants were gathered in two adjacent classrooms. To give motivation and to conceal warning focus of the experiment, it was told before the study started that, some problems which increase flight accident rate and threaten the

life of pilots had been encountered in landing and after landing procedures of F- 16 Fighting Falcon aircraft, and this study was a part of an ongoing flight safety project.

Followingly they were given one of eight types manual text booklets with regard to their groups, as arranged beforehand. It was told that all booklets were somewhat different from each other with respect to their content.

They were instructed to study these booklets as if they had been F – 16 pilots themselves and no other supplementary source (e.g. dictionary) was allowed. It was also told that an evaluation would have been made only on the content of manual text part subsequently, so that misinterpretations such as allocating time and effort to memorize vocabulary or parts of aircraft could have been prevented. It was explained that all parts of booklets other than manual text were included to help them understand procedures better, but no additional detail was given about the evaluation method.

After one hour to study, manual text booklets were handed back, and test booklets were given to participants. A short explanation was made about question types and how to mark confidence part. Twenty minutes were given for the test.

Finally, test booklets were taken back and experiment ended.

IV.7 SCORING

To reach more realistic results, a confidence scaling method, which is commonly used in warning research literature(Young and Wogalter 1995), was applied to raw test scores of participants. When a participant was sure of his answer and his answer was correct, he was accepted to have the highest degree of comprehension / recognition / recall processes, or vice versa. The scaling points are shown below:

ANSWER	CONFIDENCE	POINT
False	Very sure of the answer	1
	Fairly sure of answer	2
	Guessed the answer	3
Correct	Guessed the answer	4
	Fairly sure of answer	5
	Very sure of the answer	6

Firstly scaled points of all 4 questions in a process test were summed. Given that each question was on a single warning, mean comprehension / recognition / recall point per warning was calculated by dividing total scaled points by 4. This was the valid measure for the study since it was warning effectiveness performance that had been aimed to be measured.

A scoring example is shown below.

Table IV.2 Scaled Scores of a Participant

	Very Sure	Fairly Sure	Guessed	Points
Question 1	Correct			6
Question 2		False		2
Question 3			False	3
Question 4		Correct		5
			Total	16

Mean test score (comprehension/ recognition/recall) of participant = $16 / 4 = \underline{4}$

IV.8 STATISTICAL ANALYSIS AND RESULTS

Statistical analysis on data was carried out by SPSS software.

IV.8.1 COMPREHENSION

Table IV.3 Mean Comprehension Scores of Groups

	Red Signal Word		Black(Achromatic)Signal Word	
	Icon Present	Icon Absent	Icon Present	Icon Absent
Border Present	4,61	4,46	4,18	4,75
Border Absent	4,71	4,07	4,55	4,21

ANOVA performed (significance level of 5%) on the data revealed no significant main effects or interactions of color coding, icon and border use on the comprehension of warning messages. (Table IV.3) The spread of residuals was observed to be appropriate as presented on the residual plot. (Figure IV.1)

Table IV.4 ANOVA Table of Comprehension Scores

Dependent Variable: COMPRE

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Model	1108,187	8	138,523	137,450	,000
COLOR	2,790E-02	1	2,790E-02	,028	,869
ICON	,251	1	,251	,249	,620
BORDER	,189	1	,189	,187	,667
COLOR * ICON	,939	1	,939	,931	,339
COLOR * BORDER	1,004E-02	1	1,004E-02	,010	,921
ICON * BORDER	1,698	1	1,698	1,684	,201
COLOR * ICON * BORDER	,135	1	,135	,134	,716
Error	48,375	48	1,008		
Total	1156,563	56			

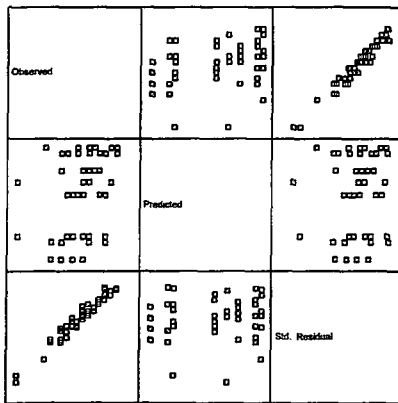


Figure IV.1 Residual Plot of ANOVA on Comprehension Scores

Trends on the means demonstrate that best performance was obtained in “black signal word/icon absent/border present”, and with a slight difference in “ red signal word/icon present / border absent” groups. Although not significant, red signal word was observed to decrease mean score when used without other factors. Increasing trend of “red signal word/icon present / border present” group supports the findings of Young and Wogalter, 1995.

IV.8.2 RECOGNITION

Table IV.5 Mean Recognition Scores of Groups

	Red Signal Word		Black (Achromatic) Signal Word	
	Icon Present	Icon Absent	Icon Present	Icon Absent
Border Present	4,14	3,5	3,82	4,00
Border Absent	4,25	3,21	3,60	3,71

ANOVA performed (significance level of 5%) on the data demonstrated that, effect of icon use ($p=0.029 < 0.05$) and interaction of color coding / icon use ($p=0.003 < 0.05$) is significant on the recognition of warning messages. (Table IV.6)

Table IV.6 ANOVA Table of Recognition Scores

Dependent Variable: RECOGN

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Model	806,527	8	100,816	301,774	,000
COLOR	1,116E-03	1	1,116E-03	,003	,954
ICON	1,698	1	1,698	5,081	,029
BORDER	,403	1	,403	1,206	,278
COLOR * ICON	3,376	1	3,376	10,106	,003
COLOR * BORDER	9,040E-02	1	9,040E-02	,271	,605
ICON * BORDER	,189	1	,189	,565	,456
COLOR * ICON * BORDER	9,040E-02	1	9,040E-02	,271	,605
Error	16,036	48	,334		
Total	822,563	56			

The plots of these significant effects are presented below in Figure IV.2 and IV.3.

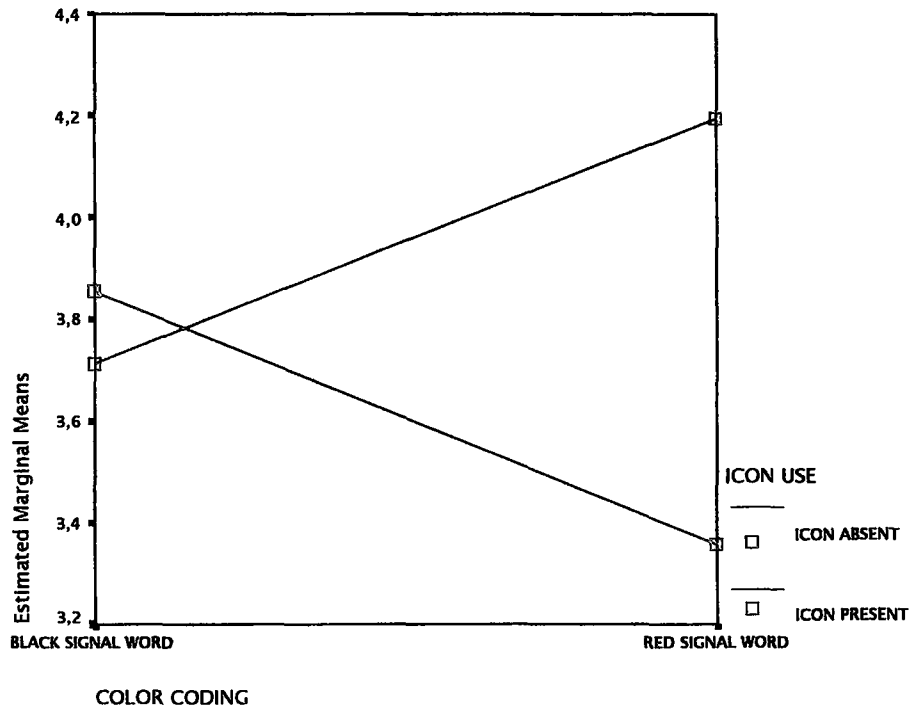


Figure IV.2. Profile Plot of Color Coding - Icon Use Interaction

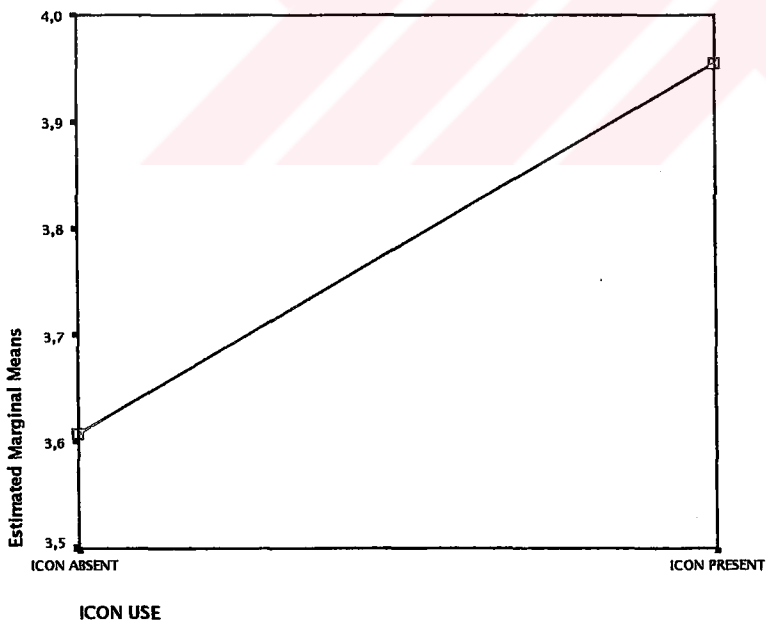


Figure IV.3. Profile Plot of Effect of Icon Use

Highest mean recognition test score is attained in “red signal word / icon present / border absent” group. Besides, increasing trend of red signal word / icon present / border present group relative to “black signal word / icon absent / border absent” (all – clear) group is parallel with mean comprehension scores.

Use of pictorial icon was found to augment the recognition of warning messages, providing easier retrieval of perceived warning messages. However T-test conducted to analyze the increase with regard to icons showed solely inserting a pictorial icon in design of warning messages did not yield a significant difference ($P=0.732 > 0.05$).

The spread of residuals was appropriate as shown on the residual plot. (Figure IV.4)

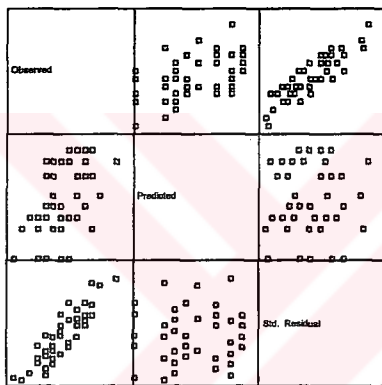


Figure IV.4 Residual Plot of ANOVA on Recognition Scores

Further T- tests were performed for these factors. Interestingly, sole application of red signal word, significantly reduced mean recognition scores ($p=0.027 < 0.05$), which is in parallel with general trend of comprehension scores.

Participants recognized warning messages best, when both red signal word and icon was present in the booklet. Increase in recognition was significant when scores of this group was compared to those of all – clear and “red signal word / icon absent / border absent” groups with ($p=0.027 < 0.05$) and ($p= 0.01 < 0.05$) respectively. Stronger significance of latter group could be attributed to reduction effect of color coding as mentioned before.

Though no significance was found, T –test value ($p= 0.056 > 0.05$) comparing performances of “black signal word / icon present / border absent” and “red signal word / icon present / border present” group supported that icon use was more effective when combined with color.

Observed trend of sole border use indicates an increase as well, relative to all – clear group, in consistency with comprehension results. This effect was also revealed by comparing “red signal word / icon absent / border absent” group with “red signal word / icon absent / border present” group.

Addition of border compensated the reducing effect of color and thus yielded higher recognition scores. When icon was inserted successively, this increase lingered on.



IV.8.3 RECALL

Table IV.7 Mean Recall Scores of Groups

	Red Signal Word		Black(Achromatic) Signal Word	
	Icon Present	Icon Absent	Icon Present	Icon Absent
Border Present	3,68	4,39	4,25	3,82
Border Absent	3,86	4,04	3,85	4,07

Table IV.8 ANOVA Table of Recall Scores

Dependent Variable: RECALL

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Model	896,795	8	112,099	157,596	,000
COLOR	1,116E-03	1	1,116E-03	,002	,969
ICON	,403	1	,403	,566	,455
BORDER	9,040E-02	1	9,040E-02	,127	,723
COLOR * ICON	1,073	1	1,073	1,508	,225
COLOR * BORDER	1,116E-03	1	1,116E-03	,002	,969
ICON * BORDER	1,004E-02	1	1,004E-02	,014	,906
COLOR * ICON * BORDER	1,215	1	1,215	1,709	,197
Error	34,143	48	,711		
Total	930,938	56			

ANOVA performed on data (sig. level of 5%) revealed that there was no significant difference on mean recall scores (Table IV.8) The residuals were spread properly as shown in Figure IV.5

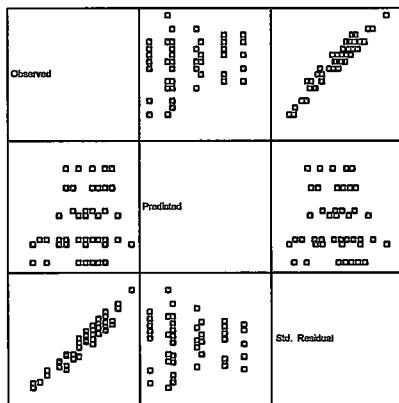


Figure IV.5 Residual Plot of ANOVA on Recall Scores

Results of recall test were in contradiction with comprehension and recognition test scores. The inclusion of all factors was found to produce lower mean than all – clear group. Highest mean score was attained in “red signal word / icon absent / border present” model.

Insertion of pictorial icons partly has a reductive effect on recall score, in contrast with consistent increase observed in both comprehension and recognition.

Recall tests were assessed to be inadequate to come to concrete conclusions.

V. CONCLUSIONS AND RECOMMENDATIONS

This thesis study sought to determine the influences of three physical WCEF, color coding, pictorial icon use and border use on effectiveness of F – 16 flight manual warnings.

Results of the conducted experiment demonstrated that solely icon use and interaction of color coding and icon use make warning messages more comprehensible and recognizable consistent with previously mentioned body of literature (Braun, Kline and Silver 1995 ; Adams and Edworthy 1995 ; Rogers, Lamson and Rousseau 2000 ; Young and Wogalter 1990)

Recognition is the initial phase of memory. Since memory is facilitated when a message is viewed amongst the distracters, retrieval of the correct message is easier relative to recall process. Hence, it can be claimed that significant increasing effect of icon use and color coding/icon use interaction on recognition addresses to memorability of warning messages. This positive effect is attributable to the richer cognitive representations produced by addition of these two factors.

Results of recall test does not show any trend. This makes interpretation less clear. Recall is the further step in memory concept, differing from recognition in profundity of cognitive processing, as mentioned in II.2.2 Psychological basis for comprehension and memory. Manual text booklet study and test steps had been conducted successively during the experiment. This pace might have alleviated the realization level of recall. If recall of participants were tested after a certain course of time (e.g. three days, a week, etc.), factorial effects could have been more apparent. With a similar approach, various results could have been obtained if the participants were directed to study manual text booklet for longer periods.

The increasing effect of border use on comprehension, referring to enhanced conspicuousness, can be utilized in visual warnings, in which memory is not a crucial concern and target users view warnings occasionally, such as warning labels or signs.

Presence of color and icon is apparently beneficial in both memory and understanding of warning messages. Enhancement in noticeability provided by red signal word and pictorial icon presumably drew the participants' attention towards warning messages. Color "red" and figure of "skull and cross- bones" probably arouse stronger hazard perception and orientated participants to study warning messages more carefully.

Role of icon use in enhancing comprehension and recognition is that it makes warning messages more distinguishable in substantially loaded context of manual. These findings about icon use is consistent with suggestions made by Young and Wogalter, 1990.

In Rogers, Lamson and Rousseau 2000, authors have presented a broad review of warning literature. Several researches mentioned in their review supports the positive contributions of pictorial icon use and color coding on noticeability, cognitive encoding and comprehension of warning messages. Consistency for pictorial icons can be mentioned in this study.

However, significant decrease in recognition scores, and same trend in comprehension with regard to sole application of color coding is inconsistent with a large body of warning research literature (Braun, Kline and Silver 1995 ; Fuller and Sulsky 1995 ; Braun and Silver 1995). Contrast between signal word and background has been considered to have potential influence on hazard perception in warning literature, however no plausible explanation could have been drawn, comparing achromatic and colorful signal words (Braun, Kline and Silver 1995).

Memory and retention of manual warnings is as important as understanding for F- 16 pilots. Thus, positive effect of icon use and color coding on memory deserves further consideration.

Design of today's F- 16 manuals can be made more effective by the addition of pictorial icons and colorful warning signal words to warn pilots.

Icon type in this study, skull and crossbones was chosen parallel to the fatality meaning in warning messages, as mentioned in IV.5 Material part. Effects of different pictorial icons should be studied so that maximum effectiveness can be produced on the target population of pilots.

Red was chosen to convey highest hazard, as suggested in warning literature and recommended in safety standards. Analogous to icons, different colors should be studied to reach higher comprehension and memory. Also, different combinations of

pictorial icons and color coding can be manipulated as well. (e.g. red icon-red signal word)

Suggestions above on icon use and color coding can be extended to “caution” and “note“ messages in flight manuals too, which demand greater attention and retention than information text, to achieve a more complete warning research. Variability in manipulated factors between these warring messages, which differ in meaning and communicated hazard level, can make contributions to cognitive differentiation and overall warning effectiveness.

Not to overly complicate experimental design and to manage to get clear results, scope of this study was confined in three majorly researched physical WCEF. However, influence of other physical WCEF such as signal word selection and typography, and interaction of those with icon use and color coding should be assessed.

Similar experiments can be conducted for various text study – test intervals , so that different terms of retention and recall of warning messages could be observed more clearly.

Hyper- text applications are also likely to contribute to immediate accesibility of these technical documents and perception of safety information.

It should not be underestimated that, particularly for flight manuals, there is an opportunity to specify actual target population, which are pilot officers in air force. Pilots are subjected to a very definitely standardized training program, beginning with Air Force Academy. This standardization creates common experience, influences mental structure and characteristics they have. Further researches can be framed for pilots, and carried beyond physical WCEF. Functional WCEF , and HCEF, which is not included in this study, can be precisely examined, and warning effectiveness can well be maximized with a wider view.

Involvement of prior knowledge is minimized in this study in order to avoid a confounding effect, and to observe sheer influence of manipulated physical WCEF. To attain more real – time results, this experiment can be designed for and performed with F –16 pilot candidate officers in their occasional squadron atmosphere.

Ergonomics of information presentation and organization in manuals should also be explored in a broader sense along with other functional WCEF and HCEF. Involvement of these factors can be more beneficial if messages are edited more explicitly, and user –friendly in technical terms.

The main goal of this study was to present concept of warnings, and visual warning design, which is almost intact in our national literature. Throughout the conducted experiment, a novel, more effective design for F – 16 flight manual warnings was researched. Findings and application potential of this study are worth noting and can be carried over to other avionics , and hi – tec weaponry systems to gather pace in ensuring the safety of users, which is one of the fundamental aims of ergonomics.



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APPENDICES

APPENDIX - 1 : F – 16 FLIGHT MANUAL TEXT BOOKLET



LANDING**NORMAL LANDING**

Refer to figure 2-3. Fly initial at 300 knots. At the break, retard throttle and open speedbrakes as required. On downwind leg, when airspeed is below 300 knots, lower the LG. During the base turn, recheck the LG down and slow to computed final approach airspeed / AOA on final at 11 or 13 degrees AOA. Check speedbrakes open and maintain computed final approach airspeed / AOA on final. Rate of descent decreases slightly when entering ground effect. Reduce thrust gradually to continue the descent while applying back stick to reduce sink rate to the minimum practical. Thrust can be reduced sooner during an 11-degree approach than during a 13-degree approach. In either case, maintain a maximum of 13 degrees AOA while reducing sink rate to the minimum practical.

WARNING

Insure that the LG handle is confirmed fully down. The LG handle can be in an intermediate position allowing LG extension and/or safe indications; however, the LG handle is not locked and LG retraction could occur during subsequent in-flight or ground operations.

CAUTION

- Failure to depress the LG handle down permission button prior to attempting to lower the LG may result in damage to the electrical solenoid.
- Failure to reduce sink rate, particularly at heavier GW's, may cause a firm landing and structural damage or failure of the LG.
- Use of the paddle switch may cause pitch and/or roll transients as control is switched from one to the other.
- Avoid landing directly on approach-end arresting cable to prevent possible cable strike damage to nozzle, speedbrakes, and ventral fins.

- Horizontal tail contact with the runway is possible if a large roll input is made at or near touchdown.

NOTE

- The HUD AOA bracket and AOA indicator display is correct AOA until NLG WOW. Therefore, these indications are valid references for aircraft attitude throughout two-point aerodynamic braking. After NLG WOW, the AOA indicator displays zero.
- The LG warning horn and the TO/LDG CONFIG warning light are inhibited at approach airspeed above 190(± 4) knots.
- Aft CG approaches may be characterized by increased pitch sensitivity which will be most noticeable upon entering ground effect.

Use two-point aerodynamic braking until approximately 100 knots ; then fly the nosewheel to runway. Maximum effective two-point aerodynamic braking is achieved at 13 degrees AOA. An AOA less than 11 degrees results in significantly reduced two-point aerodynamic braking. Although two-point aerodynamic braking is effective as low as 80 knots, runway length and condition should be used to determine when, after decelerating to 100 knots, to lower the nose to the three-point attitude.

CAUTION

- Do not touch down with brake pedals depressed. A failure in either the touchdown protection circuitry or an MLG WOW switch can result in locked wheels and blown MLG tires.
- Use a maximum of 13 degrees AOA for two-point aerodynamic braking. Nozzle, speedbrakes and ventral fins may contact runway if 15-degree pitch angle is exceeded.
- During two point aerodynamic braking, the speedbrakes (43 degrees or greater open) may contact the cable.

NOTE

Rapid roll inputs or turbulence during landing may cause the TO/LDG CONFIG warning light to blink.

After the nosewheel is on the runway, open the speedbrakes fully and maintain full aft stick for maximum three-point aerodynamic braking and wheel braking effectiveness.

CAUTION

- Crossing an arresting cable in a three-point attitude above 90 knots groundspeed with a centerline store may cause cable strike.
- Do not move SPD BRK switch to open until the nosewheel is on runway as speedbrakes may contact runway.
- Until WOW, forward stick pressure in excess of approximately 2 pounds results in full trailing edge down deflection of the horizontal tails. This horizontal tail deflection reduces wheel braking effectiveness. At high speeds in three-point attitude, forward stick results in excessive loads on the NLG which can lead to nose tire failure and possibly cause structural failure of the NLG.

Smoothly apply moderate to heavy braking to decelerate to taxi speed. Using less than moderate braking increases the likelihood of a hot brake(s). NWS should not be engaged above taxi speed unless required to prevent departure from prepared runway surface.

WARNING

NWS malfunctions at any speed may cause an abrupt turn, tire skidding or blowout, aircraft tipping, and/or departure from the prepared surface.

SHORT FIELD LANDING (DRY RUNWAY)**NOTE**

The following procedures should be used anytime stopping distance is critical, whether due to a long, fast, heavy weight, or short field landing.

When stopping distance is critical, a normal approach should be made. Select IDLE at or slightly before touchdown. Touch down as near as possible to the end of the runway at 13 degrees AOA. Two - point aerodynamic and wheel braking should be used with the nose held up at 13 degrees AOA until the nose falls. Pitch must be held at 13 degrees AOA if two-point aerodynamic braking is to be effective. Maximum effort braking is achieved by using the wheel brakes in conjunction with two-point aerodynamic braking. When the wheel brakes become effective, the nose automatically lowers. This occurs soon after brakes are applied. After the nose wheel is on the runway, maintain full aft stick, open the speedbrakes fully, and use maximum wheel braking (antiskid on)

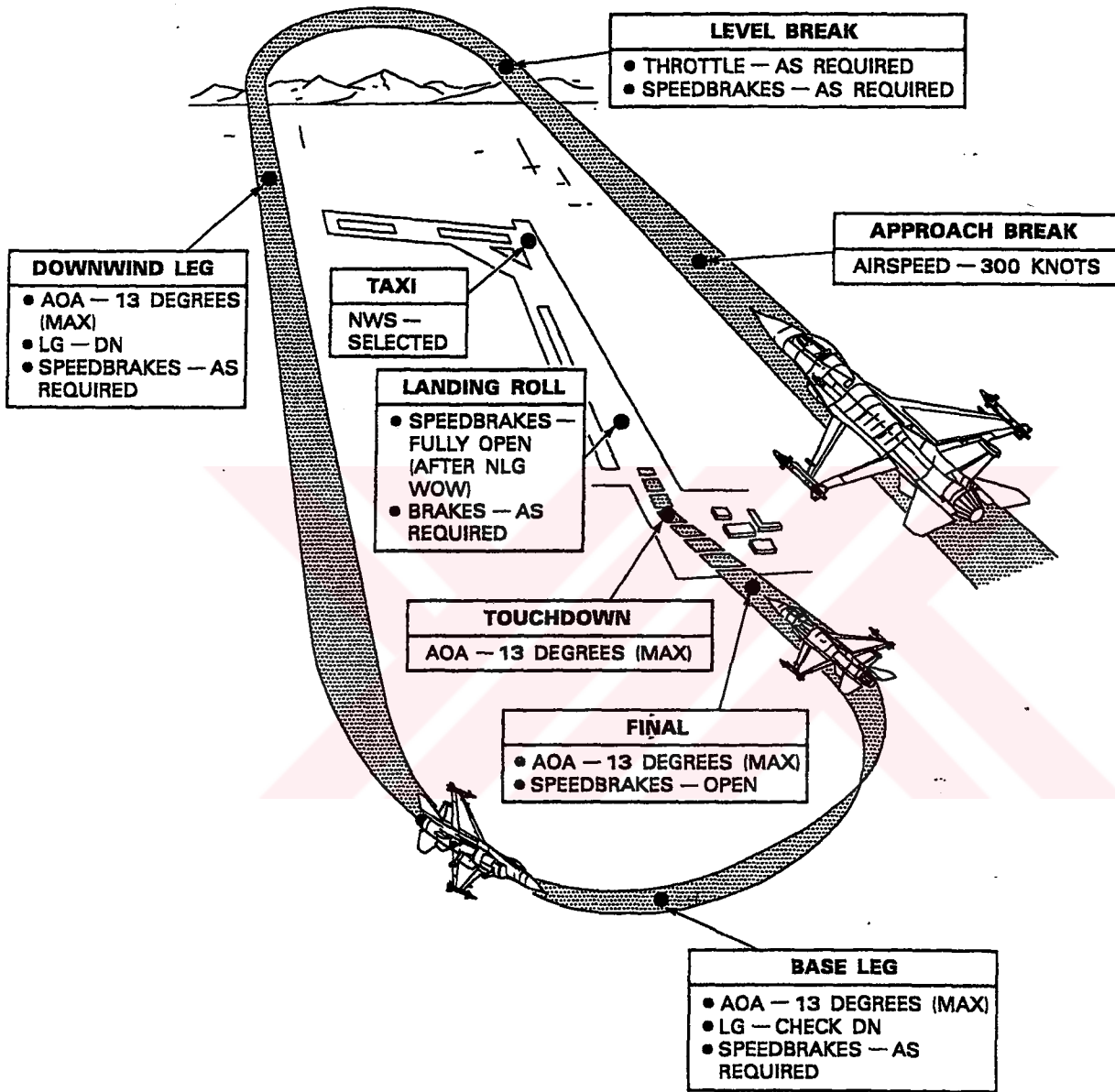
CROSSWIND LANDING

The recommended technique for landing in a crosswind is to use a wing level crab through touchdown. At touchdown, the ARI switches out. Undesirable yaw transients may occur if roll control is being applied at this time. After touchdown perform two point aerodynamic braking using the rudder to maintain aircraft track down the runway and flaperon to prevent wing rise. In crosswinds, the aircraft may drift downwind due to side loads imposed by the crosswinds or travel upwind due to insufficient directional control inputs/availability. As the airspeed decreases, increasing amounts of rudder are required to maintain track. Maintain two - point aerodynamic braking until approximately 100 knots or until roll or directional control becomes a problem. As the pitch attitude decreases, the nose tends to align itself with the ground track.

Aft stick and fully opened speedbrakes reduce stopping distance. Apply brakes after nose wheel is on the runway; however if stopping distance is a factor, refer to SHORT FIELD LANDING, this section. With all LG on the runway, maintain directional control with rudder, differential braking, and NWS if required.

During landing roll out, the main concerns are wing rise (roll control), weathervaning (directional control), and downwind drift. Wing rise is controlled by flaperon into the

Normal Landing Pattern (Typical)



NOTES:

FINAL APPROACH AIRSPEED/13 DEGREES AOA CROSS-CHECK.

- **C** 136 KNOTS + 4 KNOTS PER 1000 POUNDS OF FUEL/STORE WEIGHTS. ADD 8 KNOTS FOR 11 DEGREES AOA APPROACH.
- **D** 138 KNOTS + 4 KNOTS PER 1000 POUNDS OF FUEL/STORE WEIGHTS. ADD 8 KNOTS FOR 11 DEGREES AOA APPROACH.

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Figure 2-3.

crosswind. Excessive flaperon deflection degrades directional control. Use rudder and differential braking to control ground track, especially on wet or icy runways. Engage NWS if required to maintain directional control and to prevent departure from the runway. Excessive differential braking may result in a hot brake condition. High rudder pedal force may result in a yaw transient when NWS is engaged. NLG strut compression is required to engage NWS but sustained forward stick may result in full horizontal tail deflection which decreases weight on the MLG and thus reduces wheel braking effectiveness.

TOUCH-AND-GO LANDING

Perform a normal approach and landing. After touchdown, maintain landing attitude, advance the throttle, close the speedbrakes, and perform a normal takeoff.

AFTER LANDING

WARNING

Do not use parking brake. Use only chocks, if available, or minimum possible toe brakes pressure to hold the aircraft stationary. Parking brake use may cause residual heat damage to brakes and may increase the probability of a subsequent brake fire.

NOTE

- Avoid heavy braking below 20 knots at light GW's. Heavy braking during these conditions may cause both MLG WOW switches to momentarily go to the air position, which causes the anti-skid system to deactivate the toe brakes. The WOW switches return to the ground position after 1-1.5 seconds, restoring braking capability. If heavy braking resumes, the cycle may be repeated.
- NWS disengagements are possible when taxiing with CG near the in-flight aft limit.

1. PROBE HEAT switch – OFF.

WARNING

If the probe heaters are left on, they may be hot enough to cause serious injury if touched.

CAUTION

Prolonged ground operation of probe heat may cause failure of AOA probe heaters.

2. ECM power – Off.
3. Speedbrakes – Close
4. Ejection safety lever – Safe (up)
5. IFF MASTER knob – STBY
6. IFF M-4 CODE switch – HOLD
7. LANDING TAXI lights – As required.
8. ZEROIZE switch – As required.

NOTE

- If any FLCS single failures occurred while airborne, they are reported in the PFL 2 minutes after WOW. The FLCS FAULT caution light also illuminates.
- If an FLCS SNGL FAIL PFL occurs and FLCS 049 and 070 MFL's are the only MFL's present on the MFD test page, perform up to three additional FLCS BIT's and MFL clear actions. If these FLCS MFL's clear, no writeup is required. If these FLCS MFL's do not clear, inform maintenance.

9. Canopy handle – Up.

NOTE

- Unlock the canopy to insure that the canopy seal is deflated before the canopy is opened.
- If the canopy handle is placed to up within 2 minutes of WOW, an FDR 024 MFL is generated.

10. Armament switches – Off, safe, or normal.

ENGINE SHUTDOWN

WARNING

A postshutdown engine tailpipe fire is possible. Ignition may be indicated by a mild bang, followed by smoke, fumes, or a small fire in the combustion/turbine area. Potentially hazardous inlet and exhaust areas should be avoided within 5 minutes after engine shutdown. This phenomenon does not cause damage to the engine or aircraft. If a postshutdown fire occurs, the engine may be motored with the JFS for approximately 1 minute to extinguish the fire. If motoring the JFS is not possible, the fire extinguishes on its own within a few minutes.

1. Throttle – OFF.

After main generator drops off line :

2. EPU GEN and EPU PMG lights – Confirm off.

WARNING

If either light is illuminated, turn the MAIN PWR switch to OFF. Insure that the EPU safety pin remains installed and notify maintenance.

3. MAIN PWR switch – OFF.

NOTE

Delay placing MAIN PWR switch to OFF until after engine rpm decreases through 20 percent. This delay should allow the exhaust nozzle to remain open and makes it easier for maintenance to accomplish the postflight inspection.

4. Oxygen hose, survival kit straps, lapbelt, g-suit hose, and vest hose – Disconnect, stow.
 - Stow oxygen connector in bracket on right sidewall. Insure oxygen hose does not protrude beyond console edge.
 - Stow lapbelt and survival kit straps on seat cushion.

- Use both hands to disconnect g-suit hose to avoid excessive force on the hose-to-console connection.

CAUTION

- One handed or brute force disconnects of the g-suit connection will cause internal damage to the hose at the hose-to-console connection.
- Failure to properly stow lap belt, survival kit straps, oxygen connector, g-suit hose, and oxygen hose may cause damage to consoles and to the ejection seat during seat adjustment.

5. OXYGEN REGULATOR – OFF and 100%.

CAUTION

- Failure to position the oxygen regulator to OFF and 100% may result in particulate contamination of the regulator and the subsequent damage.
- To avoid damage to the oxygen regulator, do not pull the knob on the end of the mode lever when moving the mode lever from ON to OFF.

6. Canopy – Open.

WARNING

- If wind exceeds 30 knots, open the canopy only as far as needed to enter/exit the cockpit. Decreasing the canopy angle reduces the possibility that the canopy can be blown past full open.
- A failure of the canopy actuator could allow the canopy to fall during transit. Keep hands and arms out of the path canopy travel during opening or closing.

NOTE

If the internal canopy switch is left in the up position, the canopy automatically opens if closed from the outside.

VOCABULARY

To retard	: Gaz kolunu geriye çekmek
Speedbrake	: Pike flabı
Downwind leg	: Rüzgaraltı bacağı
LG (Landing gear)	: İniş takımı
Base turn(leg)	: Esas bacak dönüşü
AOA(Angle of attack)	: Hücum açısı,kanadın hücum kenarının eğim açısı
Back stick	: Lövyeye geri tazyik uygulama
Sink rate	: Uçağın çökme oranı
GW (Gross weight)	: Toplam ağırlık
Electrical solenoid	: Elektrik bobini
Paddle	: Direksiyon pedalı(T-41 ile aynı)
Approach end	
arresting barrier	: Pist başı hook bariyeri
Ventral fins	: Stabilizenin üstündeki statik elektrik çubukları
HUD	: Head-up display
NLG (Nose landing	
Gear)	: Burun iniş takımları
WOW (Weight over	
Wheels)	: Ağırlığın tekerler üzerine binmesi durumu
CG (center of gravity)	: Ağırlık merkezi
Aerodynamic braking	: İniş sırasında pist içine gelindiğinde uçağın burnunu nispeten yüksek bir yunuslama açısıyla kaldırarak süratin düşmesini sağlamak
SPD BRK(speed bra-	
Ke) switch	: Pike plabı düğmesi
Trailing edge	: Kanadın firar kenarı
Deflection	: Kanadın uçlarındaki veya kenarlarındaki aerodinamik hava akımlarının bozulması
Horizontal tail	: Arka kanatçıklar
IDLE	: Rölanti pozisyonu
Aft stick	: Lövyenin geride tutulması
ARI	: Aileron rudder interconnection ; kanatçıklarla dikey stabilizenin yatışlarda otomatik olarak koordineli çalışmasını sağlayan sistem
Flaperon	: Kanatçık flabı
Differential braking	: Yan rüzgarlı havalarda rüzgar içine direksiyon vererek fren kullanma tekniği
Yaw transient	: İnişten sonra pist içinde uçağın (pilot tabiriyle)kıç atması
Steering	: Jet uçaklarında bulunan,uçağın pist içinde ve rule halindeyken hassas olarak yönlendirilmesini sağlayan, lövye üzerindeki bir düğme ile kumanda edilen sistem
NWS(nosewheel steering)	: Burun tekeri steering sistemi
Hot brake condition	: Frenlerin ısınması durumu
Rudder pedal	: Direksiyon pedalı
Toe brakes	: Ayakla kumanda edilen frenler
Weathervaning	: İstikamet kontrolü

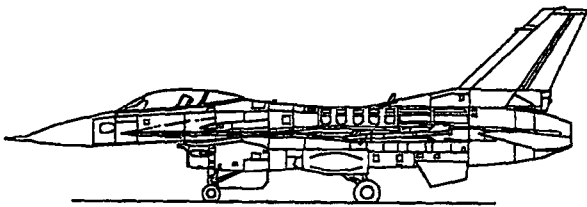
FLCS	: Flight Control System – Uçuş kontrol sistemi uçaktaki lövyeye, fletner vb. Tüm kumanda sistemlerinin genel adı
PFL	: Pilot Fault List – Pilot arıza listesi -Uçak oluşan her arızaya otomatik olarak bir kod numarası verir, (metnin 3ncü sayfadaki FLCS 049 , FDR 024 örneklerinde olduğu gibi) ve bunu pilota MFD (multi function display) üzerinde uyarı olarak iletir.Bu arızalara genel anlamda PFL denir.
FLCS SNGL FAIL PFL	: Kumanda sinyalizasyonunda tek taraflı hata olduğunu gösteren PFL
MFL	: Maintenance Fault List – Bakım arıza listesi – PFL de olduğu gibi, uçak bakım ekibinin ilgilenmesi gereken arızaları da pilota uyarı olarak iletir. Pilot bunları inidikten sonra bakım ekibine iletmelidir, yoksa arıza büyüyebilir.
MFD	: Multifunction Display – Çok amaçlı gösterge,kokpitte pilotun genel olarak uçuş bilgilerini gördüğü gösterge
FLCS BIT	: FLCS Built-In test – Uçakta tüm kumanda sistemlerini uçuş öncesi kontrol eden bir sistem vardır. Pilot bir düğmeyle bunu çalıştırır ve kumanda sistemleri otomatik olarak kontrol edilir, herhangi bir arıza varsa MFD üzerinden uyarı olarak pilota iletilir,arızaya göre bakım ekibi çağrılabilir, uçak uçuştan bile kesilebilir.
Deflate	: Söndürmek, havasını gazını boşaltmak
FDR	: Flight data recorder – Arızaları ve kalkış iniş bilgilerini kaydedip MFD ye yazan sistem
Armament	: Silah sistemleri
Engine tailpipe	: Egzos borusu
Inlet	Hava alığı
JFS	: Jet fuel starter – yakıt starteri
EPU GEN	: Emergency Power Unit Generator - Acil güç ünitesi jeneratörü – Uçakta 7 adet güç ünitesi vardır, eğer ana ve stand by güç ünitelerinin ikisi de devreden çıkarsa, jeneratör yardımıyla acil güç ünitesi devreye girer
EPU PMG	: EPU Permanent Magnet Generator – acil güç jeneratörünün yedeğidir, EPU GEN ‘ de her hangi bir arıza olursa EPU PMG devreye girer.
Vest hose	: G-suitin göğüs kısmında bulunan,suitin içine hava basma işlevini yerine getiren boru
To stow	: Dikkatle sararak istif etmek
Console	: Kokpitte G-suitin takılıp çıkarıldığı yer
Knob	: Kapı vb. tokmak

F-16

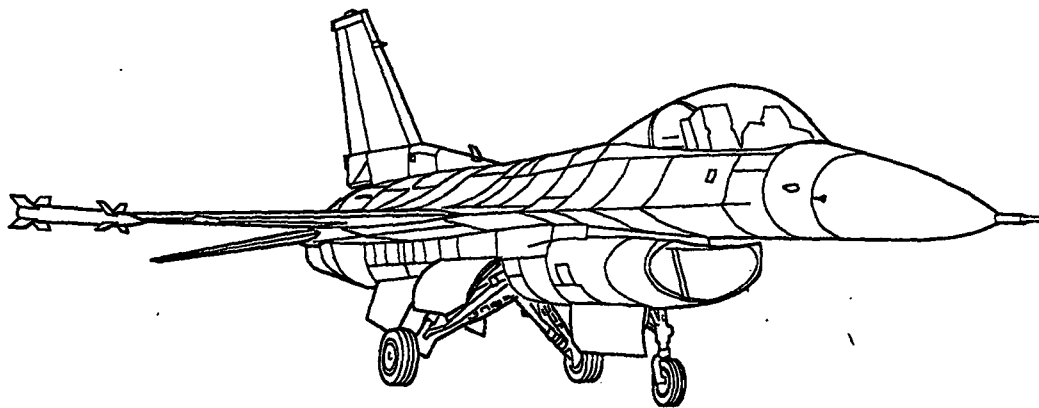
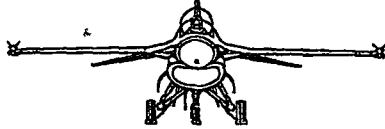
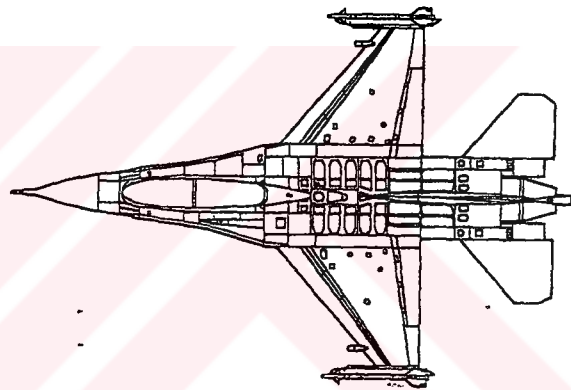
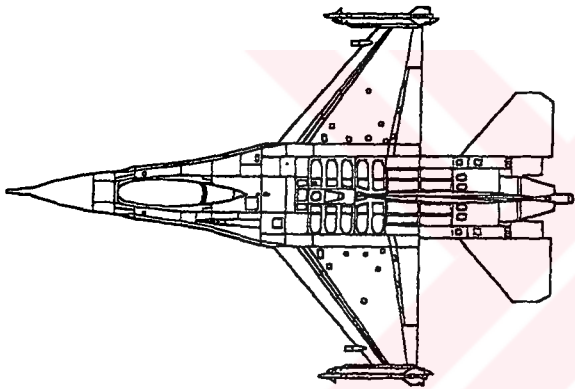
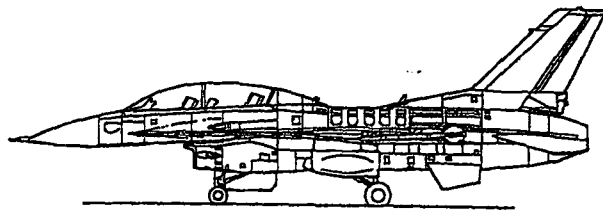
Fighting Falcon



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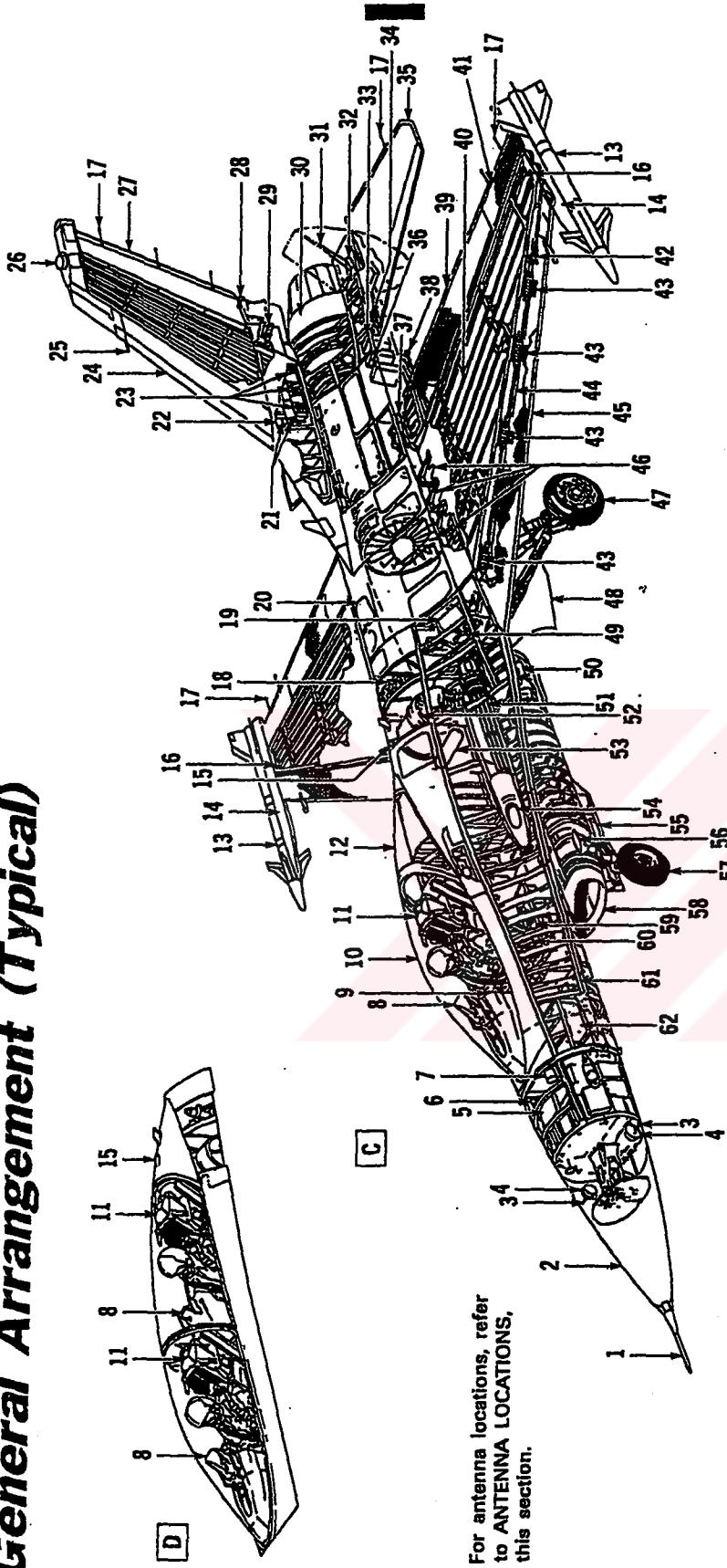


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General Arrangement (Typical)



For antenna locations, refer to ANTENNA LOCATIONS, this section.

- | | | |
|---|-------------------------------|---------------------------------|
| 1. Air Data (Pitot) Probe | 33. Chaff/Flare Dispenser | 49. LEF Angle Drive Gearbox |
| 2. Nose Radome | 34. Horizontal Tail ISA | 50. Air-Conditioning Package |
| 3. AOA Probe | 35. Horizontal Tail | 51. M61A1 20MM Gun |
| 4. AOA Transmitter | 36. Formation Light | 52. Ammunition Drum |
| 5. Forward Electronic Equipment Bay | 37. Flaperon ISA | 53. EPU Nitrogen Bottle |
| 6. Cockpit Pressure Regulator | 38. Hook | 54. Gun Port |
| 7. Cockpit Pressure Safety Valve | 39. Flaperon | 55. NLG Door |
| 8. Head-Up Display (HUD) | 40. Wing Structural Box | 56. Position Light |
| 9. Instrument Panel | 41. Fixed Trailing Edge Panel | 57. NLG |
| 10. Canopy (Movable) | 42. Asymmetry Brake | 58. Engine Air Inlet |
| 11. Ejection Seat | 43. LEF Rotary Actuator | 59. Left Console |
| 12. Canopy (Fixed) | 44. LEF Torque Shaft | 60. Throttle |
| 13. AIM-9 Missile | 45. LEF | 61. Strake |
| 14. Missile Launcher | 46. Wing Attachment Fittings | 62. Lower Equipment Compartment |
| 15. AR and Formation Light | 47. MLG | |
| 16. Position/Formation Light | 48. MLG Door | |
| 17. Static Discharger | | |
| 18. LEF Drive Unit | | |
| 19. Hydraulic Reservoir | | |
| 20. AR Slipway | | |
| 21. FLCs Accumulators | | |
| 22. Anticollision Strobe Light Power Supply | | |
| 23. Vertical Tail Attachment Fittings | | |
| 24. Vertical Tail | | |
| 25. Vertical Tail-Mounted Floodlight | | |
| 26. Anticollision Strobe Light | | |
| 27. Rudder | | |
| 28. Position Light | | |
| 29. Rudder ISA | | |
| 30. Turbofan Engine | | |
| 31. Speedbrake | | |
| 32. Speedbrake Actuator | | |

TK1F-16CJ-1-0004A33

Figure 1-2.

APPENDIX - 2: MANIPULATION OF EFFECTIVENESS FACTORS

- Group 1** : Red Signal Word / Icon Present / Border Present
 - Group 2** : Red Signal Word / Icon Present / Border Absent
 - Group 3** : Red Signal Word / Icon Absent / Border Present
 - Group 4** : Red Signal Word / Icon Absent / Border Absent
 - Group 5** : (Black) Achromatic Signal Word / Icon Present / Border Present
 - Group 6** : (Black) Achromatic Signal Word / Icon Present / Border Absent
 - Group 7** : (Black) Achromatic Signal Word / Icon Absent / Border Present
 - Group 8** : (Black) Achromatic Signal Word / Icon Absent / Border Absent
- Original Design of Manual**

LANDING

NORMAL LANDING


Refer to figure 2-3. Fly initial at 300 knots. At the break, retard throttle and open speedbrakes as required. On downwind leg, when airspeed is below 300 knots, lower the LG. During the base turn, recheck the LG down and slow to computed final approach airspeed / AOA on final at 11 or 13 degrees AOA. Check speedbrakes open and maintain computed final approach airspeed / AOA on final. Rate of descent decreases slightly when entering ground effect. Reduce thrust gradually to continue the descent while applying back stick to reduce sink rate to the minimum practical. Thrust can be reduced sooner during an 11-degree approach than during a 13-degree approach. In either case, maintain a maximum of 13 degrees AOA while reducing sink rate to the minimum practical.

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LG

LANDING

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APPENDIX - 3: EXPERIMENT TEST BOOKLET



LANDING TEST

COMPREHENSION 1

1. Is it dangerous to leave probe heaters on after landing ? Why ?

- a) No, they turn off automatically after landing.
- b) *Yes, they may be hot enough to cause serious injury.
- c) Yes they may distract the NWS system while taxiing.
- d) No, they cool off automatically

Very sure of the answer
()

Fairly sure of the answer
()

Gessed the answer
()

2. Choose the best way of action after landing.

- a) *To use chocks or minimum possible toe brakes pressure to hold the aircraft stationary.
- b) To use parking brakes to hold the aircraft stationary to make slight turns in runway.
- c) To apply heavy braking disengagement to restore braking capability.
- d) To turn MLG WOW switches on to deactivate anti-skid system

Very sure of the answer
()

Fairly sure of the answer
()

Gessed the answer
()

3. What happens if motoring the JFS is not possible when a postshutdown engine tailpipe fire occurs ?

- a) The fire fighters should be called for emergency
- b) The engine must be restarted.
- c) *The fire extinguishes on its own within a short time.
- d) We should delay placing EPU PMG switch to ON until rpm increases

Very sure of the answer
()

Fairly sure of the answer
()

Gessed the answer
()

4. What is the correct way of action if either of EPU GEN or EPU PMG remains illuminated during engine shutdown ?

- a) To delay shutdown until rpm decreases
- b) *To turn the MAIN PWR switch off
- c) To insure that oxygen regulator is off
- d) To check illuminated parts

Very sure of the answer
()

Fairly sure of the answer
()

Gessed the answer
()

LANDING TEST

RECOGNITION-1

1. Which one of the sentences below is included in a warning message?

- a)* Parking brake use may cause residual heat damage to brakes and may increase the probability of a subsequent brake fire.
- b) Reduce thrust gradually to continue the descent while applying back stick to reduce sink rate to the minimum practical
- c) Stow lapbelt and survival kit straps on seat cushion
- d) Use two point aerodynamic braking until approximately 100 knots ; then fly the nosewheel on the runway

Very sure of the answer

()

Fairly sure of the answer

()

Gessed the answer

()

2. Which one of the sentences below is included in a warning message?

- a) Smoothly apply moderate to heavy braking to decelerate to taxi speed
- b) *Insure that the EPU safety pin remains installed and notify maintenance
- c) When stopping distance is critical a normal approach should be made
- d) If heavy braking resumes, the cycle may be repeated

Very sure of the answer

()

Fairly sure of the answer

()

Gessed the answer

()

3. Which one of the sentences below is included in a warning message ?

- a) This horizontal tail deflection reduces wheel braking effectiveness
- b) As the airspeed decreases, increasing amounts of rudder are required to maintain track
- c) This delay should allow the exhaust nozzle to remain open and makes it easier for maintenance to accomplish the postflight inspection
- d) *LG retraction could occur during subsequent in-flight or ground operations.

Very sure of the answer

()

Fairly sure of the answer

()

Gessed the answer

()

4. Which one of the sentences below is included in a warning message ?

- a) Therefore, these indications are valid references for aircraft attitude throughout two point aerodynamic braking.
- b) Horizontal tail contact with the runway is possible if a large roll input is made at or near touchdown.
- c) *A failure of the canopy actuator could allow the canopy to fall during transit.
- d) Excessive flaperon deflection degrades directional control.

Very sure of the answer

()

Fairly sure of the answer

()

Gessed the answer

()

LANDING TEST

RECALL-1

FILL IN THE BLANKS

1. Potentially hazardous inlet and exhaust areas should be avoided within minutes after engine shutdown

* 5

Very sure of the answer
()

Fairly sure of the answer
()

Guessed the answer
()

2. If wind exceedsknots, open the canopy only as far as needed to enter / exit the cockpit

* 30

Very sure of the answer
()

Fairly sure of the answer
()

Guessed the answer
()

3. Insure that the.....handle is confirmed fully down.

* LG

Very sure of the answer
()

Fairly sure of the answer
()

Guessed the answer
()

4. malfunctions at any speed may cause an abrupt turn, tire skidding or blowout, aircraft tipping and / or departure from the prepared surface

* NWS

Very sure of the answer
()

Fairly sure of the answer
()

Guessed the answer
()

APPENDIX - 4: FACTOR LEVELS AND SCALED EXPERIMENT SCORES

FACTORS	LEVELS
Color Coding	1 (Black “Achromatic” Signal Word) 2 (Red Signal Word)
Pictorial Icon Use	1 (Icon Absent) 2 (Icon Present)
Border Use	1 (Border Absent) 2 (Border Present)

COLOR CODING	PIC. ICON USE	BORDER USE	COMPRE. SCORES	RECOG. SCORES	RECALL SCORES
2,00	2,00	1,00	5,50	4,00	5,25
2,00	2,00	1,00	3,50	4,25	4,50
2,00	2,00	1,00	5,25	4,25	3,75
2,00	2,00	1,00	4,75	4,00	3,00
2,00	2,00	1,00	6,00	4,50	2,50
2,00	2,00	1,00	4,25	4,75	4,75
2,00	2,00	1,00	3,75	4,00	3,25
2,00	2,00	2,00	3,50	3,25	4,00
2,00	2,00	2,00	4,50	3,50	2,50
2,00	2,00	2,00	4,50	4,00	4,75
2,00	2,00	2,00	5,00	4,50	4,25
2,00	2,00	2,00	4,75	3,75	2,00
2,00	2,00	2,00	4,75	5,50	3,75
2,00	2,00	2,00	5,25	4,50	4,50
2,00	1,00	1,00	4,50	3,00	5,25
2,00	1,00	1,00	3,00	3,25	3,75
2,00	1,00	1,00	4,50	4,00	4,00
2,00	1,00	1,00	4,00	3,25	3,00
2,00	1,00	1,00	3,50	2,25	4,50
2,00	1,00	1,00	4,50	3,00	3,75
2,00	1,00	1,00	4,50	3,75	4,00
2,00	1,00	2,00	4,00	3,50	5,00
2,00	1,00	2,00	5,50	2,50	3,75
2,00	1,00	2,00	3,75	3,50	5,00
2,00	1,00	2,00	4,25	3,50	3,25
2,00	1,00	2,00	4,00	4,75	4,25
2,00	1,00	2,00	5,25	3,00	4,75
2,00	1,00	2,00	4,50	3,75	4,75
1,00	2,00	1,00	4,75	4,25	4,00
1,00	2,00	1,00	5,75	3,75	4,25
1,00	2,00	1,00	5,75	3,25	4,75
1,00	2,00	1,00	1,50	2,75	4,00
1,00	2,00	1,00	4,75	4,25	4,00
1,00	2,00	1,00	4,75	3,00	2,25
1,00	2,00	1,00	4,50	4,00	3,75
1,00	2,00	2,00	3,00	3,50	4,50
1,00	2,00	2,00	4,75	3,50	4,75
1,00	2,00	2,00	4,75	3,50	4,50
1,00	2,00	2,00	4,75	4,25	4,25
1,00	2,00	2,00	3,00	3,50	3,25
1,00	2,00	2,00	3,50	3,50	5,00
1,00	2,00	2,00	5,50	5,00	3,50
1,00	1,00	1,00	4,75	3,75	4,00
1,00	1,00	1,00	5,50	3,25	4,25
1,00	1,00	1,00	3,75	4,50	4,00
1,00	1,00	1,00	4,00	3,50	4,00
1,00	1,00	1,00	1,50	3,50	4,00
1,00	1,00	1,00	5,50	3,75	3,50
1,00	1,00	1,00	4,50	3,75	4,75
1,00	1,00	2,00	4,75	4,75	3,00
1,00	1,00	2,00	5,75	3,50	4,00
1,00	1,00	2,00	5,00	4,25	4,75
1,00	1,00	2,00	6,00	3,50	5,75
1,00	1,00	2,00	2,75	4,25	3,25
1,00	1,00	2,00	4,75	4,50	4,00
1,00	1,00	2,00	4,25	3,25	2,00

BIOGRAPHY

He was born in Ankara, 1973. Graduated from Maltepe Military College, İzmir in 1991, and Turkish Air Force Academy, İstanbul in 1995. He was assigned as flight trainee officer in 2nd Air Base, İzmir, 1995 – 1996, logistics officer in 5th Air Base, 1997 – 1999. He attended to graduate program in Marmara University Engineering Faculty, Industrial Engineering Department in 1999, and assigned in Turkish Air Force Academy. He still teaches in Turkish Air Force Academy, Industrial Engineering Department.

